UNIVERSITY OF MICHIGAN SCHOOLS OF EDUCATION AND PUBLIC HEALTH

How SIMILAR or DIFFERENT are we?

Teacher Guide

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DISCLAIMER: These materials are still being piloted. Please check back for more fully developed materials or contact Joe Kracjik (krajcik@umich.edu).

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Genomics Unit Map

LS 1: How SIMILAR or DIFFERENT are we?

- How SIMILAR or DIFFERENT is our skin?
- What atoms and molecules are found in our body?

LS 2: What happens inside our cells to make us SIMILAR or DIFFERENT?

- Why are cells so DIFFERENT?
- Where are proteins in our body?
- How are proteins in our skin SIMILAR and DIFFERENT?
- How SIMILAR or DIFFERENT are the proteins that make up our intestines?
- Should differences in the proteins in our cells cause us to be treated differently?
- What are proteins made of?

LS 3: How does our DNA make us SIMILAR or DIFFERENT?

How can two people have different sequences for the same protein?

What does DNA Look like?

What is the structure of DNA?

How does DNA form proteins?

How can DNA change?

LS 4: Why do some people have diseases and others do not?

How can people have different red blood cells?

How can people have different hemoglobin proteins?

How SIMILAR or DIFFERENT are parents from their offspring?

Are all mutations bad?

How can people have different lactase protein?

LS 5: Are we more SIMILAR or DIFFERENT?

How SIMILAR or DIFFERENT are our genomes?

How does the environment affect how SIMILAR or DIFFERENT we are?

Table of Contents

Materials List

1 Set teacher materials per teacher (Teacher guide, Student Annotated Reader, Slides, Videos)
1 Student reader per student
microscopes (-4 per teacher)

From 3D Molecular Designs (http://www.3dmoleculardesigns.com/news2.php#toobers) Toobers for modeling (-8 per teacher)

From Flinn Scientific

Flinn DNA Molecular Model Set, 11-tier (AP6317) (-8 per teacher)
Pipet, Beral type graduated (AP1516) (-1 per teacher)
Biuret Test Solution (B0051) (-1 per teacher)
Polypropylene cups (AP5442) (-1 per teacher)
Glucose test strips (T0004) (-1 per teacher)
Ethyl Alcohol 95%, denatured, 500mL (E0009) (1 per teacher)
medicine cups - 30-mL capacity (AP5442)
bell wire (AP5417)

From Carolina Biologicals

Human Sickle Cell Anemia, smear (ER-31-7374) (-5 per teacher) Human Blood Film, smear (ER-31-3158) (-5 per teacher)

Available locally

assorted color pushpins, 100 ct (-3 per teacher) lactase pills (-1 box per teacher)- Note: generic pills often have sugars in them which will affect the results, check ingredients or buy name brand.
milk
Lactase-free milk
lemon juice
1 apple cut in pieces
strawberries
chicken (white, dark, skin, liver, bone)
gallon plastic bags for holding chicken
Red and Black licorice (represents DNA /RNA sugar-phosphate backbone)
Colored mini Marshmallows (represent nitrogenous bases)
Gumdrops (represent amino acids)
Tooth picks (represents bonds between amino acids)
hand sanitizer or gloves
dish soap
salt

OVERVIEW OF UNIT

Targeted audience, content and sequencing

This unit is intended for a high school biology course and covers molecular genetics and genomics. The unit is expected to take 6-8 weeks.

Molecular genetics is key to all modern understandings of biology. In contrast to classical genetics (which focuses on abstract concepts like dominant and recessive alleles and Punnett squares to explain the appearance of physical features and disease), molecular genetics focuses on the molecular nature of genes and how they influence cells and whole organisms. Thus, the ideas that genes are found in DNA and are instructions for building proteins are central to understanding molecular genetics. For the last three decades, researchers have actively engaged in understanding questions in molecular genetics and have actively used techniques to manipulate genes and proteins to understand the biology of organisms better. This insight has had major influences on medicine and society. For example, it is very common in the news to hear about a newly discovered gene linked to a specific disease or behavior, and it is more common now for doctors to use techniques based on gene sequences to make prognoses.

Genomics is the newest frontier in biology. Genomics is the study of the entire genetic makeup of an organism (i.e. a genome). In contrast to traditional ways of talking about genetics, which typically involve one or a few genes, genomics considers the entire genome or large portions of a genome, and therefore focuses on many genes or DNA sequences. Advances in genomics will change (and have already changed), the way both biological research and human medicine are conducted. Thus, genomics fundamentally is large-scale molecular genetics. An influx of data has and will result from genomics research. This will exponentially increase the number of genes linked to disease and the number of genes that are screened in doctor's offices. Not too far off in the future, individuals will be able to obtain the entire DNA sequence of their own genome, which will have tremendous medical and social implications. Thus, it is absolutely essential for the next generation of adults to develop deeper understandings about molecular genetics and genomics if they are to understand advances in biology and medicine.

The main objective of this unit is to connect molecular mechanisms to cellular function and appearance so that students will develop a better understanding of how genes can influence our physical features and health. Given this objective, the overall learning objective is for students to understand that genes are instructions for encoding proteins, and that these proteins carry out functions in cells that directly determine structure and function of cells, tissues, organs, and consequently whole organisms. Often the teaching of genetics leaves out this essential connection between genes and proteins; as a result a "black box" between gene and phenotype (the physical manifestation of a gene or genes, such as eye color, height or skin color) is left for many students. The bridge that connects genes to phenotype is proteins, since this is what a gene encodes and this is what does the work of the cell. Hence, a fair amount of attention is devoted to proteins in this unit. In fact the unit begins with content on proteins before going onto content about DNA in order to emphasize the centrality of proteins to cell function and organism appearance and physiology.

The unit is divided into 5 Learning Sets:

1. Similarities and differences -The students begin to explore the driving question of the unit: How similar or different are we? Students experience skin color difference at a cellular level.
2. Understanding proteins - After examining the cellular differences in the first lesson, students in Learning Set 2 begin to explore proteins as the workers in cells and begin to understand the molecular differences between different proteins using flexible protein models.
3. Genes and their relation to proteins -Armed with an understanding of proteins from the second lesson, students learn what genes are and how cells "decode" them to generate proteins.
4. The molecular basis of genetic diseases -The lesson reinforces the idea that genes are the directions for making proteins and extends students' understanding of how different forms of protein can lead to disease by exploring the molecular basis of sickle cell disease. Additionally, students explore ethical issues related to enhancing athletic performance.
5. Genomes -After learning some specifics about genes in previous lessons students explore how genes are related to chromosomes and genomes.

Topics not covered in this unit include meiosis, mitosis and classical genetics (i.e. content such as alleles and Punnett squares are touched on but not taught in depth.). Cells must be covered before this unit and it is suggested that meiosis and mitosis be covered before this lesson. Classical genetics -while typically covered before molecular genetics - might actually make more sense after this unit so we suggest covering classical genetics after this unit.

DESIGN OF THE UNIT

Standards-based

In developing this unit, first science benchmarks and standards from the Benchmarks for Science Literacy (1993) and the National Science Education Standards (1996) documents were identified that concern molecular genetics and scientific inquiry practices. We refer to these benchmarks and standards as learning goals. Having

identified learning goals, we combine content standards with inquiry standards to develop what we refer to as "learning performances", because others in science education, such as National Research Council, stress the importance of learning science content in the context of scientific inquiry. The learning performances are the means by which students will show their understanding of the standards (learning goals). As an example, take the inquiry standard from the NRC that states students will "...analyze and interpret data..." and the standard from NRC that "genes are segments of DNA molecules.." to come up with the learning performance that "students will analyze a pool of DNA sequences and make conclusions about the degree of similarity or difference in the sequences." The rest of the unit, including context, activities and assessments are designed around these learning goals and learning performances:

1. **Nature and function of proteins:** The work of the cell is carried out by the many different proteins. Proteins molecules are long, usually folded chains made from 20 different kinds of amino-acid molecules. The function of each protein molecules depends on the specific sequence of amino acids and the shape the chain takes is a consequence of attractions between the chain's parts. (AAAS, pg. 114, 5C:9-12#3)
2. **Biochemical basis for trait:** An organism's traits reflect the actions (and inactions) of its proteins. (AAAS considering this but not published yet)
3. **Nature and function of DNA:** In all organisms, the instructions for specifying the characteristics of the organism are carried in DNA, a large polymer formed from subunits of four kinds (A, G, C, and **T).** The chemical and structural properties of DNA explain how the genetic information that underlies heredity is both encoded in genes (as a string of molecular "letters") and replicated (by a templating mechanism). Each DNA molecule in a cell forms a single chromosome. (NRC, pg.185, 9-12:C2#1)
4. **Genes as information for building proteins:** The genetic information in DNA molecules provide the instructions for assembling protein molecules. The code is virtually the same for all life forms. (AAAS, pg. 114, 5C:9-12#4)
5. **Molecular nature of genes and mutations:** Genes are segments of DNA molecules. Inserting, deleting, or substituting DNA segments can alter genes. An altered gene may be passed on to every cell that develops from it. The resulting features may help, harm, or have little or no effect on the offspring's success in its environment. (AAAS, pg. 109, 58:9-12#4)
6. **Heritable material:** The information passed from parents to offspring is coded in DNA molecules (AAAS, pg 108, 58:9-12#3)
7. **Different cells use different genes:** The many body cells in an individual can be very different from one another even though they are all descended from a single cell and thus have essentially identical genetic instructions. Different parts of the instructions are used in different types of cells, influenced by the cell's environment and past history (AAAS, pg. 109, 58:9-12#6).
8. **Environment and genes:** Most physical and behavioral characteristics that an individual possesses are the combination of both genes and environment. (AAAS considering this but not published yet)
9. **Constituents of a genome:** A genome consists of all of the DNA found inside a single cell or virus. The genome contains all the genes required to build, maintain and propagate the cell, or a multicellular organism. For humans the genome includes all the DNA from all 23 pairs of chromosomes within the nucleus and the DNA in the mitochondria. The human genome consists of about 3 billion base pairs and is estimated to have 25,000 genes. The smallest free-living organism, bacteria has about 500,000 base pairs and 5,000 genes. Most of the human genome is non-coding DNA, while only a small fraction is protein coding. The non-coding

DNA includes some small parts that are highly variable DNA, which can be used to identify people. The genomes of any two humans are highly similar (99.9°/o identical to be exact). (Written by Aaron Rogat with the input of genomic experts).

Inquiry-based

This unit will be hands-on and inquiry-based so that students must actively engage with the content in order to make sense of it, and hopefully develop a deeper understanding of molecular biology and modern genetics. "Inquiry" in our unit means that students will be asked to engage in scientific practices such as asking questions, making predictions, analyzing data, developing conclusions, providing explanations and critiquing other people's conclusions.

Multiple representation and phenomena

Students will be exposed to multiple representations and phenomena throughout the unit such as pictures and videos of cells, proteins and organisms, and 3-D physical models of molecules. In addition, where possible, real-life organisms or cells will be provided for students to explore and observe. These representations and phenomena serve as additional ways to explore and engage in the content. We will also make an effort to talk about real examples that illustrate the content objectives such as the LDL protein and its role in familiar hypercholesterolemia. These phenomena and real life examples are also intended to capture the interest of the students.

Ethical and societal issues

The unit will also incorporate social and ethical issues with which to frame the learning of the science content. These issues are meant to also engage the students in the science content by adding relevance and interest to the content. In addition, it is clear that advances in molecular genetics and genomics will influence many social and ethical issues; therefore, it is critical that students also begin to think about how the science will impact their own lives. Students will learn about how advances in genetics can shed light on important social issues like race and health and help to shape our notions and views of others and ourselves. Thus, in this unit students will learn both science content and how science can influence society.

For more information about including ethical dilemma activities in the classroom:

http://www.nwabr.org/education/index.html

CLASSROOM DISCOURSE

ADAPTED FROM /QWST FRONT MATTER

Traditional "Discussion"

A traditional view of teaching and learning is that teachers "deliver" instruction, and students learn by watching and listening. In that model, classroom discourse typically involves a teacher posing questions, one or more students responding, the teacher evaluating responses as right or wrong, and the teacher moving on to the next question or task when he or she is ready to do so.

This type of sequence may involve questions such as:

- What did we learn from this activity?
- What are the 4 things we've decided are important ...?
- What are the behaviors of X that we have talked about so far?
- What did we observe/see/learn/do ...?

These types of questions are useful. For example, they provide a quick, whole-class recap of learning before moving on to new ideas. But, too often this type of question-and-answer activity is the primary form of classroom discourse. It puts the teacher at center stage, and students' questions and their learning in the background. This kind of teacher-led initiation-response-evaluation (I-R-E) sequence is what often passes as "discussion" in a classroom, disguising the fact that real discussion is a give-and-take of ideas.

Classroom discourse-including discussion

A give-and-take of ideas is the preferred form of classroom discourse. IRE should be used sparingly. Instead, classroom talk should center on engagement and thoughtfulness. Teachers pose questions that push students' to think more deeply about what they have observed, experienced, or read. Students ask questions that arise out of their own interests or confusion and they ask questions of each other as well as of the teacher. Thoughtful dialogue is critically important if students are to make sense of activities and concepts. Discussions provide them with opportunities to express their understanding and to learn from each other. Discussions also provide the teacher with information about the sense students are making-what they are "getting". Discussions and Q&A are not the same kind of activity. Aim to help students develop skills as thinkers and problem solvers, in part, through participating in thoughtful discussions.

Developing a discourse-centered classroom culture

To develop good discussion skills, students must learn what it means to participate actively in science class. Often, this means new ways of interacting. How do teachers encourage students to question one another, the teacher, and themselves-in productive ways? How do teachers establish a classroom culture in which discussion occurs among students rather than between the teacher and those students who raise their hands?

First, teachers may need to think about classroom discourse in new ways:

All students need opportunities to participate and encouragement to participate. A primary goal is to get students to listen to and respond to each other.

- Discussion is about thinking together, not about generating right answers. Even wrong answers provide opportunities to learn if the culture of the classroom is such that "figuring things out" is of primary importance.

  Writing ideas before discussing them is a good way for students to think before they are asked to share ideas aloud. Readings and other homework are intended to be followed-up with in-class discussion, thus the materials provide follow-up suggestions and alternatives.

Second, students need to learn their role in discussion:

Students need to listen to one another. To develop a culture in which listening is important, ask questions like:

How does your idea, Anna, compare with Will's idea [the previous speaker]?

- What can you add to what Will just said?

  How could you say [group A's] conclusion so that your younger sister could understand it? What could you add to make [the previous speaker's] idea clearer?

Third, after sufficient practice and a clear message that this is really what is expected of them, students begin to respond to one another without the teacher prompting them to do so. How long before that will happen? That depends, in part, on how often students have opportunities to practice and become comfortable with this way of communicating.

Three Types of Discussion

Identified below are three primary types of discussion that could be employed in a science classroom. Each type requires some time-time invested in students' sense-making and deep learning. Although a discussion is likely to be composed of more than one of these types, teachers may be better able to support student learning by recognizing the structure of each type of conversation. Part of the job of facilitating discussion is to be aware of what type of discourse is "in play," and being aware of the "rules" for each.

Generating

Ideas are written on the board or overhead as they are generated. Includes prompts such as:

What have you observed or experienced?

What else is on your group's list?

What do you/other people think about when they hear the word _____?

Who has a different idea/response/way of thinking about this?

What do you know about [topic X]?

Reviewing

Involves putting ideas together, or assembling multiple activities into a coherent whole. May also include generalizing from specific activities to a more general conclusion.

Reviewing discussions may include making connections to personal experiences; to the driving question; to the previous or the following lesson; or to knowledge gained in other units, lessons, or subject areas.

Includes prompts such as:

How does _____help us think about other times when_____?

How can we put these 4 ideas together into one process that we might call "the water cycle"? What happens 1st, 2nd ...?

What do we know about _____so far?

How does this help us think about the driving question?

Yesterday we talked about_____. How does today's activity help us think about_____?

How does this connect to_____?

Problem Solving

Involves figuring things out or making sense of readings or activities.

Pressing for understanding means going deeper, beyond the surface answers. May involve challenge, debate, or argument in which Ss justify their ideas.

May involve revision of previous ideas as students learn new information that calls into question the limitations of what they "knew" previously.

Includes prompts such as:

- How does X compare with Y?
- How can ...? How might ...?
- How do you know? What evidence supports that idea?
- What does it mean to say ...?
- Why doesn't our old model work to explain this new phenomenon?
- Why can't ...?
- How could we figure this out?
- What new questions do you have?

Additional Strategies

Reflective toss: Throw back the students response/question to the students, rather than evaluating.

Student roles: to encourage cognitive and physical engagement.

A final thought about Discourse:

It's hard work to facilitate a good discussion! In reality, one problem for teachers is they may not have seen good models of this in their own experience as students. Teachers should make it a goal to begin to establish discourse norms on the first day of class, and should give themselves and their students time to get used to a give-and-take culture of sharing, listening, and learning together.

Context (a driving question):

This unit is framed by what we refer to as the Driving Question. The Driving Question is an open- ended question that the students may not be able to answer at the beginning but by the end of the unit should be able to answer more completely. It should relate to their own lives and also serve as another means to put the content of the unit (the standards) into context in order to make sense of it all-many in science education feel that science taught as disconnected fact is not effective instruction. The Driving Question is meant to be revisited throughout the unit so that students are challenged to make sense of what they are learning currently in the unit with what they have previously learned in the unit.

Addressing students prior knowledge:

Students often approach new content with prior ideas including misconceptions. These misconceptions can impede the learning of new content. Therefore, we try to identify potential misconceptions and address these misconceptions directly or through teacher guidance. The units therefore identify student misconceptions were possible; we structure activities around these ideas or encourage teachers to address these misconceptions directly during the lesson.

Educative curriculum:

The teacher guide includes overviews and outlines of the day-to-day lessons. In each lesson, efforts are made to include instructional suggestions and tips, appropriate student answers, and potential pitfalls and conceptual challenges for students. These features are called "educative" and serve to inform the teacher so that they can better enact the material.

Grey boxes like the one below serve a few different purposes. In the case below, the box serves to explain the purpose and the objective of the preceding discussion. In other cases, the boxes help to define a term that might have an ambiguous or unclear meaning in these materials, indicate where background information about a specific topic can be found, point out when we have been purposeful about language use, or to indicate places where students previous conceptions might give them difficulties.

Discussion objective: Students should not be expected to have the right answer at this point. The objective is to consider reasonable explanations for different skin colors.

There are formative assessments throughout the unit. Although it might not be necessary to ask your students the question explicitly, you should feel comfortable that most of your students would respond correctly. If you do not feel that your students have learned the material adequately, further discussion and review of the material will be necessary.

Can your students answer the following questions:

1) What carries out most of the work of cells? Answer: proteins
2) What is one way that two people can differ biologically: Answer: they can have proteins that function differently

The Driving Question for the unit

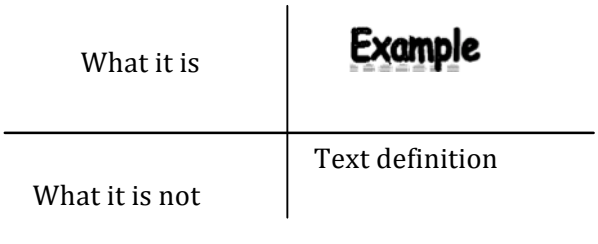
This unit is framed around one question: **"How similar or different are we ?"** By the end of the unit, students will learn how genetically similar humans are to other humans. Students will also understand what determines and influences similarities and difference between and within species (i.e. how differences in genes can influence phenotypes). It is the intent of the unit to highlight how recent findings from genomics research demonstrates how people from different races and ethnicities are actually very similar at the genetic level and that this can have a positive effect on social constructs like race. The unit will also attempt to demystify what it means to have a "gene" for a particular disease and to have a "mutant" gene" by talking about mutation as simple "variations" in genes.

Reading Strategies

Learning from text in science is often a difficult task for students. Science text is often bombarded with organization that is devastating for students who are unaware of text structure or are lacking specific domain knowledge in science. Using reading materials in science classrooms is the most prominent method of learning in science, and although they are meant to be the primary source of learning and have an impact on student learning, reading materials in science are often hard for students to grasp. These materials have provided some strategies that may be helpful for students when reading the texts in their readers. Each reading has suggested reading strategies. The strategies are NOT meant to be used as individual activities. The TEXT that the student is reading is the activity, and the reading strategies are to support the students reading comprehension. Below is a description of some of them (Additionally, there are blank templates in the Appendix):

Vocabulary Concept Cards: Students use these cards to help them become acquainted with science vocabulary and concepts. In the "What it is" quadrant, students write what the word IS or means. In the "Example" quadrant, students write an example of the word or concept. In the "What it is not" quadrant, students write what the concept or word is not. This helps them differentiate the word/concept with other words/concepts. In the "Reader/Dictionary definition" quadrant, the students research the definition of the word/concept and write it there.

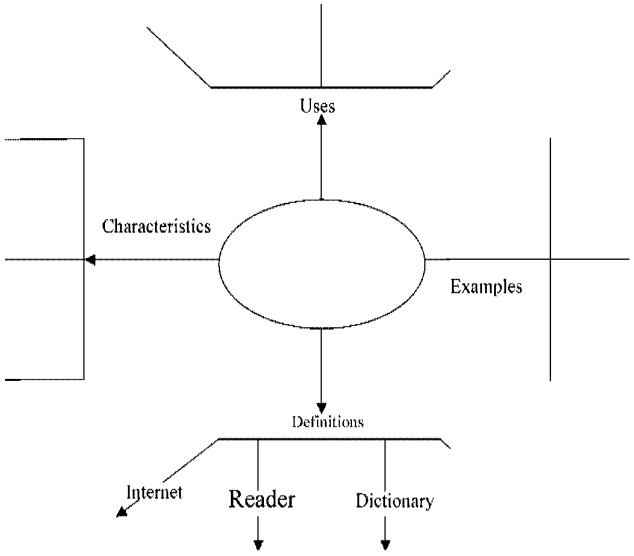
Vocabulary concept cards

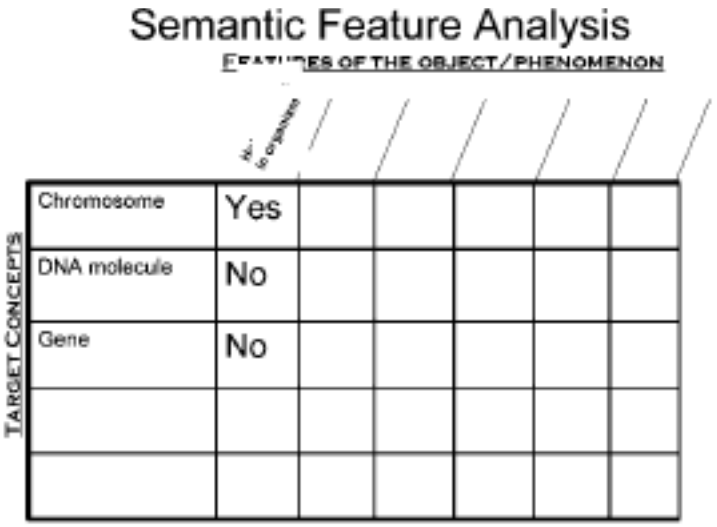


Concept Definition Maps: This strategy helps students think about different aspects of a concept they are learning, like "Gene". In the center circle, students write the concept. In the "Uses" areas, students write what the concept is used for. For example, one use for of Gene is Instructions for proteins. In the "Example" area, students write an example of the concept. In the "Characteristics" area, students write attributes of the concept. For example, one characteristic of Gene is that it is made up of DNA. Finally, in the "Definitions" area, students research the word in the specified resources and write the definitions.

Concept of Definition Map

(Schwat1z, 19HH)





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some, students would
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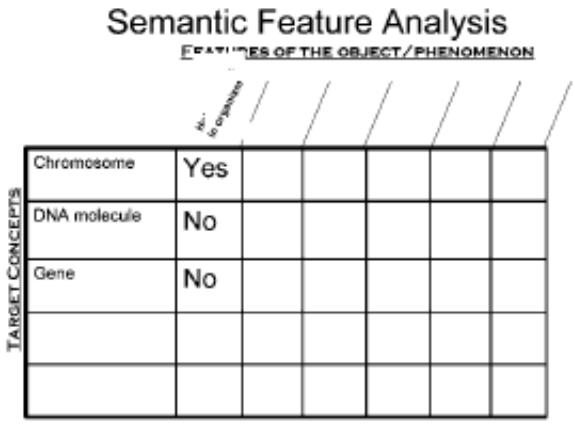


Preview Guide: This strategy helps asses students' prior knowledge, elicit and/or expand their prior knowledge, set a purpose for reading, and help organize the text. Provide questions about the text in the left column for the students to answer. Then, students answer the questions before they read the text, then after they read the text.

Preview Guides

Question	Before Rdg	After Rdg
1. Why would doctors need to know about chromosomes, genes, and DNA?		
2. How are chromosomes related to genes?		
3. How are genes related to DNA?		
4. What do proteins do for the body?		
5. How are proteins related to disease?		

Anticipation-Reaction Guides: This strategy can be used for the ethical dilemmas. This help the student think about what they think/know before they read the dilemma and afterwards.

Anticipation-Reaction Guides

	Before Reading	After Reading	
Ethical Dilemmas	What do you think?	What does the author think?	What do you think now?
Should genetic test kits be marketed to the public?			

BACKGROUND CONTENT

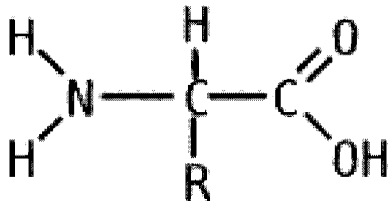
This section is intended to provide you with background information about several of the topics covered in this unit. Also included are web resources with even more information about these topics.

Proteins

While most people think of food when they hear the word protein, most molecular biologists think of the small structural and functional components that help make up the human body as well as all other living organisms. While both groups are right in how they think about protein, here we will think of proteins the way molecular biologists do.

To keep our bodies running every day, proteins perform a wide variety of functions. Acting as enzymes to speed up reactions, transporting substances throughout the body (as with hemoglobin which will be explained later), making our muscles move with proteins such as actin and myosin, giving structure to our cells so that they can grow and divide, and regulating tissues with proteins such as human growth hormone and insulin.

Proteins are made up of building blocks called amino acids, so named because they contain both an amine functional group and a carboxyl functional group (see picture below). Proteins are made up of 20 different types of amino acids, eight of which are considered "essential" because they can only be obtained through diet, and twelve of which are non-essential" body from precursors that are already in the body. Similar to a string of beads, proteins are a string of amino acids joined by peptide bonds. These peptide bonds are formed when the hydroxyl group on the carboxyl (OH on the COOH group) and one hydrogen from the amine group (H from the NH2) are removed to form a water molecule. What results are two amino acids bonded together with a peptide bond.



The general structure of an amino acid. The amine group (NH2) is to the left and the carboxyl group (COOH) is to the right. The

R group is a group that varies among amino acids. It is what makes each of the 20 different from one another.

Proteins can be all sizes. Some proteins can be as small as 12 amino acids long while others can be several thousand amino acids long.

The structures of proteins generally depend on the properties of the amino acids that they are made of and the order of the amino acids in the chain. There are three broad classifications of amino acids: non-polar hydrophobic (water fearing), polar hydrophilic (water loving) and charged. How these different side groups of amino acids are ordered determines in part how they are presented in

space. Hydrophobic amino acids like to avoid water and they generally fold so they are internal to the protein. Hydrophilic amino acids like to interact with water molecules so they tend to be external to

the protein. The opposite is true if the protein is in a lipid environment like a cell membrane; proteins

in cell membranes generally have hydrophobic amino acids on the external part of the protein. As one might expect, oppositely charged amino acids attract each other and play an important role in determining structure. Additionally, the charged amino acids also play a role in any enzymatic activity that the protein might carry out.

There are four general classifications of the structure of proteins. Primary (1°) structure refers to the

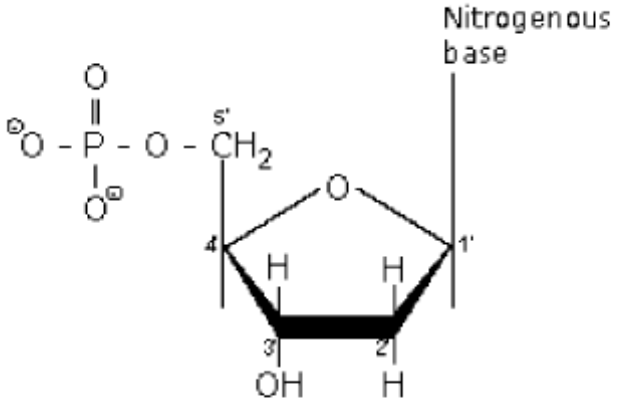
sequence of amino acids in a chain. Secondary (2°) structure describes the degree of coiling or pleated sheet formation within the chain. Tertiary (3°) structure refers to the way the chain is folded three dimensionally. Quaternary (4°) describes the interaction of two or more peptide chains. Hemoglobin (which will be discussed with sickle cell disease) is an example of a protein with quaternary structure.

To study particular proteins, scientists often use gel electrophoresis. For electrophoresing proteins a polymer called polyacrylamide, which has a consistency comparable to tough Jell-0, is used. The polymer (under magnification) looks like a thick mesh of fibers. A solution of many different proteins in a mild detergent is injected into the polymer.

The gel is connected to two electrodes, one end negative and one end positive. The detergent molecules surround each protein molecule and since the detergent molecules are negatively charged, the proteins surrounded by detergents are attracted toward the positive end. As the molecules move a separation takes place. Bigger molecules cannot move through the polymer as well and therefore do not travel as far. Smaller molecules move more easily through the polymer and make it closer to the positive electrode. Bigger proteins end up closer to the starting line and smaller proteins end up closer to the finish line. Scientist can then see the proteins by staining the gel with a dye that sticks to proteins and if they wish, harvest the proteins and study them individually.

DNA and RNA

Nucleic acids are made of chains of units called nucleotides. Each nucleotide is made of three components: a 5-carbon sugar, (deoxyribose in DNA and ribose in RNA) a base and a phosphate group.



A DNA nucleotide.

What makes each nucleotide different is the base, which is attached to the 5-carbon sugar and the phosphate group. There are five types of bases, (four in DNA and four in RNA): A (adenine), G (guanine), C (cytosine), T (thymine) and U (uracil). A, C, and G are found in RNA and DNA; Tis found in DNA and U is found in RNA. The bases are also classified as either purines (A and G) or pyrimidines. (C, U, and T). When any two nucleotide chains are bound together (DNA-DNA, DNA- RNA, RNA-RNA), a purine on one chain must bond with a pyrimidine on the corresponding chain. More specifically, A must bond to T or U and C must bond to G. C and G form three hydrogen bonds, while A and T or U form only 2 hydrogen bonds.

Each of our cells has a nearly uncountable number (about $3x10^9$) of these A-T and C-G bonds (called base pairs). All of that DNA is organized into chromosomes. Each chromosome is a single long piece of DNA. Some of the DNA on a chromosome contains instructions for making proteins, or genes, but about 98o/o of all DNA is something else. The "something else" includes genes that no longer work, viral DNA from viruses that infected our ancestors long ago, repeated sequences of the same DNA, and many more elements that seem to be important but scientists are still figuring out. Often, the extras DNA is referred to as "junk" DNA. This may be a misnomer, but until more research is done, we can not be sure.

No one knows yet exactly how many genes are in our DNA but current estimates are around 25,000. Each individual gene is made up of many sets of three bases called codons. The gene consists of the codons in between the start and stop codons. Since three nucleotides make up one codon and there are 4 possible bases then there are 64 possible codons (4x4x4). One codon is considered the "start codon" (AUG) since it begins the gene, several codons are called "stop codons" (UAG, UGA, and UAA) since they signal the end of a gene, and the others code for various amino acids.

Most human genes have breaks in their DNA sequence that are not part of the instructions for building proteins, although the entire sequence of the DNA is transcribed into mRNA. The breaks are called introns. After the gene is transcribed, special mechanisms in the cell "splice" or cut out the introns. The parts that are used are called exons. Some scientists believe that much of human complexity comes from using a single gene "spliced" in many different ways to create instructions for several proteins.

The chromosomes are not the only areas that keep DNA. Some genes (exactly 37 genes which code for 13 proteins) are found in mitochondrial DNA. This type of DNA is slightly different physically and probably evolved differently than chromosomal DNA. Physically, it is found in a double helix like chromosomal DNA, but instead of a linear string, it loops back on itself and forms a circle of DNA, not surprisingly called "circular DNA".

From DNA to RNA to Proteins

If the information kept in DNA could not somehow be translated into something useful, then no life could take place. We have discussed proteins and DNA thus far. How these two are related is that DNA (more specifically the genes within the DNA) code for specific proteins. The processes that carry protein synthesis out are called transcription and translation, and another nucleic acid called RNA (ribonucleic acid) is the molecule that makes it possible.

Genes are a set of instructions for making proteins. The processes of creating a protein from genes are called transcription and translation. Since all DNA is contained in the nucleus and protein synthesis takes place in the cytoplasm of the cell, the information contained in the DNA must somehow be transported outside of the nucleus. This is the process of transcription.

The first step in transcription involves a protein called RNA polymerase (RNAP). RNAP binds to DNA and the DNA double helix begins to unwind. The RNAP moves along one side of the unwound DNA molecule (which can now be thought of as a template) and RNA nucleotides are added to it, forming a chain. When the RNAP hits a certain sequence of nucleotides on the DNA template called the termination sequence, the RNAP stops transcribing. The newly formed chain (now called mRNA) removes itself from the DNA template, and the DNA template rewinds itself.

Once the RNA is transcribed, the splicing process described above can take place. Now that there is a working copy of the DNA in the form of RNA, proteins can be formed. This occurs in a process called translation. This process takes place in the cytoplasm and requires four components: a ribosome, the mRNA strand, transfer RNAs (tRNA), and amino acids.

First, the mRNA travels out of the nucleus where it was made, and it encounters a ribosome in the cytoplasm. The ribosome binds the mRNA strand at the ribosome-binding site that contains an AUG codon (the "start" codon). When the AUG codon is in place in the ribosome, the rest of translation can begin.

This is where a different type of RNA called tRNA comes into play. Each tRNA molecule has a three-lettered code called the anti-codon on one end and a specific amino acid (based on the anti-codon) on the other. Remember that the mRNA is bound to a ribosome. Let's imagine that the codon on the mRNA that is bound to the ribosome is AUG. A tRNA with the anti-codon UAC would bind to the AUG codon on the mRNA. The amino acid that corresponds to the anti-codon UAC is methionine. Therefore, a methionine comes off and will be the first amino acid in the newly forming polypeptide chain. All proteins start with a methionine since it is the start codon. However, many proteins are later processed and often the first several amino acids are cut off from the rest of the protein.

Now, the ribosome moves along the mRNA chain to the next three-lettered codon. Lets pretend that it is GUC. A tRNA molecule with the anti-codon CAG {with the amino acid valine attached} will bind to the GUC

codon. The valine comes off after it forms a peptide bond between the carboxyl group of the tyrosine and its own amino group. Now there are two amino acids in the polypeptide chain. The ribosome continues to move along the mRNA, the tRNA molecules continue to bind and release their amino acids, and peptide bonds continue to form among new amino acids. This goes on until the ribosome binds a special codon (UAG, UGA, or UAA) called the stop codon. A release factor binds to the mRNA and the polypeptide chain breaks away.

The newly formed polypeptide chain takes on a characteristic structure determined by the sequence of the amino acids. A new protein molecule has just been formed.

Gene Expression

If every gene were being transcribed and translated into proteins in every cell, our cells would be a mess. Genes need a way to be turned on and off based on where their cells are located in the body. Genes coding for instructions for a protein needed in muscles do not need to be expressed in the iris of the eye. Genes for generating eye color need to be expressed in the iris. The question is how does a cell turn a gene on and off? How does the cell know whether or not to transcribe a gene?

Part of this task is left up to a sequence in DNA known as the promoter. Promoters are generally found near the beginning of a gene, but not in the gene itself. Depending on what type of cell it is, several different types of proteins might bind the promoter of a single gene. RNA polymerase recognizes the promoter and the proteins bound to the DNA. It knows that it needs to transcribe the nearby gene.

Some genes are physically turned "off" by the cell. A strategy for turning a gene off is known as DNA methylation. This process is defined as adding a methyl group (-CH3) to a cytosine (the other three base pairs do not accept a methyl group). Genes where the cytosines are heavily methylated seem to not be transcribed.

Gene expression is important for several reasons:

Cell differentiation - When each zygote is still just a mass of cells, all of the cells are exactly the same. The process of cells acquiring a specific function is called cell differentiation. For instance, cells that are destined to be brain cells will begin to take on characteristics of a neuron. Certain genes important for neuron function will be turned on, while genes unrelated to neuron function will be turned off. Cells that have not been differentiated are known as stem cells in animals. Researchers are currently investigating how to take the undifferentiated stem cells and turn them into cells of their choice.

Environmental response - In order for our bodies to be able to adapt to our environment, they need to respond to our environment. One of the ways they do that is by changing what genes are on and off. Examples used in this unit include the tanning of skin and the amount of red blood cells in response to oxygen levels. Other examples include our body's response to long-term stress, hormones, or diet.

Genomes

So far, we have used the word genome, and not defined it. But what is the genome really? The simplest definition for a genome is the sequence of all of the DNA in a cell. This includes not only all of the genes coded for in the DNA, but all the other parts. We have essentially the same genome in each of our many cells.

Humans have 3×10^9 (3 billion) base pairs in one set of chromosomes. Since humans have two sets of chromosomes, that comes to 6 billion base pairs in each of our cells. This fact begs a question: How similar is each person compared to every other person in the world? Humans are genetically 99.9°/o similar to each other. While at first glance this statistic makes it seem like we are almost identical to each other, but one has to remember the number of base pairs that we possess. Being 99.9°/o similar means there is one difference in every one thousand base pairs. Since we have 6 billion base pairs in every cell, being 99.9°/o similar means having 6 million differences in base pairs.

Examples

There are many examples of how slight changes can affect phenotype in different people. The following highlight some of the biology of the four traits covered in this unit.

Skin color

A common and very visible example of how the .01°/o difference in genome can be seen in skin color. Melanin, which is the pigment responsible for human skin color is produced by melanocytes located in the epidermis of the skin. All people, regardless of skin coloration have approximately the same number of melanocytes. Additionally, we all make the same types of melanin. Differences in the amounts of three types of melanin make up all the variation you find in human skin color. The differences in skin color among people can be attributed to the extent of which the genes for proteins that make melanin are expressed. These differences in phenotype are directly related to the small differences in the genomes of each individual. Some individuals lack the gene for producing melanin all together. This condition is called albinism.

One of the proteins responsible for making melanin is tyrosinase. Tyrosinase works early in the process and catalyzes the reaction of the amino acid tyrosine with oxygen to form DOPA, a precursor of melanin. Another protein converts DOPA to another molecule and so on down the assembly line until melanin is made. A problem at the step of tyrosinase will disturb the activity further down the assembly line and melanin will not be made.

http://en.wikipedia.org/wiki/Skin http://en.wikipedia.org/wiki/Skin_color
http://en.wikipedia.org/wiki/Suntanning

Familial Hypercholesterolemia

Another example of genomic differences in people, is a disease known as familial hypercholesterolemia (FH). This genetic disease causes a condition in which carriers of this gene have abnormally high LDL (low-density lipoprotein) levels. The high LDL levels cause many problems including heart disease at a young age. Additionally, fatty deposits develop in the body, especially at joints such as the knees. FH is caused by a mutation in the gene that codes for the LDL receptor protein. The LDL receptor removes LDL particles from blood plasma. LDL cholesterol usually circulates the body for 2 days before it is cleared by the liver. Since the LDL receptor does not clear LDL particles properly in patients with FH, this genetic condition doubles the amount of time that the cholesterol takes to be cleared, thus elevating cholesterol levels.

http://en.wikipedia.org/wiki/Familial_hypercholeterolemia

http://en.wikipedia.org/wiki/LDL_receptor

Lactose Intolerance

Another example of a genetic difference is the cause of lactose intolerance. Lactose, a disaccharide, is present in dairy products. The enzyme lactase helps people and animals digest milk. Most people can break down lactose when they are very young because the cells in their intestines are still making lactase. However, for most of the world's population, lactase production slows down or stops entirely. Without lactase, naturally occurring bacteria that live in our intestines break down the lactose, but generate gas in a fermentation process. The gas produces uncomfortable and unwelcome symptoms: gas, stomach cramps, bloating, and diarrhea.

http://en.wikipedia.org/wiki!Lactose_intolerance

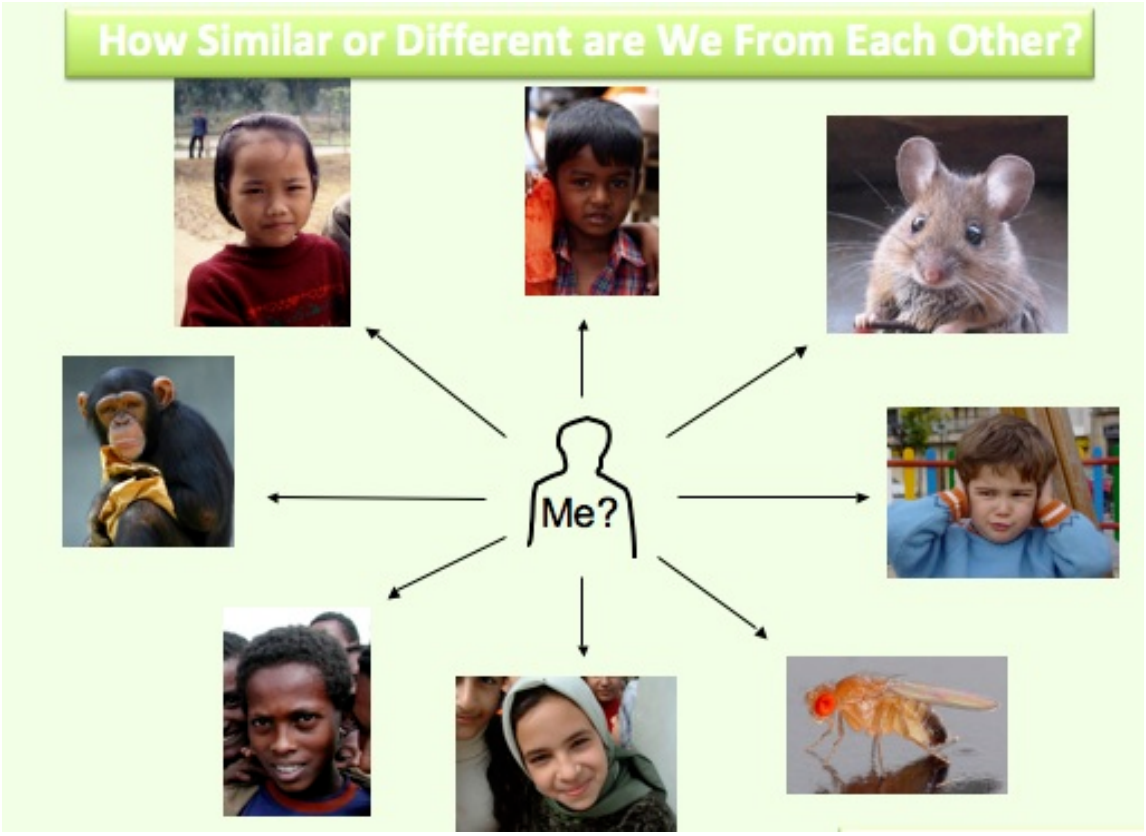
Sickle-cell disease

Some genetic differences can result in chronic illnesses and sometimes fatal. Sickle-cell disease is one such condition. Sickle-cell disease results from a change in a gene that codes for hemoglobin a main component of red blood cells. When cells with "sickle" hemoglobin de-oxygenate, the hemoglobin sticks together forming long chains that change shape of the red blood cell into a crescent moon or sickle shape. When these red blood cells change shape, they can cause clots in the arteries, blocking oxygen from getting to down stream tissues, thus causing serious consequences such as heart attacks and strokes.

Sickle-cell disease in a recessive disease that is thought to be common in populations with a high incidence of malaria because carrying a single copy of gene that makes "sickle" hemoglobin protects that person from malaria.

http://en.wikipedia.org/wiki!Hemglobin http://en.wikipedia.org/wiki/Sickle_cell
http://en.wikipedia.org/wiki/Sickle_cell_trait

Learning Set 1: How SIMILAR or DIFFERENT Are We?



Learning Set 1 – HOW SIMILAR OR DIFFERENT ARE WE??

Content Standard	Inquiry Standard	Learning Performance
		1. Students will identify similarities and differences between and within different species based on biological evidence.
	Formulate and revise scientific explanations and models using logic and evidence. (NRC, 1996, A:1D/ 9-12.).	2. Students will generate an initial hypothesis and explanation about the degree of similarity between and within different species based on biological evidence.
	Identify questions and concepts that guide scientific investigations . (NRC, 1996, A:1A/9-12)	3. Students will generate and organize questions about similarity between and within different species based on biological evidence.
In addition to the basic cellular functions common to all cells, most cells in multicellular organisms perform some special functions that others do not. (AAAS, pg. 114, 5C:9-12#2b).		4. Students will construct and revise a model of the skin that demonstrates differences in skin color at the cellular level.
		5. Students will construct an initial explanation for why skin color could vary in different people and provide a reasoning statement that includes skin cells functioning differently.
		6. Students will be able to describe the relationship among relative size from the macro world of organisms to the molecular world of atoms
		7. Students describe the relationship between molecules and atoms as well as their relationship to the relative size from the macro world of organisms to the molecular world.

Learning Set 1: How Similar Or Different Are We?

Overview

Purpose

The main purpose of this Learning Set is to introduce the driving question "How similar or different are we?" and help students begin to realize that any two humans have more biological similarities than differences. This driving question was developed to 1) help engage and interest students, and 2) help them consider themselves in relationship to others. It is useful for students to realize that even a person with a particular disease or disability can still have a lot in common with a person without the disease.

It is also important to help students realize that in order to understand this question we must explore the cellular components of our bodies and the molecules that allow those cells to function (i.e. proteins.). Students are introduced to one example— skin color— to help them understand that we have to look at cells and the functions of those cells if we are to understand how similarities and differences in people can result.

Connection

This Learning Set sets up the Driving Question that students can revisit throughout the unit. Students should learn content in each of the following lessons that will allow them to more completely answer this question at a more scientifically accurate level. This lesson also sets students up for Learning Set 2, which considers cells and proteins and their influence on physical appearance.

Description

Lesson 1

- Students compare and identify the biological similarities and differences between different people and different organisms.
- Students use biological similarities and differences as evidence in writing scientific explanations.

Lesson 2

- Students are introduced to the driving question of the unit "How similar or different are we?"

Lesson 3

- A specific example of skin color is given that allows students to consider skin differences at the cellular level — a prelude to considering the role of proteins in influencing the biology of an organism.
- Students develop a model of how differences in skin color arise. The use of models will be revisited and revised throughout the unit.

Lesson 4

- Students will create a chart showing the progression of size/scale from the macro level to the molecular level, based upon content covered thus far.

Lesson 5

- Students will identify molecules and atoms involved in skin color and their placement on the macro to molecular chart.

Learning Goals
The learning goals addressed in this Learning Set are darkened.

National Standards

- Formulate and revise scientific explanations and models using logic and evidence. (NRC, 1996, A:1D/ 9-12.).
- Identify questions and concepts that guide scientific investigations . (NRC, 1996, A:1A/9-12)
- In addition to the basic cellular functions common to all cells, most cells in multi-cellular organisms perform some special functions that others do not. (AAAS, pg. 114, 5C:9-12#2b).

Michigan Standards
B2.4d Analyze the relationships among organisms based on their shared physical, biochemical, genetic, and cellular characteristics and functional processes.

Prior Knowledge

- Basic familiarity with internal organs such as the brain, the lungs, and the heart. Students should realize that all animals have these organs.
- Tissue in the human body is made of cells.

Student Conceptual Challenges

- Students may have difficulty determining which differences are biologically based.

Time
5 days

Lesson 1: How similar or different are we? -Anchoring Activity and Scientific Explanations

OVERVIEW

Purpose

This lesson serves two primary purposes. The first is to get students to start thinking about physical differences and similarities between themselves, their classmates and other people and other species. This discussion serves as an anchor providing students with a context and a foundation for the rest of the unit. This activity should be referred to repeatedly in the unit as you revise answers to the driving question. The second purpose for this lesson is to introduce to students strategies for writing scientific explanations.

Connection

This lesson serves as the "anchoring" point for the unit. After each lesson, Students will have made progress toward figuring out "*How similar or different are we?"*

Description

In activity 1.1 students compare themselves to their classmates, to other people around the world and other species to generate a list of similarities and differences. Students will use the lists that they generated as evidence to develop scientific explanations to answer the following questions: How similar am I to my classmates? How similar am I to other people in the world? How similar am I to other species?

Safety Guidelines

None applicable

Learning Performance(s)
Students identify similarities and differences between and within different species based on physical morphological evidence.
Students generate an initial hypothesis and explanation of the degree of similarity between and within different species based on physical morphological evidence

PREPARATION

Materials

Learning Set 1 Power point slides 1-5
Student Reader pp. 4-12

INSTRUCTIONAL SEQUENCE

Lesson 1: How similar or different are we?-Anchoring Activity and Scientific Explanations

Activity 1.1
Introducing the unit:

Small Group Activity -- Explore similarities and differences
Tell students that in this unit we will be trying to find out "How similar or different are we from each other and from other organisms?" One way that we can find out about our similarities and differences is through comparing ourselves to others.

Ask students to make a prediction using a scale from 1 to 10, 1 being completely different and 10 being identical, to answer the question "How similar am I to others? " Students should record their prediction in the student reader.

Have students through direct observation; identify similarities and difference between themselves and their classmates. Break students up into groups of two or three and have students construct a list of physical features that are similar or different about himself or herself on a "T" chart in the student reader.

Ask students to consider:

- Obvious characteristics (e.g. skin color, height, number of hands etc.)
- Subtle characteristics (e.g. nose shape, length of fingers etc.)
- Health (e.g. lactose or other food intolerance, allergies, asthma, vision, acne etc.)

Differences identified should be natural or biological – encourage students to avoid considering similarities or differences like hair length, style of dress, contents of breakfast, etc.

Discuss with students the difference between biological and non-biological features. Come to a consensus on the meaning of "biological features". Tell students that this is an important concept for this unit since we are trying to determine how similar or different we are. Use chart paper to start a class list called Scientific Principles. Add biological features and the class definition of this word to the list. Post the list in the room. This list can become a part of your Driving Question Board that will be introduced in Lesson 2.

Teacher Notes: What "biologically" means in this lesson

*"**Biologically**" in this context means any features relating to the biology or living properties of an organism. This includes the cells or organs that make up an organism or the biological molecules that are found in an organism. What is not included in this term are any features that do not relate to the biology of an organism such as different clothing, or different hairstyles. Note that some behaviors – such as schizophrenia can have biological causes, however for now it might be easier to focus just on appearance differences.*

Writing Scientific Explanations - Reflect on similarities and differences.
Discuss results of observations and get students' initial thoughts about degree of similarity. Reconvene students into whole class and share what groups found. If necessary, identify features that are not biological.

Ask the students the following questions after sharing:

- Did you find more similarities or differences? Record the number of each in your student reader.
- If you spent more time do you think you could have found more similarities or more differences?
- (If health related differences were not mentioned) How would this list look if you or someone in your group had asthma? (Pick a difference that cannot be seen on the outside to emphasize biological differences.)
- Identify those features in your list that are highly similar and highly different. What do you think highly similar means? (Give students a few minutes to discuss in their group). Which features do you think were the most similar/different?

Explanation 1- How similar am I to others?
Ask the class to look back at their prediction. After looking at the observations from their "T" chart, do the observations match their prediction? Do they have enough evidence from their observations to convince someone that their prediction was accurate?

Use a courtroom analogy to describe the use of evidence in scientific argumentation and explanations. Ask students if they have ever watched a courtroom drama or reality show. Ask students why lawyers need evidence in order to go to trial. (Lawyers are constantly presenting evidence during a trial to support their claims of innocence or guilt.) Tell students that scientists also use evidence to make arguments to convince people of their claims. They make arguments using scientific explanations that consist of claims based on evidence from the data they collect. **Scientific explanations** have three parts **claim, evidence** and **reasoning**. The observations that students made about their physical similarities and differences can be used as **evidence** to support their claim. A **claim** is a statement that answers the original question. **Reasoning** ties in the scientific knowledge

or theory that justifies the claim and helps determine the appropriate evidence. The reasoning is important in an argument because it connects to the general knowledge of the scientific community, explaining how particular data support a claim. The role of scientific explanations is to build an argument to convince people that the evidence given is strong enough to support the claim.

Instructional Notes: Scientific Explanations

More detailed information regarding Scientific Explanations can be found in the front section of this unit.

Tell students that they now have observations as evidence and they can make a claim rather than a prediction. Ask the students to make a claim that answers the question, "How biologically similar am I to others?" based on their evidence. Explain that evidence should come from the data they collected in their "T" chart.

Through class discussion guide students in the construction of scientific explanations using, evidence and reasoning based on their chart of similarities and differences. First ask students to share their claims and the observations that they feel support the claim. Use their claims and observations to create a class explanation on the board. Their observations can be used as the evidence. Their reasoning should show how the evidence supports the claim using the concept of biological features. Have students record the explanation in their student reader.

Teacher Notes

Student claims could be that they are very similar, very different or anywhere in between. The important thing is for students to support their claim using their observations as evidence. Reasoning statements will be very weak at this point, as students have not learned enough content to support their claims. This can be used as a formative assessment to determine if students understand the terms claim and evidence.

Example:
Claim: On a scale of 1-10, I would rate myself as a level 3 for biological similarity to others in my group.
Evidence: Everyone in my group had different sized body structures. The group all had different colored skin and different shaped facial features. The only similarities were that two people were allergic to pollen. **Reasoning:** There were more differences than similarities in our body parts, which are biological features. Therefore we are not very similar biologically. (*Scientific principle is the concept of biological features*).

Explanation 2- How similar or different are people around the world?
Encourage students to think about similarities and differences between people from different parts of the world:

Slide 1

Ask

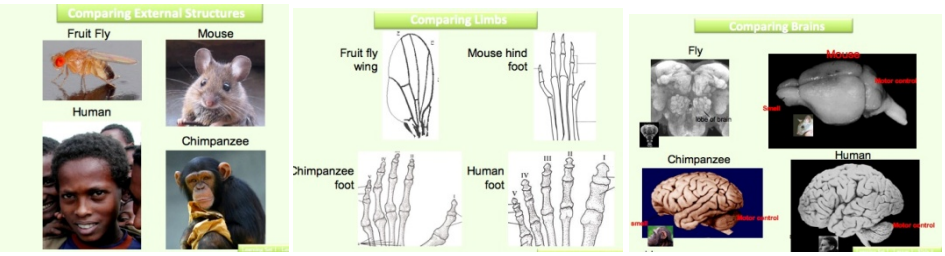
- If you were to do the same task with students from another place in the world, how would your list be different?
- Make a prediction: Do you think that people around the world have more differences than the people in your group? Use the rating system to make your prediction.
- Observe the people in the slide and complete the "T" chart of similarities and differences in the student reader.
- With your group write a scientific explanation to answer the question "**How similar or different are people around the world?"**

Ask two groups to share their explanations (groups that have opposite claims if possible). Have students identify their evidence record it on the board. Ask the class to identify any additional evidence that they have to support either claim. Add it to the list on the board. Ask students to look at the new evidence. Class discussion: Which claim do you think is the strongest?

Teacher notes: Supporting student discourse

Students need to listen to one another. To develop a culture in which listening is important, ask questions that direct students to respond to each other's comments. Ask questions such as; "How does your idea compare with 's idea? What can you add to what ___ just said? What could you add to make ____'s idea clearer? Make sure students understand that there is no right or wrong answer at this point. We are just looking at the strength of the claims based on the evidence available right now. We will continue to collect more data as the unit progresses. More information on supporting student discourse can be found in the front section of this unit.

Explanation 3- How similar or different are we from other species?



Slide 2, 3 and 4 - Encourage students to think about similarities and differences between different species.

To help students think about how humans compare to other animals, show the series PowerPoint images of a fly, a mouse, a chimp, and a human. The first slide focuses on external features, the second on limb structure and the last on brain structures

- For each slide, ask the whole class to identify what is similar or different between these different organisms.
- Ask the students to write a claim using their 1 through 10 scale to rank how similar or different they are from the other organisms on the slides.
- Ask students to write their own individual scientific explanation for the question- How similar or different are we from other organisms? Remind them that they need to add evidence and reasoning to the claim that they just wrote.
- After sharing their explanations, ask if considering the similarities and differences between themselves and other organisms makes them think about changing how they ranked the similarities between themselves and their group. If it has changed, how and why?

Teacher notes:

Point of comparison: *Students should realize from this activity that there is a continuum of similarity between these different organisms- some animals have much more in common with humans and some have very little (although even very distant ones have some similarities). Ultimately we will want students to realize that those animals that share more similarities with humans also have more similar genomes than those animals that are more different.*

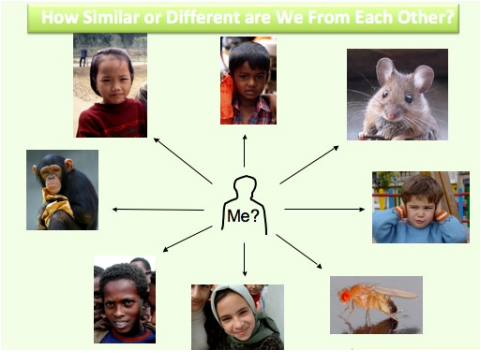
The point of thinking about internal structures is to get students to think about bodily functions and the organs that carry out those functions. Later we want students to think about explanations for diseases that affect organs such as the brain. In addition, this comparison of internal structure helps extend the structures of comparison beyond just the surface structures and pushes students to think more broadly about difference and similarities in organisms.

Will this unit provide answers to all similarities and differences identified by students?
Realize that the unit will not be able to provide specific answers to many of the specific physical features that students might identify here. Many of the traits that relate to appearance are complex, often involving many genes, and are not completely understood by scientists. Students will learn the scientific theory that will let them understand and develop explanations for how all these difference and similarities can arise.

What's the point of this activity? The point of this activity is for the teacher to assess prior ideas students have about how humans differ. It is helpful for the teacher to know whether their students initially think that humans are very different or very similar. This activity seeks to engage students, and help them consider themselves in relationship to others – relating to the driving question "how similar are we?" It is useful for students to realize that even a person with a particular disease or disability can still have a lot in common with a person without the disease.
Ultimately, (by the end of the unit), we want students to realize that any two humans are much more similar than different and this is because their genomes are very similar in DNA sequence.

Wrapping up the Lesson

Show slide 5



Ask students to discuss in their groups the following questions: Are we more similar to each other than to other species? Why or why not? What do you think might cause these biological similarities and differences? Have selected groups share their ideas.

Homework: Reading 1.1 - Student Reader

Introduce the reader and complete questions: Assign reading 1.1. To introduce the reading, the "Before You Read" should be discussed in class. Ask students to record their ideas in the reader. Set a purpose for reading by reviewing the **APPLY** and asking student to predict the meaning of key words. Assign the reading and questions for homework.

Lesson 2: How similar or different are we? –Introducing the Driving Question Board

OVERVIEW

Purpose
The main purpose of this lesson is to introduce the driving question "How similar or different are we?" and help students begin to realize that any two humans have more biological similarities than differences. This driving question was developed to 1) help engage and interest students, and 2) help students contextualize all the knowledge they will learn over the next few weeks.

It is also important to help students realize that in order to understand this question we must explore the cellular components of our bodies and the molecules that allow those cells to function (i.e. proteins.). Students are introduced to one example— skin color— to help them understand that we have to look at cells and the functions of those cells if we are to understand how similarities and differences in people can result.

Connection
This lesson sets up the Driving Question that students will revisit through out the unit. Students should learn content in each of the following lessons that will allow them to more completely answer this question at a more scientifically accurate level.

Description
In activity 1.2a Students are introduced to the driving question of the unit "How similar or different are we?" Students will generate a list of questions that will be organized into a Driving Question Board (DQB- see unit overview for description) that will be used throughout the unit.

Safety Guidelines
None applicable

Learning Performance(s)
Students will generate and organize questions about similarity between and within different species based on physical morphological evidence.

PREPARATION

Materials
Post-it notes- One set per group
Student Reader pp. 13-14
Poster board or classroom wall for display

INSTRUCTIONAL SEQUENCE

Reviewing Reading 1.1:
Start the lesson by reviewing Homework Reading in Activity 1.1. Ask students:

- How were the mothers able to identify the cause of the biological similarities in their daughters? (DNA testing)
- Where is DNA found in your body? (Refer students back to the article to show that DNA is a molecule found in the cells and that it is passed from parent to child.)
- What do you think the DNA testing showed? (The DNA in the girls' cells showed that they were probably sisters)
- Do you think that looking at cells can also help explain biological differences between people?

Always follow up these types of questions with having students defend their responses. In this case, the follow up question might be, "Why do you think so?" or "How might cells help us explain the differences?"

Activity 1.2: Driving Question Board (DQB)

Introducing the Driving Question:
Write on the board the driving question: "How similar or different are we from each other?" Ask the students to write it in their reader. Ask students how the information about cells and DNA that we just discussed might help to answer the driving question. Ask students: "Is this information enough to answer our driving question? Do we have enough evidence to create an argument that would convince people that...(insert whatever answers students gave when asked how the article helped answer the driving question)? What do we still need to know? Let's generate a list of questions you have that might help you investigate how similar or different are we from each other and help you explain what causes the similarities and differences.

Teaching Strategy:

> ***The DQB is a tool used to focus students' attention, record what they have learned and, as in a road map, show Ss where they have been and the direction they are going. After Lesson 2, you will create a DQB based on the questions your Ss raise. Look at the board with Ss in each lesson. Add your list of Scientific Principles from Lesson 1 to the board. Post on it drawings, models, concept maps, etc. your Ss create that relate to specific questions. Make sure that the class answers most of the questions by the end of the unit. It is important to make this board visible to all Ss, and to refer to it often in order make connections among activities and Ss conceptual understanding.***

Creating the Driving Question Board
Ask students to look back at the observations they made of biological similarities and differences in people. Write down any questions that they think might help to explain those biological features. Put the following two examples on the board of what they might want to know:

1. Why different people have different skin color?
2. How some people become allergic to certain foods and others do not?

- Review questioning words (Who? What? Where? When? How? Why?) and remind students that all of their questions should not start with the same word.

- After individual students have generated their own list, they should share with their group and come up with 5 questions that they all agree are the most important. Tell each group they must come up with at least 5 questions. Those questions should be put on sticky notes and grouped together by similar topics. The teacher may have to demonstrate this with the sample questions on the board. (Example: One question might go in a category called "Physical characteristics"- how we look and one might go in a category called "Internal characteristics"- how the body works) Allow students to organize their questions in whatever way makes sense to their group.

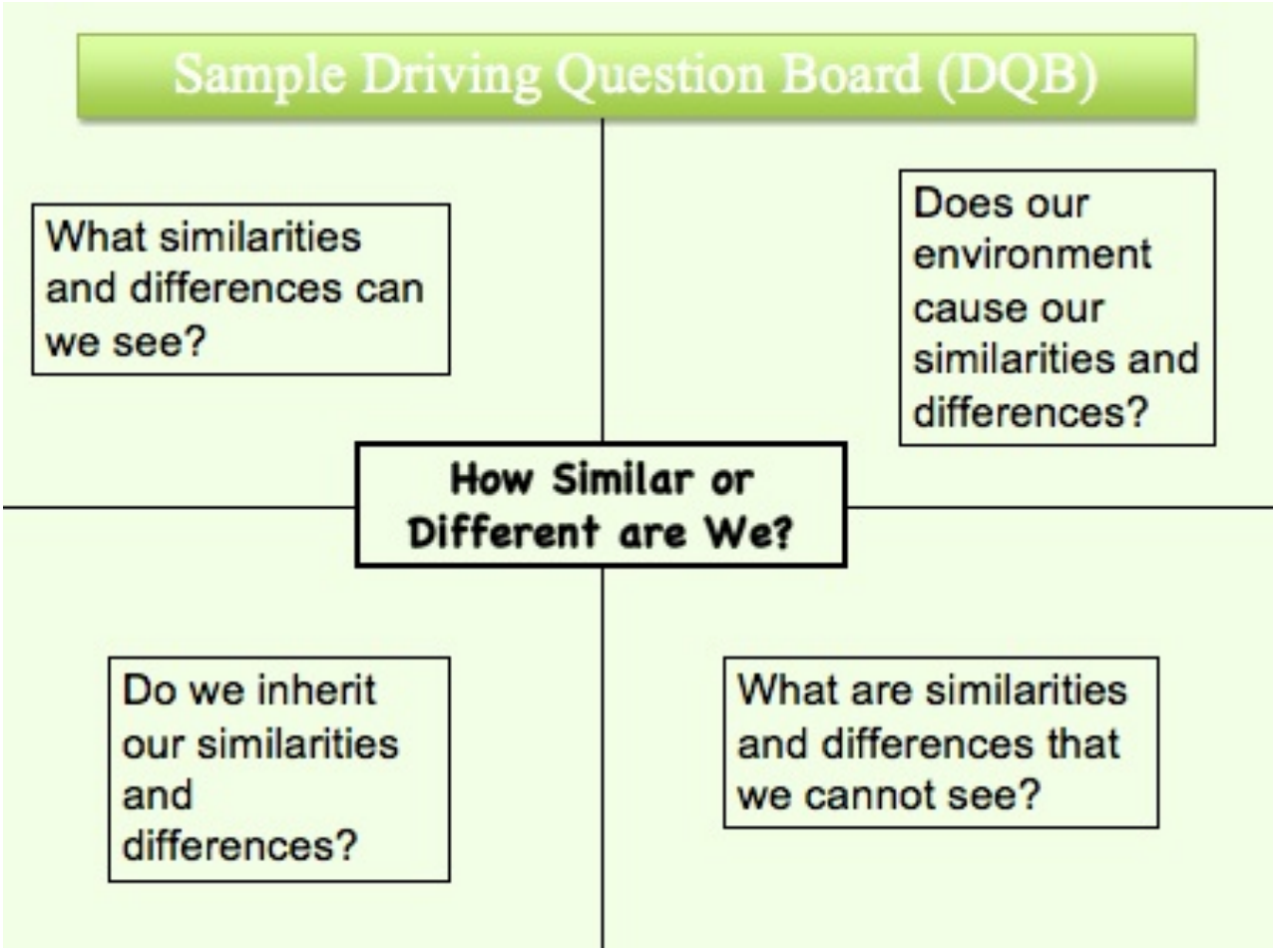
- Write the driving question at the top of the board. Ask each group to share how they classified their questions. List common topics on the board and label one column "Other".

- Model placing questions on the board by placing the two teacher questions, "Why do different people have different skin color?" or "How do some people become allergic to certain foods and others do not?" (asked earlier) into the appropriate categories developed by the class.

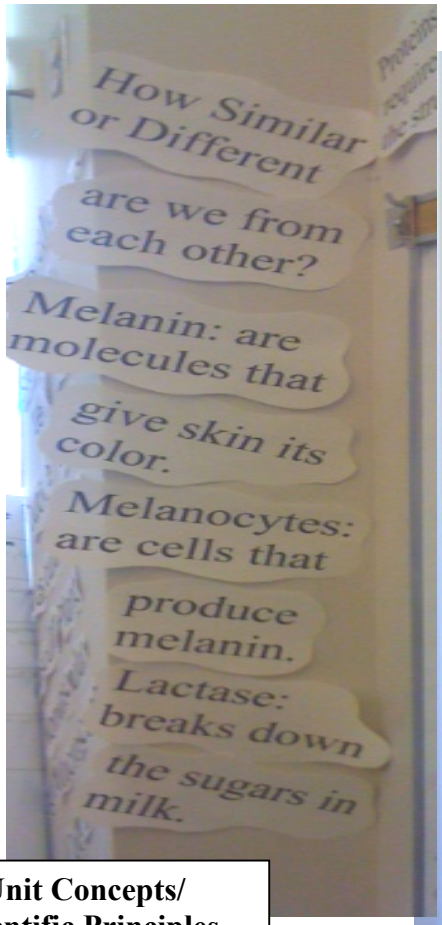
- Have each group come up to the board place their questions under the appropriate topic. If students cannot decide where their question fits, place it under "Other". After all of the groups have put up their questions support students in coming to consensus on the organization of the questions through discussion.

Wrapping up Activity 1.2
Tell students that they have just created a driving question board. The board will be displayed in the room and as they go through the unit and things will be added to it. By the end of the unit they will be able to see all of the questions that they answered and the evidence that they gathered to find out how similar or different we are.

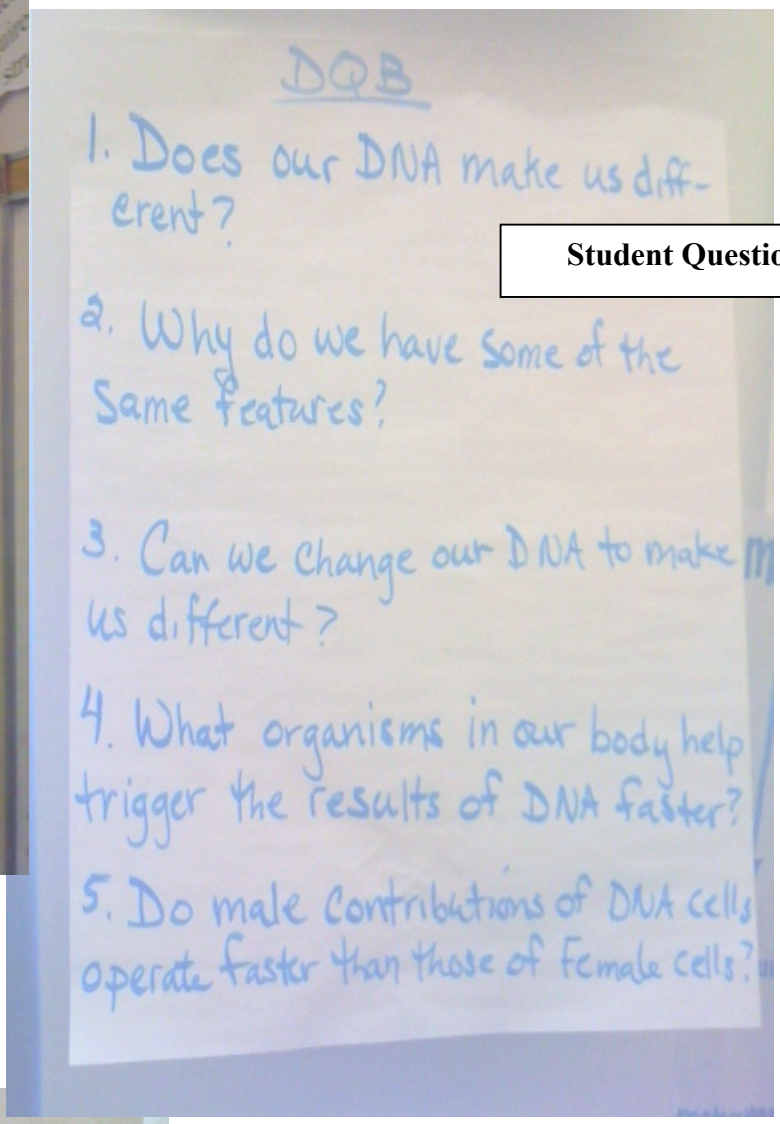
Driving Question Board



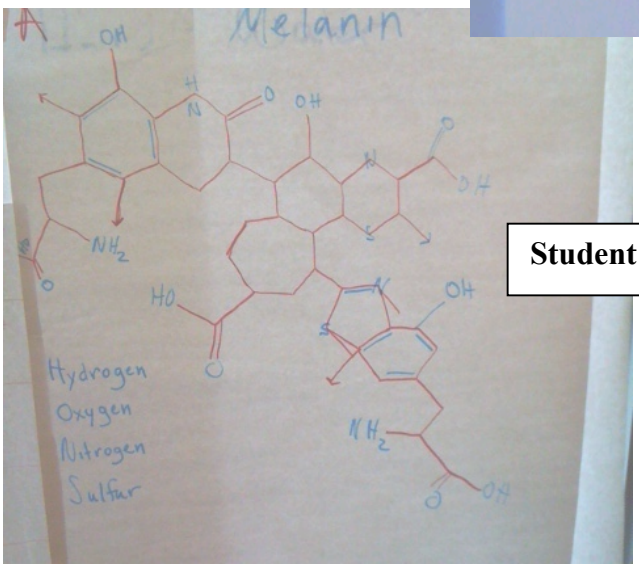
Sample Driving Question Board Elements



Unit Concepts/ Scientific Principles



Student Questions



Student Work

Lesson 3: How similar or different is our skin?

OVERVIEW

Purpose
It is important to help students realize that in order to understand the Driving Question we must explore the cellular components of our bodies. Students are introduced to one example— skin color— to help them explore similarities and differences in people at the cellular level.

Connection
In this lesson students should learn content that will allow them to more completely answer the Driving Question at a more scientifically accurate level.

Description
A specific example of skin color is given that allows students to consider skin differences at the cellular level — a prelude to considering the role of proteins in influencing the biology of an organism. Students will develop a model of how differences in skin color arise. This model will be revisited and revised throughout the unit.

Safety Guidelines
None applicable

Learning Performance(s)
Students will construct and revise a model of the skin that demonstrates differences in skin color at the cellular level.
Construct an initial explanation for why skin color could vary in different people and provide a reasoning statement that includes skin cells functioning differently.

PREPARATION

Materials
Learning Set 1 Slides 6-11
Magnifying glasses
Student Reader pp. 15-23

INSTRUCTIONAL SEQUENCE

Introducing Activity 1.3
Have students look back at the DQB that they just constructed. Say: "Let's take the question about skin color and explore it further. What do you think we need to explore in order to understand how skin color might be different or similar in people?"

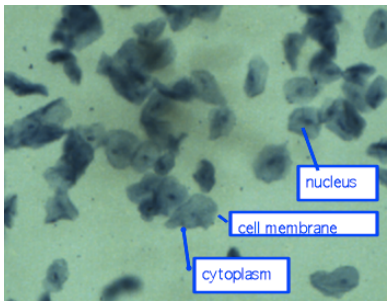
Tell students that they are going to take a closer look at skin. Give each student or group of students a hand lens and ask them to look very carefully at the skin on the back of their hand. Ask students to draw in their reader a detailed drawing of their skin. Remind students that their drawing skills are not important. It is important that they make good observations by drawing and labeling everything they see.

Building a model - Human skin color
Ask students to share their drawing with another person in their group and list similarities and differences in their skin on a "T" chart. Ask students if these observations give them enough evidence to explain similarities and differences in their skin. Ask students what else they think we need to know. Help lead the discussion to looking at "What skin is made of?" (This question could be added to the driving question board.)

A Closer Look at Skin
Encourage student to make predictions about what they would find if they looked at skin under the microscope. Student will make slides of the skin on the back of their hand using ¼ of a 3x5 card. Demonstrate making slides using the following procedure and then have students make their own.

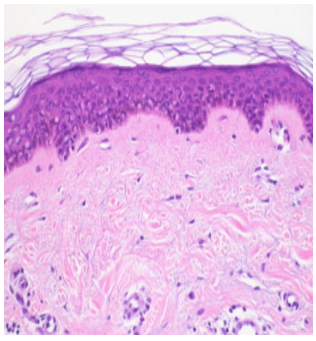
1. Cut a small square out of the center of the card.
2. Cover the hole with a piece of clear tape
3. Press the sticky side of the tape to the back of their hand.
4. Observe their slide, sticky side up, under a microscope
5. Observe another student's slide
6. Draw observations in their reader and list similarities and differences in what they saw on the slides in their "T" chart.

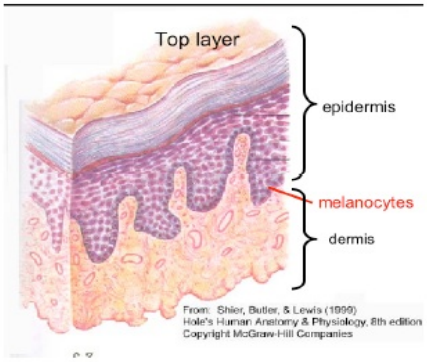
Discuss the similarities and differences that students saw. Ask students what they think the tiny pieces of skin that they observed might be. If no one says cells, then tell students that all living things are made of tiny building blocks called cells. Again ask students if looking at the cells on the slide gave them enough evidence to explain similarities and differences in their skin. Ask students if it was difficult to see differences in the cells? Why? How could they get more evidence about differences in the cells?



Slide 6 - Ask students to compare their drawings with the slide showing skin cells from your cheek as seen through a microscope. What does this slide show that yours did not? (cell structures, more details, etc) Why? (Higher magnification) Discuss the fact that they have only looked at cells from the surface of the skin. Explain to students that in order to gather enough evidence to explain differences in skin color we need to more details about the skin.

Show **slide 7 and 8** Ask students if the skin cells all look the same in each layer of the skin? Discuss similarities and differences.





Explain skin structure and organization briefly, focusing on only a few points relevant to skin color.

- Skin is an organ composed of cells that form layers.
- Tissues are a group of the same type cells with a common structure and function.
- The top layer is called the epidermis, which is made of epithelial tissue.
- The epidermis is where skin color is made so we will focus on it
    - A top layer called the epidermis is comprised of tightly packed dead and living cells – this layer provides strength to our skin.
    - It has a flat, dead layer of cells at the very surface (these are the cells we see at the surface of our body) and a deeper layer of round, living cells

Ask students to draw the skin layers in their reader and label the parts. Tell students that the pictures in these slides and the pictures they drew are models of the skin. In science, a model is something that you make or use to help explain or predict scientific phenomena.

Ask students if they have ever seen a model of your teeth at the dentist? Tell students that because it is hard to see inside our own mouth, the dentist uses the model to show us the shape and size of each tooth. They can also use the model to show how the teeth fit together when you chew your food. Scientists can use models in the same way. They use models to show the relationship between parts of things that are not easy to see. Scientists also use models to show how the parts of things work together.

Ask students what relationships are shown in the models on the slides? Ask students if they think that the model of the skin on the slide or the pictures of the skin that they drew help us to explain why people have different skin color. Ask students:

- What is missing in the model?
- How could we change it to make it more useful?

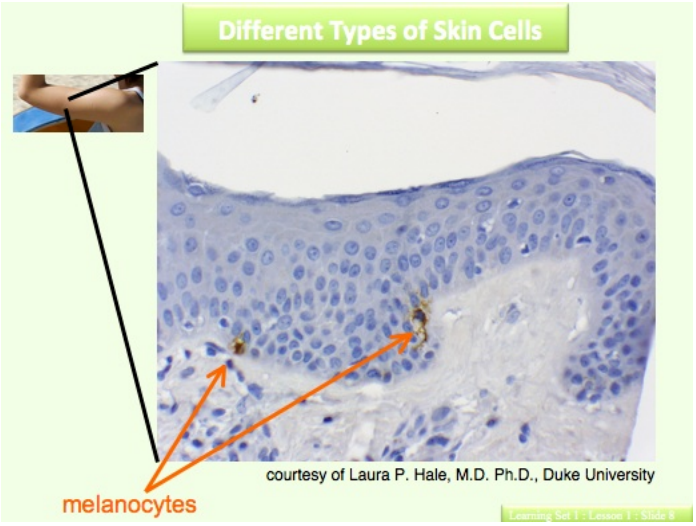
Give students a few minutes to discuss and come to consensus in their groups on a list of at least 3 things that are needed to make their model more useful in explaining differences in skin color. Ask groups to share their ideas.

If students do not talk about cells ask them:

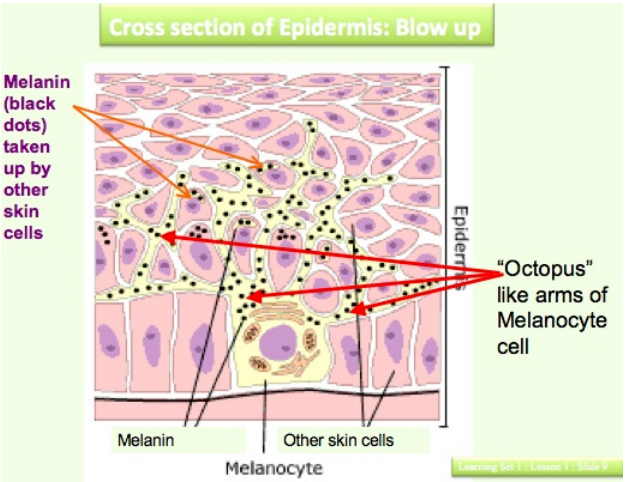
- Can you clearly see all of the parts of the skin?
- Can you see the cells? Can you see inside of the cells?
- Would a model that shows the cells in more detail be helpful?

Teacher Background Knowledge: Scientific Models

A scientific model can usually be thought of as a representation (or set of rules or relationships) that helps scientists predict and explain phenomena. Critical to the idea of a model is that it embodies portions of scientific theories and principles that help scientists generate explanations and predictions for natural phenomena. A scientific model may be a physical object, an equation, a graph, a drawing, a computer program, a paragraph, or even a mental image; however, it must be built on scientific theory and allow someone to make explanations or predictions. A representation by itself is not considered a scientific model if it does not embody scientific theory and does not help explain or help make predictions about phenomena.



Slide 9 - Ask students to compare this slide with the previous slide. How is it different? (Cells are larger which lets you see differences in the shape, size, and color of the cells.) Would this model be more useful in making predictions about differences in skin color? Why?



Show **slide 10**. Ask students to observe the slide as you explain the activity of the melanocytes.

The epidermis has different cells that do different work. Spread across the bottom of the epidermis are pigments producing cells called melanocytes. There are also other types of skin cell in the epidermis. Ask students what they think pigment is. A pigment is a substances produced by living organisms that has a color. Melanocytes produce a dark pigment molecule called melanin. (shown as dark spots in the slide)

- Melanocytes can be thought of as melanin producing factories in our skin. The melanocyte cell has an octopus-like shape that it uses like "arms". These "arms"

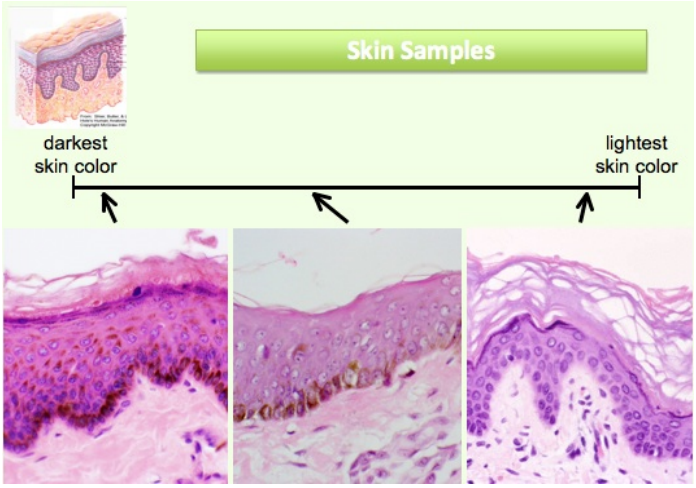
go between the other skins cells to deliver melanin to all the other cells. (see dark spots (melanin) on slide located inside the "arms" of the Melanocyte)

- The melanin pigment is released by melanocytes and is taken up by the other skin cells

Focus on melanocytes and point that these cells are active—they have to produce the melanin pigment so that other cells can take up the pigment. One could also say that these cells have to carry out the activity of producing melanin.

Explain that in general, all humans have the same number of melanocytes and the same 3 types of melanin. Add two or three statements about melanocytes and melanin, such as the ones above, to your Scientific Principles chart on the DQB. Ask students what they think might be the difference between dark and light skin. Tell them to think about their previous model and the slides that they have seen. Make sure you leave Slide 1.3.10 up for students to see.)

- Tell students to make a prediction by discussing with their group how dark and light skin might be different if the **number** of melanocytes and the **type** of melanin is the same in both types of skin.
- Tell students to draw two models that include the melanocytes and melanin to show their predictions. One model should be of dark skin and one of light skin to show the differences.
- Make sure students label their models. Student drawings of skin cells could also be added to the DQB.



Slide 11 shows different skin colors through a microscope. Point out that there are lots of different colors of skin and that these are just three examples along a spectrum. Give students a minute to think about what they are seeing. Ask students to compare the darker skin slides to the lighter skin slides. What are the similarities and differences?

Teacher notes:

The use of light and dark to describe skin color in this unit is intentional. While your students might use terms such as black and white when describing skin, describing skin as dark and light is not only culturally sensitive, it is a more accurate description of the actual color of human skin. No one has truly white or truly black skin. For the same reasons, we placed the samples of skin color on a spectrum to represent how skin color happens in nature.

Make sure students focus on the difference in the number of brown spots, these are the organelles within the cell that contain melanin.
Students may respond:

- darker skin has more melanin
- they both have melanocytes
- they both have other types of skin cells.

Teacher notes:

It is important that the teacher explain that some of the differences in the slides are due to the way the skin was prepared so it could be seen under the microscope. Differences in the amount of pink, purple and blue and the size and structure of the cells are all due to differences in this process not differences in the skin.

Were their predictions correct? Did their models show the same differences and similarities as the actual slides?
Ask students to modify their model to incorporate any new evidence from observing these slides. (Students' models should show more melanin in the model of darker skin)

Activity 1.3 Wrapping Up the lesson - Writing a Scientific Explanation
Do we now have enough evidence to explain how similar or different our skin is? Ask students why they think the dark skin cells have more melanin? Where did the melanin come from? (Melanocytes in darker skin produce more melanin)

Ask students to work together in their group to write a scientific explanation to answer the question "How similar or different is our skin?" Remind students that when they write scientific explanations they need to make a claim and use evidence from the slides and their model to support the claim. Students should use information about the activity of melanocytes from the Scientific Principles chart as their reasoning.

Example:
Claim: *Our skin is very similar.*
Evidence: *All skin is made up of epidermis and dermis. The epidermis is made of skin cells such as melanocytes that produce melanin. We all have the same number of melanocytes and the same kind of melanin.*
Reasoning: *Different skin color is produced because some people have more melanin in their cells than others. The only difference in our skin is people with dark skin have melanocytes that are producing more melanin than people with light skin. Therefore our skin has more similarities than differences.*

Students may also claim that skin is different in appearance; however, it is very similar when you look at the structure. Students may pick other similarities and differences from their models as evidence. It is not important that all students make the same claim. It is only important that they use evidence from their models and observations of slides to support their claim.

Reading 1.3 - Student Reader Homework
Ask students to look at the picture of the cell in the student reader under Reading 1.3. Ask students to compare this picture to the picture of the Melanocyte on the slide. Ask them to identify how they are similar and different. Tell students that the picture is a model of animal cells but it does not show everything about all animal cells. Ask students to read the top part of the article in class to find out how cells in the body are similar and different. Discuss the questions at the end of the reading and ask students to finish the article for homework in order to find out more about differences in skin cells.

Lesson 4: Generating the Macro to Molecular Chart

OVERVIEW

Purpose
The purpose of Lesson 4 is to develop a visual representation of the size and scale (from macro to molecular) of the different ideas presented in the unit thus far. Ideas will be added to this macro-molecular representation as students progress through the unit. Students will also begin to understand how the ideas they learn about align with this chart.

Connections
Lesson 4 incorporates ideas learned in Lessons 1-3 to generate a macro to molecular chart. This helps to provide students with a common vocabulary and base understanding so that when we refer to proteins, amino acids, DNA, etc. in later learning sets all students have a sense of where they lie on the macro to molecular chart (and therefore gain some understanding about size and scale), and they have a common representation to which they can refer throughout the unit.

Description
Activity 1.4 involves students in the development of the macro to molecular chart.

Safety Guidelines
None applicable

Learning Performance:
Students describe the relationships among the relative sizes from the macro world of organisms to the micro world of cells to the molecular world of atoms & molecules.

PREPARATION

Time: one class period

Materials
Tape
Markers
Sticky notes (for each group)
Sticky notes or index cards w/words on them to generate master class list
Student Reader pp. 24-25

Set-Up
Have words from activity (see below) pre-printed on index cards (or sticky notes) and tape to use in the generation of the master macro-molecular chart in the front of the room. Make sure words are written big enough for all students to see. Students will use sticky notes to generate their own word cards for use at their desks.

INSTRUCTIONAL SEQUENCE
Lesson 4: Generating the Macro to Molecular Chart

Introducing Activity 1.4:
In this activity students will create a chart showing the progression of size/scale from the macro level to the molecular level, based upon content covered thus far. This chart will be added to as more content is learned in subsequent lessons.

Carrying Out Activity 1.4:
Review Driving Question: Refer to the DQ (How similar & different are we?): Ask students what our DQ is, and what did we learn so far related to the DQ. Promote *brief* discussion about the first three lessons for review.

Review Reading HW to lead into today's class discussion:
Have students take out the readings & responses from HW last night ("How cells affect skin color")

Break students into small groups. Pass out bunches of sticky notes to each group. Tell them they will be given a short amount of time (5 minutes—it can be made into a competition between groups) to do the following:

- "Using *only* the readings from last night, come up with a list of all the biological characteristics that we all have that are similar, or the same." OR "…come up with a list of all the biological characteristics we all have." For each word you find, write it on a sticky note.
- Demonstrate for students with an example first: pick up the reading yourself and begin scanning. Say, "for example, the first idea I see in this reading is 'hair'. We all have 'hair' so I would write this down on a sticky note."
- Walk around to observe groups are using the readings for their list. They should already be familiar with the content from the HW, so should be able to skim quickly through and find things we all have in common.
- Students might come up with the following: hair, eyes, nose, mouth, other body parts, cells, muscles, liver, teeth, cell organelles, mitochondria, nucleus, organs, epidermis, epidermal cells, dermis, blood vessels, melanocytes, [molecules] melanin, tissues

After the 5 minutes is up, tell the groups to look at all their word cards and organize the cards on their desks from biggest in size to smallest. They should place off to the side, any objects that they are not sure of in terms of size. Also tell them to be sure to have an explanation for any order they provide. Give them a couple minutes to do this.

Have student groups share out their ordering, starting with the biggest objects on their lists. If there are differences between groups, have students discuss and present explanations to resolve. As students share each word and agree to where it should be

placed, put the appropriate pre-made teacher word card on the board. Make sure the class comes to consensus on the final list. Student groups should arrange the cards on their desks if necessary to align with the class master list.

Teacher note: A reminder about supporting student discourse (from Lesson 1)

Students need to listen to one another. To develop a culture in which listening is important, ask questions that direct students to respond to each other's comments. Ask questions such as: "How does your idea compare with _____ 's idea? What can you add to what just said? What could you add to make 's idea clearer? Make sure students understand that there is no right or wrong answer at this point. We are just looking at the strength of the claims based on the evidence available right now. We will continue to collect more data as the unit progresses. More information on supporting student discourse can be found in the front section of this unit.

Generating the Macro-micro chart:
Next, ask students to look at the list we just created and take a minute to discuss with their group: What words in our list appear to be the more general, overarching words? And, how do the more specific words match up with the more general overarching words?

Then have groups share their ideas. As students suggest ideas, pull those words out of the master class list previously generated and place them on the left side of the board. Students should see **body, organs, tissues, and cells** (they may or may not suggest **molecules**) as the more general words. If they do not, promote discussion so they can see that the other words are specific things relating to these words. In other words, hair, eyes, nose, mouth are all parts of the body. Melanocytes are cells. Also if necessary, work in a discussion about why these things were arranged in the order they were.

With the general biological structures pulled out on the left side of the board, have students (in groups if time permits, if not, then as a whole class) decide what specific words on the right side "match" the general words on the left, and organize them accordingly. Promote discussion about words that might be less easy to match. For example, epidermis, dermis, and the various organelles.

Teacher Note: Word Placement

Epidermis and dermis are layers of skin that make up the organ skin, but also contain tissues. They can be placed next to organ and skin in the chart, but would fit better being placed between organ and tissue.

Organelles are not cells, although they are found in cells, and they are larger than molecules. The particular placement of organelles is up for some debate by the students, however, though they might not match one of the general biological structures, they should be placed somewhere between "cells" and "molecules" on the right side of the chart.

Teacher Note: Student Misconception

Because of medical shows on TV, movies, or even their own experiences at the doctor, students might think of our skin as a tissue. Everyone has heard doctors say they need to take a tissue sample, and the surface of skin is often where they take the sample. Be prepared to confront this misconception. Provide students with an example (or two) when doctors have needed to take tissue samples of organs (like skin). For example, when a doctor suspects a tumor somewhere in your body, like your liver, might be cancerous, they will conduct a biopsy, which takes a tissue sample of the liver, or other organ.

In the end, a diagram showing the macro-molecular chart is created with the general biological structures on the left and specific structures on the right. Have students copy this chart into the appropriate place in their student reader. We will refer back to this chart again and again.

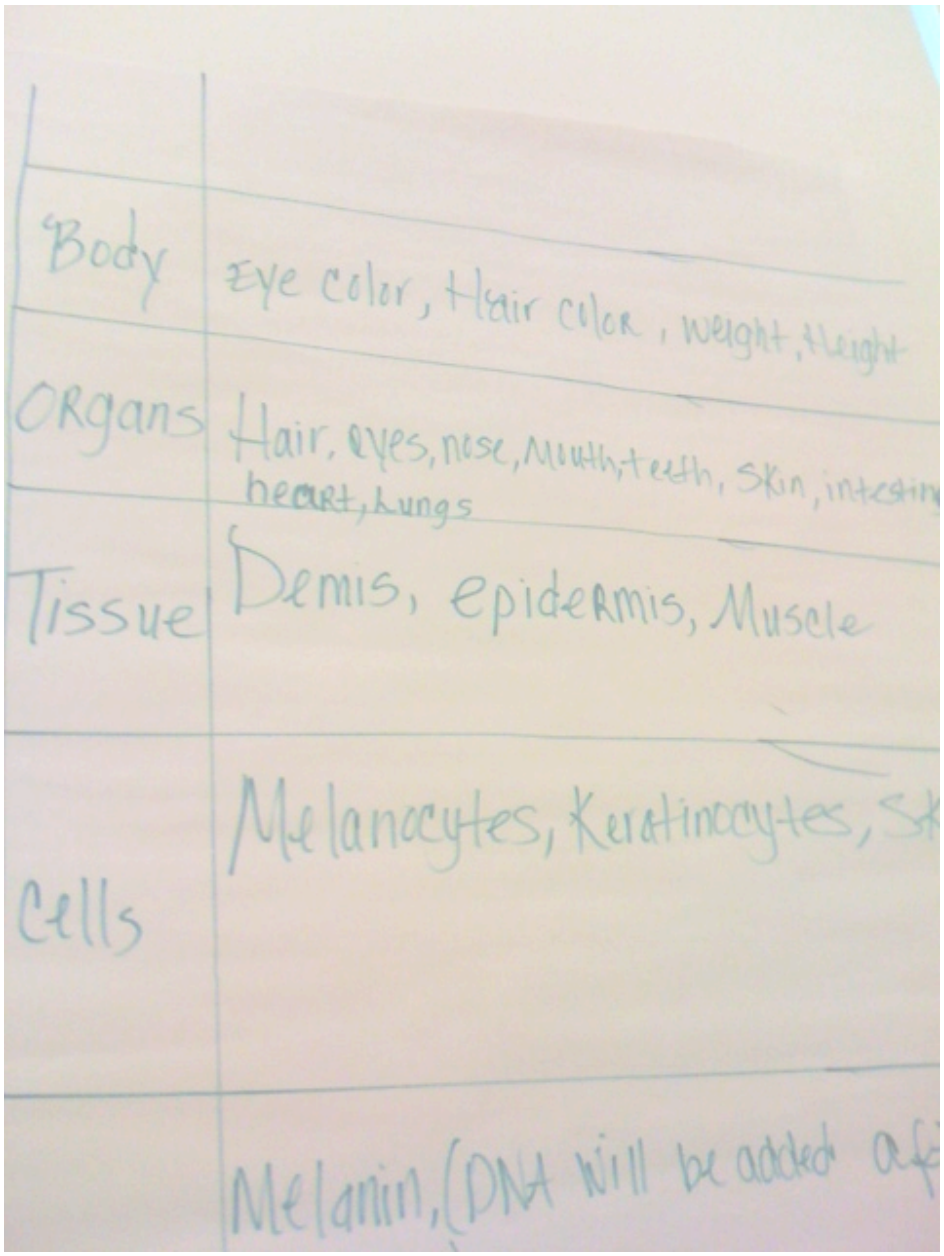
Teacher Note: Macro and Molecular

Before students start to make their macro-molecular chart, discuss what the words macro and molecular mean. Students should know that macro is short for macroscopic, and objects that are visible to the naked eye are placed on this end of the scale. When we discuss items at the molecular level, we are specifically looking at the interactions between the atoms that make up a certain molecule. Items at the molecular level cannot be seen with the naked eye or even a light-microscope.

Sample macro-molecular chart:

Macro **Larger** **size** **Smaller** **Molecular**		
	body	eye color, hair color, weight, height, etc.
	organs	hair, eyes, nose, mouth, teeth, skin, intestines, heart, lungs
	Tissues	Dermis, epidermis, muscle
	cells	melanocytes, keratinocytes, skin cells cell organelles, mitochondria, nucleus (smaller than the cells themselves)
	molecules	melanin, *DNA*
	atoms	*O, H, N, C, S, P, Na, Cl (some possible)*

Sample macro-molecular chart:



Wrapping Up Activity 1.4:

Students should now have written a progression of size from the macro level of the body down to the level of cells, and possibly the molecular level of atoms and molecules. Ask students to look at the chart and see what pattern they are noticing. Students should see that the chart shows the progression of bigger to smaller.

Check for understanding:
Have students write in their reader a response to the following:
Look back to the reading "DNA helps families find adopted kids' siblings". Skim through this reading to find any specific biological structures that are not already in our macro-molecular chart. Identify where you would put the structure(s) in our chart, and explain why. If you don't think the specific structure(s) you find matches with any of our general biological structures, explain why, and suggest a general structure we might be able to add to our chart.

Student should find "DNA" in the reading. It points out that DNA is a ***molecule*** *so students should be able to place it next to "molecule" in the macro-molecular chart. If "molecule" is not in the chart yet, students should see from the reading that because DNA is a molecule, we might want to add molecule to our chart. At the very least students might suggest that it goes below cells.*

Lesson 5: What atoms and molecules are found in our body?

OVERVIEW

Purpose

The purpose of Lesson 5 is to review/provide a *very* basic introduction to molecules and atoms. This lesson is by no means meant to be a complete or detailed chemistry lesson. The students should have a basic idea of what molecules and atoms are and their relative size so they can be placed in the macro-molecular chart. Students should be able to identify atoms and molecules when they come across them in later lessons, as well as tell the difference between atoms and molecules.

Connections

Lesson 5 builds off the macro-molecular chart to dig into our world at an even deeper level than cells in an attempt to explain how we are similar or different. Lesson 5 also provides students with a common vocabulary and base understanding so that when we refer to proteins, amino acids, DNA, etc. in later learning sets all students will have a sense both of where they lie on the macro to molecular chart (and therefore gain some understanding about size and scale) and of the basic chemistry involved.

Description

Genomics is a new way of looking at genetics at the molecular level, so it is important for students to have at least a basic understanding of certain chemical ideas. Lesson 5 reviews/introduces the basic descriptions of atoms and molecules.

Safety Guidelines

None applicable

Learning Performance:
Students describe the relationship between molecules and atoms, as well as their relationship to the relative sizes from the macro world of organisms to the molecular world of atoms & molecules.

PREPARATION

Time: one class period

Materials
Learning Set 1 Slides: 12-13
Large chart paper for each student group
Student Reader p. 26

Introducing Activity 1.5:
This activity includes a mini-chemistry lesson aimed at giving students a review of the most basic fundamentals of molecules and atoms. It is assumed students have all had at least some exposure to atoms/molecules in middle school. For students with no previous exposure, this mini-lesson is not intended to teach in any detail about atoms/molecules. Rather, it is meant to communicate to students that there are things smaller than cells that we will look at throughout the course of the unit, and everyone needs to be on the same page in terms of vocabulary, and have at least a vague conceptualization.

Carrying Out Activity 1.5:
Revisit the macro-molecular chart:
NOTE: If "molecule" was mentioned and added to the list in the previous activity, skip to the next step. If the chart ended with "cells" continue on. Point out to students that our chart ended with "cells." Ask them to work in their small groups to look through the readings again and see if they can find evidence of anything smaller than a cell that we can add to our chart. They should find where it says, "In later sections, you will learn about different components of the cell, such as proteins and different molecules, such as pigment molecules". Add **molecule** to the chart below "cells." Ask students what this location in the chart implies now about the size of molecules.

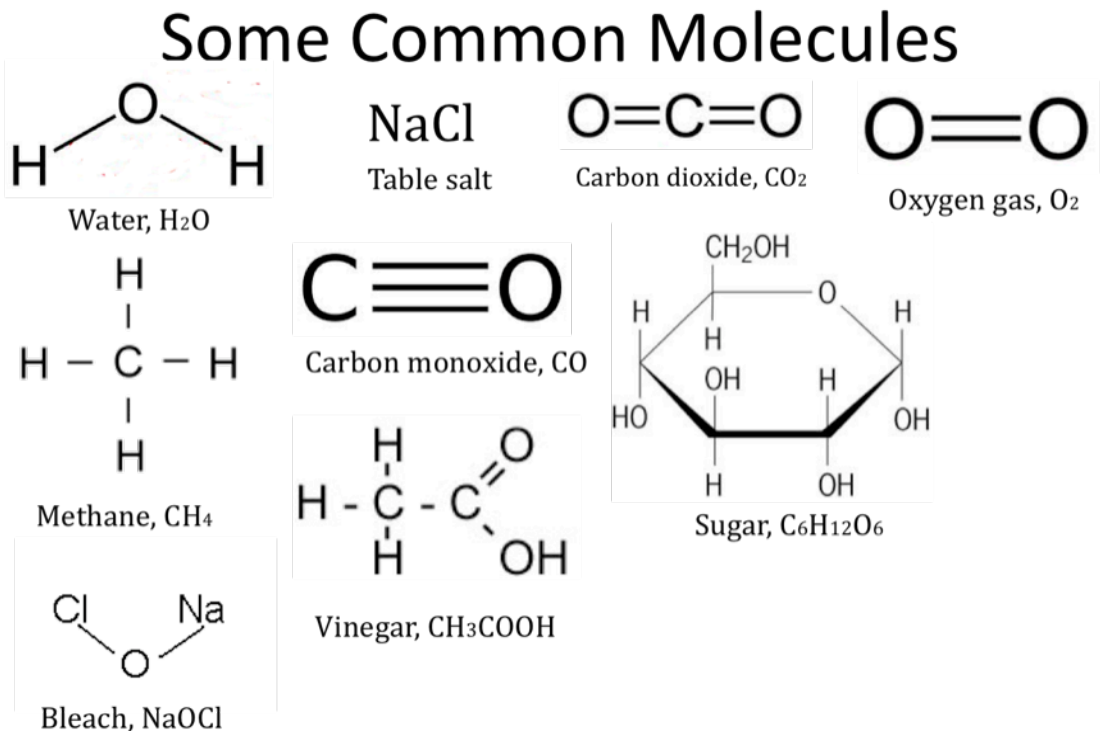
Teacher Note: Molecule size

We are able to see cells under a microscope. Most molecules, however, are too small to see with the naked eye or with a microscope. The device used to "see" molecules is an atomic force microscope. This device interprets signals, which appear as the outlines of individual atoms that make up the molecule. DNA, which will be covered later on in this unit, is an exception, and can be seen with the naked eye. Other "macromolecules", such as polymers, are other exceptions.

Reviewing molecules & atoms:
Write the molecular formula H_2O on the board. Ask students what this is and what they know about it. Accept all responses to uncover their prior knowledge. Hopefully a student will have mentioned that H_2O is a molecule. Ask students if they have heard of the word "molecule".

Have students write down *anything* they know about molecules in their reader on activity sheet 1.5. Can they define molecules? Give examples? Draw pictures? Have students take turns sharing out their ideas and discuss. See if students can provide examples of molecules from their everyday lives (water, H_2O, salt, NaCl, carbon dioxide, CO_2, etc.). If students struggle to identify molecules from their lives give them hints such as "you exhale this molecule" or "you probably use this molecule to flavor your food". Students can identify any molecule they are familiar with. Once students have had enough time to share their own ideas refer to Slide 12 with different representations of simple molecules students should be familiar with.

Slide 12



Ask: Looking at these representations of molecules with which we are already familiar, do you think there is anything smaller than molecules? For example, are any of these molecules made up of anything smaller? If so, what?

Students should come up with **atoms**. Ask them where they would place "atoms" on the macro-molecular chart and why. Elicit their prior knowledge about atoms—Have students write down *anything* they know about atoms in their reader. Can they define? Give examples? Draw?

Have them share out their ideas and discuss. If it seems like students have good basic knowledge about molecules and atoms, move on to "Referring back to phenomenon" below. Good basic knowledge about molecules and atoms for the purposes of these lessons is:

- **Atoms** are commonly defined as the smallest piece of everything that makes up our world (smallest piece of matter, if students are familiar with the term matter). They are usually represented pictorially as circles/spheres. NOTE: There is no need for students to have a conceptual understanding of electrons, protons, or neutrons.
- **Molecules** are made up of two or more atoms. They are usually represented pictorially with circles/spheres joined together. NOTE: There is no need for students to have a conceptual understanding of bonding. It is simply enough for them to know that the atoms that make up any given molecule are chemically joined.
- *Further discussion (if needed):*

Teacher Note: Atoms & A Thought Experiment

Atoms are commonly referred to as the smallest pieces or building blocks of matter. What does it mean to be the "smallest piece"? A THOUGHT EXPERIMENT: If you were to take any single substance and cut it in half and discard one half, then cut the remaining half in half again, and keep cutting in this manner until you got down to the smallest thing possible where you couldn't cut any more, you have an atom (or molecule if it is not a single substance). We know, of course, that atoms can be "cut" further with very large amounts of energy, and that there are in fact things smaller than atoms (e.g. electrons, protons, neutrons) but that is beyond the scope of this unit and not necessarily knowledge for this lesson.

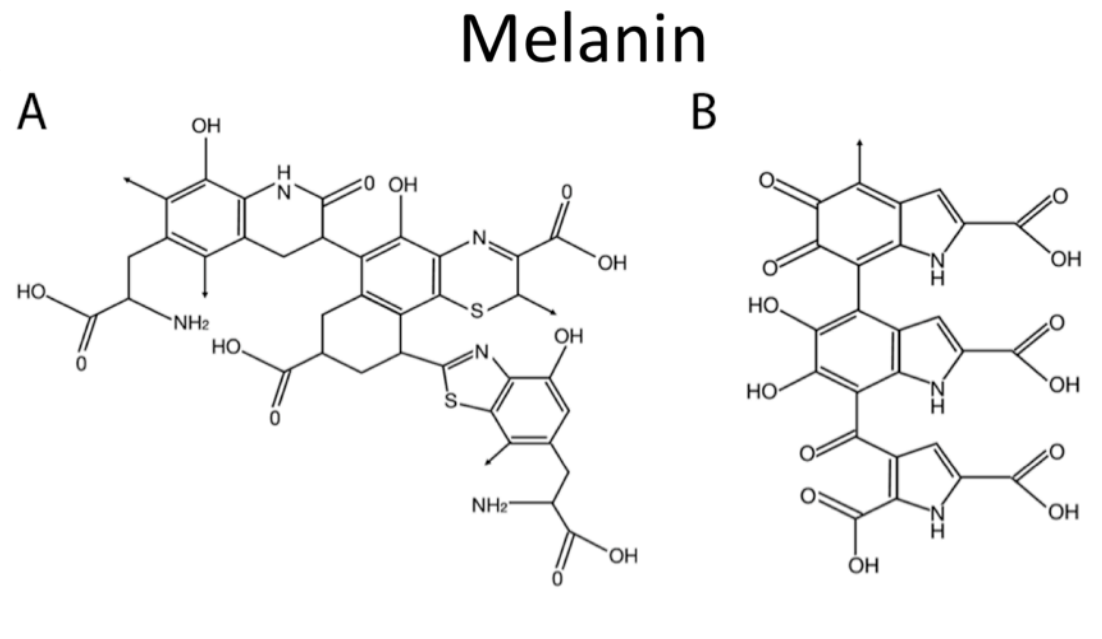
For the purposes of this lesson, the traditional definition is enough. Atoms can exist by themselves, as in the case of the noble gases like helium (He) and Neon (Ne). Other atoms such as oxygen or hydrogen bond with each other to form molecules. It is not within the scope of this unit or this lesson to spend time discussing the make-up of atoms (electrons, protons, neutrons) or bonding between atoms in specific detail. It is enough right now that students are familiar with some of the main elements that make up most organic molecules that will be covered in this unit, namely: oxygen (O), hydrogen (H), carbon (C), and nitrogen (N). We might encounter other elements such as sulfur (S) and phosphorus (P), which can be discussed when they come up.

Referring back to the phenomenon: Skin color & melanin

The word "melanin" may or may not already be on the chart. If not ask students if there is anything else from the previous readings we can add to our chart related to molecules. If

"melanin" is already on the list, ask how it relates to the word "molecule". Students should be able to say, from the readings, that melanin is a molecule—a pigment molecule.
Point out that we have "cells" on the chart. Ask students how they think molecules are related to cells. Students should be able to say that cells are made up of molecules. Refer to Slide 1.b, which shows the molecular structure of melanin.

Slide 1.5b



Molecular structure of phaeomelanin (A) and eumelanin (B).
[Diagram from http://photoprotection.clinuvel.com/node/204.]

Teacher Note: Melanin

Shown on the slide are two types of melanin (phaeomelanin and eumelanin) that are responsible for different skin colors. You should point out to students that "melanin" does not mean a single molecule, but a class of molecules that have similar characteristics. Two types of melanin are shown, but there are more than these two. The molecular structure shows carbon rings, which will be covered in detail in a later lesson. The point of this is to expose students to the structure of the molecule and to have them be able to identify the different elements that make up the molecule. You may want to tell students that the lines in the structure represent chemical bonds, and when two lines meet there is a carbon atom.

Ask: What is melanin made of? See if students can specifically identify any of the specific elements that make up melanin. They should be able to identify oxygen, hydrogen, possibly nitrogen and sulfur, from their symbols. Also, some students might be able to identify carbons

where lines meet (See teacher note above). If not, spend a little time reviewing these chemical symbols, which students will need to be able to recognize in future lessons. Have them write the names and symbols of these common elements in their readers.

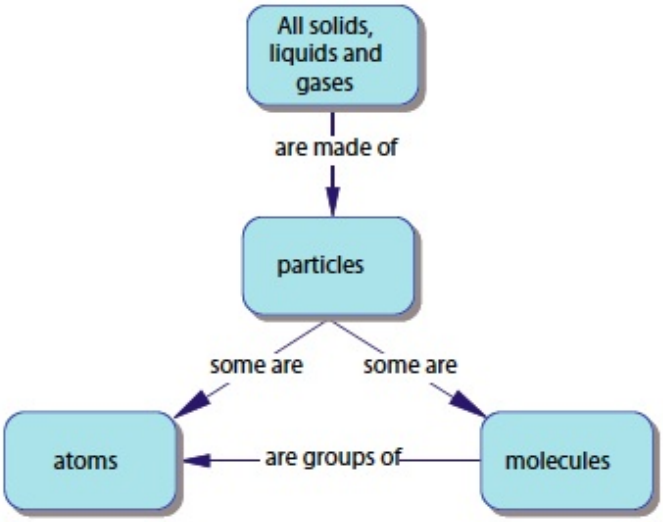
OPTIONAL Activity- Concept Mapping:
In order to help your students better understand connections between items in their macro-molecular chart, especially atoms and molecules, they can create a concept map (see example below of a concept map).

[Taken from LS6, Lesson 2]:
Teacher Background: Concept Maps

Students should realize that a concept map is a visual representation of ideas and how the ideas are related to each other. Words are placed on the map and are connected with lines. Also on the lines there should be linking words that illustrate the relationship indicated by the line connecting the concepts. Other things can be added to the concept map as well to make it more complete, for example, definitions and examples, or diagrams. Students should also realize that there is no one right way to make a concept map. There are many "right" ways, as long as students can show why two or more words link together.

You will do a simple practice example with the class. If your students are very familiar with concept mapping you can skip the practice and move on to the rest of the lesson.

Practice:
Work as a class to make a concept map (on chart paper or on the board) that incorporates the following words: organs, cells, organelles, molecules, melanin, atoms, oxygen, hydrogen, nitrogen and sulfur. You could even have a student lead the creation of the concept map at the board while you facilitate. Try to encourage students to find as many logical connections between concepts as possible, even ones that might not be immediately obvious. After the initial connections are made have each group of students complete their own map. Encourage students to use words to describe the connections between concepts and add concepts as needed.
Sample concept map:



OPTIONAL, Go back to the macro-molecular chart:
Providing a semi-quantitative look at the macro-molecular chart:

Students often struggle to visualize things they cannot see. Even if they see pictures of them, they struggle to conceptualize really just how small something like a cell or atom really is. You may want to incorporate this piece into your lesson to provide students with a more conceptual understanding of the relative size of items in their macro-molecular chart.

Show your class a dime. Tell them that a dime is just about a centimeter in diameter (a little more than a centimeter). Hold up a meter stick (or point out an object that is about the size of a meter in your classroom). *Ask students: How many centimeters are in a meter? And, If we lined up dimes along this meter stick, how many dimes would fit?* (you could fit about 100 dimes along the meter stick). This means that a dime is **one hundred times smaller than** a meter.

Cells are 10,000 (ten thousand) times smaller than a dime. *Ask that just like we did with the dimes and the meter stick, if we lined up skin cells along the diameter of the dime (OOOOO…), about how many skin cells could fit, just in a line along the diameter?* (about 10,000!) This means that a cell is **ten thousand times smaller than** a dime. We can see cells this size through a microscope.

A big molecule like DNA is 1000 times smaller than a cell, and 10,000,000 (ten million) times smaller than a dime. *Ask, again, if we lined up a DNA molecule along the diameter of a dime, about how many would fit?* (10,000,000!) This means that a DNA molecule is **ten million times smaller than** a dime. We cannot see that small, even with a regular microscope.

Smaller molecules, and atoms are even smaller! A water molecule, for example, is about 1000 times smaller than a DNA molecule. It is about 1,000,000 (one million) times smaller than a cell. And, it is about 10,000,000,000 (ten billion) times smaller than a dime! Molecules and atoms are very very small!

Another useful tool that you could discuss through your students is found here:
http://learn.genetics.utah.edu/content/begin/cells/scale/
This interactive demo starts at the scale of a coffee bean and grain of rice and allows you to zoom further down into the size of cells, and viruses, and atoms.

Wrapping Up Activity 1.5:
Tell students that so far we've looked at relatively small molecules to develop a basic common understanding. But, in this unit we will be looking at bigger, more complex molecules that may consist of hundreds of atoms bonded/joined together. Remind students that this was a basic review/discussion about atoms and molecules and was not meant to go into great detail, so it is okay if they feel like they don't fully understand atoms and molecules. They will learn about these in much greater depth in their chemistry class. Ask if they have any general questions.

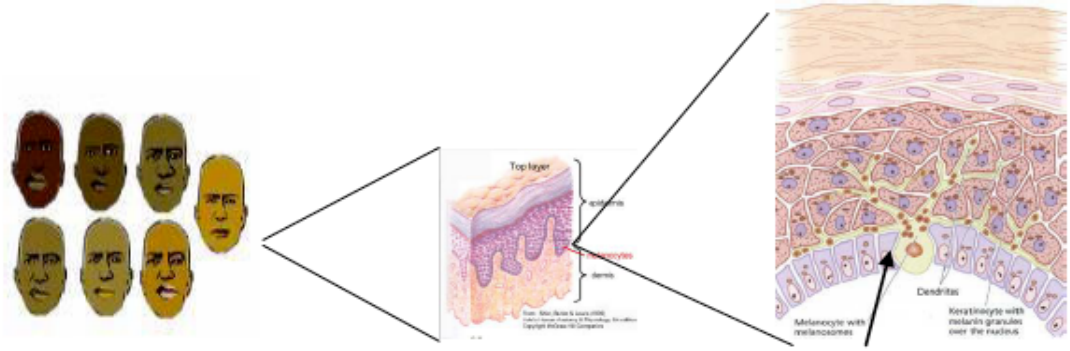
Check for understanding:
1) Describe how atoms and molecules are related to each other.
Students should say that atoms make up molecules.

2) Look back at the macro-micro chart we created in the previous lesson. Describe how atoms and molecules are related to the other general structures listed on the left hand side of our table.
Many possible answers. Students can say something about the progression of size: the body is made up of organs, which is made up of tissues, which is made up of cells, which is made up of molecules, which is made up of atoms. (or vice-versa)

Concluding the Lesson
To conclude this lesson, which wraps-up Learning Set 1, you want to refer back to the Driving Question Board (DQB). See if there have been any questions that we have answered based on what we've learned, or if any new questions have come up.

Specifically, ask students how what they learned/know about atoms and molecules relates to the driving question. Get students to see that the same atoms and molecules make up all of the parts of our bodies. This is a similarity from person to person, no matter your skin color. Add this idea to the DQB (hopefully suggested by the students themselves): We are more similar than different when we think about the atoms and molecules that make up all the parts of our bodies.

Learning Set 2: What Happens Inside Our Cells to Make Us SIMILAR or DIFFERENT?



Skin Colors Cross Section of Skin Melanocyte

Learning Set 2 – What Happens Inside Our Cells to Make Us SIMILAR or DIFFERENT?

Content Standard	Inquiry Standard	LS 2 Learning Performance
Nature and function of proteins - The work of the cell is carried out by the many different proteins. Proteins molecules are long, usually folded chains made from 20 different kinds of amino-acid molecules. The function of each protein molecule depends on the specific sequence of amino acids and the shape the chain takes is a consequence of attractions between the chain's parts. (AAAS, pg. 114, 5C:9-12#3)		Students generate a list of cellular activities and identify proteins as being responsible for carrying out those activities.
		Students collect data that provides evidence that proteins are found throughout our bodies by performing an assay for protein on chicken parts.
	Formulate and revise scientific explanations and models using logic and evidence. (NRC, 1996, A:1D/ 9-12.).	Students will draw a model of the function of the protein tyrosinase in beginning the process of creating melanin inside of skin cells.
		Describe the importance of multiple models to represent the same protein
		Explain that proteins are made of amino acids and consequently the order of amino acids in a protein determines its structure
		Students assemble proteins as a way to describe the protein's structure
	Design and conduct scientific investigations. **(NRC, 1996, A:1B/ 9-12.).**	Students will investigate the production of melanin in fruit.
		Students will generate an explanation of how the structure of the protein tyrosinase supports its functions inside the cell in beginning the process of creating melanin.
		Students will investigate the effect of the protein lactase on milk products.

	Communicate and defend a scientific argument.(NRC, 1996, A:1F/9-12)	Students will use ethics to develop arguments for solutions to problems related to the fair treatment of people with lactose intolerance.
		Students use gel electrophoresis data to write a scientific explanation diagnosing unknown lactose samples.
The physical properties of compounds reflect the nature of the interactions among its molecules. These interactions are determined by the structure of the molecule, including the constituent atoms and the distances angles between them, (NRC, 1996, B:2D/9-12).		Students explain that these differences among amino acids lead to different amino acid properties.
		Explain that the order of amino acids in a protein determines its structure and consequently its function.
		Students explain how properties of amino-acid side chains such as charge, hydrophobicity and size can affect protein folding.
		Explain how a change in amino acid order can affect protein function and consequently cell function
Carbon atoms can bond to one another in chains, rings, and branching networks to form a variety of structures, including synthetic polymers, oils, and the large molecules essential to life, (NRC, 1996, B:2F/9-12).		Students describe the similarities and differences among amino acids.
Chemical reactions occur all around us. Complex chemical reactions involving carbon-based molecules take place constantly in every cell in our bodies, (NRC, 1996, B:3A/9-12).		Explain how a change in amino acid order can affect protein function and consequently cell function

Learning Set 2: What Happens Inside Our Cells to Make Us SIMILAR or DIFFERENT?

Overview

Purpose
The purpose of this learning set is for students to learn what proteins do in cells, how proteins carry out their functions, and what influences their function. Students should understand by the end of this learning set that (1) proteins carry out most of the work of the cell, (2) that each protein has a specific shape that allows it to carry out its work (much like a tool has a specific shape for its function), and (3) that the order of amino acids in a protein determines its shape. These concepts are investigated in the context of skin color and lactose intolerance.

Connection
This is a key learning set to understanding what proteins are and do. It takes off where learning set 1 one left off with cell function and goes to the molecular level. It also is a prelude to learning set 3 where students learn that genes are instructions for building proteins.

Description

Lesson 1
- Students observe different cellular activities, and they learn that proteins are responsible for most of the activity of cells.

Lesson 2
- Students learn proteins are located in cells in all different parts of our bodies.

Lesson 3
- Students create models of skin color differences at the cellular level and investigate the tyrosinase protein and its influence on the appearance of an organism.

Lesson 4
- Students investigate lactose intolerance by reading about a fictional character that has this problem. Students will observe the role of lactase in the production of glucose in milk.

Lesson 5
- Students will develop arguments for solutions to the problem of lactose intolerance by applying ethics and their understanding of the role of the lactase enzyme in breaking down

sugar in milk products. Students will compare the activity of two proteins, lactase and tyrosinase and their influence on the biological similarities and differences in people.

Lesson 6

- Students learn that proteins are made up of amino acids, and that the amino acid sequence can affect the protein structure. Students also explore multiple models that represent the same protein.

Lesson 7

- Students learn about the chemical structure of amino acids by identifying the common chemical structure in all amino acids. Students also identify differences in the chemical structure of amino acids, as these differences determine the unique properties of amino acids.

Lesson 8

- Students learn about amino acids and their role in determining protein shape by building models of proteins. Students build models of a random amino acid sequence. Students also consider the function of lactase's shape in influencing lactose intolerance by building a model of part of the lactase protein.

Lesson 9

- Students learn how to read pictures of electrophoresis gels, so they can write a scientific explanation diagnosing lactose intolerance in two unknown protein samples.

Learning Goals
The portion of the learning goals addressed in this Learning Set are dark.

National Standards

- Nature and function of proteins - The work of the cell is carried out by the many different proteins. Proteins molecules are long, usually folded chains made from 20 different kinds of amino-acid molecules. The function of each protein molecule depends on the specific sequence of amino acids and the shape the chain takes is a consequence of attractions between the chain's parts. (AAAS, pg. 114, 5C:9-12#3)

Michigan Standards
B2.2 Organic Molecules - There are four major categories of organic molecules that make up living systems: carbohydrates, fats, proteins, and nucleic acids.
B2.2C Describe the composition of the four major categories of organic molecules (carbohydrates, fats, proteins, and nucleic acids).
B2.2D Explain the general structure and primary functions of the major complex organic molecules that compose living organisms. (Proteins only)
B2.2x Proteins - Protein molecules are long, usually folded chains composed mostly of amino acids and made of C, H, O, and N. Protein molecules assemble fats and carbohydrates; they function as enzymes, structural components, and hormones. The function of each protein molecule depends on its specific sequence of amino acids and the shape of the molecule.

Prior Knowledge

- Cells: Students should realize all living organisms are made up of different organs, which are in turn made of different tissues which are made up of many different types of cells. Students should now be familiar with a specific type of cell found in skin: melanocytes
- Molecules & atoms: Students should be able to identify and differentiate between molecules and atoms.
- Size & scale: Students should be able to describe relative sizes of things, from the macro world of organisms to the molecular world of cells, molecules, and atoms

Student Conceptual Challenges

- Students may be unaware of the central role proteins play in biological processes.
- Students confuse the difference between amino acids and protein--sometimes calling proteins amino acids, and amino acids proteins.

Time

13 days

Lesson 1: Why are cells so Different-What causes different cell functions? - Cellular Activities

OVERVIEW

Purpose
The purpose of this lesson is for students to learn about some of the activities of cells, and more specifically that proteins are responsible for the work that cells do. They explore skin cells and three other different types of cells that will be looked at throughout the curriculum.

Connections
This is a key lesson to begin learning what proteins are and do. This lesson picks up with a review of content from learning set 1, specifically the macro-molecular chart. It also is a prelude to lesson 2 where students learn more about proteins, specifically, where proteins are located.

Description
Students read brief articles about different types of cells in our bodies. In doing this they identify the different possible activities of cells. They learn that proteins are responsible for the activities of cells.

Safety Guidelines
None applicable

Learning Performance
Students identify activities within cells that lead to specific changes within the cell.

PREPARATION

Materials
Cells readings
Student Readers pp. 28-36
Driving question board
Macro-molecular chart
Chart paper and markers for each group

INSTRUCTIONAL SEQUENCE

Teacher Note: Cells

This lesson focuses on the activities of cells and does not go into detail about the structure of cells. If you have time and would like to include a lesson on cell structure, including how the cell membrane works to allow nutrients and waste to pass into and out of the cell, this would be a good place to do it.

Activity 2.1: Cell Readings

Introducing Activity 2.1:
In this activity students will break into small groups and each read about a different type of cell found in our bodies. This will lead into a whole-group discussion about the activities that are done in cells, and a determination that proteins are responsible or are needed for most of these activities in cells.

Begin by referring back to the Driving Question and the macro-molecular chart. Tell students we started to address the DQ by looking at skin color. We looked at similarities and differences in our skin--what we could see with our eyes.

Ask: What did we need to examine to understand why some people might have darker skin than others? *We had to look at the layers of skin, and tissues that make up our skin, and specifically at the cells in our skin's tissues (melanocytes).* Point to these locations on the macro-molecular chart as the students identify them: our bodies, our skin/organ, skin's tissues, and skin cells.

But we all have melanocytes. We needed to dig even deeper than that to see how we might also be different. So what did we need to examine to do this?

Ask: What inside these skin cells helped us learn something about why we have different skin colors? *We had to learn about a molecule (melanin) inside the cells that give us different skin colors.* Point to this location (molecules) on the macro-molecular chart to show students that we began with bigger and gradually have been digging deeper to learn even more about our driving question and similarities and differences.

Follow up by asking: How do you think melanin inside the cells gets made? (Also, add this question to the DQB because it is not likely that students will know the answer at this point in the unit). Listen to whatever ideas students present about how they think melanin gets made inside cells. Tell students they will learn about how melanin gets made soon. First, we need to take a step back in our macro-molecular chart to look at cells, and the different activities that take place inside of cells in our bodies.

Carrying Out Activity 2.1:
Have students turn to Activity Sheet 2.1. Break students into 4 groups and assign each group one of the cell readings (either on skin cells, liver cells, intestine cells, or blood cells). All readings have been included in the student readers. Walk around after you assign each group a

reading to make sure they've turned to the correct page. Also pass out a sheet of chart paper and markers for each group to keep track of their notes, to be presented to the class later.

Explain to students that as they read they need to focus on what the **cells do** and what happens in the cells of their specific organ. (Make sure students are not confusing what the **organ** does with what the **cells that make up the organ** do, although sometimes these functions will be the same.) They will take notes on this on the chart paper and in their student readers. Also, remind them that they will be the expert on their specific type of cell, and will be sharing their results with the rest of the class, who will not be reading about that type of cell. Therefore, each group must be sure to do a thorough job of describing the function of their specific type of cell. Their classmates are relying on them!!!

Readings
Below is a table, similar to the one the students must complete, of the important cellular activities that students should get from the readings. As they are working in their group, walk around and make sure they are arriving at most of these activities. If they are struggling, point to specific excerpts of the reading to guide their thinking along the right track.

Reading	**Cell Function/Activities**	**Specific proteins identified**
What happens inside skin cells?	• Covers & protects the body • Some skin cells work to make new skin cells (self-renewing) • Produce melanin (which leads to skin color) • Keeps skin waterproof & tough • Provide structure, strength, and elasticity for skin	Collagen, elastin, keratin
What happens inside intestine cells?	• Secrete digestive juices • Digestion & absorption of food (nutrients) • Absorb water • Excretion of solid waste • Transport substances • Protein synthesis • Regulate bacterial flora • Release hormones	(no specifics mentioned) Digestive proteins, hormones, secretin (a hormone)
What happens inside liver cells?	• synthesizing protein, cholesterol, bile salts, fibrinogen, phospholipids and glycoproteins • ensure that our blood coagulates so we don't bleed to death • cell communication is tip-	None mentioned

	top • Carries fats in the bloodstream • transformation of carbohydrates • protein storage • start of the formation and secretion of bile • detoxification and excretion (release) of substances • fight off disease • produce waste • transport materials throughout the body • process everything from drugs and insecticides to steroids and pollutants	
What happens inside red blood cells?	• Transport oxygen around the body • Disposal of carbon dioxide	Hemoglobin, carbonic anhydrase

After students have taken notes on the specific cellular activities based on their assigned reading, have groups present their findings, which they have written on the chart paper. As each group presents their chart paper, students from other groups should be filling in the tables in their own student readers of the different cell activities. It is not necessary that students identify ALL the possible cell activities from the readings. The focus for this lesson is to show students that cells perform numerous functions and get them to understand that **proteins** are important in performing those functions.

Wrapping Up Activity 2.1:
After each group has presented, all students should have a completed table of cell activities, similar to the one above (again, it is not necessary for them to have identified all of the possible cell activities). Break students into different groups now (any number of groups is fine), making sure each group has at least one person from each reading group in it. Have them complete the follow-up questions in their readers in these new groups.

After giving students time to complete the questions, review the answers as a whole class. It should be pretty obvious from the readings that **proteins** are responsible for the different cellular activities they identified. Add "proteins" in the appropriate place (student-identified) in the macro-molecular chart.

Teacher Note—Students' prior ideas: Protein as part of the diet.

Generally students will have heard about proteins in regard to nutrition. Acknowledge that this is true, but that they will learn in this Learning Set why proteins are important to cells. For the purposes of this lesson it's enough for students to know that proteins are somehow involved in all the different activities of cells in all parts of our bodies.

Because of students' ideas about eating protein (likely they think of meat) as part of their diet, there might be some misconceptions associated, namely that the proteins we eat are then shuttled off to different parts of our bodies and used as is. If this comes up, it might be useful to explain the following, in more basic terms than provided here because students are currently unaware of amino acids: When taken in as food, proteins are eventually broken down into amino acids in the stomach and large intestine. Then the amino acids are absorbed in the last part of the small intestine and passed into the blood stream so that cells all over the body can take in the amino acids. Different amino acid transporters in the membranes of our cells are used to take in amino acids. Once inside cells, amino acids are then be assembled in to different proteins as needed. Therefore, it is not the case that proteins are taken in and immediately used by the body as they are.

Concluding the Lesson

Revisit the Driving Question Board and Macro – Molecular Chart. Ask students if they can answer any questions on the DQB or if they need to add any new ones. Also, ask the students if they have anything new to add to their Macro – Molecular Chart (they should add "proteins").

OPTIONAL Lesson 1: Why are cells so different? - Cellular Activities Videos

OVERVIEW

Purpose
This lesson is meant to supplement (but not replace) the lesson in LS2, Lesson 1, Cell Activities Readings. The purpose of this lesson is for students to learn the purpose of proteins in cells, and more specifically that proteins are responsible for the work that cells do.

Description
Students view videos of cellular activities that require energy. They then identify the specific activity of cells. They learn that proteins are responsible for the activities of cells.

Safety Guidelines
None applicable

Learning Performance
Students identify activities within cells that lead to specific changes within the cell.

PREPARATION

Materials
Internet access (for cell videos)
Learning Set 2 Slides- Optional Slide 1
Student Reader pp. 37-38

Set-Up
Make sure you watch each video first--you may need to direct students' attention toward a specific part of the video.

INSTRUCTIONAL SEQUENCE

Optional Activity 2.1: Cellular Activity Videos and Chart

Introducing Optional Activity 2.1:
Have students turn to Optional Activity Sheet 2.1. You should have Optional slide 1 from Learning Set 2 Lesson 1 up at this point. Double click on the video name and the video will play. Explain to students that they will be watching some videos that show real live examples of some cells. Tell students all they have to do right now is look carefully at the videos (they're

short and should be shown multiple times). You may need to point out specific things for students to focus their attention on. While they are observing they should:

- briefly describe what they see happening (they can draw a picture in addition, but should focus on describing) in the space provided in their reader.
- tell students to use verbs (action words).
- tell them the focus is NOT on what things look like, but on the action that is taking place. What is being DONE in each video?

Videos

1) "Stuff being transported" (Cytoplasmic streaming video in plant cells):

   http://www.microscopy-uk.org.uk/mag/imgnov00/cycloa3i.avi

Teacher Background: cytoplasmic streaming video
In this video, a plant cell is observed. It is undergoing a process called cytoplasmic streaming, in this process the contents of the cytoplasm are being pushed and pulled inside the cell. Green chloroplasts are in the cytoplasm and can be observed moving inside the cells. Cytoplasmic streaming is required to maintain equal distribution of organelles around the cell. This process is thought to be mediated by ***proteins*** *called* ***actin*** *and* ***myosin****. Actin are structural proteins and myosin is a motor protein with the ability to move objects along actin filaments. The point to emphasize here is that cytoplasmic components (namely the chloroplasts) of the plant are being moved which means energy is being used;*

2) "Stuff breaking apart" (Cells dividing--Mitosis):

   http://www.youtube.com/watch?v=0oJZDKdperU&feature=related
   go to "dynamic cell" and click on "mitosis" to see live cell dividing

Teacher Background: mitosis video
In this video, a plant cell is being video taped undergoing mitosis. The chromosomes are observed moving about, organizing at the center and separating. This process requires proteins that are thought to push or pull the chromosomes. The actual proteins involved are ***tubulin*** *(a structural protein) and* ***kinesin*** *(a transport protein). The point to emphasize here is that chromosomes must be moved during this process which means energy is being used on the chromosomes.*

3) "Taking things in" (Engulfment of large particles by cells--phagocytosis):

   http://www.molbiolcell.org/cgi/content/full/13/2/402/F2
   Click on "view videos" on the right hand side then click on "figure2.move"

Teacher Background: phagocytosis video
In this video a cell from the immune system is first found ruffling its membrane at the surface. Moments later, round beads (seen as large round bright shiny spheres) are added to the liquid

*media surrounding the cell along with a special molecule that stimulates the cell to engulf the beads. Notice a few of these round spheres are taken inside the cell (when the beads are completely inside the cell they become darker because they no longer reflect off the light from the lamp on the microscope) This process is mediated by **actin** and **myosin** proteins. The point to emphasize here is the movement of beads from outside the cell to inside the cell; energy is being used by the cell.*

4) "Responding to environment/changing shape" (Neutrophil, an immune system cell, chasing a bacterium):

http://www.hopkinsmedicine.org/cellbio/devreotes/neutrophil.mov

Teacher Background: Neutrophil video
*This video shows a cell from the immune system, called a neutrophil, chasing down bacteria (the tiny wiggling dot in front). Note how the neutrophil is pushing it's membrane forward in order to drive its motility to chase down the bacteria. This motility is driven by **actin** proteins. The neutrophil can "sense" the bacteria (the bacteria releases chemicals that the neutrophil can detect). Proteins in the neutrophil are "sensing" the bacteria and help to "steer" the neutrophil. The point here is that membrane shape is being changed and energy is being used on the membrane. This can also be seen as the immune system cell responding to its environment--an "invader" in the bacteria is in the neutrophil's environment.*

5) "Releasing waste" (Paramecium exocytosis)

http://www.youtube.com/watch?v=U9pvm_4-bHg

Teacher Background: Exocytosis video
This video shows a paramecium expelling waste. Exocytosis is the process by which a cell directs the contents of secretory vesicles out of the cell membrane. These membrane-bound vesicles contain soluble proteins to be secreted to the extracellular environment, as well as membrane proteins and lipids that are sent to become components of the cell membrane. The point here is that cells use energy to release waste.
(from Wikipedia)

6) "Growth/reproduction" (Bacteria reproducing)--Can be substituted for the Mitosis video

http://www.youtube.com/watch?v=eqrtNef7w38&feature=related
(don't let students see video title)

Teacher Background: Bacteria reproduction video
Bacteria are prokaryotic organisms that reproduce asexually. Bacterial reproduction most

commonly occurs by a kind of cell division called binary fission. Binary fission results in the formation of two bacterial cells that are genetically identical. Proteins are responsible for this.

Have students share out their ideas about what actions were occurring in each video. Accept all possible responses.

Carrying Out Optional Activity 2.1:
Tell students to go back to Optional Activity Sheet 2.1. We will look again at the cell videos, but this time we are going to identify the specific change that is happening for each cellular activity. Show each video one at a time. You may need to show the videos again a couple of times. Also have students refer back to the notes/drawings they did at the beginning of class. Try to get students to identify what is actually happening (in terms of a cellular activity) in each video. Guide students as necessary while they are watching to identify individual activities/changes. They may work with their group or a partner. As students identify the change taking place, have them write this into their activities chart next to the corresponding cellular activity.

Tell students there is not a video for #7 on their table, instead show them the next slide. Students should recognize this slide from Learning Set 1 - Lesson 1. Ask students if they can figure out the cellular activity and change from looking at the slide.

Have students make connections between the Cell Activities they learned about in the types of cells readings, and the activities they see in the videos.

Teacher Table about cell activity videos

Video	**Cellular Activity**	**Change**
1) cytoplasmic streaming	transporting stuff within the cell	move stuff from one part of the cell to another part.
2) Mitosis	dividing/reproducing	change size/shape/amount
3) phagocytosis	take in "food"/molecules from outside the cell	move/transport across cell membrane (outside --> in)
4) Neutrophil chasing bacterium	respond to environment	Receive signals and send signals to the rest of the cell--this cannot be seen in the video, but point out to students that it is the job of an immune system cell to seek out "invaders", they receive a "signal" to do this.
5) paramecium exocytosis	releasing waste	Movement/transport across

		membrane from inside to outside
6) bacteria reproducing	reproduction/growing	changing size/shape/amount
7) melanocyte	producing melanin	melanin is moving from the lower layers of the skin to the upper layers of the skin where it can be seen

Bring students back together and review the changes each group came up with. Make a master chart of all the cellular activities and changes. Students can change/add to their own charts in their readers if necessary. It's worth it to spend more time allowing them to work this out in groups with your guidance so that this is just a quick share-out.

Wrapping Up Optional Activity 2.1:
Ask students to reflect on the similarities between the activities they read about, and what additional activities they found when they watched the videos. Help students also understand that the activities they read about and saw in the videos are all the result of **proteins!!!**

Concluding the Lesson
Revisit the DQB and Macro – Molecular Chart. Ask students if they can answer any questions on the DQB or if they need to add any new ones. Also, do the students have anything new to add to their Macro – Molecular Chart.

Lesson 2: Where are proteins in our bodies?

OVERVIEW

Purpose
The purpose of this lesson is for students to see that proteins are in all parts of our bodies.

Connection
In this lesson students learn that proteins are in cells throughout our bodies doing these activities that enable us to live. They also learn in a reading about some of the activities that proteins are responsible for in our bodies. In Lesson 2 students revisit the skin color phenomenon with this knowledge and learn in more detail about what the proteins in our skin cells are doing.

Description
Students test for proteins in different parts of a chicken using a chemical test called the Biuret test in which an indicator changes color in the presence of protein. Through this activity, they see that proteins are everywhere in chicken bodies and infer they are everywhere in human bodies.

Safety Guidelines
Make sure students do not touch the chicken with their hands (it should remain in the plastic bags). Also make sure students wash their hands with soap and water after the activity is completed.

Lesson Learning Performance(s)
Students collect data that provides evidence that proteins are found throughout our bodies by performing an assay for protein on chicken parts.

PREPARATION

Time
2 days: 1 class period to do the activity, 1 class period to debrief and discuss the activity

Materials
Biuret solution
Water
Dish soap
Table salt
Chicken pieces – meat, liver, skin, fat, bone, etc.

Plastic bags
Beral-Type pipets, or other device for measuring liquid
Small cups or test tubes for Biuret reaction
Slide 1
Student Reader pp. 39-43

Prior to Lesson:

1) Read through the entire lesson so you have a sense of the activity to be done.
2) Cut chicken into pieces about the size of a large pea, enough so that each group has each type of chicken part.
3) Put each piece of chicken into a separate plastic bag and label bag with chicken part type.
4) Make the mixing solution by adding 1 drop of dish soap and 1 tsp of salt to every 15 mLs of water – make enough so that each group has about 15 mLs.
5) Prepare sets of the following for each group:
    a. Set of ____# bags with each type of chicken piece
    b. 15 mLs Biuret solution
    c. 15 mLs mixing solution
    d. 5 small cups or test tubes for reaction
    e. ____ # pipets (1 for mixing solution, 1 for Biuret solution, 1 for each type of chicken piece)

INSTRUCTIONAL SEQUENCE

Introducing Activity 2.2:
Review a little bit with students: What have we looked at in our investigation of why people have different skin colors? (*We looked at our skin itself, using a magnifying glass. We looked at cross-sections of our skin's layers. We saw the types of cells in our skin, like the melanocytes and keratinocytes.)*

Remind students about the cellular activities you watched yesterday and that you speculated the proteins might be the reason for all of these activities that take different cells. Today, the students are going to collect evidence to see if proteins are even in all cells.

Carrying Out Activity 2.2:
Remind students that we've begun to learn cellular activities, and we're trying to figure out if proteins are responsible for these activities. Ask students to answer Question 1 on Activity Sheet 2.2: Where do you think proteins are found in our bodies? Accept all student responses. If necessary, ask students to clarify or explain their ideas.

Tell students that today we're going to do an activity to figure out where proteins are in our bodies using pieces of chicken. Show awareness for all students and ask if anyone has a problem working with chicken parts, pointing out that no one will have to touch any of the chicken. If there is a student who refuses to participate in the actual activity, tell them they should watch their group do the activity, but they are still responsible for all other work.

Explain to students that they will be conducting a laboratory procedure to determine where proteins are present in the different pieces of the chicken. We will then use the results of the activity to make inferences about where proteins can be found in human bodies to help us continue to answer our Driving Question and some of the other questions on our DQ board. Explain to students some features of the procedure and some of the materials they will be using.

Teacher Note: Biuret Test for Proteins
*The **Biuret test** is a chemical test used for detecting the presence of peptide bonds, found in proteins. Biuret reagent is a blue solution that, when it reacts with protein, will change color to pink-purple. See **Slide 1***

Where are proteins in our bodies?

Testing for Protein

Where are proteins in chicken parts?

Part being tested	Prediction – Is protein present?	Result – Is protein present?
Mixing solution without any chicken		
skin		
liver		
muscle		
fat		
bone		
feather		

Slide 1

Tell students not to touch any of the chicken parts, or anything inside the plastic bags (make sure students wash their hands with soap and water after the activity). Explain the purpose of the mixing solution (dish soap, salt and water).

Teacher Note: Purpose of Mixing Solution
The meat proteins can be extracted by adding salt (in the mixing solution) that derives the soluble proteins. This step is facilitated by tumbling and massaging actions (hence the need to "mash" the meat once the mixing solution is added). The amount of extracted proteins will depend upon salt present and tumbling and massaging actions.
From http://labs.ansci.illinois.edu/meatscience/Library/processing%20meat%20products.htm

If necessary, show the pipet and demonstrate how to use it. Also show them the Biuret solution, but tell them to read carefully through the procedure before they begin so they understand what to do with this solution and what its purpose is in the test. Demonstrate to students what "mashing" looks like. Remind students to read through the entire procedure before beginning. Also remind them to make predictions before allowing them to get the materials. Discuss with students the purpose of doing a control test prior to doing the experimental test.

Teacher Note: Control & Variables
A controlled experiment tests only one factor at a time. In a controlled experiment, there is a control group and one or more experimental groups. In this activity, having students do the Biuret test with only the mixing solution is the control group, and the other groups with the different chicken parts are all experimental groups. All of the variables for the control group and the experimental groups are the same except for one. In this activity, the variable that changes is the particular chicken part. Because there is (or should be) only one variable that differs between the control group and the experimental groups, scientists can be more certain that the changed variable is the cause of any differences that they observe in the outcome of the experiment. In this case, they will be observing the color of the indicator for the Biuret test without any chicken parts, and see how this color changes when exposed to different chicken parts (proteins).

Tell students that when they are done with the activity, have cleaned up, and washed their hands with soap they should answer the questions that follow the activity in their student readers, including writing a scientific explanation. Your may need to review with students how to write a scientific explanation (see LS1, Lesson 1).

Concluding Activity 2.2:
When students have completed the activity, discuss the results. If there isn't enough time to do this in class, assign the questions for HW and review at the beginning of the next lesson.

- What were the results of your experiment? (*Students should find proteins in all parts of the chicken*)
- How did your results compare with your predictions?
- Are there any parts of the chicken that don't have protein?
- Do you think the same is true for humans? (*Allow time for discussion of this. It's important that students make the inference that the same is true for humans on their own. It's not enough for the teacher to tell them. Rather, they should use the results of their experiment to infer the same thing can be said of all living organisms, including humans. If students do not infer this, promote discussion that will lead them to this.*)
- What is your scientific explanation? (Where are proteins found in chickens?) *You may want to have students do the claim and evidence part after they complete the experiment, then do the reasoning after they've completed the reading on proteins for homework.*
    - Possible example:

- Claim: Proteins are found in all parts of the chicken.
- Evidence: The Biuret test showed a color change from blue to pink for the following body parts tested: _____. This is a representative sample of body parts of chickens.
- Reasoning: I learned from the reading (Proteins, what are they for?) that proteins could be responsible for many important functions in living things such as _____, so it makes sense that proteins exist in cells all over chickens' bodies.

- How does this activity relate to you and you and your body? *(Accept all reasonable student responses)*.

Homework

Tell students for homework they need to cover Reading 2.2 Proteins: What Exactly Are They For? After reading this, they may want to revisit the last question on activity sheet 2.2, so you can discuss as a class any new connections they discovered.

Lesson 3: How are proteins in our skin cells similar or different?

OVERVIEW

Purpose

The purpose of this lesson is for students to learn what proteins do in skin cells, how proteins carry out the function of producing melanin, and what influences their function. Students should understand by the end of this lesson that this protein has a specific shape for its function (much like a tool has a specific shape for its function)

Connection

This is a key lesson to learn what proteins are and what they do. It builds from lesson two by identifying protein and goes to the molecular level to show how proteins enable the cell to carry out activities. It is a prelude to lesson 6 where students learn that genes are instructions for building proteins. This lesson also links to Learning Set 1 by explaining what is happening inside of the skin cells to cause light and dark skin.

Description

Students begin with skin color differences and the tyrosinase enzyme as an example and an introduction to proteins and their influence on the appearance of an organism. Students draw a model of the process of the formation of melanin inside the skin cell. Students observe the affect of pH on the formation of melanin in fruit. Students then write a scientific explanation. Students read about skin whitening creams that claim to inhibit the activity of tyrosinase.

Prior Knowledge Needed

- Basic chemistry: students should know what atoms and molecules are and the difference between these two (See Learning Set 1, Lesson 5)
- Cells: Students should realize all living organisms are comprised of cells and that for humans (as well other animals and plants) have tissues and organs that are comprised of many cells. It would be useful if students know that organs are made up a group of cells all devoted to the same function. In addition it would be useful if students were familiar with a few specific cell types – e.g. red blood cells. (See Learning Set 1, Lesson 4)
- Activities done by cells that are important to all living organisms: e.g. taking in food, breaking down food, building molecules, releasing waste, etc. (See Learning Set 2, Lesson 1)

Student Conceptual Challenges

- Students may be unaware of central role proteins play in biological processes.

Safety Guidelines
Make sure that the teacher precuts the apple or banana pieces.

Learning Performance(s)
Students will draw a model of the function of the protein tyrosinase in beginning the process of creating melanin inside of skin cells.
Students will investigate the production of melanin in fruit.
Students will generate an explanation of how the structure of the protein tyrosinase supports its functions inside the cell in beginning the process of creating melanin.

PREPARATION

Materials

Power point Learning set 2 slides 2-10
Student Reader pp. 44-52
Small pieces of fruit: banana or apple
Hand lenses

Set-Up

- The day before class, prepare enough pieces of fruit so that each group has 2 sets (6 small pieces) of fruit to observe.
- Dip one set in lemon juice and leave the other set untreated.
- Let the fruit sit out overnight

INSTRUCTIONAL SEQUENCE

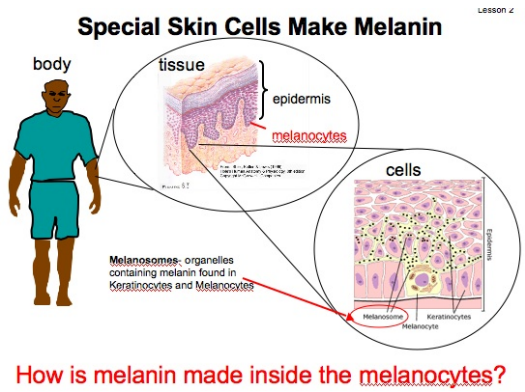
Introducing the Lesson
In this lesson students will revisit similarities and differences in skin cells and the role of proteins in the process. This introduction will help them make connections between what they have learned up to this point and skin color.

Ask students to think back to Lesson 1 when we were looking at biological similarities and differences. Ask students to name some of our biological similarities. (Bring up some of the body parts that were tested in the chicken activity if students do not mention them.) Remind students that in order to really identify our similarities and differences we have to look closer at

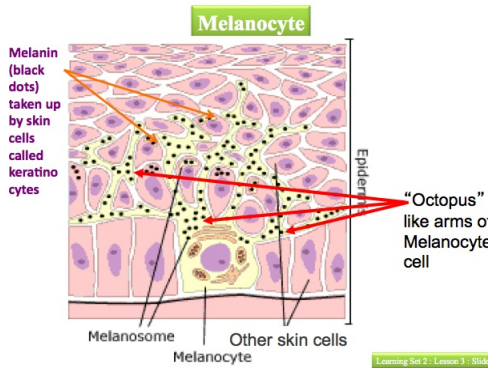
what is going on in the cells that make up our bodies. In the lab activity with the chicken they tested many of these body parts. Ask students:

- What did you find?
- How were the chicken parts similar?
- Why do you think so many parts of our body contain protein?
- Was protein found in the skin?

Remind students that they already know a few things about proteins. Point them to the Macro to Molecular chart to determine that protein is a molecule and that it is smaller than a cell. Also remind them of the role of proteins in the cellular activities that they observed in the videos. Remind students that they also learned a lot about the skin and what causes different colors. **Show slide 2 and 3.** Ask student volunteers to describe the process and name the cells involved.



Slide 2



Slide 3

Ask students:

- Do you think that proteins could have anything to do with this process?
- What else do we need to know about proteins in order to determine if they have anything to do with differences in skin color.

Have each group work for a few minutes to come up with one or two questions that they have about proteins and write them in their reader under number 1. Have them share their questions with the class and add them to the DQB.

Activity 2.3A- Modeling Proteins in Skin Cells

Slide 4 - Introduce the question. - How is melanin made inside the melanocytes?
Tell student that as we work through today's lesson we may be able to answer some of the new questions that were added to the DQB. You already said that differences in skin color are due to the different amounts of melanin made by the melanocytes. Today we will be looking closely at

what is happening inside the melanocyte cell to determine how melanin is made. We will try to find out what role if any protein plays in the process.

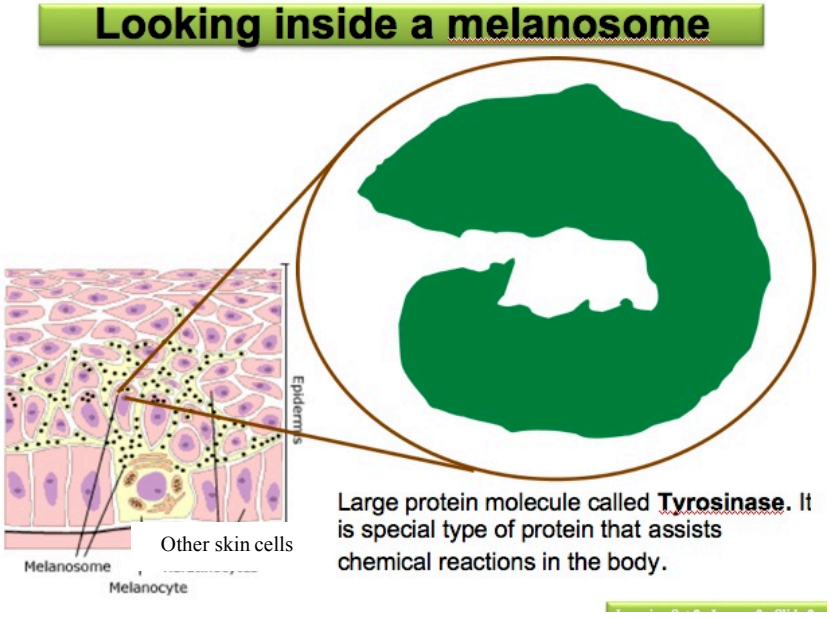
Teacher Background Knowledge: Melanin and Tyrosinase

Melanin is a complex molecule – it is actually a polymer composed of multiple unit rings. Multiple enzymes act before actually producing a melanin molecule—much like an assembly line producing a car. Each enzyme acts to modify (or change) the molecule in one spot at a time. However, tyrosinase is the first enzyme to act in the process and is therefore a very important enzyme. In fact, if tyrosinase does not function at all, then no melanin is produced -- this results in albinism.

Enzymes are proteins that facilitate chemical reactions and therefore they enable specific modifications to occur quickly and in a controlled fashion. Tyrosinase is just one of six enzymes involved in the process of making melanin.

You will notice that in this unit tyrosinase is identified as a type of protein. The word "enzyme" is not used. This is intentional in order to keep the emphasis of the unit on proteins. Many times students become confused when both terms are introduced and begin using them interchangeably. The enzyme activity is described as a function of some types of proteins. Since students probably have limited chemistry knowledge, we do not emphasize the chemical reaction aspect in this unit.

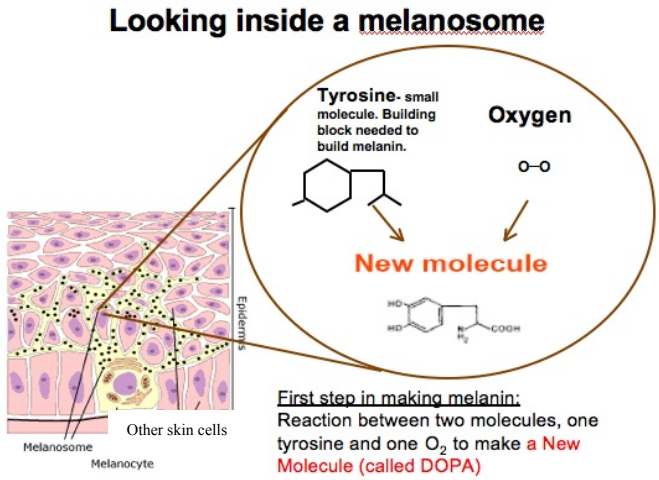
If you would like to use the term enzyme with your students it is recommended that more time be taken to make sure that students understand the difference between the terms.



Slide 4 - What is inside the melanosomes?

Tell students that when we look closely at the melanosome we find a large protein molecule called tyrosinase. We already know that proteins in our cells do many things. Tyrosinase is a protein molecule that that has a special job. These special proteins assist chemical reactions that occur inside of your body. This type of protein can help start chemical reactions without being changed itself.

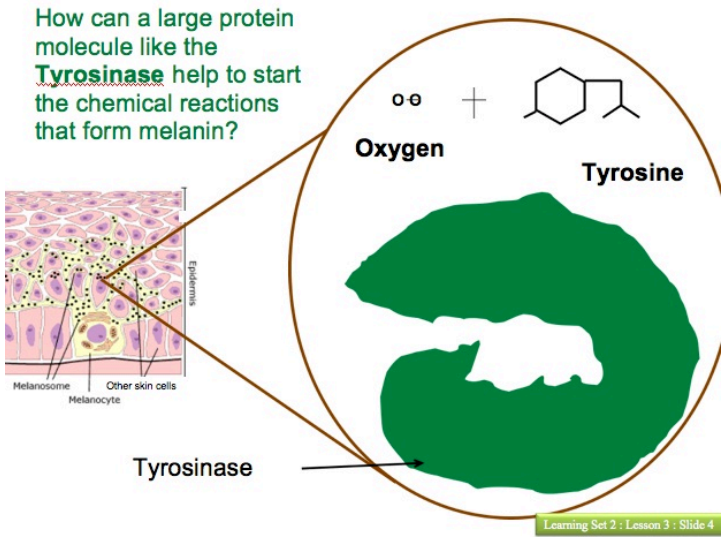
Ask students to think of a street fight. If someone gets two people to fight, but does not fight themselves, they are doing the same job as this type of protein. These proteins can bring molecules together so that they can react or they can pull them apart to produce new molecules. They can either help make reactions happen or speed them up inside of our bodies.



Slide 5 -Tell students that each enzyme in the body only works on certain specific substances. Let's look closely at the chemical reaction that produces melanin. The first step in making melanin is a reaction between oxygen and a molecule called tyrosine. Tyrosine is a building block for melanin.

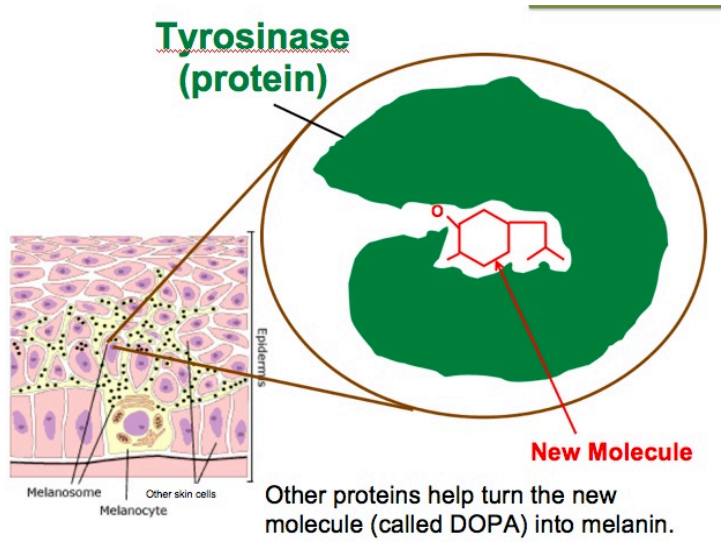
Ask students to compare the way tyrosine and oxygen is drawn in the diagram. How are they different? Students should notice that oxygen has circles to represent the atoms and tyrosine does not. If students cannot tell the difference refer to the "Macro to Molecular" chart and ask them what they think the circles in the model of an oxygen molecule might represent. Once they understand that the circles represent atoms tell them that tyrosine has so many atoms that sometimes when scientists draw models of it they use lines instead just to show the shape of the molecule.

When tyrosine and oxygen react it makes a new molecule that begins the chain of chemical reactions that produce melanin. All of these chemical reactions take place in the melanosomes inside of the skin cells.



Slide 6 How can tyrosinase help to start the chemical reaction that makes melanin?
Tell students to look closely at the tyrosinase molecule. Look at the shape of the tyrosinase molecule and the shapes of the substances needed for the reaction. Ask students to think about the example of the street fight. Tyrosinase is a protein molecule that helps the reaction but will not be changed during the reaction. How could tyrosinase help these two substances react?

Give each group a short time to brainstorm ideas and write them into their student reader on number 2. Show the next slide with the animation of tyrosinase (**Slide 7**). Ask students to discuss what they think happened with their group and write a description in their reader. Ask students to complete the pictures in their reader by drawing the tyrosine and oxygen molecules inside of the tyrosinase to show the new molecule that is being formed.



Slide 8 Tyrosinase protein

Show **slide 8** and ask students to compare what they see in the slide to what they saw in the animation.

- How are they similar? How are they different?
- Ask students to look closely at the shape of the tyrosinase. Would a water molecule fit inside this enzyme?
- How is the shape of the tyrosinase important to its function as an enzyme?

Remind students that what they have just talked about is only the first step in making melanin. More atoms must be added and removed to form the complete melanin molecule. This process is like a production line in a factory where cars are produced. In assembly lines a series of machines work – one by one—each machine doing something different. Machines keep adding new parts and in the end a car is produced. Similarly a series of tiny protein machines called enzymes act on other molecules – adding and changing parts in order to produce melanin in cells.

Wrapping Up Activity 2.3A

Tell students to look back at the DQB? We now know how melanin is formed in the skin cells. Does this help us answer our driving question? If students have trouble making connections between this information and the Driving Question ask them: Is tyrosinase something that makes us similar or different? (Students could answer either way- we all have tyrosinase; for some reason tyrosinase makes different amounts of melanin in different people)

Ask students what else we need to know about tyrosinase in order to find out how similar or different we are? Ask students to discuss this with their group and record at least 2 questions in their reader on number 4.

Activity 2.3B – Observing Tyrosinase

Tell students that one question we might want to ask about tyrosinase is "Does Tyrosinase always make the same amount of melanin?" Tell students that they will be making some observations to answer this question.

Teacher Background on Browning of Fruit

The browning of produce such as apples, bananas, and pears is facilitated by the same enzyme that causes differences in skin color in humans, tyrosinase. When produce is cut and the tissues are exposed to oxygen some fruits begin to brown. The cells in the fruit contain tyrosine and the enzyme tyrosinase. The reaction of the tyrosin with oxygen is the beginning of the production of melanin that is the pigment that you see when fruit begins to brown.

In this investigation students will observe the affect of lemon juice on the production of melanin. They will observe that the fruit dipped in lemon juice does not turn brown as fast. The lemon juice lowers the pH and removes the copper cofactor necessary for the enzyme (Tyrosinase) to function. A cofactor is a non protein chemical compound bound to the enzyme that is required for it to perform its biological activity.

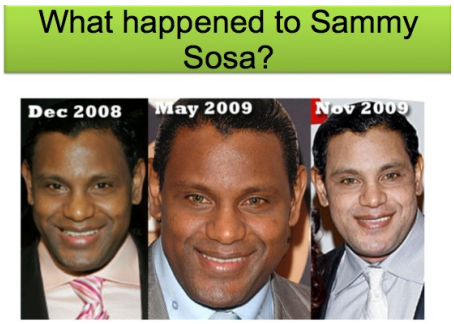
The point of this activity is to help students see that the activity of enzymes can be changed. The lemon juice changes the enzyme so that it can no longer produce melanin.

A more detailed experiment related to enzymatic browning of fruit can be found at www.umaine.edu/NSFGK-12/images/PDFs/**browning**2.pdf

- Tell students that fruit also contains the enzyme tyrosinase. Have students read the introduction to this activity that tells about the purpose of tyrosinase in fruit.
- Pass out samples of fruit (apples or bananas work best) that have been sitting out. Give each group a sample of fruit labeled dipped in lemon juice, and a sample labeled without lemon.
- Let students know that their samples both came from the same piece of fruit.
- Ask students to make observations using a "T" chart comparing the similarities and differences in the samples.
- Ask students to share their observations and create a class "T" chart on the board.
    - Ask students according to the reading what are the brown spots on the fruit made of? (Melanin) Ask students to think back to the PowerPoint slides. What is needed in order to begin to produce melanin? (tyrosine, oxygen and tyrosinase)
    - Ask students if the pieces all came from the same fruit? Do they think they would have the same amount of tyrosinase and tyrosine in their cells?
    - If the fruit all sat out in the same place for the same amount of time would it be exposed to the same amount of oxygen?
    - Ask student why they think the pieces of fruit look different? Discuss their answers and record them on the board and in their readers.
- Ask students to think about the answers to these questions and their observations and write a scientific explanation to answer the question "**Does tyrosinase always make the same amount of melanin?"** Review the parts of a scientific explanation, claim, evidence and reasoning before students begin to write. Ask students to work together and come up with one explanation for their group.

Homework Reading 2.3

In the last activity students saw that lemon juice in fruit could somehow keep tyrosinase from making melanin. In this reading, students will read about skin whitening products that work by inhibiting the ability of tyrosinase to create melanin. Show **slide 9.**



Slide 9

Ask students to look at the picture of Sammy Sosa, the famous baseball player. Ask them what they think happened to him? Have students look at the pictures and the headings in the article. What do you think the article will tell us about Sammy Sosa? How do you think he changed his skin color? Do you think people should change their skin color? Is it safe? Does skin color matter? Ask students to think about these issues as they complete the reading for homework.

Lesson 4: How similar or different are the proteins that make up the cells in our intestines?

OVERVIEW

Purpose

The purpose of this lesson is for students to learn what proteins do in the cells of the intestines, how proteins carry out the function of breaking down lactose, and what influences their function. Students should understand by the end of this lesson that this protein, called lactase, has a specific shape for its function (much like a tool has a specific shape for its function)

Connection

This lesson builds from lesson 3. It allows students to apply their understandings from the previous lesson to a new phenomenon of lactose intolerance. This lesson connects back to learning set 1 where students were identifying biological similarities and differences. This introduces students to another biological characteristic that they will investigate at the molecular level.

Description

Students investigate lactose intolerance by reading about a fictional character that has this problem. Students will observe the role of lactase in the production of glucose in milk. Students then write a scientific explanation.

Prior Knowledge Needed

- Basic chemistry: students should know what atoms and molecules are and the difference between these two (See Learning Set 1, Lesson 5)
- Cells: Students should realize all living organisms are comprised of cells and that for humans (as well other animals and plants) have tissues and organs that are comprised of many cells. It would be useful if students know that organs are made up of a group of cells all devoted to the same function. In addition, it would be useful if students were familiar with a few specific cell types – e.g. red blood cells. (See Learning Set 1, Lesson 4)
- Activities done by cells that are important to all living organisms: e.g. taking in food, breaking down food, building molecules, releasing waste, etc. (See Learning Set 2, Lesson 1)

Student Conceptual Challenges

- Students may be unaware of the process of digestion at the cellular level.

Safety Guidelines

None applicable

Learning Performance(s)
Students will generate an explanation of how the structure of the protein tyrosinase supports its function in making melanin inside the cell.
Students will investigate the affect of the protein lactase on milk products.

Lesson Duration
3 Days

PREPARATION

Materials

Power point slide 11-16
Student Reader pp. 53-62
Large "KWL" chart (What do we **K**now?, What do we **W**ant to know?, What have we **L**earned?)
Per student group:

- Crushed ½ lactase pill
- 5-10 mLs milk
- 5-10 mLs of lactose free milk
- 3 glucose test strips

INSTRUCTIONAL SEQUENCE

Day 1
Lesson 4: What makes our cells similar or different? - Modeling Protein in the Cells in Our Intestines

Introducing the Lesson

Review Discussion of Sammy Sosa Reading and Scientific Explanation
This discussion is meant to help the students summarize what they learned in their reading and prepare for the next section.

Think-Pair-Share: Ask students to look at their answers to question number 3, 4 and 5 in Reading 2.3 and then share their answers with their neighbor or small group. Remind students that they should have looked back in their readers at their original explanation for skin color in Learning Set 1, Lesson 3. Information about tyrosinase should have been added to form a new explanation in order to answer question number 5.

3. Sammy Sosa said that he used skin-lightening creams. How do you think Sammy Sosa's skin change from dark to light?
4. Think back to the fruit investigation from the last lesson. Is what happened to Sammy Sosa's skin similar to what happened to the fruit? Why or Why not?
5. Turn to back to page ___ in your reader. Look at the explanation you wrote. Write a new scientific explanation to answer the question, "How similar or different is our skin?". Add new sentences to reflect any new information that you feel is important to answering the question.

After students have had a chance to share their answers and discuss them in small groups, discuss the answers with the entire class. Make sure to discuss their new explanation for the question "How similar or different is our skin?" which should include information about tyrosinase. After a few students share their explanations guide students in forming a consensus explanation that incorporates the most important components. See example below:

Our skin is very similar. All skin is made up of epidermis and dermis. The epidermis is made of skin cells such as melanocytes that produce melanin. We all have the same number of melanocytes and the same kind of melanin. Different skin color is produced because some people have more melanin in their cells than others. Both dark and light skinned people have a protein called tyrosinase in their skin cells. Tyrosinase is an enzyme that helps the melanocytes to make melanin. The shape of the inside of the enzyme helps the chemical reaction that produces melanin. The only difference between dark and light skinned people is a difference in the tyrosinase enzyme that causes less melanin to be produced in people with light skin. Therefore our skin has more similarities than differences.

Supporting Student Discussions

When students give answers, here are some things you can do:
Encourage students to use complete sentences.

Make Knowledge Explicit:
Evidence: What evidence did they use to explain their answer? Use follow-up questions, such as "Why" and "How do you know?" when students give answers (claims). This can push them to think deeper about why they think they know something.

Student Centered: *Encourage the STUDENTS to initiate the discussion questions, follow-up questions, challenging of evidence, etc. Try to GUIDE the discussion rather than lead the discussion.*

Addressing Other Students:

- *Encourage students to address other students in the classroom.*
- *Ask students to consider a previous answer while formulating their own.*
- *For example: Student: "Suzie said that protein shape would stay the same. I disagree. I think that if the protein shape changes then they will not be able to produce melanin."*
- *Encourage students to ask other students about their predictions.*
- *For example: Student: "Why do you think that the shape of tyrosinase makes a difference?"*

Reading 2.4A: "Don't Pass the Milk, Please"

Introducing the Reading
Tell students that in lesson one, we listed many ways that we are similar and different. In order to understand similarities and differences in our skin color we looked at the activity of proteins in our skin cells. Tell students that in this lesson you are going to investigate another protein that has an important function in the body.

This reading is the case of a young boy who is lactose intolerant. Ask students if they have ever heard of lactose intolerance. Complete the "K" and "W" of the class KWL chart as students share what they know. Introduce key vocabulary listed at the beginning of the reading as they come up in discussion. Connect the "W" to the driving question by asking students if they think lactose intolerance is a similarity or a difference in people? Add this question as well as whatever other questions the students come up with to the "KWL chart. Ask students to keep the questions in mind as they read the story. Encourage students to work in pairs as they read the story and answer the questions. After students read the case ask students:

- What was wrong with Jason?
- What is the name of Jason's condition?
- What are some of the symptoms of his condition?
- In this reading what did we learn about these key words: lactose, lactase, lactose intolerant, digest, enzyme.

Wrapping up the lesson
Discuss and record student answers on the class KWL chart. You will refer to these statements again in later lessons.

Day 2
Activity 2.4: Investigating the Enzyme Protein Lactase

Introducing the Activity
In this activity students will determine whether the medication taken for lactose intolerance has lactase in it. They will gather the evidence that when the medication is added to milk, glucose is generated. Students will also test lactose free milk for glucose and compare.

This entire activity will take 2 days. Plan to complete the hands on portion of the lab in one day. Review the process of breaking down lactose using the PowerPoint slides on the 2nd day. Return to the lab and then have students analyze data and write a scientific explanation.

Teacher Prep
Materials

- Lactase enzyme supplement pills (check ingredient list to make sure that the pills do not contain dextrose or sucrose)

- Pill crushing tool (mortar and pestle, kitchen mallet, hammer)
- Milk
- Lactose free milk
- Glucose strip,
- Small cups for reaction

Preparation

- Crush ½ pill for each group
- Pour 5-10 mLs of milk for each group in a small cup
- Pour 5-10 mLs of lactose free milk for each group in a small cup
- Give each group two glucose strips
- Make sure that glucose test strip bottle is at central location so that students can compare colors or print out a color chart for each group found in the teacher materials.

Teacher Notes:

The glucose test strips will continue to change color as time passes. It is important that the students compare their strip to the bottle at the 30-second time point and record the results. They should not compare their strips at the end of the experiment. The lactase pills will probably not dissolve completely, but this did not generate problems in our trials.

Before students start the activity, ask if they have heard of medicine people can take for lactose intolerance. What do they think is in the medicine? Why do you think so?

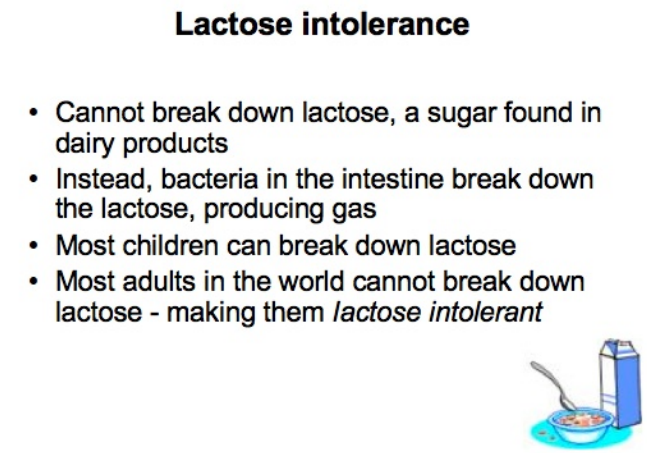
Accept all answers at this point.

The students will also make this prediction in their reader. Explain that they are going to explore how lactose intolerance medicine works. They will also explore the contents of lactose free milk. Break students into groups and follow the procedure in the student reader to complete the activity. Make sure students graph their results in their reader. (Review parts of a graph if necessary.) If time is an issue, assign students to graph their data for homework rather than doing it in class.

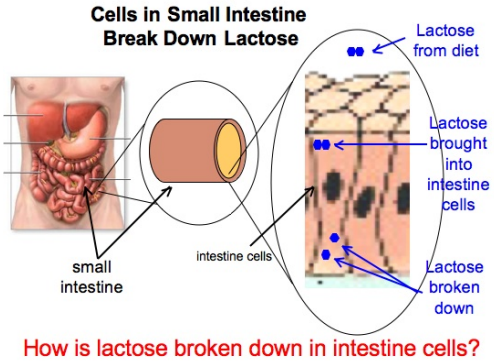
Day 3

Introduce the lesson by reminding students of our driving question- "How similar or different are we?" Ask students to think back to the story " Don't Pass the Milk Please" How was Jason different from his sister?

Review lactose intolerance with the following slides. As you discuss lactose intolerance at the cellular level ask students to add information to the "L" in their KWL chart.



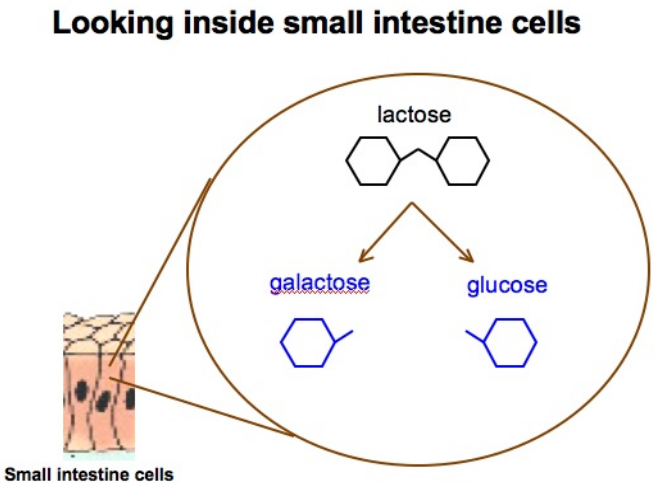
Slide 11 Tell students that as with skin color, in order to understand the differences between Jason and his sister we have to look at what is happening inside the cells.



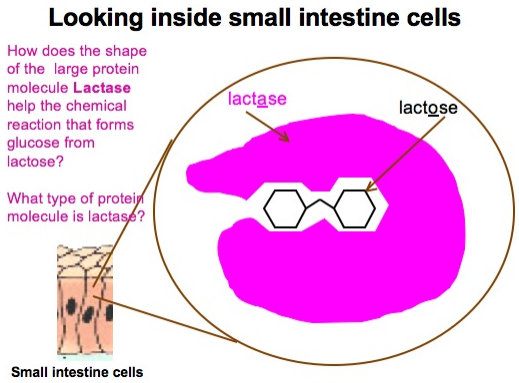
Slide 12 - Remind students to think about what happened to Jason when he drank milk. Where did the milk go? Refer students back to the Macro to Molecular chart as you make the connection from visual whole body traits, to tissues, and to cells. This connection is one of the common places students struggle when learning this material. Introduce the question

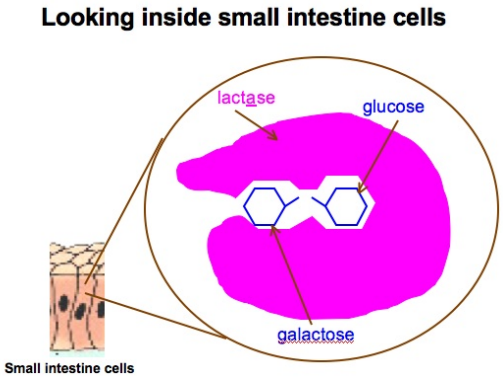
How is how is lactose broken down inside intestine cells?

Remind students of their investigation of skin color. Ask students what type of molecules helped produce melanin. Help students make connections to their previous activities with proteins called enzymes. Ask students what protein helped Jason's sister in breaking down lactose? Ask students to refer back at their KWL chart.



Slide 13 - Introduce the process of lactose being broken down into galactose and glucose. Again the emphasis on the molecules is that they have a specific **shape**, not to memorize the name of the molecule. Ask the students if they think lactose can break down all by itself or if it needs help





Slide 14 and 15- Show the cartoon image of lactase turning lactose into galactose and glucose. Point out that students do not need to know the molecules or processes. Focus on the way the **shape** of the protein matches the shape of the lactose, and the lactase inside of cells helps break down lactose. The words lactase and lactose are very similar. This is a perfect opportunity to remind students that that many proteins end in -ase and sugars end in -ose. Ask students to add a sentence telling why the shape of lactase is important under "L" in their KWL chart.

Remind students of the similarities and differences in Jason and his sister. Prompt students to think about how people could differ because of their proteins. Ask students the following:

What might be the difference between a person who can break down lactose and one who is lactose intolerant?

Answer: There might be a difference in their proteins (Lactase enzyme).

Ask students: What could Jason do so that he does not get sick anymore? Accept whatever answers students come up with.

- *Stop drinking milk*
- *Take medicine*
- *Drink milk designed for people with lactose intolerance*

Remind students that yesterday they were investigating medicine and milk for people with lactose intolerance. Ask students to turn to the investigation that they began the day before in their readers. What were we trying to find out? Why would we use glucose strips to show that lactase is in the medicine?

Lactase is a protein molecule that helps break down lactose into glucose. The strips will show if glucose is present.

Have students review their data and graph of the results. Review parts of a graph if necessary.

Ask students to share their data and discuss the results. Students may need support in identifying data that supports each question.
When students have completed the activity, ask them as a class:

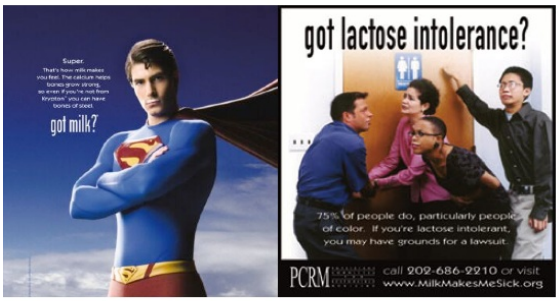
- Was there glucose in the milk before they added the medication? After?
  No, before. Yes, after
- What do they think happened?
  The medication broke down the lactose into glucose and galactose
- Would the medication do the same things if you swallowed them instead of mixing them into milk ahead of time?
  Students might have a harder time, but the medication does work the same in the human body
- What evidence do they have that the medication is lactase?
  They know that glucose was produced, if they look at the box, they will see that the pills are made of lactase

Ask students to complete the questions and write a scientific explanation as their conclusion to answer the questions posed in the lab. Encourage students to work in pairs as they write their explanations. If time is an issue assign one of the two questions to each pair of students.

Wrapping Up the Lesson

Reading 2.4B: "New Spoof of Milk Mustache Ad Spotlights Lactose Intolerance"
Ask students to think back to the story "Don't Pass the Milk, Please". Jason could not digest milk. After doing this activity, how do you think the results of your experiment might help Jason?

> *Student answers may vary, but the idea is that Jason can use lactase pills to help him break down lactose when he drinks milk or any other dairy products. This will prevent him from getting cramps from drinking milk. He could also drink or eat dairy products that already have lactase in them.*



Lactose intolerance?
Is it really an illness or are we victims of false advertising?

Slide 16- Use slide to introduce the homework reading**.** Ask students if they think the cells in our intestines are more similar or more different? Ask students what they think the captions in slide 2.4.6 mean? What is false advertising? Who sponsored each ad? Who would benefit from more people drinking milk?

Tell students that they will be reading an article about people who think that it is unfair for dairy producers to advertise for milk without warning people of the problems dairy products can cause. Ask students to read the article and think about whether they agree with the writers.

Lesson 5: Should differences in the proteins in our cells cause us to be treated differently?

OVERVIEW

Purpose
The purpose of this lesson is for students to apply their understandings lactose intolerance as they develop, communicate and defend an argument to solve an ethical problem.

Connection
This lesson allows students to apply their understandings from the previous lesson to an ethical dilemma. This lesson connects back to learning set one where students were identifying biological similarities and differences. This introduces students to argumentation which they will later use as they prepare for their final presentations.

Description
Students will develop class rules for using ethics to solve problems. Students will role-play the concerns of different stakeholders related to the issue of fair treatment for people with lactose intolerance. Students will develop arguments for solutions to the problem by applying their understanding of lactose intolerance.

Prior Knowledge Needed
Parts of a scientific explanation (see Learning Set 1, Lesson 1)

Student Conceptual Challenges
Students may have difficulty understanding the term "ethics" and identifying the ethical problem.

Safety Guidelines
None applicable

Learning Performance(s)
Students will use ethics to develop arguments for solutions to problems related to the fair treatment of people with lactose intolerance.
Students compare the causes of lactose intolerance and skin color at the molecular level.

PREPARATION
Before the activity begins, place four sheets of paper around the room, one that says "completely agree", one "agree", one "disagree", and the last "completely disagree". Large pieces of butcher paper would work well. Alternatively, each group could be provided with an overhead.

Materials

Student Reader pp. 63-71

INSTRUCTIONAL SEQUENCE

Reading 2.5: Thinking about Ethical Problems- Think, Pair, Share

Introducing the Reading

In this activity, students will consider the ethics of a proposal about the regulation of lactose in dairy products sold in the United States. Before addressing this topic, it will be important for your students to spend some time considering what ethics is, why it might be important, and how ethics will be discussed in the classroom. Ask students to think about the article that they read for homework. Ask students to compare their answers before and after reading the article with their partner. Ask a few groups to share their answers with the rest of the class. Discuss the following questions with the class.

- Did you have the same answers before and after reading the article?
- How did your ideas about lactose intolerance compare to the authors of the article? To each other?
- How did the authors think the problem of lactose intolerance should be solved?
- What were they doing to bring about a solution?

Tell students that the authors of the article were using the courts to help solve the problem of lactose intolerance. Another way to help people come up with solutions to problems such as how to treat people with lactose intolerance is by using ethics. Ask students what they think ethics is. Ask students to read about ethics in their reader and answer the questions included. Ask a few students to share their answers. As a class brainstorm about additional rules the class should include when dealing with an ethics problem.

Instructional note - Reading strategy

Consider using a concept card to help students think about the term “ethics”. What is ethics? What is not ethics? What is an example of an ethics problem?

Activity 2.5A- How Should People with Lactose Intolerance Be Treated?

Have students read about the proposed change to the sale of dairy products in their student reader and answer the first three questions. Ask individuals or groups to share some of their answers to the questions.

Discuss the meaning of "stakeholders". Use a school policy as an example such as wearing uniforms to describe stakeholders. As a class, brainstorm about potential stakeholders for the issue of lactose intolerance. (Some examples include: people who are lactose intolerant, people who are not lactose intolerant, dairy farmers, supermarket owners, companies that make lactase, government, etc.). Keep track of the stakeholders on the board, the overhead, or on sticky notes. Assign groups or individuals a stakeholder to consider and have each group consider the next questions in the student reader.

Ask each group to determine whether or not their stakeholder agrees with the position of adding lactase to all dairy products. Once they have determined their level of agreement, one member of the group can add their stakeholder to that piece of paper or overhead (completely agree, agree, disagree, completely disagree).

As a class, review which stakeholders agree or disagree. Ask groups to explain what concerns their stakeholder had and why their stakeholder agrees or does not agree. For the stakeholders who do not agree with the solution, what other solutions would they agree with? How do other stakeholders feel about the alternative solutions?

Wrapping up the Activity
Wrap up this activity by asking students to consider what solution they think is the best one and why? Some students might find it intimidating to share their personal opinions with the whole class, but encourage each student to write what they think. **Remind students that there is not a right or a wrong answer here, but it is important to have a reason for what they think.**

Activity 2.5B: Research Project- Exploring a Specific Disease or Trait

One of the main activities that students will do in this unit is a research project on a specific disease or trait. A collection of diseases or traits to choose from can be found in the teacher guide at the end of this lesson and in the Research Project section at the end of the Reader. It is up to your discretion to decide to let students choose diseases or traits outside of these.

Students will choose a trait or disease to research related to:

- Skin color
- Lactose intolerance
- FH disease (high cholesterol and heart disease)
- Sickle cell anemia
- Other possible topics from list provided

The list has a little bit of information about the trait and websites with information for further research. Students will use the ethical decision making framework to guide their research. Students must present an argument to support their position on an ethical question related to their topic. It is up to the teacher to determine how students will present their argument, either in groups or individually. Some suggestions are:

1. Poster or Powerpoint- Groups could do a poster/PowerPoint presentation on an ethical issue related to their topic.

2. Pamphlet- Groups could design a pamphlet from the perspective of a stakeholder in an ethical issue related to one of the above topics. They would present the pamphlet and the issues from as if they were the stakeholder.

3. Demonstrate a lab related to their topic- browning apple lab- skin color, protein lab, lactase lab- lactose intolerance, DNA extraction lab.

4. Performance- Groups could write and perform a skit or rap related to one of the topics.

5. Art project- Groups could create an artwork, sculpture, painting related to their topic. They must also include a short report or poster providing information about the topic and art work.

You may allow students to choose or you may assign them a specific format for their presentation. The presentations must include a **claim, evidence and reasoning** for the actions that are recommended. More detailed descriptions can be found in the Student Presentation Guidelines included in the teacher materials. Students may also identify a career from the list provided in the Presentation Guidelines as one of their stakeholders. Students may research that career as a part of their presentation. Students will share these products with their peers and possibly their communities.

To help students with the final product, several steps are included:

Step 1- Students pick a topic and reflect on why they are interested and what they already know about it. Their choice will be submitted to the teacher using the Presentation Proposal form in their reader.

Step 2- Students use suggested websites to help answer questions provided in the student reader.

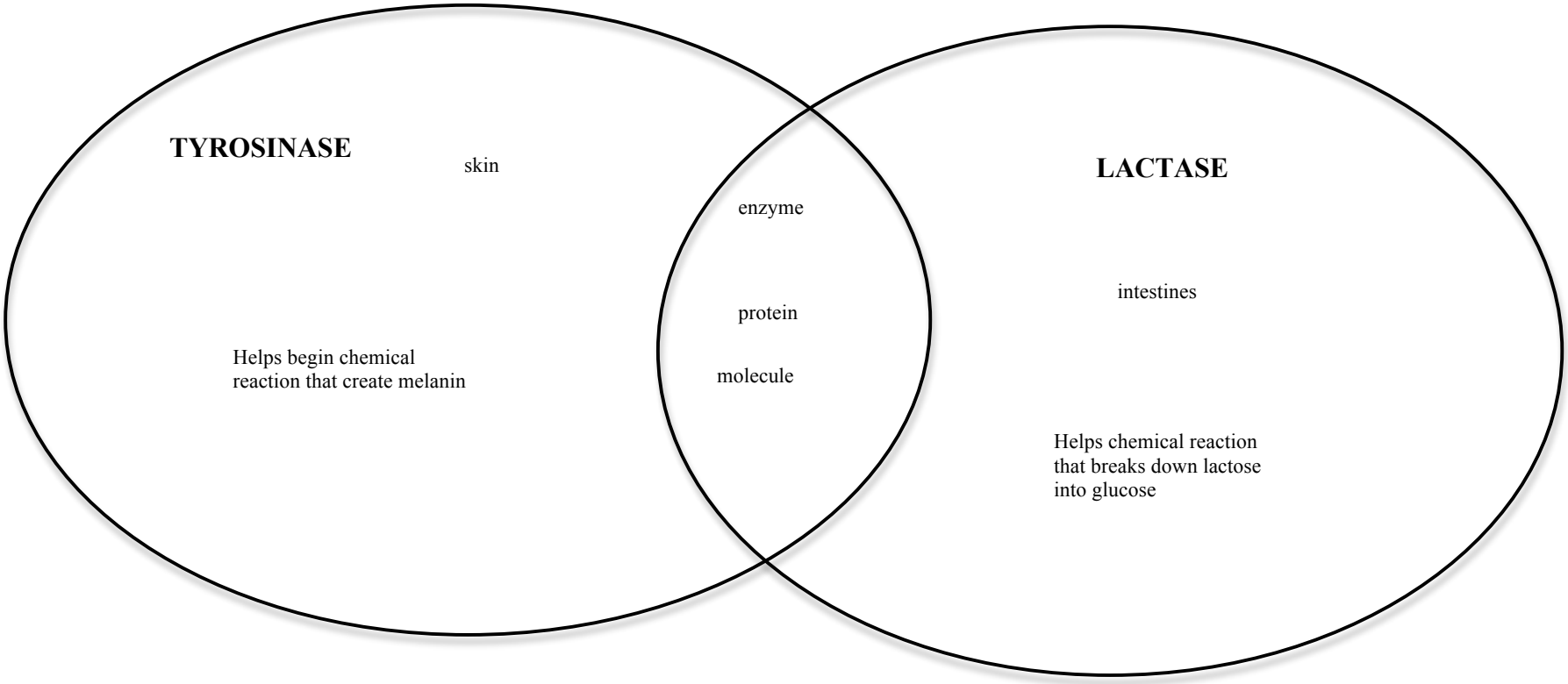
Step 3- Students identify an ethical question to address related to their topic from the list provided in the reader.

Step 4-Students use a provided template and the answers they have researched to generate a final product.

It is up to your discretion to establish a time line and to use class time to research and work on the projects. Some suggestions are provided in the teacher guide in future lessons.

Activity 2.5C: Revisiting the Driving Question-Comparing tyrosinase and lactase

Ask students to think about our driving question, "How similar or different are we?" Remind them that they have investigated two differences in people, the way their digestive system works and skin color. Remind student that both of these differences were caused by differences that occur at the cellular level. Ask students to identify the proteins that cause these differences. Have the class brainstorm words that describe tyrosinase and lactose such as enzyme, protein, molecule, intestines, skin, melanin, glucose, shape etc. Guide students in using a Venn diagram to discuss the similarities and differences in tyrosinase and lactase. Have students complete diagram for homework if more time is needed. See sample on next page:


TYROSINASE
skin
Helps begin chemical reaction that create melanin
enzyme
protein
molecule
LACTASE
intestines
Helps chemical reaction that breaks down lactose into glucose

Lesson 6: What are proteins made of?

OVERVIEW

Purpose
This section is intended to introduce students to the idea that amino acids make up proteins and that proteins can be modeled in multiple ways. By the end of this lesson, students should understand that (1) proteins are made up of amino acids and (2) and that different models can represent different aspects of the same protein.

Connection
This is a key lesson to learning what proteins are made of. Students started constructing models in learning set 1, and in this lesson they continue to look at models and learn why scientists often use a different representation of the same object to point out different features. This lesson also builds on lesson 3 by identifying the molecules that make up proteins. This lesson is a prelude to lesson 7 where students build the active site the lactase proteins using a toober.

Description
Students learn that proteins are made up of amino acids, and that the amino acid sequence can affect the protein structure. Students also explore multiple models that represent the same protein.

Safety Guidelines
None applicable

Learning Performances
- Explain that proteins are made of amino acids and consequently the order of amino acids in a protein determines its structure
- Describe the importance of multiple models to represent the same protein

PREPARATION
Materials
PowerPoint LS2 slides 11- 23
Student Reader pp: 72-78

INSTRUCTIONAL SEQUENCE
In previous lessons, students considered differences at the cellular level and differences between proteins, like lactase and tyrosinase. In this lesson, we will go deeper to find out what proteins are made of causing these differences in proteins.

Extended Preview Guide for Reading 2.6A – "Protein Shape is Dependent on Amino Acids"
Start the lesson by explaining to students that they are going to make predictions about the information in Reading 2.6A, "Protein Shape is Dependent on Amino Acids". Inform students that they should be prepared to share their predictions and the reasoning for their predictions in small groups. When the students are finished making predictions and sharing/discussing their predictions in a small group, they

should complete the "Answer" column of the preview guide while reading "Protein Shape is Dependent on Amino Acids" – Reading 2.6A, and then answer the "After Reading" questions.

Teaching Strategy:

This preview guide will cue students to the major ideas in the reading, activate their prior knowledge about what proteins are made of and what gives them their specific shape, motivate them to read so they can confirm their predictions and to refute their classmates' predictions. Student misconceptions will be addressed openly and are more likely to be changed after reading and discussing what the students learned.

After the students finish the "After Reading" questions, have them share which predictions the reading supported or did not support and then where they found that information in the reading. Ask students if they were surprised by any of their predictions that were refuted and why?

Introducing Activity 2.6

Have students turn to activity sheet 2.6 in their student reader, as the activity sheet will have pictures for them to reference and questions for them to respond to.

Brainstorming:

Ask students to write on their activity sheet why scientists use models, such as a globe or a map. Remind students that they made models of their skin in learning set 1. After a couple of minutes, ask for students to share their ideas.

- Students may respond that models make it easier to:
    - see objects or processes in nature that we normally cannot see because they are too big or too small to see with our own eyes (e.g. cells, the water cycle)
    - move (or manipulate) something that we could not under normal circumstances (e.g. organs or atoms)
    - allows us to work with something that might be dangerous or will not stay still to work with normally (e.g. animals, bugs)

Reference the macro – molecular chart and ask students why scientists might make models of proteins. (Since proteins cannot be seen with the naked eye, we need to build models of them to be able to manipulate them.)

Class Discussion of Modeling (using slides 2.6.1 – 2.6.3)

Teacher explanation

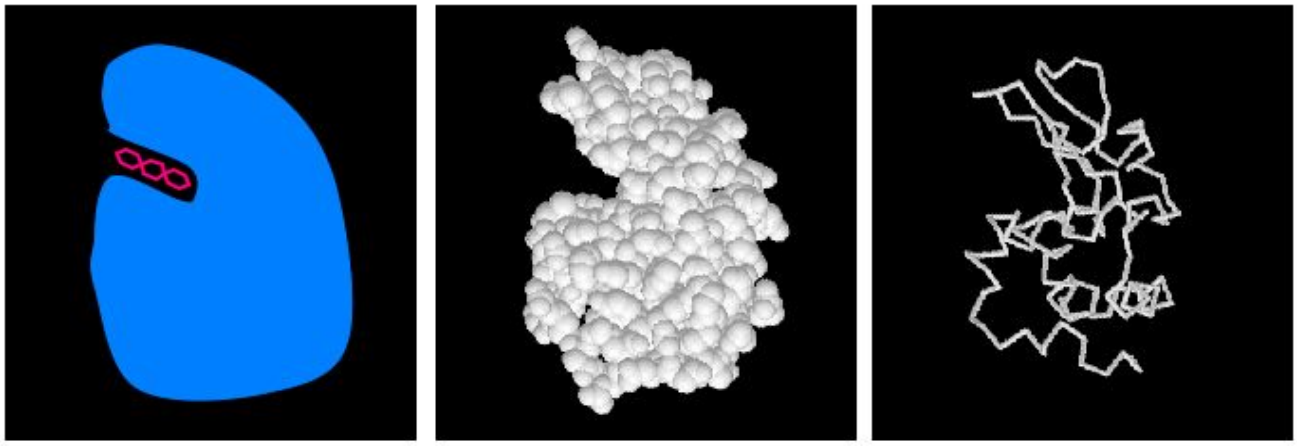
Remind students that they just read in Reading 2.6A that proteins are actually 3-dimentional molecules. 2-D images do not always convey this, so scientists try to construct multiple 2-D models to show different aspects of the 3-D object since a single 2-D model cannot. These three images of the protein lactase can be found at the bottom of activity sheet 2.6 and in color on slide 2.6.1. Explain to the students that these are all images of the protein lactase and that scientists often use a different representation of the same thing to point out different features.

Carrying out Activity 2.6

Ask students to:

1. Look at the three images.
2. What do you think are the advantages of each image?
3. Write those ideas in the space provided below each image.

After a couple minutes, ask students to share their ideas. You can use the Think-Pair-Share strategy and have the students pair up before sharing with the class if you think this will help students flush out their ideas better.



Class Discussion

During this discussion, emphasize the difference of each model:

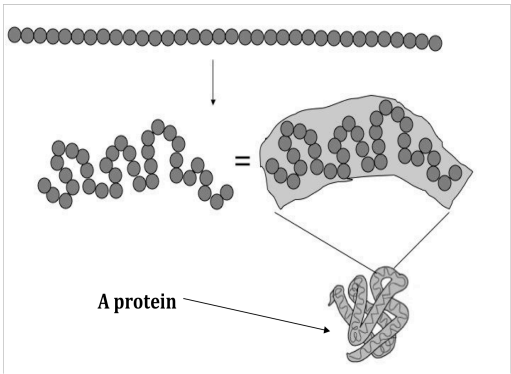
1. The cartoon version of the protein (blue packman like structure on the left) can be easier to understand and so sometimes scientists simplify molecules in a cartoon fashion.
2. The image in the middle shows a more realistic image of the protein, because it shows all the atoms that make up the protein. We call this particular image a space-filling model.
3. The image on the far right shows the chain that is folded on itself. We call this the backbone or ribbon model.

Instructional Note:

It is common for students not to realize that different representations of molecules actually are referring to the same thing or certain models can show different aspects of the same object or process. Be explicit and help students make this connection. So if you show a representation that is new to students (i.e. one they have not seen before such as a ball and stick model or a ribbon diagram) do not assume students will know it is a protein or that they know how to interpret the image, you may have to point out what they are looking at is a protein and help them make sense of the new representation. It may also be useful here to point out what each kind or representation affords the viewer to help students realize why different representations are used

(e.g. better 3-D understanding, easier to visual the chain, easier to recognize all the atoms and types of atoms, etc.)

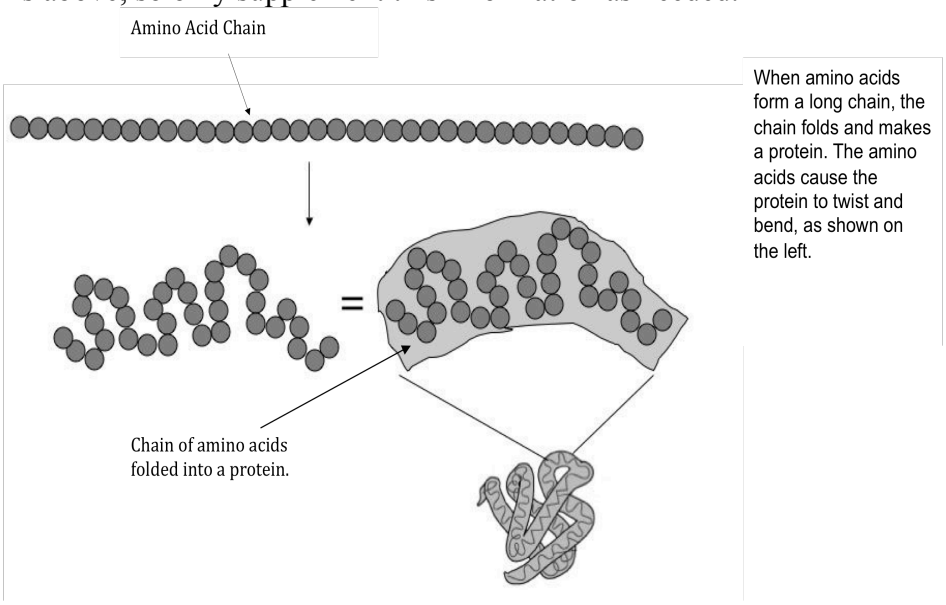
Next have students look at slide 2.6.2. Ask students what they see in the slide.



They may respond:

- a protein
- a chain of amino acids
- each circle represents an amino acid
- an amino acid chain folded on it self

Show slide 2.6.3 and remind students that they just read in reading 2.6A that proteins are made up of smaller subunits called amino acids. Focus your students' attention on the individual parts of the chain in slide 2.6.3 (the beads in the image above and below) and that these individual beads represent each individual amino acid. Point out the "beads" (amino acids) fold on them selves, which makes up part of a bigger fold, as seen in slide 2.6.4 (shown below). Students should also remember from the reading that there are only 20 amino acids used in most organisms to make up proteins. Students may have stated parts of this above, so only supplement this information as needed.



Return to Driving Questions Board:

Ask students:

- How do the unique properties of different proteins and different amino acids help us answer the DQ (How similar or different are we?)?
    - Students might respond:
        - We are similar because all proteins are made from the same 20 amino acids.
        - We are different because those 20 amino acids can be arranged in any order.
        - We are different because not all proteins fold the same…folding is dependent on the amino acid arrangement.
        - We are similar, because we all need proteins to do the same critical functions.

- Do you have more questions that need to be added to the driving question board (DQB)?

Reading 2.6 – Bonding of Amino Acids

Tell students to turn the page to reading 2.6B – Bonding of Amino Acids. Before assigning the reading for homework ask:

- When looking at the picture at the top of reading 2.6B, does anyone know what this chemical structure is representing?
    - Possible responses:
        - an amino acid
        - a molecule
        - atoms joined together
- Can anyone guess why there are lines drawn between some of the atoms?
    - Possible responses:
        - because those atoms need to be next to each other
        - because those atoms are joined together
        - so that we know how they are arranged

Students may discuss molecules that were introduced during lesson 5 in learning set 1. Ask students how this image is similar and different to the structures they looked at during that mini-chemistry less. Having the correct answer is not important. This dialogue is meant to create a purpose for the reading – stress to students they do not know how all of these atoms stay "joined" together to make an amino acids or how all the amino acids stay "joined" together to make a protein. This purpose will also help students discover chemical bonding!

The first paragraph of the reading is an overview of the organic chemistry that surrounds amino acids. You should go through this information with the students in case they have questions.

Lesson 7: How are cells different? - How do amino acid properties affect protein structure?

OVERVIEW

Purpose

This section is intended to introduce students to the idea that the order of amino acids determines the structure of the protein. Students will then explore how amino acids influence protein structure by building models of proteins.

Connection

This is a key lesson to learning how protein structure is determined. It continues the idea that the order of the amino acid sequence determines protein shape/function from lesson 6 by looking at how the differences in amino acid sequence leads to different protein properties. This lesson is a prelude to lesson 8, because students move on from looking at models of proteins to how scientists detect the presence of proteins.

Description

Students learn about amino acids and their role in determining protein shape by building models of proteins. Students build models of a random amino acid sequence and then the "mouth" of the lactase protein, and learn how amino acid sequence determines the shape proteins.

Safety Guidelines

None applicable

Time

2 days

Learning Performances:
Students assemble proteins as a way to describe the protein's structure
Explain that the order of amino acids in a protein determines its structure and consequently its function
Students explain how properties of amino-acid side chains such as charge, hydrophobicity and size can affect protein folding.
Explain that different cells' function differently because they have different proteins in them

PREPARATION

Materials

PowerPoint LS 2 slides 24 - 28
Student Reader pp:79-82

INSTRUCTIONAL SEQUENCE

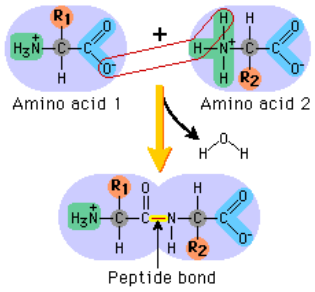
Review Reading 2.6B – Bonding of Amino Acids

Discuss the after reading questions from reading 2.6B with students. Emphasize with students that:

- Proteins are made from 20 different amino acids
- Each amino acid has its own set of unique properties
- These amino acids join to each other to make a protein
- Protein folding is a result of each amino acid's unique properties interacting with the properties of the amino acids that it is joined to
- An amino acid chain that creates a protein can have anywhere from 50 to over 3,000 amino acids to joined to each other
- The different combinations of amino acids is what produces unique proteins with unique properties

This information should come out while discussing the after reading questions. Supplement the above information as needed. The after reading question #3 could be used as a formative assessment.

Class discussion
Now that we know that atoms can be joined together, we were also able to learn that individual amino acids join to form a chain. You do not have to know how these amino acids are joined together for this unit, just that individual amino acids are brought together to form a long chain. The image on this slide (2.7.1) summarizes this mechanism.



Point out that "R" represents the variable region in each protein.

Instructional note: Putting protein into cellular context

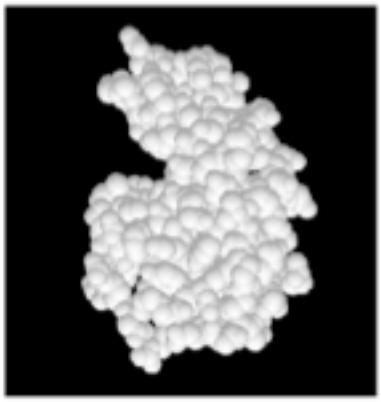
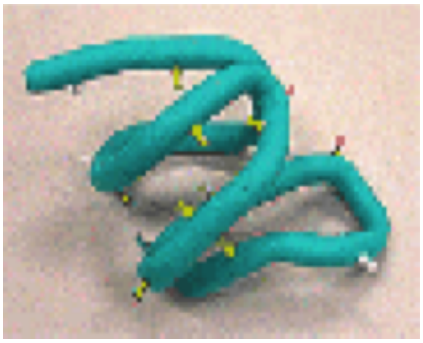
Make sure when talking about proteins that you remind students that proteins are made inside of cells and can be found in the environment surrounding cells when they are secreted by a cell. The goal is to keep students constantly aware of the fact that when we are talking about proteins, we are doing so in the context of a cell. Reference the macro-molecular chart often to remind students where on the scale they are working.

Activity 2.8A – Toober Models

Toober Intro Discussion:

1. Remind students that proteins are essentially a long chain folded on top of itself and protein structure is important for protein function and that is why they need to understand what influences protein structure.
2. Inform students they will now engage in a activity that will show them how amino acids influence protein structure

3. Pull out a toober (flexible tube that can be bent and folded) and explain this will mimic a protein chain. Show side by side images of a lactase toober model and 2 other models of lactase (slide 2.7.2) to:

   a. emphasize the point that these toobers are used here to model the amino acid chain of a protein
   b. point out the toober is representing all the central carbon atoms of each amino acid (absent are all the variable side chains and all other atoms that make up each amino acid)
   c. ask students why they think we are building models of proteins (they should remember this from our discussion of the different possible ways to model amino acids and proteins)
      i. students may respond:
         1. that models are representations of objects (phenomena) that we normally cannot see because amino acids and proteins are too small. We can't even see them with a light microscope
         2. models allow us to make predictions, and test predictions, so we can understand objects (phenomena) that we cannot see easily
         3. models here will allow us to make prediction about how proteins work and function

Explain that the chemical and physical properties of amino acid influence how proteins fold and consequently their shape. Properties that students should be aware of are:

- charge (positive or negative)
- hydrophobicity (hydrophobic = water hating; hydrophilic = water loving).

These properties can also be found on the students' activity sheet 2.8A.

Teacher Note

Your students may not be familiar with the above physical properties. Below you will find a brief explanation for each:

***Positive and Negative Charges**: Students need to understand that amino acids with a similar charge repel each other (e.g. negatively charged amino acids repel other negatively charged amino acids), and that oppositely charged amino acids attract each other (e.g. negatively charged amino acids attract positively charged amino acids and vice versa). You might compare this repulsion and attraction to magnets. Students have probably noticed magnets attract each other. Ask if any of them have ever noticed two magnets push each other apart when you put the end of one of the magnets to the end of the*

other. This is due to the magnets having a negatively and a positively charged end also.

***Hydrophobicity**:*
One of the strongest driving forces for determining protein shape is the hydrophobic nature of some amino acids. Since hydrophobic amino acids like to be next to other hydrophobic amino acids, this causes most of the hydrophobic amino acids to fold into the center of the protein and leave hydrophilic amino acids on the surface. Most proteins therefore have a hydrophobic core. One important exception are the membrane proteins in particular the channel proteins which have some hydrophobic amino acids on the surface to interact with the hydrophobic lipids in the membrane (channel proteins also some hydrophilic amino acids on the inside of a pore to allow water to flow through).

To help your students with the idea of hydrophobicity, show the animation found at http://www.stolaf.edu/people/giannini/flashanimat/proteins/hydrophobic%20force.swf .

This link is also found on slide 2:7:??. Before playing the animation, point out to your students that parts of the protein chain found at the top are hydrophilic (they like water) while the others are hydrophobic (they do not like water). Each red and black section of this protein represents a different amino acid. Tell students to first watch where the water molecules go while the animation plays. They will see the water molecules are attracted to the hydrophilic amino acids (the black sections of the protein) and NOT to the hydrophobic amino acids (the red sections of the protein). Play the animation again, so the students can specifically watch the water molecules moving towards the hydrophilic amino acids. Show the students the animation a 3rd time telling them to watch what happens to the water as the protein folds. Ask students, "Where are the hydrophilic and hydrophobic amino acids in reference to each other?" It is important that your students understand that the hydrophobic amino acids will move to the center of the protein during folding creating a hydrophobic center to the protein, while the hydrophilic amino acids will move towards the outside of the protein surrounded by water.

5. Explain the following "rules" that amino acids follow. Please make sure that you have discussed charges and hydrophobicity with your students, because the below rules will make much more sense after you have had these discussions with your students.

a. Positive and negative charged amino acids attract each other
b. Amino acids with the same kind of charged repel each other
c. Hydrophobic amino acids repel both water and other hydrophilic amino acids
d. Hydrophilic amino acids attract water
e. Hydrophobic amino acids attract each other.

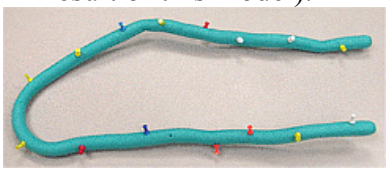
These rules can also be found on the students' activity sheet 2.7A and slide 2.7.6.

Toober Activity Instructions

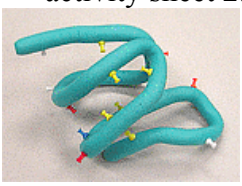
1. Ask students to turn to activity sheet 2.7A. Break students into groups. Students take 15 thumbtacks at random (pick out of a box without looking). Explain that each thumbtack represents an amino acid with a different property. Explain the following key for colored thumbtacks. Projector this key on the board so student can view during the entire activity.

   Red = positive charge (+)
   Yellow = negative charge (-)
   Green = hydrophobic
   Blue = hydrophilic

2. Ask each group to place the thumbtacks into the Toober like seen below in any order they want to. Remind students that they need to visualize each thumb tack as a different amino acid and that in reality each is pieced together to form a chain – unlike this model where tacks are placed on an existing piece (we don't want any misconceptions about protein assembly to develop as a result of this model).



3. Ask students to bend the Toober with tacks according to "the rules" for amino acids. Have them draw as best they can what the folded amino acid sequence looks like that they created on activity sheet 2.7A.



4. Now ask the students to replace two of the red tacks with yellow tacks and ask them to draw the resulting folded protein on activity sheet 2.7A. Then ask them to swap two of the blue tacks with green tacks and ask them to draw the resulting protein. Also ask students to describe in words what is different. Suggest to students that they fold the toober into the correct position after switching the tacks on activity sheet 2.7A. This will make it easier to draw the new protein structure with folding.

5. Reconvene the class and as a class answer the following question after comparing protein from each class
   a. How many different shapes were created as a whole class?
      a. Answer: There should be as many different toober shapes as ther are groups. This means there are a huge number of shapes that can be created from just a certain number of amino acids.
   b. Did the shape change after swapping differently charged amino acids?
      a. Answer: Yes

c. Did the shape change after swapping hydrophilic amino acids with hydrophobic amino acids?
    a. Answer: Yes
d. The human body is estimated to have at least tens of thousands of proteins even though there are only 20 amino acid that make up proteins. Explain how you can get so many different proteins using just 20 parts.
    a. Answer: There is a huge number of different ways these proteins could be put together leading to a huge number of different shaped proteins.
e. Remember amino acids are actually bonded or joined together (unlike the model here where), if you were to delete a amino acid (i.e. thumb tack) or add a new one. Do you think it would change the shape of the protein?
    a. Answer: Yes, because it would change the order of the amino acids with different amino acid properties interacting with each other.
f. Would it be possible to just swap one amino acid and get a change? Would it be possible to swap an amino acid and not get a change?
    a. Answer 1: Yes, you could swap one amino acid for another and get a change, because the amino acid might have different properties and this would change the interactions between amino acids in the protein.
    b. Answer 2: Yes, you could swap an amino acid for another one and NOT get a change, because two amino acids might have similar properties (like swapping a hydrophobic amino acid for another hydrophobic amino acid) therefore the swap would not change the amino acid interactions.

Concluding Activity 2.7A

Tell students they will build a lactase protein tomorrow, and they will use the rules to protein folding that they learned today to see how mutations affect protein shape.

Teacher Background Knowledge - Protein folding:

One of the strongest driving forces for determining protein shape is the hydrophobic nature of some amino acids. Since hydrophobic amino acids like to be next to other hydrophobic amino acids, this causes most of the hydrophobic amino acids to fold into the center of the protein and leave hydrophilic amino acids on the surface, because the average adult body is about 60-70% water. Most proteins therefore have a hydrophobic core. One important exception are the membrane proteins in particular the channel proteins which have some hydrophobic amino acids on the surface to interact with the hydrophobic lipids in the membrane (channel proteins also some hydrophilic amino acids on the inside of a pore to allow water to flow through).

For more background information about protein and protein folding check out the following websites.

http://folding.stanford.edu/education/protein.html

- Check "proteins" "protein structure" and "protein folding"

http://www.learner.org/channel/courses/biology/textbook/proteo/proteo_2.html
- Check out the introduction to protein folding. If you go to the figure there is also a nice narrated video on protein structure. Note we will not go into the detail of structure that this covers nor any of the methods for analyzing protein structure talked about here, but if you are interested in more information about proteins, and the newest frontier in biochemistry, proteomics, this site provides plenty of information to understand this.

Teacher Background Knowledge: Number of proteins found in humans.

One could estimate at a minimum number of proteins in humans to be 20,000-25,000 based on the knowledge that one gene encodes one protein (the human genome has identified at least 20,000-25,000 genes). But in actuality several proteins can be made from one gene as a result of cutting and pasting RNA molecules after transcription, therefore the actual number of different protein found in the human body is much higher- probably more like 100,000. However the notion that more than one protein can be encoded by one gene goes beyond the scope of this unit.

Carrying Out Activity 2.7B

Explain to students they will now make a model of a real protein, lactase. Ask students if they remember what lactase does and have them write it or draw it on activity sheet 2.7B. Show previously used slides if necessary.

Next have students write how proteins work as proteins:
• facilitate the formation or breakage of bonds helping to form new molecules
• "fit" with substrate (lactose in this case)

Break students into groups and project slide 2.7.8 (15 amino acid sequence). Explain that this part of the protein is part of the "mouth" of lactase. It is only a small part of the protein; the whole protein is almost 2000 amino acids long! Have each group collect the appropriately colored thumbtacks for each amino acid following the rules stated on activity sheet 2.7A.

Let students know that the folds they generate may not be completely accurate, but will form a representation of the molecule that they can manipulate. Sometimes models are not completely accurate, but they can give us information and ways to think about problems that are hard to visualize.

DIPIY ITENGVGLTN (AA 1266-1280)

Note this is only part of the active site (i.e. the mouth) of lactase.

A = alanine	C = cysteine	D = aspartic acid
E = glutamic acid	F = phenylalanine	G = glycine
H = histidine	I = isoleucine	K = lysine
L = leucine	M = methionine	N = asparagine
P = protline	Q = glutamine	R - arginine
S = serine	T = threonine	V = valine
W = tryptophan	Y = tyrosine	

Teacher Reference: Full lactase amino acid Sequence:

```
MELSWHVVFI ALLSFSCWGS DWESDRNFIS TAGPLTNDLL HNLSGLLGDQ
SSNFVAGDKD MYVCHQPLPT FLPEYFSSLH ASQITHYKVF LSWAQLLPAG 100
STQNPDEKTV QCYRRLLKAL KTARLQPMVI LHHQTLPAST LRRTEAFADL
FADYATFAFH SFGDLVGIWF TFSDLEEVIK ELPHQESRAS QLQTLSDAHR 200
KAYEIYHESY AFQGGKLSVV LRAEDIPELL LEPPISALAQ DTVDFLSLDL
SYECQNEASL RQKLSKLQTI EPKVKVFIFN LKLPDCPSTM KNPASLLFSL 300
FEAINKDQVL TIGFDINEFL SCSSSSKKSM SCSLTGSLAL QPDQQQDHET
TDSSPASAYQ RVWEAFANQS RAERDAFLQD TFPEGFLWGA STGAFNVEGG 400
WAEGGRGVSI WDPRRPLNTT EGQATLEVAS DSYHKVASDV ALLCGLRAQV
YKFSISWSRI FPMGHGSSPS LPGVAYYNKL IDRLQDAGIE PMATLFHWDL 500
PQALQDHGGW QNESVVDAFL DYAAFCFSTF GDRVKLWVTF HEPWVMSYAG
YGTGQHPPGI SDPGVASFKV AHLVLKAHAR TWHHYNSHHR PQQQGHVGIV 600
LNSDWAEPLS PERPEDLRAS ERFLHFMLGW FAHPVFVDGD YPATLRTQIQ
QMNRQCSHPV AQLPEFTEAE KQLLKGSADF LGLSHYTSRL ISNAPQNTCI 700
PSYDTIGGFS QHVNHVWPQT SSSWIRVVPW GIRRLLQFVS LEYTRGKVPI
YLAGNGMPIG ESENLFDDSL RVDYFNQYIN EVLKAIKEDS VDVRSYIARS 800
LIDGFEGPSG YSQRFGLHHV NFSDSSKSRT PRKSAYFFTS IIEKNGFLTK
GAKRLLPPNT VNLPSKVRAF TFPSEVPSKA KVVWEKFSSQ PKFERDLFYH 900
GTFRDDFLWG VSSSAYQIEG AWDADGKGPS IWDNFTHTPG SNVKDNATGD
IACDSYHQLD ADLNMLRALK VKAYRFSISW SRIFPTGRNS SINSHGVDYY 1000
NRLINGLVAS NIFPMVTLFH WDLPQALQDI GGWENPALID LFDSYADFCF
QTFGDRVKFW MTFNEPMYLA WLGYGSGEFP PGVKDPGWAP YRIAHTVIKA 1100
HARVYHTYDE KYRQEQKGVI SLSLSTHWAE PKSPGVPRDV EAADRMLQFS
LGWFAHPIFR NGDYPDTMKW KVGNRSELQH LATSRLPSFT EEEKRFIRAT 1200
ADVFCLNTYY SRIVQHKTPR LNPPSYEDDQ EMAEEEDPSW PSTAMNRAAP
WGTRRLLNWI KEEYG DIPIY ITENGVGLTN PNTEDTDRIF YHKTYINEAL 1300
KAYRLDGIDL RGYVAWSLMD NFEWLNGYTV KFGLYHVDFN NTNRPRTARA
SARYYTEVIT NNGMPLARED EFLYGRFPEG FIWSAASAAY QIEGAWRADG 1400
KGLSIWDTFS HTPLRVENDA IGDVACDSYH KIAEDLVTLQ NLGVSHYRFS
ISWSRILPDG TTRYINEAGL NYYVRLIDTL LAASIQPQVT IYHWDLPQTL 1500
QDVGGWENET IVQRFKEYAD VLFQRLGDKV KFWITLNEPF VIAYQGYGYG
TAAPGVSNRP GTAPYIVGHN LIKAHAEAWH LYNDVYRASQ GGVISITISS 1600
DWAEPRDPSN QEDVEAARRY VQFMGGWFAH PIFKNGDYNE VMKTRIRDRS
LAAGLNKSRL PEFTESEKRR INGTYDFFGF NHYTTVLAYN LNYATAISSF 1700
DADRGVASIA DRSWPDSGSF WLKMTPFGFR RILNWLKEEY NDPPIYVTEN
GVSQREETDL NDTARIYYLR TYINEALKAV QDKVDLRGYT VWSAMDNFEW 1800
ATGFSERFGL HFVNYSDPSL PRIPKASAKF YASVVRCNGF PDPATGPHAC
LHQPDAGPTI SPVRQEEVQF LGLMLGTTEA QTALYVLFSL VLLGVCGLAF 1900
```

`LSYKYCKRSK QGKTQRSQQE LSPVSSF`

After students have built their model try to identify a mouth in the model (i.e. a spot that looks like a mouth where a lactose molecule can fit). This step might take a creative eye. After identifying a mouth in the protein, ask the students to swap a tack in mouth to see how the protein shape changes due to a change in amino acid.

Activity 2.7B Discussion

1. Based on what you learned from these activities with protein models, what general statements can you make about amino acid sequence in proteins and its relationship to function?
Answer: The amino acid organization (i.e. the arrangement of amino acids) in the protein determines the protein's shape or structure.
2. If the protein structure is disrupted, could the function of the protein be affected? (Note - Students may not immediately come up with these ideas. If this is the case, ask prompting questions like:
- Since you just related changes in the order of amino acids to protein shape or structure, what can you say about this relationship?)
Answer: Yes, the protein function could be changed, because the protein shape's is specific to the substrate that fits in it (like a lock and key). If the substrate cannot fit inside the protein, the protein cannot do its job.

Once students are finished experimenting with changing amino acids in the lactase active site, give them time to answer questions on activity sheet 2.7B.

Ask students to answer the following questions
a. What happened to the shape of the mouth after each amino acid change (i.e. tack change)?
b. Do you still think the lactose will fit in the mouth?
c. How do you think these changes would affect the ability of lactase to break down lactose?
d. What might happen to the person who has this abnormal protein?

Checkpoint: Ask students to write their answers in their student guide.

Lesson 8: Why are cells so different? - How can we detect the presence of proteins?

OVERVIEW

Purpose
For students to see how scientists detect proteins, since they are not large enough to be seen with a microscope.

Connection
This lesson connects to learning set 3, as students will use electrophoresis data again to detect the presence of specific proteins.

Description
Students learn how to read pictures of electrophoresis gels, so they can write a scientific explanation diagnosing lactose intolerance in two unknown protein samples.

Safety Guidelines

None applicable

Learning Performances:
Students use gel electrophoresis data to write a scientific explanation diagnosing unknown lactose samples.

PREPARATION

Materials
PowerPoint LS2slides – Slide 29-35
Student Reader pp:84-85

INSTRUCTIONAL SEQUENCE

Class discussion - Understanding gel electrophoresis

Ask the students if they have any ideas about how scientist might be able to detect proteins like lactase or tyrosinase. If students say a microscope, reference the macro – molecular chart to help remind them that proteins are too small to be seen with the naked or even a microscope.

> *The answer to this question is hard because there are not a lot of good ways to look at proteins, since they are too small to be seen with a microscope. This is why modeling proteins is so important. Scientists are still looking for good ways to look at proteins. Current techniques focus on taking large samples of proteins and analyzing them in indirect ways - such as gel electrophoresis.*

Where should scientists look if they want to study tryrosinase? What about lactase?

Hopefully students think to look in the skin and the intestine respectively, if not prompting to recall where their functions are needed might be necessary.

Ask the student to imagine that we have samples of both tyrosinase and lactase and that we are going to use a technique called gel electrophoresis to analyze them. Explain that we can learn two types of information about our samples:

1. What size each molecule of protein is.
2. How many molecules of protein we have (relatively)

Introducing Activity 2.8
Since students most likely will not have any previous experience with gel electrophoresis, give them a simulated tour of a gel using slides 29-35

Slide 29 - Give the students a tour of a gel. A gel is a thin rectangular square that roughly has the consistency of a thick Jell-O. If one looked at the gel under a very powerful microscope they would see a thick jungle- like mesh for fibers. There are holes where we are going to add our samples.

Slide 30 - We start to add our samples to our gel. The first sample is a solution of lots of different proteins. This will give us something to compare our samples of lactase and tyrosinase to.

Slide 31 - We put our samples of lacatase and tyrosinase in the holes in the gel. Each sample has billions of lactase and tyrosinase proteins even though only a few are shown.

Slide 32 - We turn on the gel by putting a positive electrode at the bottom and a negative electrode at the other end, creating an electric current that runs through the gel. Our proteins are negatively charged so they want to move towards the positive electrode.

Slide 33 – Before showing this slide, ask the students whether they think the small or the big protein can move through the Jello like substance more easily? It is easier for small proteins to move through the gel, so they move faster than the big proteins.

Slide 34 – Good scientists always keep a record of their work so we need a picture of the gel. The picture captures all the places where the proteins have moved.

Ask students to open readers to activity sheet 2.8 on page 84. The gel electrophoresis picture is the same as the one on slide 33. Students should notice that the 3rd column that contains lactase has two darkened rectangles indicating proteins are present in those locations. On activity sheet 2.8, have students write why they think the column with lactase has two darkened rectangles while the column with tryosinase only has one darkened rectangle.

Carrying Out Activity 2.8 - Analyzing gel electrophoresis data
Divide the students into groups. Explain to the students that they are going to look at some gel electrophoresis data. There are three samples on the gel. One of the samples came from a person who

does not have lactose intolerance. The other two samples came from people who don't know whether or not they are lactose tolerance. Show students slide 35. Tell students they will find the same picture on activity sheet 2.8 on page 35.

Ask each group to diagnose person 2 and person 3 and then write a recommendation for each person indicating whether or not they think the person should drink milk. Remind them to include a scientific explanation about why they have made this decision.

Answers: *Hopefully students realize that person 2 does not have the protein and would not be able to effectively break down lactose. Person 3 has less protein and it is open to interpretation whether or not this person should drink milk.*

Concluding Activity 2.8
Ask a few groups to share their scientific explanations on whether person 2 and 3 should drink milk. Tell students that we will use gel electrophoresis and other forms of data in the next learning set look at diseases that are caused by changes in the amino acid sequence.

CONCLUDING LEARNING SET 2
Return to Driving Questions Board:
Ask students:
How does the amino acid sequence's affect on protein folding help us answer the DQ (How similar or different are we?)?

Students might respond:

- We are similar because all amino acids are made from the same general chemical structure (a central carbon, connected to a nitrogen on one side, a carbon with oxygen on another side and a variable group)
- We are the same because our amino acids follow the same "rules" when proteins are folding
- We are different, because people can have different amino acid sequences even though the protein ultimately functions the same.
- Students will come up with other ideas. These are just suggestions

Do you have more questions that need to be added to the driving question board (DQB)?

Return to the Macro – Molecular Chart
Ask students:

Are there any new words that we can add to our macro – molecular chart?

- any of the amino acids listed in lesson 8
- any of the categories that the amino acids were broken up into in lesson 8
- any of the atoms found in the amino acids in lesson 8
- and anything else students think of

Learning Set 3
How Does Our DNA Make Us SIMILAR or DIFFERENT?

Learning Set 3- How does our DNA make us SIMILAR or DIFFERENT?

Content Standard	Inquiry Standard	LS3 Learning Performance
Nature and function of DNA - In all organisms, the instructions for specifying the characteristics of the organism are carried in DNA, a large polymer formed from subunits of four kids (A, G, C, and T). The chemical and structural properties of DNA explain how the genetic information that underlies heredity is both encoded in genes (as a string of molecular "letters). Each DNA molecule in a cell forms a single chromosome. (NRC, pg. 185, 9-12:C2#1)		Students determine the amino acid sequence of a protein given a DNA sequence.
		Students use multiple representations to model DNA.
Genes as information for proteins - The genetic information in DNA molecules provide the instructions on assembling protein molecules. The code is virtually the same for all life forms. (AAAS, pg. 114, 5C:9-12#4)		Students assemble and talk about models of protein molecules based on a prescribed DNA sequence.
Molecular nature of genes and mutations - Genes are segments of DNA molecules. Inserting, deleting, or substituting DNA segments can alter genes. An altered gene may be passed on to every		Students write a prediction and write about the affect of changing the DNA sequence on protein structure and function.
		Students use models of proteins to talk about the effect of deletions, insertions, or substitutions on protein

cell that develops from it. The resulting features my help, harm, or have little or no effect on the offspring's success in its environment. (AAAS, pg. 109, 58:9-12#4)		structure and function.

Learning Set 3: How does our DNA Make us SIMILAR or DIFFERENT?

Overview

Purpose

The purpose of this learning set is to help students learn that genes are instructions for building proteins by building protein models from a given DNA sequence. Students also learn that DNA is comprised of four chemical subunits and that the order of these subunits determine the amino acid sequence of proteins. Finally, students explain that changing a gene sequence (i.e. a mutation) can lead to changes in the protein which can also have negative effects on cell function and the health of the organism.

Description

Lesson 1

- Students are introduced to a genetic disease called Familial Hypercholesterolemia (FH) that can be caused by a faulty protein, specifically the LDL Receptor protein. This leads to a discussion of what might be different or similar among individuals with, and without, FH by looking at hypothetical protein data (gel electrophoresis data).

Lesson 2

- Students extract DNA from a strawberry and build 2 different DNA models while considering how DNA, genes, chromosomes and proteins relate to each other.
-

Lesson 3

- Students learn about the processes of transcription and translation, then practice doing these processes by assembling part of the LDL Receptor protein (in the form of a Toober).

Lesson 4

- Students view the case history of a patient with Familial Hypercholesterolemia. Student work in groups to use evidence from five patients' DNA sequences to identify mutations and determine if they have FH disease. Students will present their findings to the class.

Learning Goals

The learning goals addressed in this Learning Set are darkened.

National Standards

- Nature and function of DNA - In all organisms, the instructions for specifying the characteristics of the organism are carried in DNA, a large polymer formed from subunits of four kids (A, G, C, and T). The chemical and structural properties of DNA explain how the genetic information that underlies heredity is both encoded in genes (as a string of molecular "letters). Each DNA molecule in a cell forms a single chromosome. (NRC, pg. 185, 9-12:C2#1)
- Genes as information for proteins - The genetic information in DNA molecules provide the instructions on assembling protein molecules. The code is virtually the same for all life forms. (AAAS, pg. 114, 5C:9-12#4)
- Molecular nature of genes and mutations - Genes are segments of DNA molecules. Inserting, deleting, or substituting DNA segments can alter genes. An altered gene may be passed on to every cell that develops from it. The resulting features my help, harm, or have little or no effect on the offspring's success in its environment. (AAAS, pg. 109, 58:9-12#4)
- Heritable material - The information passed from parents to offspring is coded in DNA molecules. (AAAS, pg. 108, 58:9-12#3)

Michigan Standards

- 82.2 - Organic Molecules -There are four major categories of organic molecules that make up living systems: carbohydrates, proteins, and nucleic acids.
- B2.2C - Describe the composition of the four major categories of organic molecules (proteins, nucleic acids and carbohydrates).
- B2.2D - Explain the general structure and primary functions of the major complex organic molecules that compose living organisms.
- L4.p2 - Heredity and Environment (prerequisite)- The characteristics of organisms are influenced by heredity and environment. For some characteristics, inheritance is more important. For other characteristics, environment is more important. Genetics and Inherited Traits - Hereditary information is contained in genes, located in the chromosomes of each cell.

- 84.2 - The genetic information encoded in DNA molecules provides instructions for assembling protein molecules. Genes are segments of DNA molecules. Inserting, deleting, or substituting DNA segments can alter genes. An altered gene may be passed on to every cell that develops from it. The resulting features may help, harm, or have little or no effect on the offspring's success in its environment.
- B4.2C - Describe the structure and function of DNA.
- B4.2D - Predict the consequences that changes in the DNA composition of particular genes may have on an organism (e.g., sickle cell anemia, other).
- B4.2x - DNA, RNA, and Protein Synthesis - Protein synthesis begins with the information in a sequence of DNA bases being copied onto messenger RNA. This molecule moves from the nucleus to the ribosome in the cytoplasm where it is "read." RNA brings amino acids to the ribosome, where they are connected in the correct sequence to form a specific protein.
- B4.2f - Demonstrate how the genetic information in DNA molecules provides instructions for assembling protein molecules and that this is virtually the same mechanism for all life forms.
- B4.2g - Describe the processes of replication, transcription, and translation and how they relate to each other in molecular biology.
- B4.4a - Describe how inserting, deleting, or substituting DNA segments can alter a gene. Recognize that an altered gene may be passed on to every cell that develops from it and that the resulting features may help, harm, or have little or no effect on the offspring's success in its environment.
- B4.4c - Explain how mutations in the DNA sequence of a gene may be silent or result in phenotypic change in an organism and in its offspring.

Prior Knowledge

- Cells: Students should realize all living organisms are comprised of cells and that for humans (as well other animals and plants) have tissues and organs that are comprised of many cells. Students should also know that cells have a nucleus which is an organelle in the cell. They will learn in this lesson that the nucleus contains DNA.
- LG1 (Nature and function of proteins): Students need to be familiar with content covering proteins from Lesson 2, especially the idea that proteins are long chains of amino acids and that the order of amino acids determine the protein shape, which in turn determines the protein function. Students should have been introduced to the LDL Receptor protein from Lesson 2 (if students did not get this content from the previous lesson, more time will need to be spent talking about how this protein works and functions).

Student Conceptual Challenges

- Students are unaware of the central role proteins play in biological processes.
- Some students are unclear about where genes are found -- some students think genes are found in places other than the nucleus of every cell (i.e. such as in "the blood" or "the brain")
- Some students don't always realize genes exclusively code for proteins or that a gene produces
- a product. Students sometimes think genes can also code for cells and cell functions (something beyond proteins).
- Some students have difficulty making connections between genes and proteins.
- Some students have difficulty understanding the function of RNA.
- Some students are unaware that nucleotides are actually a unit on the DNA strand, and that the letters "A, T, G, C" each represent one of these units on the DNA strand.
- Some students are unclear about the relationship between chromosomes, genes and DNA and often mislabel these parts. Related to this challenge, students are unclear where all chromosomes, genes, and DNA are located.
- Some students may be able to connect genes to protein by listing all the pieces, but still be unable to transfer knowledge about this connection to explain the underlying cause to a disease or physical appearance they have not studied before.

Time

9 days

Lesson 1: How can two people have different sequences for the same protein? – FH and LDL Receptor Protein

OVERVIEW

Purpose
Set students up to explore the differences in proteins by talking about differences in people with FH. Students analyze hypothetical gel electrophoresis data and amino acid sequence data of the LDL Receptor protein.

Connections
Students use gel electrophoresis data to identify the presence of particular proteins like they did in learning set 2 lesson 9.

Description
Students are introduced to a genetic disease called Familial Hypercholesterolemia (FH) that can be caused by a faulty protein, specifically the LDL Receptor protein. This leads to a discussion of how proteins could be built improperly because the amino acid sequence is altered.

Safety Guidelines
None applicable

Learning Performance
Students write a prediction and write about the affect of changing the DNA sequence on protein function.

PREPARATION

Materials
Projector
Slides: Learning Set 3: Lesson 1: Slides 1, 2, 3
Student Reader pp: 92-98

INSTRUCTIONAL SEQUENCE

Introducing Activity 3.1
Ask students to think back to the previous lesson and ask: Can the lactase protein found in one person be different than the lactase protein in another person? After you get a consensus that yes people can have different forms of the lactase protein. Ask, what is your evidence? Students might respond: when looking at gel electrophoresis data some peoples' lactase protein moved farther down the column or the lactase protein in some people is different causing them to be lactose intolerant. Finally, ask students to brainstorm why they think people might have a different version of the same lactase protein? Accept all answers here, as students have only discovered (learning set 2) that a protein (lactase) can have a different function. They have not specifically discovered that different amino acid sequences can produce the same protein or the same protein with an impaired function.

Reading 3.1 – part 1
Reading 3.1 – part 1 will set a purpose for students to look at gel electrophoresis data on the LDL receptor protein. Have students turn to Reading 3.1 – The Medical Case: Familial Hypercholesterolemia in their student reader. Tell students that today we are going to look at a disease similar to lactose intolerance.

During learning set 2 lesson 9, students discovered that different amino acid sequences can code for the same lactase protein. Now students are going to read about a patient that has Familial Hypercholesterolemia.

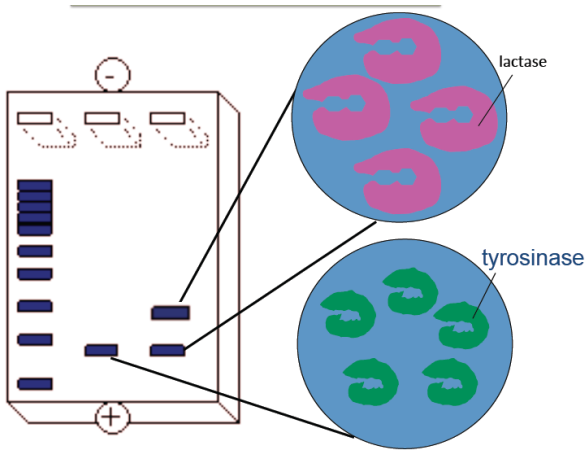
Extended Preview Guide for Reading 3.1
Explain to students that they are going to make predictions about the information in Reading 3.1. Inform students that they should be prepared to share their predictions and the reasoning for their predictions in small groups.

When the students are finished making predictions and sharing/discussing their predictions in a small group, they should complete the "Answer" column of the preview guide while reading "The Medical Case: Familial Hypercholesterolemia" – Reading 3.1 – part 1. Let students know that they will not be able to fill in all of the "Answer" column of their extended preview guide until they read the 2nd half of reading 3.1, so they should just fill in as much as they can. Students will share which predictions the reading supported or did not support and then where they found that information in reading after they read the rest of reading at the end of this lesson.

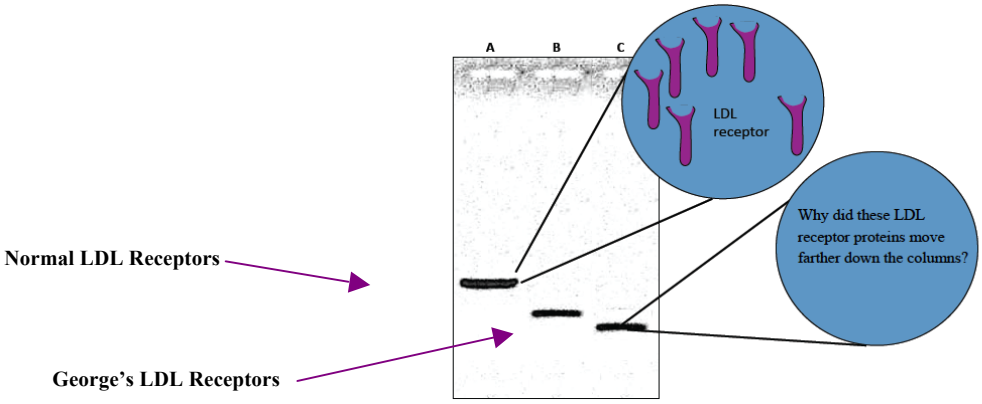
Teaching Strategy:

This preview guide will cue students to the major ideas in the reading, activate their prior knowledge about what the LDL receptor protein, motivate them to read so they can confirm their predictions and to refute their classmates' predictions. Student misconceptions will be addressed openly and are more likely to be changed after reading and discussing what the students learned.

Activity 3.1
Tell students now they are going to help Rachel and Dr. Lewis diagnosis the patient they read about and one other by analyzing gel electrophoresis data for the LDL receptor protein. Tell students they will learn more specifics about this patient later in this lesson, but for right now we are just concerned about learning if there is a difference between the patient's LDL receptor protein and that of a person that does not have familial hypercholesterolemia. You may want to quickly review how to read gel electrophoresis data. For example, slide 1 (as seen below) shows that smaller proteins move down the column farther than larger proteins.



Show students slide 2 (make sure the lower blue bubble is empty) and ask them to turn to activity sheet 3.1 in their student reader.



Tell them that the LDL receptor protein has been added to all three columns of the gel. As students analyze the electrophoresis data, have them answer questions #1, 2 and 3 on activity sheet 3.1.

After students have had a few minutes to work on question #1, click next so that "Why did these LDL receptor proteins move farther down the column?" appears in the lower blue bubble.

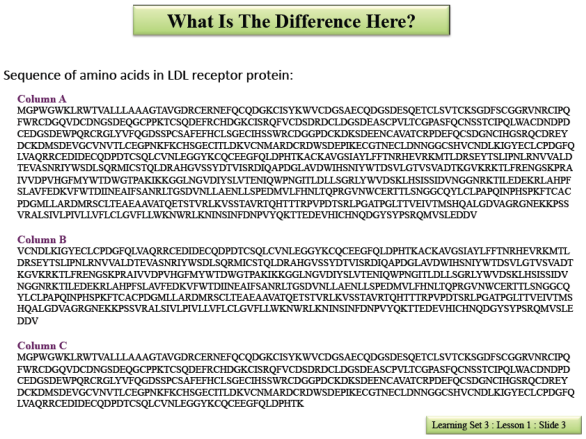
Activity sheet 3.1 asks students what the electrophoresis data is telling them. Students may respond:

- the protein is visible in all three columns
- the proteins are different sizes
- the two of the proteins moved farther down the column than the other

Then students are asked to predict why they think these three LDL receptor proteins are acting differently in the gel. Students should respond that the size of the proteins is different. If students do not remember that smaller proteins move farther down the column, show them slide 1 again to remind them. When the students say that the LDL receptor proteins put in columns B and C must be smaller

than the LDL receptor protein put in column A, ask them what evidence we would need to support this? Give students a chance to brainstorm. If they do not start talking about the amino acid sequence of each protein being different, ask students what proteins are made of. Could the amino acid sequence for each of these LDL receptor proteins be different?

Tell students that slide 3 shows the amino acid sequence for each LDL receptor protein that was put into the gel. This slide is also found on the back of activity sheet 3.1 in the student reader.



Ask students if they see any difference between the three amino acid sequences? Students should notice that the amino acid sequence for the LDL receptor protein put in columns B and C are much shorter. Give students a few minutes to answer #4 on activity sheet 3.1, then ask students to share their ideas of why the LDL receptor protein moved down the gel column the farthest. This is a good question to use as a formative assessment.

Students might respond:

> *The LDL receptor protein in column C moved the farthest down the gel column, because it is the smallest protein. I know it is the smallest protein, because its amino acid sequence is the shortest. We know that the smallest proteins move down the gel column the farthest.*

Concluding Activity 3.1

Once students have discovered that all three of our LDL receptor proteins have different amino acid sequences, have students break up in to groups to discuss: Could these differences in amino acid sequence affect the LDL receptor's ability to function properly? They should write their thoughts on #6 of activity sheet 3.1. Once students have had time to brainstorm, have students share out their ideas. If necessary, help students consider the idea that the three LDL receptors might function differently.

Concluding Lesson 1

Have students read Reading 3.1 – The Medical Case: Familial Hypercholesterolemia – part 2, finish any of the extended preview guide they need to and then answer the "After Reading" questions. Once students are done with the after reading questions have them get into small groups to "think-pair-share" their scientific explanations from after reading question #4. Encourage students to make changes to

their scientific explanation if need be. Follow-up with groups sharing their claim, evidence and reasoning and create a class scientific explanation. End with having students share which predictions the reading supported or did not support and then where they found that information in reading. This will give you the opportunity to discuss any lingering misconceptions students might have.

Lesson 2: What does DNA Look Like? – DNA Extraction

OVERVIEW

Purpose
Introduce students to the nature of DNA and the idea that DNA condenses into a smaller form called chromosomes.

Connections
In lesson 1, students discuss how people can have different amino acid sequences for the same LDL receptor protein. Students were also introduced to the idea that different amino acids sequences are due to differences in genes and that genes are parts of DNA. In this lesson, students will learn where DNA is found inside the cell to prepare for lesson 4 and 5 where students will learn how to transcribe and translate DNA into the LDL receptor protein.

Description
Students extract DNA from strawberry cells.

Safety Guidelines
None applicable

Learning Performance
Students observe DNA they extracted from strawberry cells.

Time
1 day

PREPARATION

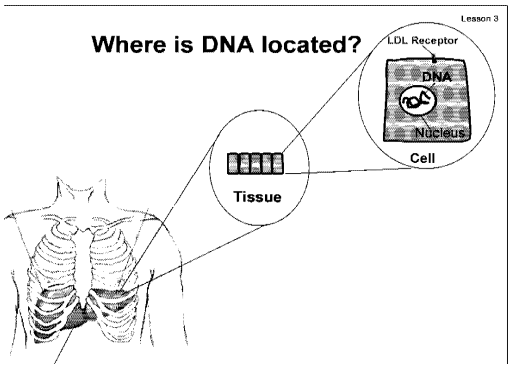
Materials
Projector
Slides: Learning Set 3: Lesson 2: Slides 4, 5
Student Reader pp:99-102
Strawberries
Test tubes
Salt
Detergent or Shampoo
Ethanol
Funnels
Cheesecloth
Popsicle sticks
Ziploc freezer bags

INSTRUCTIONAL SEQUENCE

Remind students during lesson 1, they read that DNA can cause medical conditions and that DNA holds instructions for proteins. Students also considered a relationship between genes and proteins. As a form of formative assessment, ask students what they think that relationship is. This will help you see what students already know and what misconceptions they may have. After students have shared their ideas, tell them we need more evidence to support their ideas, so we need to find out more about DNA to see if there is a connection between DNA and proteins.

Introducing Activity 3.2a
Ask students:

- Where do you think DNA is located?
    - After students have had a chance to respond, show **slide 4**
    - Point out while referring back to the macro-molecular chart. DNA is found in the nucleus, which is in a cell, which is in a tissue, which makes up an organ, which make up our bodies (shown below and on the students' Activity sheet 3.2a).



Slide 4

- Do you think DNA is in every cell?
    - The above slide image only shows a liver cell, but in fact, DNA is in every cell of our body. It is in the nucleus of our bone cells, skin cells, brain cells, muscle cells, etc. We just show a blow up of a liver cell because the **LDL** Receptor protein, which was discussed earlier, is found in liver cells.

Ask students: now that we know that DNA is found in cells, do you think you can see DNA with the naked eye (or without the aid of a microscope)? Let students discuss. Make sure you ask for their evidence or reasoning for their response. Many students will most likely respond that they would need a microscope to see DNA, because it is found in inside of cells and they cannot see

individual cells without a microscope. This would be a good time to return to the micro-molecular chart again, so students get an idea of where DNA is. Tell students that today we are going to attempt to extract DNA from a strawberry in hopes of being able to see a real piece of DNA.

Activity 3.2a
Prior to class, prepare the DNA extraction buffer by combining 900 mL water with 50 mL of dishwashing detergent (or 100 mL of shampoo), and then add 2 teaspoons of salt to the water/detergent mixture. You will want to prepare the extraction buffer in a bottle that has a lid, so you can invert the bottle to mix the solution.

Materials (per group)
1 - Ziploc Freezer bag (It is important to use a freezer bag, because the thicker plastic is necessary.)
1 – strawberry
10 mL - DNA extraction buffer in a small plastic cup
Small funnel
Cheesecloth to fit a small funnel (~ 4" x 4" should be appropriate)
50 mL vial or test tube
Glass stirring rod or popsicle stick
20 mL - Cold ethanol
Ice in a bowl

Strawberry DNA Extraction Background Information

The purpose of each ingredient in the procedure is as follows:

Shampoo or dishwasher soap: helps to dissolve the cell membrane, which is a lipid bi-layer.

Salt: helps to remove proteins that are bound to the DNA. It also helps to keep the proteins dissolved in the aqueous layer so they don't precipitate in the alcohol along with the DNA.

Ethanol or isopropyl alcohol: causes the DNA to precipitate.

When DNA comes out of solution it tends to clump together, which makes it visible. The long strands of DNA will wrap around the stirrer or transfer pipet when it is swirled at the interface between the two layers.

Procedure:

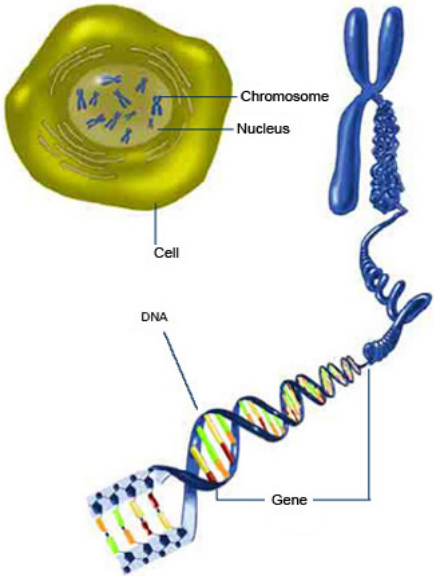
1. Place one strawberry in the Ziploc bag.
2. Smash the strawberry using your fist and fingers for 2 minutes. (Be careful not to break the bag!)
3. Add 10 mL of extraction buffer to the bag.
4. Kneed/smash the strawberry in the bag again for 1 minute.
5. Assemble your filtration apparatus as shown below.

6. Pour the strawberry slurry into the filtration apparatus and let it drop directing into your test tube.
7. Once your strawberry slurry has filtered through, slowly pour cold ethanol into the tube.
8. Observe what is happening inside the test tube. What do you think the string-like material in your test tube is?
9. Dip the popsicle stick into the tube where the strawberry extract and ethanol layers come into contact with each other. You should see thin string-like material. Try to gently twirl one of the strings around your popsicle stick, so that you can gently pull it out of the test tube. DNA is extremely fragile, so it is extremely important for you to be gentle when trying to remove the DNA string-like material from your test tube.

When your student groups are finished extracting their DNA, they should answer the questions on Activity Sheet 3.2a before cleaning up, so they can look at their DNA while answering the questions. Once groups are finished with their questions, have them clean up.

Concluding Activity 3.2a

Ask students: what their strawberry DNA looked like? Were they surprised that they were able to see actual DNA without using a microscope? Do you have any ideas why you can see DNA without a microscope, but you cannot see a cell (which is where DNA is found) without the aid of a microscope? After students have had the opportunity to discuss, show **slide 5** (found below and on activity sheet 3.2a). There is also a link to a video below the picture on the slide. You will only want to show students a small portion of the video at this time (you will show the rest in lesson 3). At this time show students the first minute (1:20) of the video clip



DNA Condensing into Chromosomes Video

Slide 5 and the video show how DNA (just like the DNA that students extracted from the strawberry) coils up very tightly. So much so that the coiled up DNA can fit inside the nucleus of a cell. When DNA is tightly coiled up it is called a chromosome. Walk through the video with your students numerous times ensuring that they are comfortable with the progression of an uncoiled DNA strand being visible but then coiling up so tight into a chromosome that the chromosome can fit inside the nucleus of a cell. There is space for the students to write about slide 5 on their activity sheet. Students will revisit this concept and this slide in lesson 4.

Reading 3.2
For homework, have students read reading 3.2 in their student reader. This short reading will connect the "genes" that students learn about in classical genetics to how the same genes that contain the information for protein production.

Tell students while reading, they should write down any questions they have about how genes, DNA and proteins relate to each other. Tomorrow have students break up into groups to share their questions. As groups are sharing their questions, you will ask them how that question relates to the driving question and to place the question on the driving question board.

Lesson 3: What is the structure of DNA? – DNA Models

OVERVIEW

Purpose
Student identify the important structural characteristics relevant to DNA (see below for characteristics students should identify).

Connections
In lesson 2, students discovered that DNA can be extracted from cells and be observed without the aid of a microscope. In this lesson, students will learn the structure of DNA to prepare for lesson 4 and 5 where students will learn how to transcribe and translate DNA into the LDL receptor protein.

Description
Students explore models of DNA.

Safety Guidelines
None applicable

Learning Performance
Students explore and create multiple models of DNA.

Time
2 days

PREPARATION

Materials
Projector
Slides: Learning Set 3: Lesson 3: Slides 6-12
Student Reader pp:103-107
DNA Model Kits
Licorice
10 - 15 cm pieces of bell wire per group
Marshmallows – Take the marshmallows out of the bag a couple of days in advance, so they will dry out and be less sticky.

INSTRUCTIONAL SEQUENCE

Follow up to Reading 3.3a
Reading 3.3a discusses genes. Ask students where genes are found. Students often have difficulty understanding that genes are small segments of DNA. Discuss with students that the DNA they extracted from the strawberry was composed of many genes that code for many different proteins.

Instructional note – Student conception

Some students incorrectly separate DNA and genes (in other words they often think they are separate entities) and do not realize that genes are segments of DNA. Some students may think that DNA or genes, or both, are located in the cytoplasm of the cell and not in the nucleus. Some students may think genes act all over the cell and have a very unclear understanding of where DNA and genes are located. Some may not appropriately relate DNA to genes. Some students confuse genes and chromosomes and don't' always know the proper relationship between these.

*We give several opportunities in this unit to talk about the relationship between these entities during this **unit**-during such opportunities ask students questions that push them to identify these relationships and after students identify relationships, clarify them as explicitly and clearly as possible.*

The relationship between proteins and genes is important for students to consider and understand. Ask students to describe that relationship. Make sure students consider the idea genes as "instructions for making proteins" and that all proteins have a corresponding gene. So every protein they have learned about from the previous lessons has a gene that provides instructions for building it.

Note to Teacher

If your class has already discussed genes as they relate to heredity, tell the students that these are the same genes, but that now we are going to look at what genes actually look like and how genes work in cells.

Students are likely to hold onto the idea of genes relating to heredity. Build on these ideas. Ask them where they got their genes? If genes are the directions for how to make a specific protein, do they think that their parents make the same proteins as they do?

Ask students to consider what would happen if genes are changed, for example, if the gene for the LDL Receptor protein was changed how would this affect the LDL Receptor protein?

Have students break up into groups to discuss the above question and to share their questions from last night's reading. As groups are sharing their ideas and questions, ask them how that question relates to the driving question. Bring the students back to the large to share questions. Students should be encouraged to place questions they have on the driving question board.

Introducing Activity 3.3A

Students just read about genes being instructions for how to build proteins and that genes make up DNA. Students also saw what real DNA looks like yesterday. Ask students to describe what their strawberry DNA looked like. Ask students if any of them know what DNA looks like at the molecular level? (If students struggle with what the "molecular level" means, guide them to the macro-molecular chart to help remind them that the "molecular level" means to look at the molecules that make up DNA.) Is DNA 3-dimensional? Do you need a microscope to see the molecules that make up DNA? At this point, you are not looking for correct answers. Some students might have some ideas, but this question is mostly to lead into the building of DNA models. You just want to see what students already know or if there are any misconceptions that will need to be addressed during this lesson or later lessons. Tell the students that today they are going to explore the structure of DNA by building a model.

Teacher Note

If your class has already discussed genes as they relate to heredity, tell the students that these are the same genes, but that now we are going to look at what genes actually look like and how genes work in cells. Students are likely to hold onto the idea of genes relating to heredity. Build on these ideas. Ask them where they got their genes? If genes are the directions for how to make a specific protein, do they think that their parents make the same proteins as they do?

Activity 3.3A

1. Divide the students into groups
2. Give each group a kit with the components to build the DNA models. **Slide 6** shows pictures of each part. (Note: these kits have been slightly modified from the packaged version: the DNA bases are labeled with A, C, T, or G; the deoxy-ribose and phosphate chains are intact to reduce the amount of time spent on a part of the activity with less instructional value.)
3. Direct the students to the instructions for building their models in their student readers.
4. The point here is not to tell students what the structure is, but to allow students to explore and find out some of its features on their own.
5. Students are given instructions on how to put together the model. It might take students a while to assemble the whole model.
6. Help students figure out what the order of the bases is in their model. It will differ between the groups depending on how they put the bases on the model. This is the first step in reading the instructions for making a protein.

Concluding Activity 3.3A

Reconvene the groups and discuss the following questions

a. How many different types of pieces are found in the center? Are there any patterns to how these pieces fit? What are they?
b. How many different pieces are found on the outside of the model? Is there a pattern to these pieces? What are they?
c. What else did you notice about their models? Does it look like what you expected?

The goal of having the students build the DNA model and discuss these questions is for them to realize there is a specific pattern to how "pieces" of DNA fit together and twist. At this point, students do not need to know any specific vocabulary about the DNA model. This experience will help students remember that specific pieces fit together instead of memorizing the structure later.

Reading 3.3
For homework, ask students to read "Structure of DNA" and answer the questions. Tell students that during this reading they are going to read about the specific pieces of the DNA double-helix structure, so they should think back to the DNA model they just built when reading.

DAY 2

Follow-up to Reading 3.3
Last night students read about the components of DNA, specifically nucleotides and base pairs. Ask students: when they were building their DNA models if they noticed that any pieces fit together while others did not? Were these same pieces discussed in the reading? Ask students: do you think the order of base pairs could be similar to an amino acid sequence? Today and in future lessons we are going to look for evidence to help us answer this question.

Introducing Activity 3.3B
Have students divide back up into their groups and tell them to open up their reader to activity sheet 3.3B. Allow them to have their completed DNA models in front of them. In their groups, have students answer the questions at the top of activity sheet 3.3B. Ask students what the chemical bases are found in DNA and how do these bases pair with each other. Either referring back to reading 3.3B or looking at their DNA model from yesterday, students should be able to state that thymine, guanine, cytosine and adenine are the chemical bases, and that thymine pairs with adenine and guanine pairs with cytosine. Tell students this information will be important for activity 3.3B.

Activity 3.3B
Tell students: Yesterday they explored the structure of DNA model of a random base pair sequence. But to be able to find out if DNA holds instructions for building proteins, we need to start out with building the DNA structure for a real protein to see what it tells us. Today you are going to build a model for a portion of a specific piece of DNA that codes for the LDL receptor protein. **Students will use this same model again in lesson 4.**

Before students can start building their model, they need to add the matching base pairs for given DNA strand. This table can be found on **slide 7**.

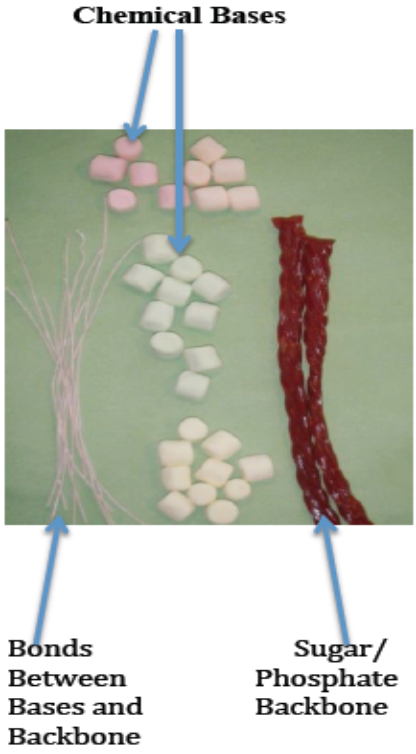
Given DNA Strand	Matching DNA Strand
T	**A**
G	**C**
G	**C**
C	**G**
G	**C**
C	**G**
T	**A**
G	**C**
T	**A**
G	**C**
DNA Base Pairs	

Slide 7

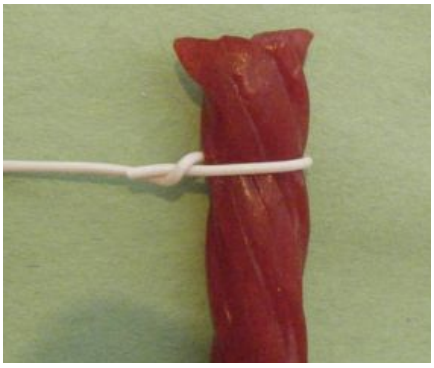
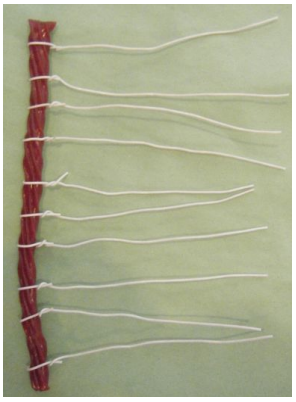
Give each group a kit with the components to build the LDL receptor protein DNA models (**slide 8** shows pictures of the below pieces) and direct the students to the instructions for building their models in their student readers. Below you will find those instructions and a key for the marshmallow colors (**slide 9** also shows this key).

Materials:
5 Orange Marshmallows
10 Green Marshmallows
10 Yellow Marshmallows
5 Pink Marshmallows
2 pieces of Licorice
10 - 15 cm pieces of bell wire per group

* You will have a couple extra marshmallows of each color just in case you lose one. It is ok if you have 2 or 3 of each color leftover when you are finished.

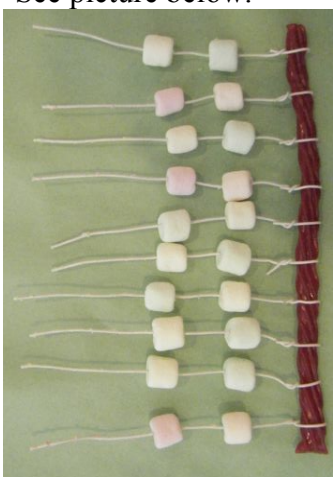


1. Attach your wire to one of your pieces of licorice. See pictures below.

Slide 10

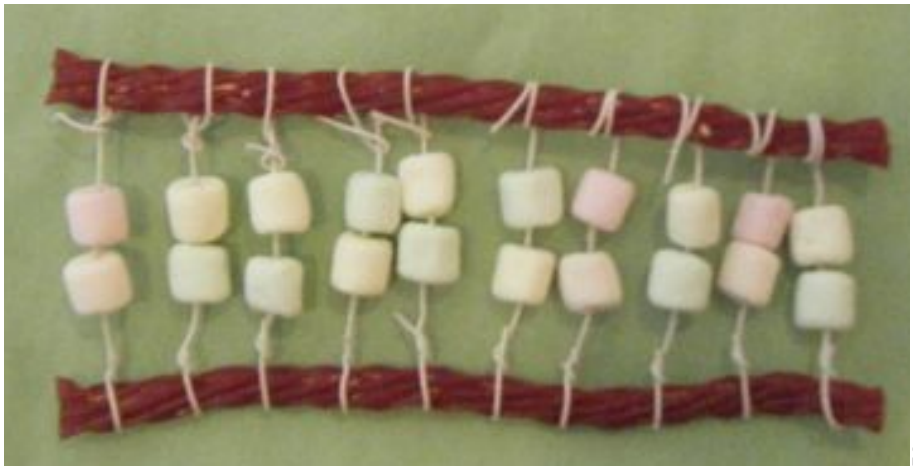
2. Using the LDL receptor protein DNA strand that you worked on above and the Marshmallow Color Key found below, start attaching the base pair marshmallows to your wire. See picture below.



Marshmallow Color	Chemical Base
ORANGE	THYMINE (T)
GREEN	GUANINE (G)
YELLOW	CYTOSINE (C)
PINK	ADENINE (A)

Slide 11

3. Attach the other piece of licorice so your model looks like a ladder like in the picture below.



Slide 12

4. Carefully, twist your DNA model so that it looks like the double-helix model you made yesterday.

Concluding Activity 3.3B
When students are finished with their DNA model of the LDL receptor protein, store them somewhere in the classroom where they will not get damaged, because the students will be using them again in lesson 4. Tell students they will be using these DNA models to build the actual LDL receptor protein with toobers. Once the models are stored, return to the DQB to see if students can answer any of their questions, particularly questions about DNA, genes and chromosomes.

Lesson 4: How does DNA form Proteins? -Transcription & Translation

OVERVIEW

Purpose
Students use the model marshmallow DNA sequence from Lesson 3 to assemble part of the LDL Receptor protein (in the form of a Toober) to understand how genes can provide instructions for making proteins. They do this by using multiple models to illustrate the processes of transcription and translation. This serves to reinforce the idea that genes are instructions for assembling proteins.

Connections
In this lesson students learn about the complex processes involved in making proteins from DNA. This sets them up to learn in future lessons about how mistakes can be made during these processes, causing mutations, which lead to different proteins, or proteins that do not function properly.

Description
Students learn about the processes of transcription and translation, then apply their understandings by modeling the process of making the LDL Receptor protein. They are given a piece of the gene sequence for assembling the protein (made in Lesson 2), and must determine the corresponding RNA sequence, and amino acid sequence.

Safety Guidelines
None applicable

Learning Performance
Students use multiple representations to model the cellular processes of transcription and translation

Time
3 days

PREPARATION

Materials
Slides: LS3: Lesson 4:Slides 13-27
Student Reader pp: 108-117
For each group:
1 piece of licorice
9 marshmallows – 5-pink, 2 white, 1- green, 1- yellow (You may want to add some extra random colors as well)
9 pieces of wire (7 cm)

6 gumdrops -different colors
marshmallow DNA model
White paper to represent the nucleus of the cell
Tooth picks

INSTRUCTIONAL SEQUENCE

Introducing Activity 3.4a (Day 1)
Refer students back to the Driving Question.. Point out that most people have the same LDL Receptor protein. Remind them that the patient (George) that we were looking at did not have the same LDL receptor protein as other people. Ask: How does this happen? How does the body know how to make this protein? Accept all responses to see what students think.

Remind students that they also found evidence that the patient had a problem with his DNA. Remind students that in the last lesson they used models of DNA in order learn more about the relationship between chromosomes, genes and DNA. In this lesson they will use models to determine if there is a relationship between the patient's DNA and his LDL Receptor protein.

Review:
Ask students to answer the review questions in their student reader.
1) We learned in a previous lesson that there is a relationship between DNA, chromosomes, genes and protein. Describe this relationship. *Chromosomes form when our DNA coils up. Genes are pieces of our DNA. DNA contains the instructions for making proteins.*

Carrying Out Activity 3.4a
Overview animation: from DNA to protein
Refer students to the macro-molecular chart. In this lesson we're going to learn how proteins are made.

Ask: Where did we learn proteins were located? (*in all different types of cells, by doing the chicken activity*) Point to, or have a student point to, where "cells" are in the Macro to Molecular chart.

Ask: Where do we find the instructions for making proteins? (*students may say genes, DNA, or nucleus. You want them to recall from the previous lesson that genes are small pieces of DNA, which is located in the nucleus of a cell*) Point to where these words are located in the macro-molecular chart. If "gene" is not in the chart, have a student write it on a stickie note and place it in the appropriate location.

Before beginning this activity students should realize (from bigger to smaller) that a **cell** contains a **nucleus**, which contains our **DNA** (sometimes in the form of **chromosomes**), which contains our **genes** [which are the instructions for all the different proteins that do all different jobs in our bodies, including determine who we are (how similar or different we are)]. Review these concepts by having students organize these words from largest to smallest on the macro to

molecular chart. If further explanation is needed here is a website that can be used to illustrate relative size. http://learn.genetics.utah.edu/content/begin/cells/scale/ (See link in **slide 13**)

Teacher Background: chromosomes & DNA condensation

The file containing the animation is called 3D copy.mov. The animation is called "The Humane Genome: Exploring our Molecular Selves". The animation begins with the body, then the cell then progresses to the nucleus, then to chromosomes, and finally to DNA. As defined in the animation, DNA is stored in the nucleus of cells in the form of chromosomes (tightly coiled DNA). Often students struggle to see that chromosomes are DNA that has been tightly wrapped up around special proteins (yet another job that proteins do in our bodies).

Supplemental material if necessary to help students visualize the coiling of DNA into chromosomes: http://www.hhmi.org/biointeractive/dna/DNAi_packaging_vo2.html
(video also is on your flash drive)

Students should understand that DNA is very long (human DNA when stretched out is about six feet long). It usually just hangs around in the nucleus in a loose, blob-like state, like how one might crumple up headphone wires to put them in your pocket. It's only when a cell needs to divide that the DNA coils up (condenses) into chromosomes.

Teaching Strategy:

During the animations, it may be useful to tell the students what they should focus on and what is a happening at each step. This is a strategy that one can employ whenever a video or diagram is shown that includes a complicated molecular or cellular process. You can also tell students ahead of time what they will see and what they need to focus on.

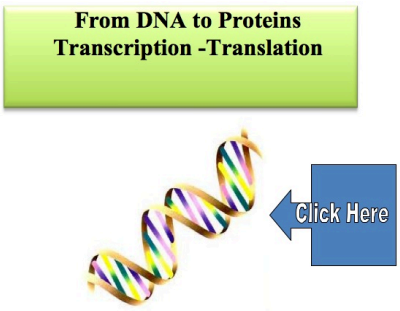
Teaching Strategy: Models

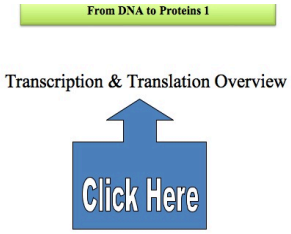
Promote a brief discussion with students about models. We discussed models in the previous learning set, so this should be a review. The idea is to get students to understand that the animations, their drawings, and then later when they practice transcribing and translating are all different kinds of models.

Models are representations of things we cannot see easily and which allow us to manipulate the things we can't see in order to ask questions or make predictions. Models are not always exact copies of the thing to be modeled, which is the case with the activities in this lesson. However, our models can help us learn about the complex processes of transcription and translation.

In the previous lesson you used a pre-made plastic 3D DNA model from a kit. Today you will see a computer model of DNA, which is a 2D models. You may want to ask students questions to promote their thinking about the benefits of using multiple, different representations. You can do this before or after the activities. For example:
What were some benefits to using the DNA models in the previous lesson?

You're going to watch an animation showing the process of how the instructions found in genes make proteins, what might be the benefits of watching an animation of a process?



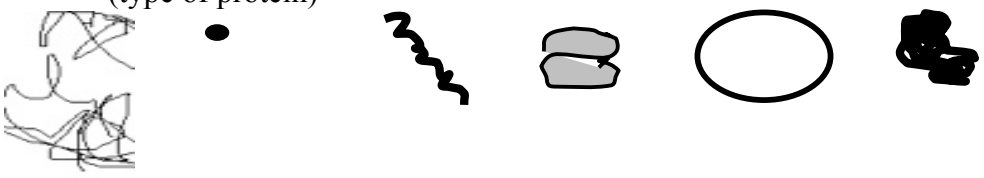


Slide 14 and 15
Explain to students that this first activity is just an overview to introduce the processes of transcription and translation and situate everyone as to where in the cell each process occurs. Open up the video by clicking on the slide 13. Quickly guide students through the first couple of minutes. Show the entire video. Rewind and show it again this time stopping the film after the section on the formation of mRNA. The next slide (**slide 14**) shows a step-by-step animation with much simpler drawings. Use this to review the steps after you show the movie. Discuss differences in these models.

Instruct students to turn to Activity 3.3a, and to draw the basic steps as you describe them. Continue the animation, stopping at appropriate places to allow students time to draw. They should label everything in their drawing, and also write a brief statement about what is shown in their picture. **NOTE:** If necessary, remind students that all of this takes place within the cell! It might seem unclear from the animation. Students can imagine that each box they draw in is the cell.

Make sure to tell students not to get caught up in drawing every little thing they see in the animation, as it is shown. In fact, you should literally rewind the animation and point to the key features. You may want to identify simple symbols for students to use in their drawings since the video shows very detailed graphics. You don't want students trying to reproduce those graphics rather than focusing on the process they are trying to represent. An example is shown in **Slide 16**. After students draw the first step restart the animation and continue with the next step. You might want to do the first couple of slides with them.

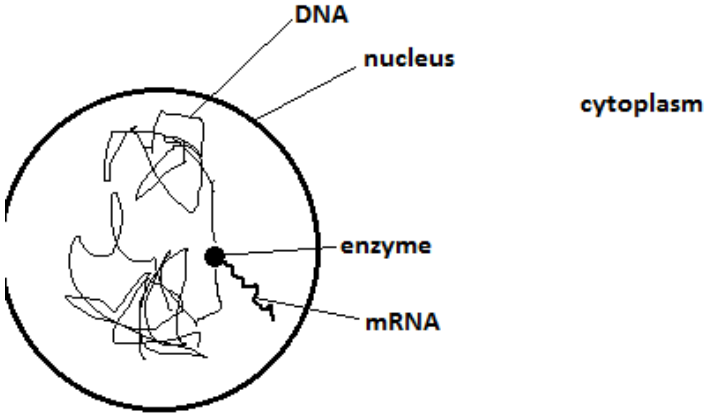
Symbols: DNA enzyme (type of protein) mRNA ribosome nucleus protein



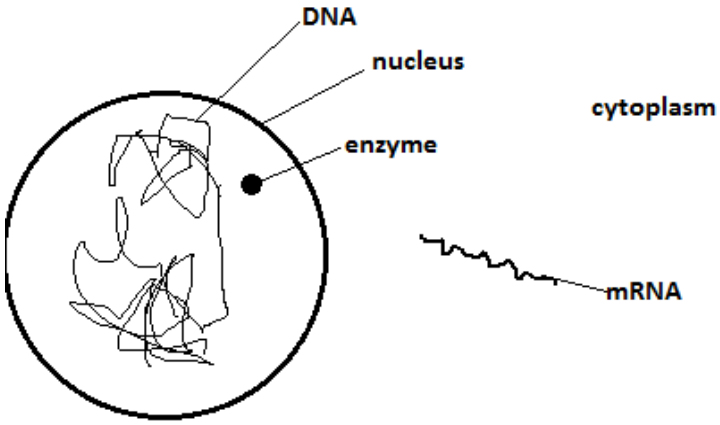
Slide 16 Amino Acids 

The first step happens in the nucleus of the cell, and it's called **transcription**.

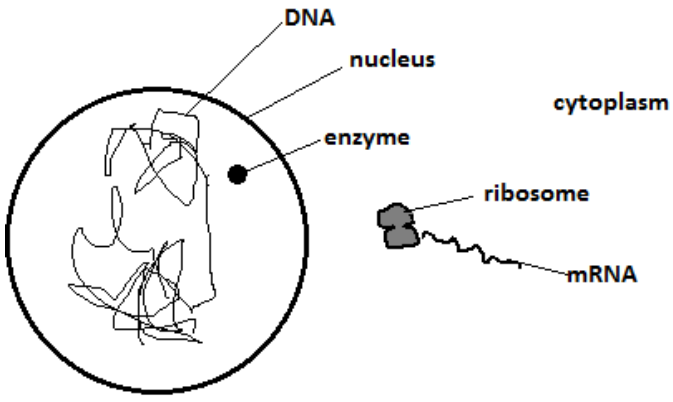
The enzyme (type of protein) copies the piece of DNA (the gene) with the instructions on it. The "gene copy" is called mRNA.



The mRNA (which has the instructions for a protein) leaves the nucleus and goes into the cytoplasm.

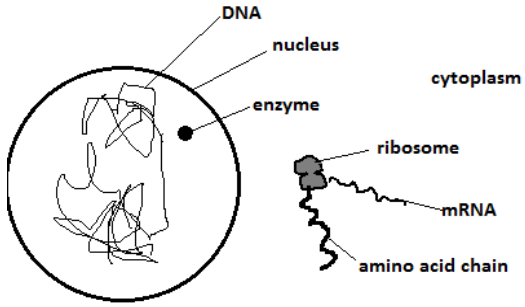


The next step of the process takes place in the cytoplasm, and it's called **translation**.

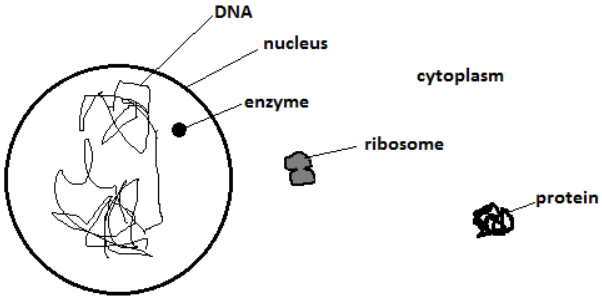


Inside the ribosome, the code in the mRNA is translated so that amino acids are put together in

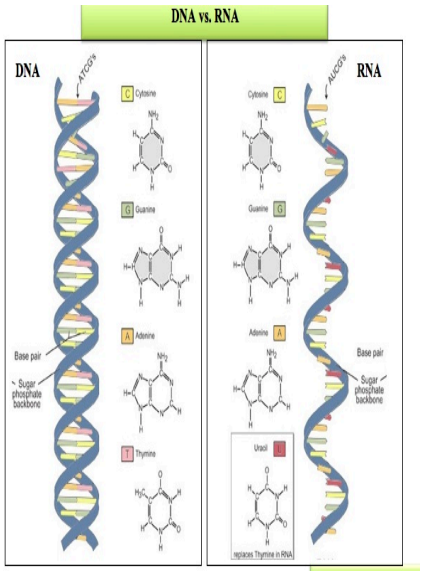
the proper order.

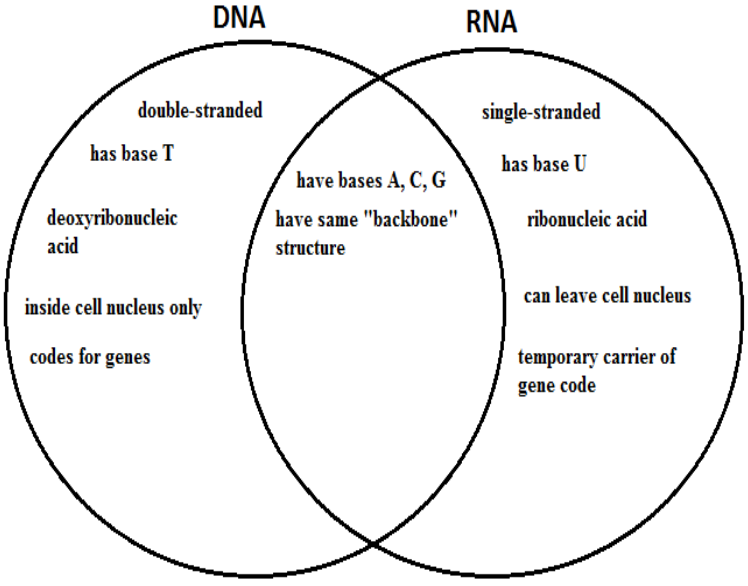


The amino acid chain folds up, and a functional protein is made, and ready to perform cellular functions!



Show **Slide 17** , which compares the structure and bases of both DNA and RNA. Encourage students to identify differences and similarities between the two molecules. They can complete the Venn diagram . Possible answers are included below. Students should be able to get information about the structure by looking at Slide 17. They can then add other information learned in this lesson later on.





Slide 17 and 18

Teaching Strategy: Vocabulary

When you first introduce the students to the terms "transcription" and "translation" you should activate some prior everyday understanding of these terms to help them better understand the processes that are taking place in using the instructions in DNA to make proteins.

Ask students what word(s) "transcription" sounds like, or what smaller words are in this bigger word. Students should be able to see the word "transcript." Ask students what a transcript is, like when you need your high school transcript. They should be able to say that it is a copy of their grades. So, in the process of transcription, the cell is basically making a copy of a gene (a piece of DNA).

Ask the same about "translation." Students should easily see "translate" and be able to say what it means to translate something. Essentially, inside the ribosome the mRNA, which contains the code for a protein, is translated so the protein can be made.

Wrapping Up Activity 3.4a

Ask students what new terms we need to add to our macro-molecular chart, and where do they go? Allow students to add whatever terms seem pertinent to them. They should definitely include mRNA.

Have students complete the Check For Understanding questions in their Readers.

Check For Understanding:

1) Using the pictures you drew and what we discussed as a class, describe the process of transcription in your own words. Be sure to include specific cellular vocabulary and include the location where transcription takes place.

Students may say that in transcription a piece of DNA/a gene is copied to make mRNA. This process takes place in the nucleus of a cell.

2) Describe the process of translation in your own words. Be sure to include specific cellular vocabulary and include the location where translation takes place.

Translation takes place in the cytoplasm. Inside the ribosome the mRNA code is translated so that amino acids are put together in the correct order to make a protein.

3) What does it mean to say that DNA contains the instructions for making proteins?

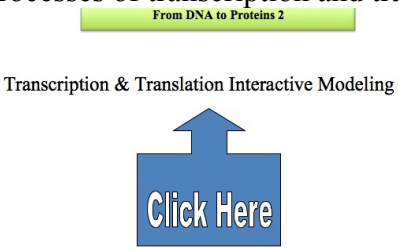
DNA contains our genes that are instructions for making proteins. These instructions can be copied in the nucleus so the proteins can be made in the cytoplasm.

Introducing Activity 3.4b (Day 2)
Have students answer the review questions in their Student Readers, Activity 3.4b.

Review:
1. What did we learn the letters A, T, G, and C stand for? *adenine, thymine, guanine, cytosine*
2. What do these letters represent? *DNA bases*

Carrying Out Activity 3.34b
Tell students that in this activity they're going to learn in greater detail what is happening inside the cell to make proteins.

Model for the students how to go through the process of reading the instructions in a gene that is made up of DNA. **You can do this as described below either on the board, or making a marshmallow DNA model similar to the model the students practiced with in lesson 3**. If you have access to the Internet you can model (with the help of the students) the processes of transcription and translation here:



http://learn.genetics.utah.edu/content/begin/dna/transcribe/ (Slide 19)

Teacher Background: Student Misconceptions

Students may struggle to keep track of where the processes of transcription and translation occur, and what exactly is happening in each step, and what differentiates the two processes. By modeling more of the specifics and by physically moving cell parts around it will help students understand "where" in the cell each step takes place. If you are not using the computer animation to model the processes, you should combine the modeling you do in Activity 3.4b with what the students do in Activity 3.4c.

Have students take notes in their reader as you model this process. Make sure as you model this process that you relate it back to the pictures the students drew in Activity 3.4a by asking them where in the cell each step occurs. Brief statements the students can write down as their notes are in bold below. These notes will become directions that will help them do Activity 3.4c.

STEP 1 - **Start with the gene (piece of DNA) to be transcribed**. ASK: Where is the gene? (*In the DNA*) Where is the DNA? (*In the nucleus*). One is written below as an example, however, using an assembled DNA model for your starting sequence (or assembling it to match this one)

will help students to make the connection between the model they made in a previous lesson and the activity they will do in this lesson. Hold up the DNA model for the class to see.

A T G T A C A A A G
I I I I I I I I I I
T A C A T G T T T C

If you build a marshmallow model the colors should be A- pink, T- orange, G- Green and C- Yellow

STEP 2 - **Split the DNA so that the mRNA copy can be made.** (Split the first 9 and leave the last pair connected) The "bottom" of the DNA is to be transcribed. Where in the cell are we in this step? (*We're still in the nucleus, transcribing*) If the model can be split down the middle, do this. If not, explain to students that there is one enzyme (which should be in their drawing, and which they saw in the animation) that splits the DNA open so the appropriate gene can be copied. Also, the DNA is split open only where the gene is located, and then closed back up again once it is copied.

TACATGTT

Teacher Background: Enzymes

If necessary, you can briefly remind students that enzymes are proteins that facilitate chemical reactions in our bodies.

STEP 3 - **Make the mRNA copy of the gene match A to T, G to C, C to G, and U to A**. Explain to students that the base **uracil** replaces **thymine** in the RNA molecule. Where in the cell are we in this step? (*Still in the nucleus, transcribing*) Tell students that another enzyme copies the gene sequence to make the mRNA. Mimic this process by having students help you identify the corresponding RNA bases.

AUGUACAAA
If you use marshmallows the colors should be A- pink, U- white, G- Green and C- Yellow

Ask students: What happens after the RNA copies the gene? (*The RNA leaves the nucleus to go to the cytoplasm*)

STEP 4- The ribosome, the "protein factory," looks at mRNA three letters at a time (**codons**). We will also look at mRNA three letters at a time. **Break the mRNA into codons.** Where in the cell are we now? (*We're in the cytoplasm, inside the ribosome*). Simply separate the RNA sequence into codons to provide students with the visual.

AUG UAC AAA

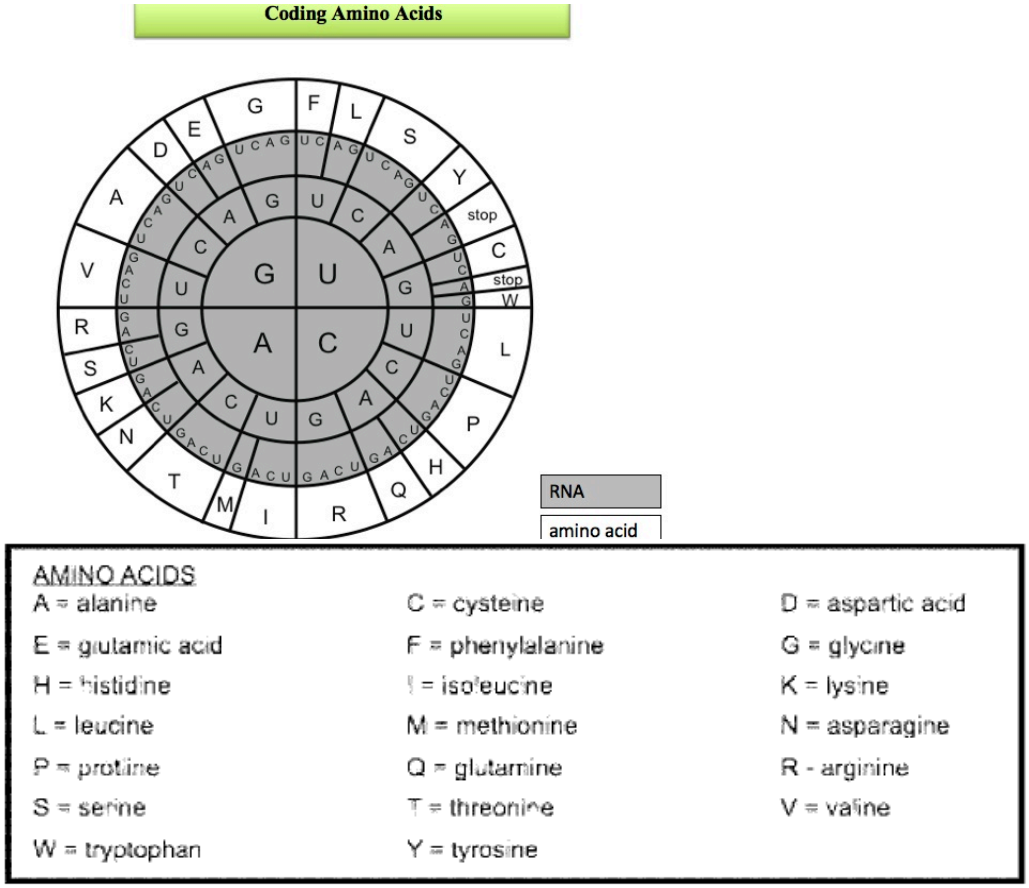
STEP 5 - **Match the codons with the amino acids using the amino acid chart (Slide 20) .** Based upon the codons, the appropriate amino acids are retrieved from the cytoplasm and

connected to each other to form the protein. If you are modeling with the marshmallows use gumdrops (one color for each) to represent the amino acids. String them onto a toothpick to simulate the ribosomes. Point out that the codon AUG signals the beginning of the gene to be translated. This corresponds to the amino acid Met. Point out that there are also several "STOP" amino acids that signal when the gene translation is complete. Show in the amino acid chart which ones the STOP amino acids are. Go over the amino acid chart in the context of this modeling to make sure students understand how to use it before beginning Activity 3.3c.

M-Y-K

Teacher Background: Amino acid chart

To read the circular codon chart, start in the middle with the first DNA base in the three-letter codon. Then progress further outward. The letters in the white outer circle are the amino acids. The key below the chart tells specifically the name of the amino acid. For example, if the codon is UAC, start in the middle with U. Move to the next ring, A, and then the next ring, C. This results in the amino acid, Y, which is tyrosine.



Slide 20

After you have quickly modeled with them how to transcribe and translate a gene to make a protein, provide time for students to practice this themselves in small groups.

Concluding Activity 3.4b

Check for understanding:
Explain why the sequence (the order) of the DNA bases that make up a gene is important for making a protein.
The sequence of DNA bases determines the order of bases in the RNA strand, and consequently the order of amino acids in a protein. (Ultimately, the order of the amino acid sequence, which determines the functionality of the protein, is determined by the DNA sequence).

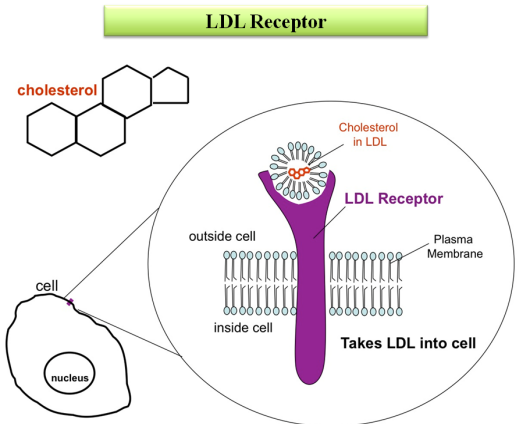
Carrying Out Activity 3.4c (Day 3)
Making the LDL Receptor Protein

Teacher Background: Preparing for Activity 3.4c
Materials
1 piece of licorice
9 marshmallows – 5-pink, 2 white, 1- green, 1- yellow (You may want to add some extra random colors as well)
9 pieces of wire (7 cm)
6 gumdrops -different colors
marshmallow DNA model
White paper to represent the nucleus of the cell

Note that for Activity 3.4c students will be modeling the processes of transcription and translation in the cell. They will do this using the spaces in your room. Small groups of students will work together and gather around a desk (or lab bench) to model their "cell." Each group needs the materials listed above (as well as in the student readers).

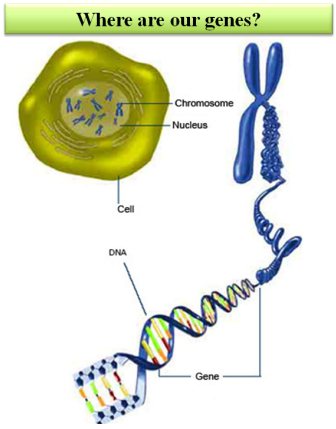
Review with students things they learned about the LDL Receptor. What is it and what is the function of the LDL Receptor protein? *(LDL receptors are proteins found in our liver cells that remove cholesterol from the blood, preventing the buildup of fatty deposits)*

Show the image (**Slide 21**) of this protein in a cell and ask students to share out what they wrote down about the function of the LDL Receptor. Remind students that we learned that if there is a protein, there must be a gene in our DNA that codes for (contains instructions for) the protein.



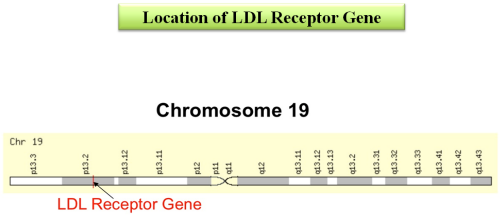
Slide 21

Show **Slide 22**. It shows students again where genes are located (chromosomes are tightly coiled DNA found in the nucleus of cells, and genes are just a piece of the DNA).



Slide 22

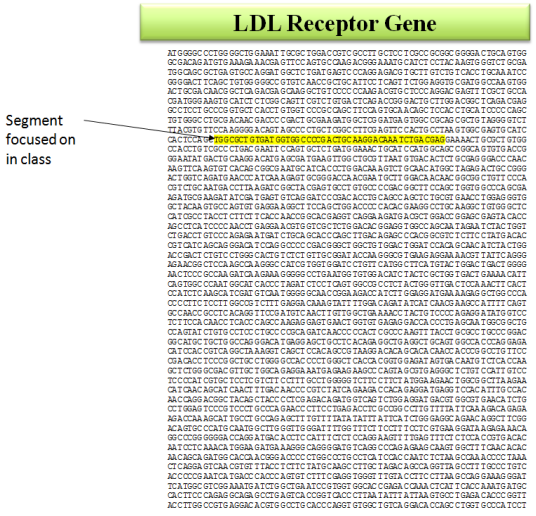
Ask students to remind you where specifically (which chromosome) the LDL receptor gene is found (*on chromosome 19*). Show them **Slide 23** which points out specifically where on the chromosome the gene can be found. This is to emphasize that a gene is one segment of a chromosome, but make sure students do not confuse genes with whole chromosomes because this is a point of confusion for some students. Students need to realize that genes are only tiny segments of whole chromosomes.



Slide 23

Teacher Background: LDL Receptor Size

The LDL Receptor is very large (800 amino acids long), and this would take too long to make in class, so we will only make part of it. We will make 9 pieces of the part that binds the LDL molecule. Since this is a segment from the middle of the gene sequence there is no start or stop codon. You should inform students of this. The sequence for the full length LDL receptor can be found in ***Slide 24****.*



Slide 24

Students work in small groups to practice transcribing and translating, using their desks as the model cell, and their marshmallow DNA models from Lesson 3. A sheet of plain white paper (printer paper is fine) will be the nucleus. The rest of the space on the desk is the cytoplasm, the edge of the desks is the cell membrane. Each group should receive gumdrops (they should not worry about the color for this activity) to represent the amino acids. Ask them where the amino acids should be placed (*in the cytoplasm*)

Remind students that in Lesson 3 they already made a marshmallow model of part of the gene that contains the instructions for making the LDL Receptor protein do its job. They will be doing what cells do to transcribe and translate this gene. They are taking on the role of enzymes first to open the DNA and transcribe the gene, then the ribosomes to translate the gene. A copy of the gene sequence is included in their Readers, Activity 3.4c, as a reminder. Students will transcribe 9 pieces of this gene sequence.

TGGCGCTGTGATGGTGGCCCCGACTGCAAGGACAAATCTGACGAG

ACCGCGACACTACCACCGGGGCTGACGTTCCTGTTTAGACTGCTC

Ask students: Where should the gene sequence be in the cell? (*In the nucleus*). Make sure students put their DNA physically on the white piece of paper. Show **slide 25.**

Ask students what happens next. They should say that an enzyme opens the DNA (splits the two sides of the DNA) and copies/transcribes the bottom piece. Have them use the scissors

to cut the wire in 9 pieces of the DNA down the middle. Leave the last one connected so that the DNA stays together.

Pass out an RNA licorice backbone to each group. They should transcribe the bottom segment (beginning ACC) as a group. They do this by connecting wire to their licorice backbone then stringing on the extra colored marshmallows using the white marshmallow to represent uracil. Walk around while they are doing this to make sure they are pairing corresponding bases correctly. When they have finished physically making their mRNA model, they should write the mRNA sequence in their Readers, Activity 3.4c. **See Slides 26 and 27**

Give them time to do all of this. While they are transcribing encourage them to try to keep everything in the nucleus (over the white paper). Students should come up with the following mRNA sequence:

UGG CGC UGU

Ask: What happens with the DNA? (*The DNA zips back up and stays in the nucleus*). Have students push the DNA back together.

Ask: What happens with the mRNA? (*The mRNA leaves the nucleus and goes to the cytoplasm.*) Have students move the mRNA they created to another part of their desk.

Pass out gumdrops and a toothpick to each group. Tell students that the toothpick will represent a protein. Ask where this goes right now (*the protein hasn't been made yet, so it should remain off the desk/out of the cell for now until the protein is made*)

Continue to get students to guide themselves (and you) through the process. They should now say that the ribosome (them) "translates" the mRNA codons to find the amino acids. For each codon and each amino acid they record in their reader they should take a gumdrop and put it onto the toothpick.

Students should come up with the following amino acid sequence corresponding to the mRNA sequence determined from above. Students should make their own key to show what colors represent each amino acid.

W-R-C

As student groups model this process, walk around to make sure they are moving things around the "cell" appropriately and using the amino acid chart correctly. You should also periodically check to make sure they are coming up with the correct sequences. At the end of the activity, review the amino acid sequence students should have gotten and resolve any conflicts or confusion.

Check for understanding:
1) Where does transcription (DNA to RNA) take place? *(the nucleus)*

2) Where does translation (RNA to protein) take place? *(cytoplasm, in the ribosome)*

3) In your own words, describe the processes where our genes are used as instructions to make proteins. (*An RNA copy is made of* a *DNA sequence in the nucleus of our cells. The RNA is moved to the cytoplasm, where it is read in groups of three bases called codons. The order of the bases determines the order of the amino acids that are joined together to make the protein.*)

4) Using what you've learned in this lesson about how we go from DNA to proteins, write a scientific explanation to answer the question: How similar or different are we?
Possible Claims: We are all similar. OR, We are different.
Possible Evidence:
When we made the DNA models we used the same nucleotides (DNA bases).
When we modeled the process of transcription we all had our DNA in the nucleus, and then when we modeled translation we all moved our DNA to the cytoplasm.
When we modeled transcription and translation we all did the same things with our models and ended up with the same amino acid sequence and we all ended up with the LDL receptor protein.

Accept all reasonable responses, but encourage students to use evidence from the class activities.

Concluding Activity 3.4c:
Revisit the Driving Question board. What new information do we have about how similar or different we are?

Are there any questions we can answer? What new questions have arisen?

Assign Reading 3.4 for homework. Reading 3.4 brings students back to the original phenomenon of skin color and encourages them to relate what they've learned in this lesson to the original phenomenon.

At the beginning of the next lesson, review student responses. Focus in detail on Questions 3, 4, 5, as those specifically relate to what we've been learning about. Question 5 leads into the next lesson about mutations.

TAIPEI TIMES

Published on TaipeiTimes
http://www.taipeitimes.com/News/world/archives/2005/12/27/2003286244 (Edited)

Fish research helps uncover genetics of human skin color

DPA , WASHINGTON
Tuesday, Dec 27, 2005, Page 7

Scientists in the US have discovered what they believe is the gene that helps determine whether a human has dark or light colored skin. In an article published in the journal *Science*, a team from Pennsylvania State University said two variations of the same gene strongly influence skin pigmentation.

The researchers reported that according to their findings 99 percent of the population of Europe has one version of the gene SLC24A5. In Africa, between 93 and 100 percent of the population have the other type. According to the main author, Keith Cheng, the discovery reveals important insights into the evolution of skin color in humans.

In an accompanying article also published in *Science*, molecular biologist Richard Sturm described the discovery as "absolutely original and pioneering". Dark pigmentation protects skin from harmful ultraviolet rays emitted by the sun. Ultraviolet light destroys vitamin B (folic acid) in the body which can lead to a number of serious health problems and in some cases to birth defects. But in climates with relatively little sunshine, dark pigmentation also prevents important chemical processes that take place in the skin such as vitamin D production. So as humans migrated to colder climates in the north it became important for skin to evolve to adapt to changing conditions.

Cheng and his colleagues identified the color gene for the first time in a rare breed of zebra fish. They examined the genetic code of a variety of zebra fish that had a golden pigmentation as well as lighter colored stripes than the common version. They concluded a gene that influences the melansomes -- granules that make the pigment melanin -- in the skin caused the difference between the two types of fish. The equivalent gene in humans is called SLC24A5. It causes melansomes to either grow in size and clump together causing dark skin, or to shrink, and the space between the particles to increase causing light colored skin.

Answer the following question based on both the newspaper article and what you learned in this lesson.

1. Why do people in Africa have different skin color than people in Europe?

Dark pigmentation protects skin from UV rays from the sun—something people would get a lot of living in a place like Africa. When people moved to Europe, where there wasn't as much exposure to sun, humans didn't need the same protection from the sun, so developed lighter skin color.

2. How did scientists find that a gene affects skin color? (What did they look at?)
   To find a gene that affects skin color scientists studied different varieties of zebra fish—some that had golden pigmentation, and some that had lighter pigmentation.

3. We learned that Tyrosinase was the protein responsible for the production of melanin. How could a gene for skin color have an effect on the protein Tyrosinase?
   DNA contains genes. Genes code for different proteins. Genes code for the protein Tyrosinase,, which results in humans having different skin color.

4. How does the information in this reading and the processes of transcription and translation help us answer the question "How similar or different is our skin?"
   Accept any answers that describe the proteins in all skin being coded for by genes and different shades of skin may have different genes

Lesson 5: How can DNA change?-The Effect of Gene Mutations

OVERVIEW

Purpose
Introduce students to types of mutations and links mutations in a gene to changes in protein structure and function. Explore nucleotide substitutions, deletions, and additions.

Connection
This lesson also sets the stage for understanding how individual differences can come about (i.e. through gene mutations that affect proteins), understanding that is central to answering the Driving Question of the unit

Description
Students will view case history of a patient with Familial Hypercholesterolemia. Student work in groups to use evidence from five patients' DNA sequences to identify mutations and determine if they have FH disease. Students will present their findings to the class.

Challenging ideas
Some students are unclear about the relationship between chromosomes, genes and DNA and often mislabel these parts. Related to this challenge, students are unclear where all chromosomes, genes, and DNA are located.

Some students may be able to connect genes to protein by listing all the pieces, but still be unable to transfer knowledge about this connection to explain the underlying cause to a disease or physical appearance they have not studied before.

Safety Guidelines
None applicable

Duration
3 Days

Learning Performances:
Students predict the affect of DNA mutations on protein structure and function.

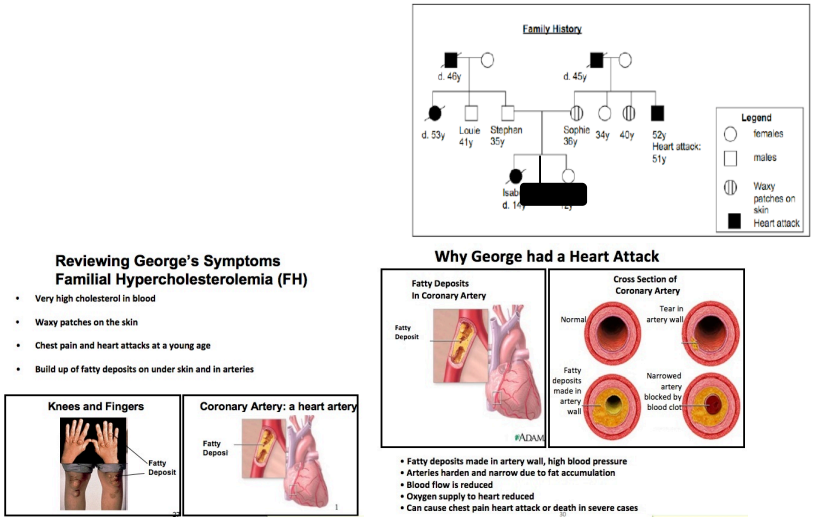
PREPARATION

Materials
Projector
Slides: Learning Set 3: Lesson 5: Slides 28-36
Student Reader pp: 118-127

INSTRUCTIONAL SEQUENCE

Introducing the Lesson- Day 1
Reading 3.5a- Revisiting the Medical Case: Familial Hypercholesterolemia

Tell students that today we are going to look back at our FH patient George. Remind students that the premed student Rachel looked at his medical history in order to determine that he had Familial Hypercholesterolemia. Use the **slides 28-30** to review with students the patient's symptoms and family history.



Slides 28-30

Ask students:

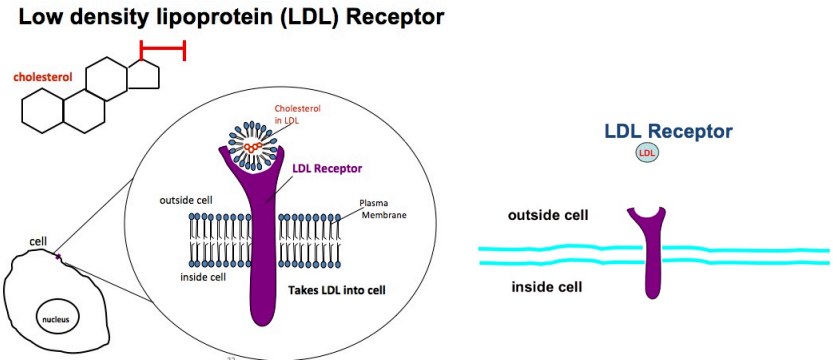
- What is cholesterol? (Use **slide 31** to discuss how the body uses cholesterol to build cell membranes, hormones and vitamin D)
- Why do you think George has these symptoms?
- Why does he have Familial Hypercholesterolemia (FH)?
- Do you think his diet and lifestyle could affect his symptoms? Why? Why not?

Record students' ideas on the board and tell students that doctors just like scientist need to make diagnosis based on evidence. Ask students:

- What evidence did the premed student find in his medical charts that could help the doctor diagnosis George's condition? If students do not remember have them turn back to the reading. (She found a problem with his DNA and his LDL Receptor Protein)

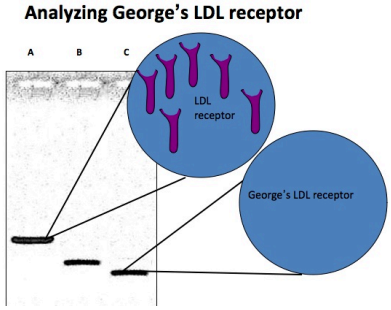
Tell students to think back to the last medical condition that they investigated- Lactose intolerance. The Lactase protein helped the body to digest the sugar in milk. Tell students that in order to understand George's condition we need to know how the LDL receptor protein

works in the body. Use slide 32 and the animation in slide 33 to describe how the LDL Receptor protein works.



Slides 32 and 33
Reading 3.5a
Ask students to read the medical journal article in their reader (Reading 3.5a) describing how the receptor protein transports cholesterol into the liver cells. Assign each group a different question to answer. Have each group present their answer and discuss the answers. Ask the class to record the correct answer as the other group presents.

Show slide 34 as you discuss the question about how George's LDL receptor might be different from others in his family.



Slide 34
Tell students that by looking at the electrophoresis we have evidence that George's LDL receptor protein may not be the same as a normal person's. This would help explain why George has the symptoms of FH but it does not tell how why his protein is different. Use **slide 35** to discuss the difference found in George's DNA. Ask students to think back to the last lesson:

- What does George's DNA have to do with his proteins? Use this question to review transcription and translation.

Tell students that they need to look more closely at George's DNA to find out why his protein is different.

Day 2
Activity 3.5 How do differences in DNA affect proteins?
Revisit the Driving Question board and ask if any questions have been answered. Ask students:

- How are people with FH disease similar or different from others?

- How might their LDL receptor Proteins be different from others?
- What evidence do we have that their LDL receptor proteins are different?

In this activity, students will work in groups to determine the effect of specific changes in DNA on the LDL Receptor protein. Show **slide 36**. Tell students that the DNA sequence for the LDL Receptor was determined for 4 individuals in George's family including George. Tell students they will now use their knowledge of genes and proteins to predict, who in George's family might have FH? Each of the individuals is a person who has high cholesterol. The doctor is unsure of whether it is FH or another disease. The students will determine the likelihood that it is FH by comparing their DNA sequence for the LDL receptor with a normal person.

Assign each group of students a different patient. Patient 4 is George. Ask the students to compare their patient's DNA sequences for the LDL receptor gene with a normal person's genes. Have students identify what is different in each of the sequences and then convert the sequences to mRNA sequence to determine what affect the sequence will have on the proteins, and the health status of the individual. Explain to students that they need to look carefully for changes in the DNA sequences as they compare their patient with the normal sequence. Some of the changes they may identify are:

- Deletions- missing nucleotides
- Additions- added nucleotides
- Substitutions- exchanging one nucleotide for another

Students should answer the following questions for each change. Model the process for students by doing the normal DNA together as a class. You can have students work in groups and then be prepared to present their finding to the rest of the class on day 2. For their assigned patient the students should write a report for the doctor explaining:

- What was is different for each sequence?
- Scientific explanation: What affect did each change have on the amino acid sequence encoded? (First, convert the DNA sequences to RNA sequences, then determine the amino acid sequences)
- Scientific explanation: Is the person with each mutation likely to have FH?

Answers

Normal Sequence:
UGG CGC UGU GAU GGU GGC CCC GAC UGC AAG GAC AAA UCU GAC GAG
healthy

Patient 1
UGG CGC UGU GAU GGU GGC CCC CAC UGC AAG GAC AAA UCU GAC GAG
Substitution, C for G in 1st GAC, substitute aspartate for histidine (neg to pos), LDL Receptor probably does not work, likely has FH

Patient 2:
UGG CGC UGU GAU GGU GGC CCC GAU UGC AAG GAC AAA UCU GAC GAG

Substitution, U for C in 1st GAC, no change in amino acid, LDL Receptor should work okay, does not have FH

Patient 3:
UGG CGC UGU GAU GGU GGC CCC GGA CUG CAA GGA CAA AUC UGA CGA G
Addition, G added in front of 1st GAC, many amino acids changed, LDL Receptor probably does not work, likely has FH

Patient 4 (George):
UGG CGC UGU GAU GGU GGC CCC ACU GCA AGG ACA AAU CUG ACG AG
Deletion, G deleted in 1st GAC, many amino acids changed, LDL Receptor probably does not work, likely has FH

Patient 5:
UGG CGC UGU GAU GGU GGC CCC GAC UGA AAG GAC AAA UCU GAC GAG
Substitution, A substituted for C in UGC, stop codon, short protein, LDL Receptor probably does not work, likely has FH

Reading 3.5b – Mutations: Are they good or bad?
Ask students:

- Why do you think that some member's of George's family have differences in their DNA sequences for the LDL receptor protein?

Give students a chance to share their ideas. Explain to students that the differences that they saw in the DNA sequences are called mutations. Explain to students that "mutation" in the context of genetics means that the DNA sequence has changed from the typical or normal sequence to a different sequence (as little as one difference can be considered a mutation).

Assign the reading about types of mutations and explain that they will read more about mutations. This text will help students learn more about the various mutations that they encountered in the last activity. This could be assigned as homework if time is short.

Day 3 Reading 3.5b – Mutations: Are they good or bad? Cont'd

Discussion
Review questions at the end of the reading. Explain that mutations can be caused by radiation, a chemical agent in our environment, or on rare occasion can occur spontaneously (spontaneous mutations are essentially typos that occur when the DNA is being copied before cell division occurs). Ask students if they have heard of the term "mutagen." This refers to an agent that causes DNA mutations. Mention that these mutations can be passed on to future generations if they exist in sperm or egg cells. As we noticed above, some mutations could be harmful to the organism and some may not be. FH is an example of what can happen if a mutation in a gene is harmful.

Presentations
Have students go back to their Lab report and identify the type of mutation for their patient. Give each group a few minutes to review their findings from the day before and prepare to present them to the class. Presentation should consist of answers to questions 1-3 in Activity 3.5b, as well as identifying the type of mutation their patient has. As each group presents, the rest of the class should fill in their chart at the top of the activity sheet.

After the presentations review the chart as a whole class. Obtain class consensus on the types of mutations and also label types of changes to proteins as no change, amino acid substitution, new amino acid sequence, or short proteins (due to the formation of a stop codon).

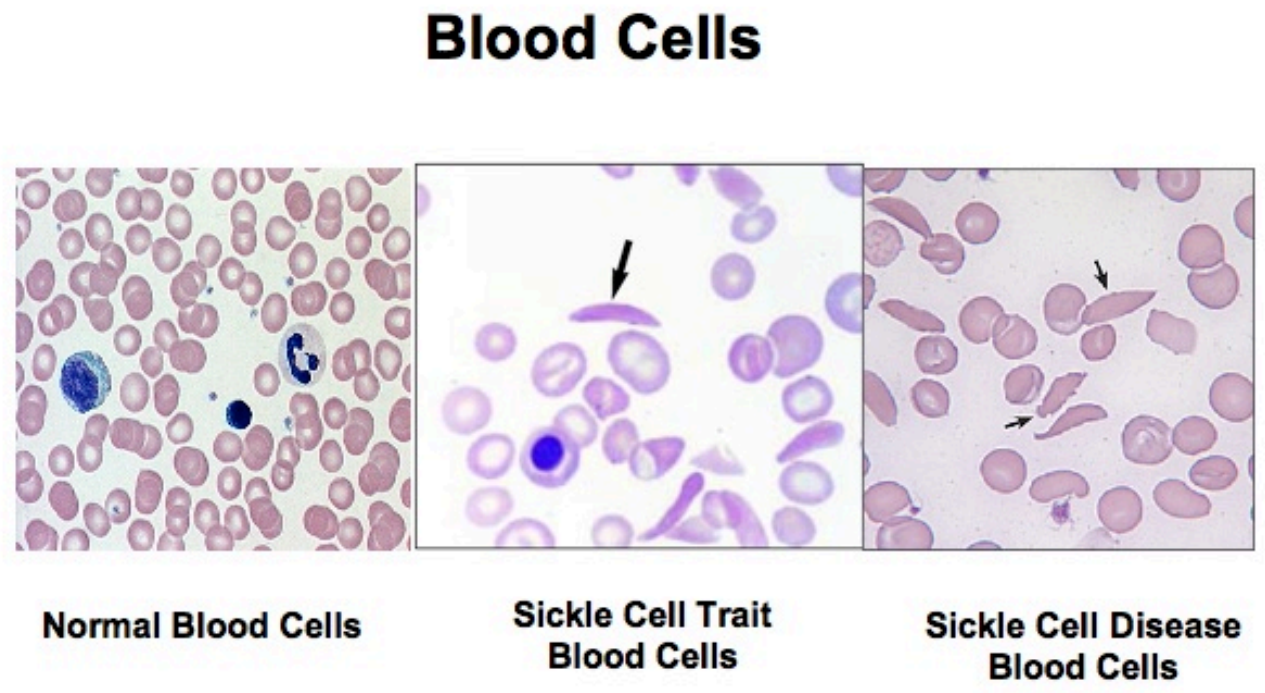
Teacher Background

The part of the DNA sequence that is added or substituted is highlighted. In the DNA sequence for patient 3, the G in the first "GAC" is deleted. The deletion is a frame shift mutation because it changes all of the codons downs stream of the mutation. Most of the mutations here affect this first GAC, which encodes Asp (D). We suggest referring to these mutations as single nucleotide changes. Note that this codon is actually one of the codons mutated in the genetic disease FH.

Concluding Lesson 5
After the presentations discuss with students the question; "**How can two people have different versions of the same proteins?**" Ask students where this new question should be posted on the DQB. Ask students if there is any new information that should be added to the board to answer this question. Use post –its to post information as students supply it.

In small groups have students work together to write a scientific explanation based on what they learned in this lesson to answer the following question in their readers. "**How similar or different is George from the rest of his family? How similar or different is he from others?"**

Learning Set 4
Why Do Some People Have Diseases Others Do Not?



Learning Set 4-Why do some people have diseases others do not?

Content Standard	Inquiry Standard	LS3 Learning Performance
Molecular nature of genes and mutations - Genes are segments of DNA molecules. Inserting, deleting, or substituting DNA segments can alter genes. An altered gene may be passed on to every cell that develops from it. The resulting features my help, harm, or have little or no effect on the offspring's success in its environment. (AAAS, pg. 109, 58:9-12#4)	Identify questions and concepts that guide scientific investigations . (NRC, 1996, A:1A/9-12)	Students describe the causes and health affects of sickle cell anemia and sickle cell trait.
		Students predict that changes found in blood cells are dependent on differences in protein structure and function.
	Formulate and revise scientific explanations and models using logic and evidence. (NRC, 1996, A:1D/ 9-12.).	Students use models to predict the affect of changing the DNA sequence on protein structure and function..
Heritable material - The information passed from parents to offspring is coded in DNA molecules. (AAAS, pg. 108, 58:9-12#3)		Students explain how mutations are passed from one generation to the next.
Natural selection provides the following mechanism for evolution: Some variation in heritable characteristics exists within every species; some of these characteristics give individuals an advantage over others in surviving and reproducing; and the advantaged offspring, in turn, are more likely than others to survive and reproduce. As a result, the proportion of individuals that have advantageous characteristics will increase. 5F/H3*(AAAS, 2009)		Students explain how the frequency of organisms within a population carrying gene mutations can change from one generation to the next when influenced by environmental pressures such as malaria.

Learning Set 4: Why do some people have diseases and others do not?

Overview

Purpose

Through this example of sickle cell anemia, students get another chance to learn about the idea of genes as information for building proteins. Students also get to revisit the ideas of mutations and the effect of gene mutation on proteins— which in some cases can cause disease. In this learning set students have the opportunity to make connections between their understanding of classical genetics (homozygous, heterozygous, recessive, dominant, etc.) and what they have learned in this unit. Students will also explore the role of natural selection in the presence of some genetic diseases. In the case of sickle cell disease, students can learn about the benefit of resistance against malaria. We chose sickle cell anemia in this unit because it is particularly frequent in African American and Hispanic populations, thus those classrooms with a high proportion of these students should find this lesson personally relevant.

Description

Lesson 1

- Students are introduced to a genetic disease called Sickle Cell Anemia that can be caused by a faulty protein, specifically the LDL Receptor protein. This leads to a discussion of how proteins could be built improperly because the instructions for the proteins (i.e. genes) are altered.

Lesson 2

- Students learn about the link between sickle cell anemia and the mutation in the Hemoglobin gene. Students will construct models to compare normal and sickle cell hemoglobin. Students construct molecular explanations for the different in the health of individuals with and without the trait at all biological levels.

Lesson 3

- Students will read about the work of Mendell in classical genetics. Students will use Punette squares to explain how sickle cell trait is passed from one generation to another generation.

Lesson 4

- Students watch a video and read about malaria resistance in Africa. Students use beans to model the changes over time in the sickle cell trait within the population due to the pressure of sickle cell disease.

Learning Goals

The learning goals addressed in this Learning Set are darkened.

National Standards

- Genes as information for proteins - The genetic information in DNA molecules provide the instructions on assembling protein molecules. The code is virtually the same for all life forms. (AAAS, pg. 114, 5C:9-12#4)
- Molecular nature of genes and mutations - Genes are segments of DNA molecules. Inserting, deleting, or substituting DNA segments can alter genes. An altered gene may be passed on to every cell that develops from it. The resulting features my help, harm, or have little or no effect on the offspring's success in its environment. (AAAS, pg. 109, 58:9-12#4)
- Heritable material - The information passed from parents to offspring is coded in DNA molecules. (AAAS, pg. 108, 58:9-12#3)

Michigan Standards

- L4.p2 - Heredity and Environment (prerequisite)- The characteristics of organisms are influenced by heredity and environment. For some characteristics, inheritance is more important. For other characteristics, environment is more important. Genetics and Inherited Traits - Hereditary information is contained in genes, located in the chromosomes of each cell.
- 84.2 - The genetic information encoded in DNA molecules provides instructions for assembling protein molecules. Genes are segments of DNA molecules. Inserting, deleting, or substituting DNA segments can alter genes. An altered gene may be passed on to every cell that develops from it. The resulting features may help, harm, or have little or no effect on the offspring's success in its environment.
- B4.2D - Predict the consequences that changes in the DNA composition of particular genes may have on an organism (e.g., sickle cell anemia, other).
- B4.2x - DNA, RNA, and Protein Synthesis - Protein synthesis begins with the information in a sequence of DNA bases being copied onto messenger RNA. This molecule moves from the nucleus to the ribosome in the cytoplasm where it is "read." RNA brings amino acids to the ribosome, where they are connected in the correct sequence to form a specific protein.
- B4.2f - Demonstrate how the genetic information in DNA molecules provides instructions for assembling protein molecules and that this is virtually the same mechanism for all life forms.
- B4.2g - Describe the processes of replication, transcription, and translation and how they relate to each other in molecular biology.
- B4.4a - Describe how inserting, deleting, or substituting DNA segments can alter a gene. Recognize that an altered gene may be passed on to every cell that develops from it and that the resulting features may help, harm, or have little or no effect on the offspring's success in its environment.

- B4.4c - Explain how mutations in the DNA sequence of a gene may be silent or result in phenotypic change in an organism and in its offspring.

Prior Knowledge

- Cells: Students should realize all living organisms are comprised of cells and that for humans (as well other animals and plants) have tissues and organs that are comprised of many cells. Students should also know that cells have a nucleus, which is an organelle in the cell.
- LG1 (Nature and function of proteins): Students need to be familiar with content covering proteins from Lesson 2, especially the idea that proteins are long chains of amino acids and that the order of amino acids determine the protein shape, which in turn determines the protein function. Note that this lesson is meant to give students another opportunity to understand this content so it is not necessary that students are completely proficient with this content prior to this lesson.

Student Conceptual Challenges

- Students are unaware of the central role proteins play in biological processes.
- Some students are unclear about where genes are found -- some students think genes are found in places other than the nucleus of every cell (i.e. such as in "the blood" or "the brain")
- Some students don't always realize genes exclusively code for proteins or that a gene produces a product.
- Students sometimes think genes can also code for cells and cell functions (something beyond proteins).
- Some students have difficulty making connections between genes and proteins.
- Some students may be able to connect genes to protein by listing all the pieces, but still be unable to transfer knowledge about this connection to explain the underlying cause to a disease or physical appearance they have not studied before.

Time

2 days

Lesson 1: How can people have different red blood cells?

OVERVIEW

Purpose

Through this example of sickle cell anemia, students get another chance to learn about the idea of genes as information for building proteins. In this lesson students will be introduced to the health affects of sickle cell disease and sickle cell trait.

Connection

This lesson serves to reinforce the connection between genes, proteins, and health introduced in Learning Set 3.

Description
Students read about the death of a college football player who has the trait for sickle cell anemia. Students are introduced to the symptoms of sickle cell anemia through videos and images and learn about the link between sickle cell anemia and the Hemoglobin protein and the mutation in the Hemoglobin gene.

Challenging ideas
Some students are unclear about the relationship between chromosomes, genes and DNA and often mislabel these parts. Related to this challenge, students are unclear where all chromosomes, genes, and DNA are located.

Some students may be able to connect genes to protein by listing all the pieces, but still be unable to transfer knowledge about this connection to explain the underlying cause to a disease or physical appearance they have not studied before.

Safety Guidelines
None applicable

Duration
2 Days

Learning Performances:
Students describe the causes and health affects of sickle cell anemia and sickle cell trait.
Students predict that changes found in blood cells are dependent on differences in protein structure and function.

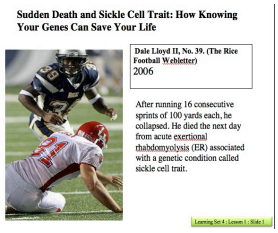
PREPARATION

Materials
Projector
Slides: Learning Set 4: Lesson 1: Slides 1-6
Student Reader pp: 130-136
Microscope slides of blood smears

INSTRUCTIONAL SEQUENCE

Reading 4.1a - "Sudden Death and Sickle Cell Trait: How Knowing Your Genes Can Save Your Life"
Remind students that in the last lesson they found that differences in DNA could cause diseases such as Familial Hypercholesterolemia. Ask students the following questions:

- How was George's DNA different? (The gene that controlled the LDL receptor was different)
- What are changes from the normal sequence of DNA called? (mutations)
- What type of changes can occur? (deletions, insertions or substitutions)
- How did the difference in George's DNA affect his health? (He was not able to break down fats to use in his body, higher risk of heart attack)



Show **slide 1**. Tell students that in this lesson they will learn about another young man whose DNA had an affect on his health. Assign students to read "Sudden Death and Sickle Cell Trait: How Knowing Your Genes Can Save Your Life". Discuss the questions at the end of the reading.

Accept all answers as this reading is designed to start student thinking about and discussing sickle cell. Give some time for the ethical questions raised in question #4 (Should college athletes be forced to test for sickle cell?). Let students know that in order to make a good argument to support their ideas they must have evidence. Students need to understand more about sickle cell disease in order to have evidence for a strong argument.

Activity 4.1a Examining blood cells with a microscope
Set up stations with slides of normal and sickle cell blood smears. Have students make a prediction about what differences they might see in the blood of a person with sickle cell disease. Have the students examine pre-made slide of blood smears from healthy individuals and those with sickle cell. Divide students into groups and assign them to microscope stations to look at slides and report differences. You will have the best result with at least a 40 X lens. Have students report on what they observe in student reader.
What differences do they notice? Are there similarities?
Teacher note:

Ask students to focus on differences in shape. The differences in color are due to the differences in the preparation of the samples, not to differences in the blood.

Generating discussion - Sickle cell disease
Students should get the opportunity to share what they already know about sickle cell disease and start to think about it as it relates to the other genetic diseases they have learned about. In this discussion allow students to share their ideas without fear of evaluation.

Ask the students to describe what they saw in the microscope. Tell the students that one of the samples was from a healthy person and one was from a person with sickle cell disease. Ask them the following questions:

- Which slide is from a healthy person?
- What do you know about sickle cell disease?
- What are the symptoms?

Discussion Strategies:
Point out that a person of any race can have the disease, but it is more frequent in some population of humans, for example the rate of sickle cell disease is higher in some African and Asian populations than it is in some European populations. Approximately 1 in every 500 African-American's has sickle-cell disease. It is also frequent in Hispanic populations –

Think/Pair/Share: You can have the students first try it on their neighbor, then reconvene as a class and share their explanations.
When students give answers, here are some things you can do:.
Make Knowledge Explicit:
Evidence: What evidence did they use to explain their answers?
Student Centered: Encourage the STUDENTS to initiate the discussion questions, follow-up questions, challenging of evidence, etc. Try to GUIDE the discussion rather than lead the discussion.
Addressing Other Students:

- Encourage students to address other students in the classroom.
- For example: Student: "Suzie said that protein shape would stay the same. I disagree. I think that if amino acids change, then the protein shape changes too."
- Ask students to consider a previous response while formulating their own. (See above example in quotes).
- Encourage students to ask other students questions about their predictions and similarities and differences. For example: Student: "Why do you think that this disease can be passed to offspring?

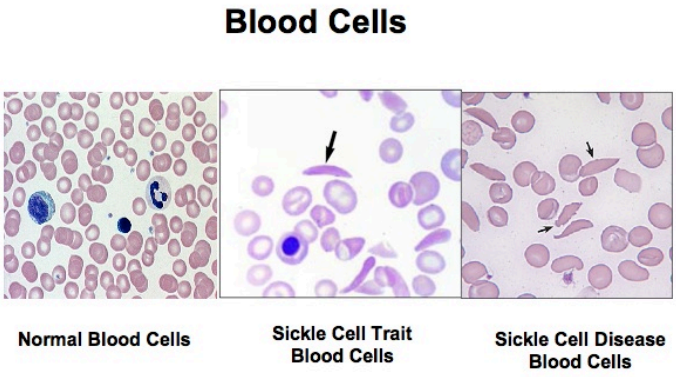
Follow-up Questions: Use follow-up questions, such as "WHY" and "HOW DO YOU KNOW THAT" when students give answers (claims). This can push them to think deeper about why they think they know something.
Additional follow-up questions include:
•What have you observed or experienced?
•What else is on your group's list?
•What do you/other people think about when they hear the word ___?
•Who has a different idea/response/way of thinking about this?
•What do you know about [topic X]?

affecting every 1 in 1000- 1400 Hispanics. It is also frequent in people of Mediterranean, Middle Eastern and South Asian decent (chances high that are someone in the class will know someone who has it).

Day 2 -How can people have different red blood cells?- Analyzing hemoglobin

Refer students back to the article, "Sudden Death and Sickle Cell Trait: How Knowing Your Genes Can Save Your Life". Ask students to look back at their drawings of normal and sickle cell blood samples:

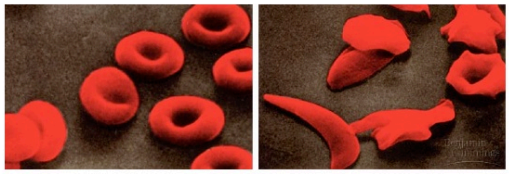
- Predict what the young man in the article's blood might look like.
- What evidence do you have to support your ideas?



Show students **slide 2**. Ask students:

- What similarities and differences you see in the 3 blood smears?
- How might those differences affect a person's health?

Video - information about sickle-cell disease



View video on sickle cell

Interview with sickle cell patient: pain

Learning Set 4 : Lesson 1 : Slide 2

Show **slide 3**. In the view mode of PowerPoint, click on "interview with Sickle Cell patient: pain." Once at the site click on "pain" on the left hand side (you may need Quicktime for this as well). A girl talks about the type of pain she suffers from. This video puts a human face on the disease.

Ask students to think back to the other differences that they have studied; skin color, lactose intolerance and FH disease. Ask students to use what they already know about the cause of those differences and make a prediction.

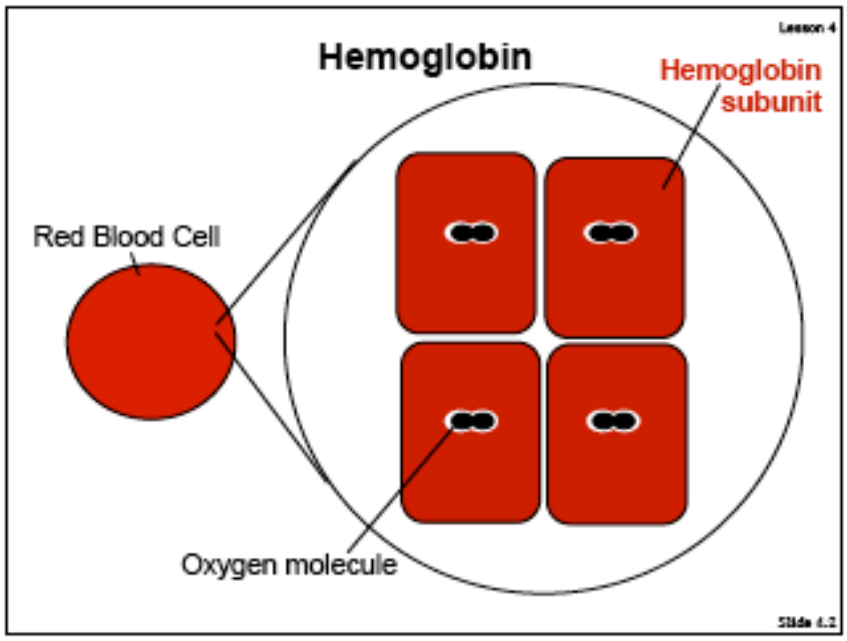
- What might have caused the differences in the blood cells of people with Sickle Cell trait or Sickle Cell anemia?
- Why do you thinks so? Give evidence from what you already know about what causes differences in the activities of cells in the body.

Have students work with their groups to come to consensus and write their prediction in their readers. Accept all answers. Discuss predictions asking each group to identify evidence from

other lessons for their ideas. If no students mention differences in the protein, ask students about differences in the skin cells, cells in the intestines and the liver from past lessons.

Go back to **slide 3**. Show links to movie about Sickle Cell Disease and Sickle Cell Trait. Ask students to record in their reader any information that supports their prediction as they watch the movie. After the movies discuss the following points:

- Red blood cells become banana shaped when oxygen is low in the blood.
- The oddly shaped cells cause blockages.
- The blockages cause pain, damage to tissue and organs, even death.
- Sickle shape of cells is caused by differences in the protein (hemoglobin) in the red blood cells



Slide 4 - 6 - Tell students hemoglobin is a protein in red blood cells. Review with students the function of red blood cells in the body. Refer back to the Macro to Molecular chart. Ask students where you would place red blood cells? Hemoglobin? Oxygen? Show cartoon image of the protein and ask students to describe what is going on in this image and what they think hemoglobin does.

Point out hemoglobin is made of four subunits. Each subunit is a single chain of amino acids. But, unlike the other proteins they've studied, in order for hemoglobin to function it needs three partner proteins. Carrying oxygen is a four-protein job. Each individual protein chain is called a subunit.

Instructional Note: Definition of subunit

If students do not know what subunit means explain that "sub" means below as in a level below, so subunit, means a small part of a larger complex. For example, a bicycle chain link could be considered a subunit of a chain. However not all subunits have to be identical—for example a nucleotide in DNA could be considered a subunit of DNA.

Wrapping up the Lesson
Refer students back to the reading "Sudden Death and Sickle Cell Trait: How Knowing Your Genes Can Save Your Life". Remind students that the reading said that Dale Lloyd died from a "genetic condition" called sickle cell trait. Ask students:

- Why do you think the author called Sickle Cell a "genetic condition"
- Why do you think most athletes don't know that they have this condition?
- Do you think the trait or the disease might affect athletes more than other people?

Homework
Ask students to think about these questions as they read, "**Sickle Cell Disease: The Crooked Red Blood Cells".** Ask students to respond to the reading by:

1. Putting a question mark in the margin next to any statement that they have a question about
2. Putting an exclamation point next to any statement that surprises them.
3. Putting a ☹ next to any statement they do not agree with.
4. Putting a ☺ next to any statement that they like.

Lesson 2: How can people have different hemoglobin protein?

OVERVIEW

Purpose
Through this example of sickle cell anemia, students get to revisit the ideas of mutations and the effect of gene mutation on proteins— which in some cases can cause disease.

Connection
This lesson serves to reinforce the connection between genes, proteins, and health introduced in Learning Set 3.

Description
Students learn about the link between sickle cell anemia and the mutation in the Hemoglobin gene. Students construct molecular explanations for the different in the health of individuals with and without the trait at all biological levels.

Challenging ideas
Some students may be able to connect genes to protein by listing all the pieces, but still be unable to transfer knowledge about this connection to explain the underlying cause to a disease or physical appearance they have not studied before.

Safety Guidelines
None applicable

Duration
1 Day

Learning Performances:
Students use models to predict the affect of changing the DNA sequence on protein structure and function.

PREPARATION

Materials
Sticky Notes
Projector
Slides: Learning Set 4: Lesson 2: Slides 7-11
Student Reader pp:137-139
Toobers
Push pins

INSTRUCTIONAL SEQUENCE

Revisiting the Driving Question Board
Ask students to write at least 3 questions that they have from the reading or any other questions they have about sickle cell disease on sticky notes. Have students compare questions with their

partners and consolidate any similar questions. Have each group present their questions and post them on the Driving Question Board. Revisit other questions on the board to see if they have been addressed so far in the unit.

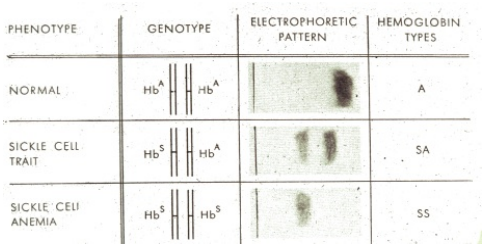
Activity 4.2a - Analyzing Hemoglobin

Ask students how what we have learned about sickle cell disease helps us to answer our driving question. Remind students that the reading mentioned that scientists have discovered that people with sickle cell have a difference in their hemoglobin.

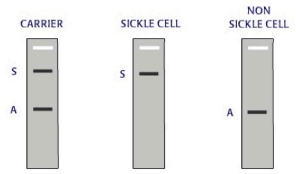
Ask students:

- What evidence is needed to find out if there is a difference in the hemoglobin causes sickle cell disease?
- What was done to diagnosis people with FH?
- How could we find out if people with sickle cell disease or sickle cell trait have differences in their hemoglobin protein?

Remind students that to diagnose differences in proteins for FH disease we used the process of electrophoresis. Ask students how electrophoresis gel might help identify a relationship between hemoglobin and sickle cell disease?



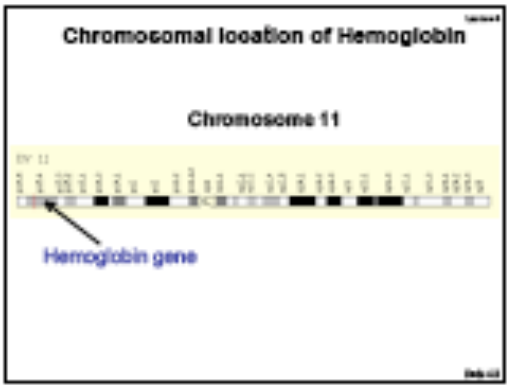
Electrophoresis of Sickling and Non Sickling Hemoglobin



Show **slides 7 and 8**. Ask students to observe the data from the electrophoresis gel. Ask students:

- What are differences and similarities in the hemoglobin for people with the disease, with the trait and people without sickle cell?
- How are proteins like hemoglobin formed?
- What could cause the same proteins to form differently?

Make sure student can identify that the sickling hemoglobin must be bigger because it is higher on the electrophoresis gel. Remind students to think back to the marshmallow models of DNA that they used to make the LDL receptor protein in Learning Set 3. A mutation in the LDL receptor gene changed the protein so that it no longer was able to work properly.

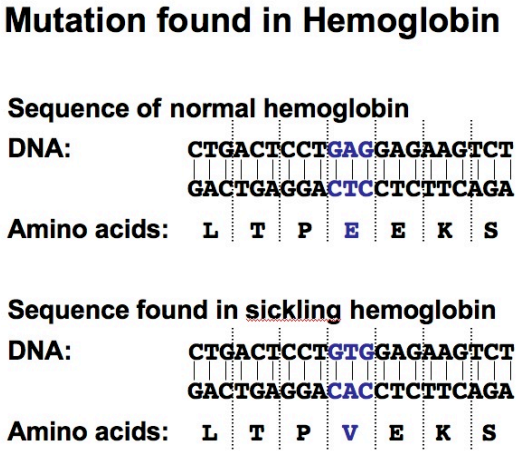


Slide 9 - Point out to students that if we are going to examine the hemoglobin gene, we need to know where it is. Point out the location of one of the hemoglobin genes on chromosome 11.
Divide students into groups
Post the following DNA sequence from the hemoglobin gene and have students determine the RNA sequence and amino acid sequence for this DNA sequence (like done in Learning Set 3).
Part of hemoglobin gene from healthy person

```
ATGGTGCACCTGACTCCTGAGGAGAAGTCTGCCGTTACTGCCCTG
||||||||||||||||||||||||||||||||||||||||||||||
TACCACGTGGACTGAGGACTCCTCTTCAGACGGCAATGACGGGAC
```

Answer:
mRNA sequence
AUG GUG CAC CUG ACU CCU GAG GAG AAG UCU GCC GUU ACU GCC CUG

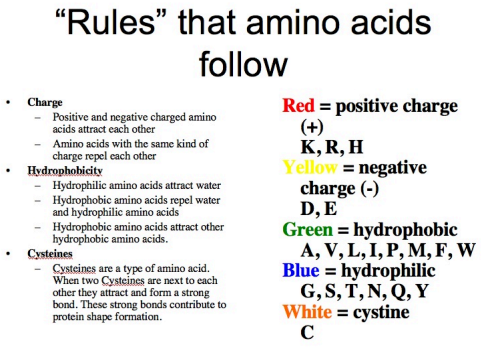
amino acid sequence
M V H L T P E E K S A V T A L
Full gene and protein sequences can be found in the appendix.



Show **slide 10 and 11**, which show a portion of the DNA. Give students a new genetic code with the sickle cell mutation

```
ATGGTGCACCTGACTCCTGTGGAGAAGTCTGCCGTTACTGCCCTG
||||||||||||||||||||||||||||||||||||||||||||
TACCACGTGGACTGAGGACACCTCTTCAGACGGCAATGACGGGAC
```

Ask students to predict how the mutation will affect to the protein structure and function.



Show **slide 12**. Divide each group of students in half. Remind students of the "rules" for building proteins. Have one group build the normal hemoglobin amino acid sequence and one build the sickling hemoglobin amino acid sequence with their Toobers. Have students draw their models and describe similarities and differences.
Discuss results as a class.

- Will the hemoglobin function properly in cells?
- Could there be an association between hemoglobin and Sickle Cell?
- What evidence do we have to support an association between hemoglobin and Sickle Cell?

Teacher Note:

The sickle-cell hemoglobin proteins can function somewhat, in the sense that they can still bind oxygen. They do display other abnormal behaviors and function as will be discussed below.

Day 2-Activity 4.2a Cont'd- Analyzing Hemoglobin

Reviewing discussion - How does the mutation in the hemoglobin gene affect red blood cells? Think-Pair-Share
Put this question on the board and ask students to first write their answer. Ask students to then share their answers with a partner and then with their entire group.

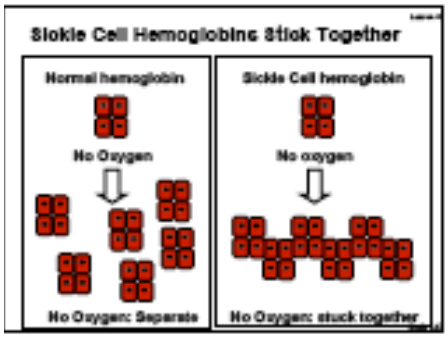
Discussion Rationale: In this discussion, students put ideas together and make connections between information learned. This discussion should help students understand how changes to the hemoglobin gene lead to change in the hemoglobin protein and how changes in the proteins lead to changes in the cells and changes in the blood cells lead to health problems.

Supporting Communication:

Public Documents: On the board, create a public document of what the students say, so that everyone can keep track of what has been said. You can ask a student to do this. This will encourage the students to listen to one another and use other responses to reflect on their own responses.
Reflective toss: Throw back the students response/question to the students, rather than evaluating. This will encourage them to think about what was just stated/asked. For example: Suzie, "How come DNA is passed to the offspring?" Teacher, "Why do YOU think DNA is passed to the offspring?"

Have students observe and compare their Toober models from the day before. Ask students what was the property of the amino acid before and after the swap on the model. Students should realize a charged amino acid was swapped for a hydrophobic amino acid.

Explain that this mutation causes a hydrophobic patch to form on the surface of the protein that normally is not there. Ask students, what might happen to a hydrophobic patch (note that there would be other hemoglobin protein neighboring it that would have a similar patch)



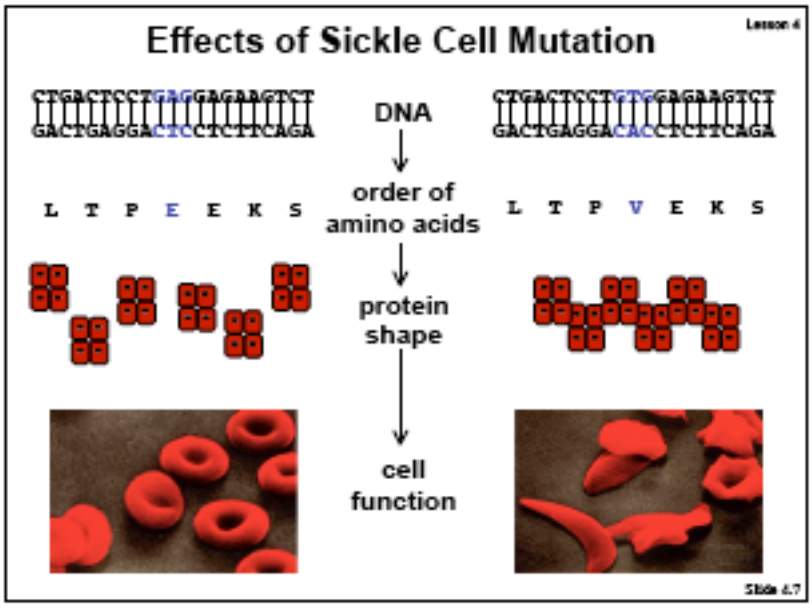
Slide 13 - Explain that scientists have explored this mutation and its affect on hemoglobin and have determined there is a problem. Hemoglobin forms long chains inside red blood cells. Then show cartoon images showing this.
Explain to students that the hydrophobic parts of proteins like to clump together (like hydrophobic amino acids). In this case the abnormal hydrophobic patch on the outside of the protein, can interact with other nearby sickle cell hemoglobins when no oxygen is present forming long crystals of hemoglobin inside of the red blood cells. In contrast normal hemoglobin proteins stay separated when no oxygen is present. The long chains in of sickle cell hemoglobin stretch the red blood cell so that it looks banana shaped.

Show students **slides 14**. Ask how the electrophoresis gel supports the idea that the hemoglobin in sickle cells forms long chains. *The hemoglobin in sickle cells is higher up on the gel plate meaning it is larger.*

Wrapping Up the Lesson

Revisit the Driving Question Board and ask:

How similar or different are people with and without sickle cell disease?



Show **slide 15** - Students struggle to make connections from genes to traits so use this slide to walk through the steps from gene to protein to trait. Have students complete chart in their reader in order to answer the question.

Lesson 3: How similar or different are parents from their offspring?

Purpose
The purpose of this section is for students to make connections between their understanding of classical genetics (homozygous, heterozygous, recessive, dominant, etc.) and what they have learned in this unit.

Connection
This lesson serves to reinforce the connection between genes, proteins, and health introduced in lesson 2 by explaining how traits move from generation to generation.

Description
Students will read about the work of Mendel in classical genetics. Students will use Punett squares to explain how sickle cell trait is passed from one generation to another generation.

Challenging ideas
If your students have not covered some of these classical genetics concepts yet, this section of the lesson might need more support.

Safety Guidelines
None applicable

Duration
1-2 Day

Learning Performance:
Students explain how mutations are passed from one generation to the next.

PREPARATION

Materials
Learning Set 4: Lesson 3:Slide 16
Student Reader pp:(140-142 Optional Activity) 143-147
Red and green pasta (optional activity)
3 cups per group (optional activity)

INSTRUCTIONAL SEQUENCE

Introducing the Lesson
Remind students of the article about the football player Dale Lloyd who had the sickle cell trait. Ask students:

- What do you think caused Dale's hemoglobin to react differently under extreme exercise than other football players?
- Do you think anyone else in his family might have similar problems with their hemoglobin? Why or Why not?

- What do you think it means when people say Dale had a genetic disease?

Problem solving discussion - What is a genetic disease?
Discussion Rationale: Students should realize that since genes are contained in DNA, that DNA is what is passed on from generation to generation—this therefore means that mutations can be passed on from one generation to another. In this discussion, students go beyond surface answers. They are making sense out of information.

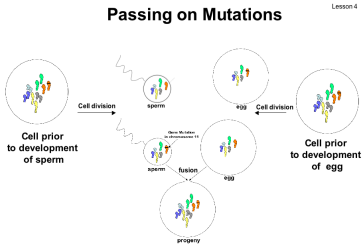
Here are some points/questions to guide you:
Through class discussion about the meaning of "genetic disease" introduce the idea that DNA is the material that is passed from one generation to another and in doing so can pass on mutations. Ask students:

- Have you ever heard of the word "genetic" or have you every heard a disease be called genetic. What do you think that means?

Focus on root of word "gene" in "genetic" and encourage students to consider what they have thus far learned about genes. Use class discussion to help student make connections between genetic diseases, genes and mutations.
Ask students:

- How many copies of each type of gene do you have?
- Where did you get your genes? Genes are passed from parents to children.
- If genes are passed on from parents to children does someone who has sickle cell disease have a parent with the mutation?

How are gene mutations passed from parent to child?



Show slide 16. Explain that genes in humans come in pairs of two because we have two of every chromosome. We get one chromosome from our mother and one chromosome from our father. If one parent has a mutation, like the sickle cell hemoglobin mutation, on one chromosome but not on the other (i.e. they are heterozygous for the mutation) there is a 50% chance (or 1 in 2 chance) that the mutation will be passed on from the parent to the child.

You can use the PowerPoint image provided to help explain this 50% chance of passing off mutations. The image shows a cell (either from a male or female) that undergoes cell division to produce several sperm or eggs. Explain that these sperm or eggs get half of the chromosomes and these are the only human cells that have only one of every chromosome. If one of those sperm or eggs gets a chromosome with a mutation on it, the embryo created (progeny) will get the mutation.

Activity 4.3a (Optional)
In addition (or alternatively) one can engage the class in a quick and easy demonstration the heritability of gene mutations. In this activity students will use colored spiral shaped pasta to

represent human chromosome 11 carrying the beta hemoglobin gene. This activity will allow students to collect data to determine the possible effect on offspring when a mutation is passed on from one generation to another.

- After discussing the slide give each group of students 3 cups and have them label them mother, father and embryo.
- Both parents are heterozygous and carriers of the sickle cell trait. Each the cup labeled mother and father should have 2 chromosomes represented by a red and a green pasta piece.
- The embryo cup should be empty until students start the simulation.
- Students should follow the directions in the activity to simulate the creation of embryos.
- Students should use the data they collected to answer the questions at the end of the activity.

Reading 4.3 - How Can Sickle Cell Disease Be Passed On?

Ask students:

- Do you have traits that they inherited from your parents?
- Why do you think you have some traits like your parents and some that are different?
- How do you think scientists began studying these types of questions?

Teacher Note
Error! Reference source not found.

Assign students to read "**How Can Sickle Cell Disease Be Passed On?-** Connecting the Punnett Square and Genetics" for homework or in class and answer questions in the appropriate part of the student reader.

Activity 4.3b

In this activity students will be using Punnett squares as a modeling tool to demonstrate how genes can be passed from parents to offspring. If your students have covered Mendelian genetics, push them to make connections between what they have already learned and the relationship between genes and proteins.

Guide
ring?

Teacher Tip: Explaining dominant and recessive genes:
This is also an opportunity to introduce the terms ìdominantî and ìrecessiveî mutation if teachers want to— but it is not necessary right now since introducing these terms goes beyond the scope of this unit. However, if a teacher would like to introduce these terms, ìdominantî in the context of this unit can be referred to as the condition in which only one of the two genes in an individual has to be mutated to express the trait or symptoms.î Recessiveî can be referred to as the condition in which both genes have be mutated to express the trait or symptoms. The exception to these rules is mutations on the X and Y chromosomes, since these genes do not always come in pairs of two (males are XY and females are XX).

One can also explain recessive alleles with an understanding that genes encode proteins. Since recessive mutations usually inactivate or disable a protein, they can be compensated for by the presence of a gene that does not have a mutation and which encodes an active protein (this is the heterozygous condition). In the homozygous condition, no functional proteins are around to compensate for the defective proteins because both genes contain mutations.

Unfortunately, dominant mutations are more difficult to explain in an intro level biology course because they require a more advanced understanding of biochemistry and protein function.

Introduce the Punett Square by reminding students of other modeling tools that have been used during the is unit (drawings, toobers, candy models, etc.) Tell students that the toobers were especially helpful models because they allowed us to make changes in the amino acids and then use the model to predict the affect it might have on the shape of the protein. Tell students that the Punett square is also a tool that can be used to make predictions.

- Have students look at the circles in Activity 4.3b and compare them to the diagram on slide 16. Ask students which circles represent the egg and sperm, parents, offspring?
- Complete the first empty circle as a class. Allow students to complete the rest of the circles in their small groups.
- Demonstrate the use of a Punnet Square by first completing one for the gene combination shown by the circles on the board.
- Allow students to complete the rest of the Punnett in their small groups.
- Through class discussion help students identify the fraction of the offspring that will have each genotype. Discuss student answers to questions at the end of the activity.

Wrapping Up the Lesson
Returning to the Driving Question- Ask students to look back at the driving question board. Ask the following questions:

- Have we answered any of our original questions?
- Are there new scientific principles that we need to add?

Ask students how similar or different they think the offspring in these two scenarios are. Ask students to give evidence for their answers.

Lesson 4: Are all mutations bad? Selective pressures on sickle cell trait

Purpose
Describe story of malaria resistance and sickle cell mutation to show how some mutations are actually beneficial, not always bad. This lesson will explore the effect of environmental pressures on gene variation in a population.

Connection
This lesson serves to reinforce the connection between genes, proteins, and health introduced in lesson 3 by explaining how traits can be influenced by the environment.

Description
Students will read about malaria resistance in Africa. Students will use beans to model the changes over time in the sickle cell trait within the population due to the pressure of sickle cell disease.

Challenging ideas
If your students have not covered concepts related to natural selection or evolution yet, this section of the lesson might need more support.

Safety Guidelines
None applicable

Duration
1 Day

Learning Performance:
Students explain how the frequency of organisms within a population carrying gene mutations can change from one generation to the next when influenced by environmental pressures such as malaria.

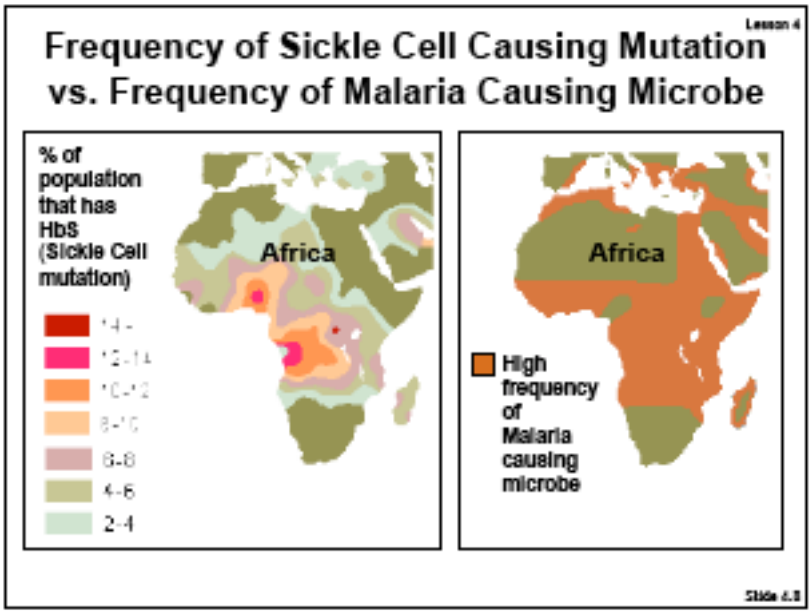
PREPARATION

Materials
Learning Set 4: Lesson 4:Slide 17
Student Reader pp: (148-150 Optional Activity)151-153
75 Red and 25 white beans per group (optional activity)
1 coin per group (optional activity)
5 cups per group (optional activity)

INSTRUCTIONAL SEQUENCE

Introducing the Lesson
Ask students if mutations can be beneficial? Ask them to think back to the diseases that they have already studied that were caused by mutations in the genes that code for proteins. Did any

of the mutations have a benefit for people? If students do not come up with any ideas ask about Lactose Intolerance. Tell students that in this lesson they will be trying to find out if other gene mutations like sickle cell could have advantages as well as disadvantages.



Slide 17 - Present maps of malaria and sickle cell to introduce an interesting finding. Present the interesting finding that malaria frequency and the frequency of the sickle cell mutation are correlated in geographic areas of the world. Have students identify overlap in areas. **Think, Pair, Share**: Ask students:

- Do you see an overlap?
- What do you think the relationship might be between malaria and sickle cell?

Explain that scientist have looked into this case and have found surprising results. Show video on malaria resistance. Click on link in **slide 17.** Ask students to summarize what they just saw in maps and video of sickle cell. Correct any misconceptions student might that might emerge from discussion. Ask student:

- How can a mutation be harmful in one environment and helpful in another?
- Why would a mutation persist if it kills people?
- Why are there more people with sickle cell anemia in one part of the world than in other parts?

Activity 4.4 (Optional)

In this activity students will simulate changes in a population when malaria is present. Red and white beans are used to represent the normal and mutant hemoglobin gene.

- Review the introduction for this activity in the student reader.
- Make sure that students understand that the coin toss tell whether the offspring is exposed to malaria. The chart tells whether they die from the malaria or are resistant.
- Model one or two rounds for the class to make sure that they understand the directions.

- Stress the importance of keeping accurate records in order to determine the effect on the population.
- Check student data between rounds to make sure they are on the right track.
- Collect class data when students have completed both rounds. Calculate % frequency of the normal and mutant hemoglobin gene.
- Through class discussion help students make connections between this simulation and information from the movie.

Reading 4.4: Are All Mutations Bad? The Case of the Sickle Cell Mutation
If students did not do activity 4.4 make sure that they have an understanding of why there might be a higher frequency of the sickle cell mutation in a country with malaria than in the United States where there are fewer cases of malaria. Ask students to make a prediction:

- What might happen over time to the frequency of the sickle cell mutation in Africa if malaria was eliminated?
- Ask students to use the article to find evidence for their claim.

Wrapping Up the Lesson
Returning to the Driving Question- Ask students to look back at the driving question board. Ask the following questions:

- Have we answered any of our original questions ?
- Are there new scientific principles that we need to add?

Students write a scientific explanation to answer the following question:

How do environmental conditions, such as "selective pressures" caused by malaria, affect how similar or different we are?

Lesson 5: How can people have different lactase protein? Exploring the biology of lactase intolerance

OVERVIEW

Purpose
Students will use their understanding of the relationship between genes and proteins to analyze a set of data about a family with some occurrence of lactose intolerance. Student will also have the opportunity to connect their molecular understanding of genetics to their classical understanding of genetics.

Connections
Students discussed in learning set 3 - lesson 4 how gene mutations affect protein production and function. Students will apply this information to help determine why Jason is lactose intolerant (learning set 2).

Description
Students further explore Jason's case of lactose intolerance and use gel electrophoresis to examine proteins, RNA and DNA. They investigate the question, "Why is the lactase gene there, but the lactase protein is not?"

Safety Guidelines
None applicable

Learning Performance
Students analyze multiple data sources to investigate the molecular cause of lactose intolerance.

PREPARATION

Materials
Slides Learning Set 4: Lesson 5: Slide 18-23
Student Reader pp: 154-159

INSTRUCTIONAL SEQUENCE

Tell students that today we are going to build on what they learned about yesterday, mutations. In the last lesson you looked at mutations in the DNA of different LDL receptor proteins. Today, we are going to investigate whether a mutation causes lactose intolerance, specifically whether or not a mutation in Jason's DNA is the cause of his lactose intolerance.

Introducing Activity 4.5
Ask students to recall Jason's story – Please Don't Pass the Milk (Learning Set 2). If necessary, allow students time to review the story. Then ask students to explain what is happening to Jason in the story. Make sure students discuss the following points:

- Jason does not have the ability to break down lactose.
- Jason's body is not producing the lactase protein.
- Jason's mom and sister are not lactose intolerant.

Ask students:

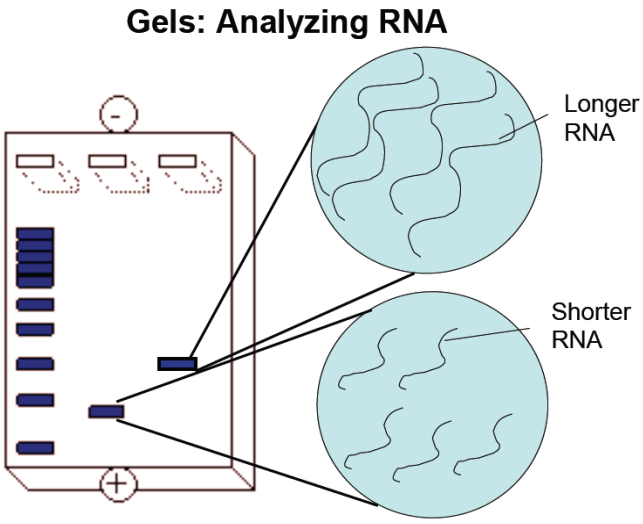
- Do you think Jason has the gene that codes for the lactase protein?
- If so, do you think Jason's gene maybe has a mutation?

Once students have had the chance to consider maybe Jason has a mutation, ask students how they think we should go about figuring out why Jason is lactose intolerant. If students are having a hard time coming up with ideas, ask if they think we should look at Jason's genes, his RNA, his proteins or maybe all of these. Hopefully, students will want to look at all of these things to try to figure out why Jason is lactose intolerant.

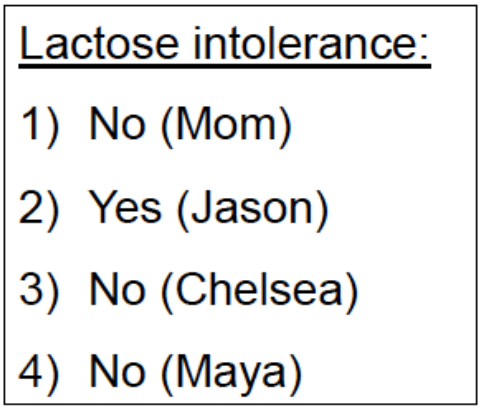
Once your students have determined that we should examine Jason's genes, RNA and proteins. Ask students if anyone can explain the process behind how scientists analyze proteins, since we know that we cannot see them under the most powerful microscopes. Below are main points the students should touch on:

- using gel electrophoresis
- gel electrophoresis tells us the size of the protein (because smaller proteins move farther down the gel column than larger proteins
- gel electrophoresis tells us relatively how many molecules of protein we have (the darker the line on the gel column the more proteins are present)

Tell students that scientists can analyze RNA using gel electrophoresis also. Slide 18 shows that we can look at RNA on a gel in the same way that we can look at a proteins, because RNA separates by size in the same way that proteins separate by size.



Activity 4.5
Tell students that we are going to use what they already know about genes, proteins and gel electrophoresis to try to figure out why Jason is lactose intolerant. The first data we have is information about Jason's family – his mom and his two sisters, Chelsea and Maya. Slide 19 tells students which individuals in Jason's family have lactose intolerance. Tell students to fill in this information in the first column of their data table on activity sheet 5.1.



Have students write a prediction for the below questions found on the back of activity sheet 5.1.

- Why do you think Jason might be lactose intolerant?
- Why does the rest of his family not have lactose intolerance?

Students might respond:

- Jason has a mutated protein
- There is a problem with how Jason's RNA is made
- Jason's DNA has a mutation

- Jason's RNA is not coding for the correct amino acids

Once students are finished with their hypotheses, show slide 20 – Results: DNA sequence analysis of lactase gene (shown below).

Results: DNA sequence analysis of lactase gene:

Mom:	no mutations in lactase genes
Jason:	no mutations in lactase genes
Chelsea:	no mutations in lactase genes
Maya:	no mutations in lactase genes

Have students fill this data into their data table and answer question #1, and then ask: Since all 4 family members have the same DNA sequence, would their RNA be the same? Would their proteins be the same? This reminds the students that just a mutation in the gene is not enough evidence. They will need to look at more data to come to a conclusion.

Tell students that since we need more evidence, we are going to investigate these questions using gel electrophoresis of Jason's family's lactase protein and gel electrophoresis of Jason's family's RNA.

Before dividing students up, tell students: You are going to analyze data and draw conclusions about Jason and his family based on this data. Using the data on activity sheet 5.1, you will fill in the data table and the questions your group is assigned (both around found on Activity Sheet 5.1).

Divide students up into 6 groups. Two groups will each be assigned the same piece of evidence off of Activity Sheet 5.1 to become experts on (each group is still expect to do all of the questions on Activity Sheet 5.1 before meeting with their corresponding group). For example groups 1 and 2 will be assigned the Gel Electrophoresis: Lactase Protein Samples from Jason's Family piece of evidence and questions 2 - 4, groups 3 and 4 will be assigned the RNA Analysis of Lactase Protein Gene piece of evidence and questions 5 - 8, groups 5 and 6 will be assigned the DNA Sequence of the Area Near the Lactase Gene piece of evidence and questions 9 – 10.

Below are slides of the different data sets the student groups will be analyzing. There are questions below each slide that may help you facilitate discuss about each data set.

Lactose intolerance:

1) No (Mom)
2) Yes (Jason)
3) No (Chelsea)
4) No (Maya)

Why does Jason have no protein?
Why Mom and Chelsea have less protein?

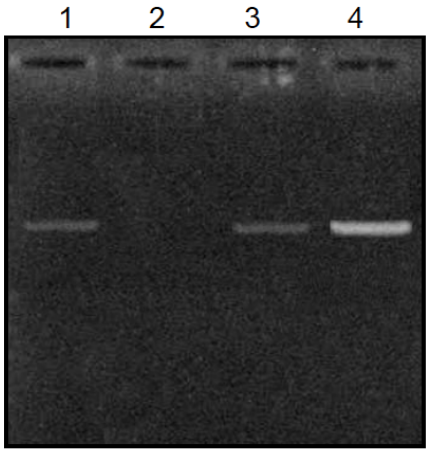
Slide 21– The gel on this slide shows how much lactase protein each of these people have. These results are similar to the RNA results.

While students are analyzing this information, make sure they consider:

- Does Jason have any lactase?
- Without lactase could he break down lactose?
- Do Mom and Chelsea have the lactase protein?
- Is this the amount of lactase protein you would expect based on the amount of RNA they have?
- How much lactase protein does a person need to be able to digest lactose?
- What is not happening in Jason's cells (Transcription? Translation?)?

Do they think that Jason's cells are still making other proteins? (Is he still able to digest other foods?)

Results: RNA analysis of lactase gene



Lactose intolerance:

1) No (Mom)
2) Yes (Jason)
3) No (Chelsea)
4) No (Maya)

Above is slide 22 – RNA Analysis - This slide shows that Jason does not have RNA for the lactase protein. Mom and Chelsea have less RNA for the lactase protein. Maya has the most RNA for the lactase protein. All of the Ranks are the same size (since all 3 present RNAs moved down the gel column the same distance), which indicates that there are no mutations in the genes.

While students are analyzing this information, make sure they consider:

- Does Jason have any lactase RNA?
- Without RNA could he make lactase?
- Do Mom and Chelsea have RNA?
- How much RNA do you think someone needs to make enough protein to digest lactose?
- Is transcription or translation happening in Jason's cells?
- Do you think Jason's cells are still making other proteins? (Is he still able to digest other foods?)

Hopefully, students conclude that Jason is not making RNA. Mom and Chelsea are making some RNA, which is enough to be able to digest lactose in their diets. Since Jason is likely to be otherwise healthy, we can assume that all other proteins are being made normally and that there is not a general problem with transcription and translation.

Explain to the students that their group is analyzing the 3rd piece of evidence. Since we discovered earlier that there is not a mutation of the DNA segment that codes for lactase, we're going to look at the DNA around the lactase gene to see if that tells us anything.

Show students slide 23 – Examining DNA Sequence. Tell them they will also find this data on activity sheet 5.1.

Mom:	ATTTGC |||||| TAAACG ATCTGC |||||| TAGACG	**Jason:**	ATCTGC |||||| TAGACG ATCTGC |||||| TAGACG
Chelsea:	ATCTGC |||||| TAGACG ATTTGC |||||| TAAACG	**Maya:**	ATTTGC |||||| TAAACG ATTTGC |||||| TAAACG

While students are analyzing this information, make sure they consider:

- Do you notice any differences in the sequence of these short segments of DNA?
- What are the differences?
    - (For Area 3 – Maya has 2 T-A, Mom and Chelsea only have 1 T-A and Jason doesn't have any. Is this the difference that causes lactose intolerance? Does this mean Mom and Chelsea could become lactose intolerant?
    - There are no other differences
- Do you think these differences have anything to do with Jason's condition (lactose intolerance)?
- Make sure students notice that there are two different sequences for each person. Ask students why this is? Students should recall from their biology class that they have two copies of all their DNA, one copy from their father and one from their mother.

Once students are finished analyzing their data and answering their questions, they will meet with their corresponding group, to compare responses to the questions they were assigned, ask any questions and make any changes necessary before sharing with the whole class. Once groups are done meeting, each group will share their responses to the questions they became experts on. While groups are presenting data, the other groups should be comparing their responses to the same questions and asking the "expert groups" questions.

Once all groups have shared, they should return to their original groups to fill in their entire data table first, **EXCEPT the last column**.

	Lactose Intolerance (Yes or No)	**DNA Mutation (Yes or No) If yes, what is the mutation?**	**Protein Present (Yes or No)**	**RNA (Yes or No)**	**The DNA Sequence Found Near the Lactase Protein Gene – If there is a difference, what is it?**	**Genes On or Off?**
Jason	Yes	No	No	No	Has zero T-A in 3rd area - has 2 C-G instead	
Mom	No	No	Yes, but less than Maya	Yes, but less than Maya	Has 1 T-A in 3rd area and 1 C-G instead	
Chelsea	No	No	Yes, but less than Maya	Yes, but less than Maya	Has 1 T-A in 3rd area and 1 C-G instead	
Maya	No	No	Yes	Yes	Has 2 T-A in 3rd area and zero C-G instead	

Wrapping Up Activity 4.1
Ask the students to examine their data table for patterns. Do they recognize a pattern between the DNA sequences and whether or not a person is lactose intolerant?

Ask students if they think there is a relationship between the sequence of the DNA near the lactase gene and whether or not RNA is made from the lactase gene?

- Students should notice that Jason has a C-G in both of this DNA strands and has lactose intolerance.
- Students should also see that Maya produces the most lactase and has a T-A in both of her DNA strands.
- Push students to think about Mom and Chelsea.
    - They both have 1 C-G and 1 T-A, and they both produce less lactase than Maya but more than Jason.
    - What could this mean?

Once students have had a chance to discuss, they should return to activity sheet 5.1 to write a scientific explanation on why Jason has lactose intolerance. Student may only be able to write

the claim and evidence at this point. (They will return to this explanation shortly with reasoning.)

Ask students to share why they think Jason has lactose intolerance while no one else in his family does.

- Students should make the connection between the T-A and C-G in the DNA sequence near the lactase gene. Stating that T-A must help the gene make lactase while C-G must inhibit the gene from producing lactase.

Make sure students share their evidence with you:

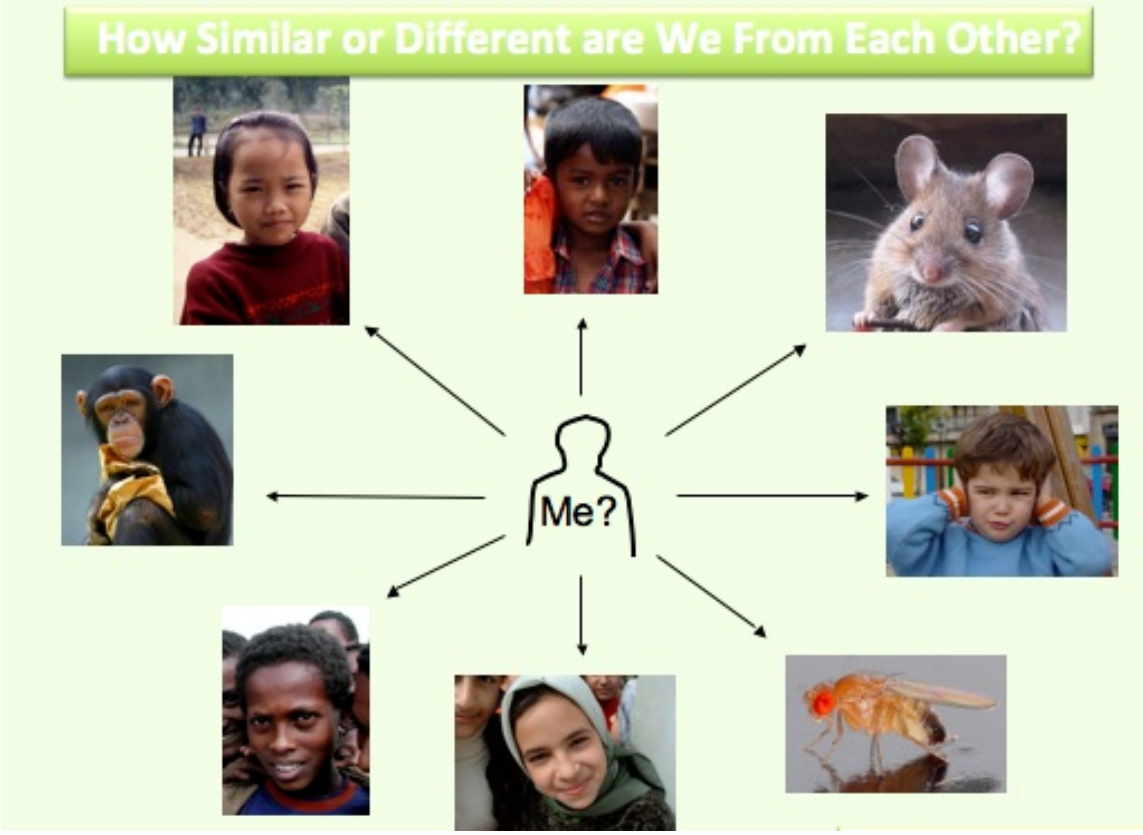
- No mutation in the lactase gene
- Chelsea and Mom make less lactase and less lactase RNA
- Chelsea and Mom have 1 T-A and 1 C-G
- Maya makes the most lactase and lactase RNA
- May has 2 T-A
- Jason makes no lactase and no lactase RNA
- Jason has zero T-A and 2 C-G

Explain that the T-A or the C-G is part of the "switch" that determines if the lactase gene is on or not. For genes with the T-A nearby, intestine cells are always making lactase. For genes with a C-G nearby, the switch gets turned off.

- Ask the students if they think that Jason ever made lactase?
  - Explain that almost all humans digest milk early in their life. For many people all over the world their genes turn off at some point and they can no longer digest lactose. Scientist have figured out that people with a lactase gene with the C-G near are more likely to turn off the gene than people with genes that have an A-T near.
- Ask the students why they think the genes might turn off? Would it be helpful to know which people have the "off" switch?
  - Scientists don't yet know the answer to why they turn off. But, if we knew how they became turned off, perhaps we could keep them from turning off and people could drink more milk.

After discussing the "switch", have student fill in the final column in their data table and allow students to return to their scientific explanation if they want to make any changes.

Learning Set 5
Are We More SIMILAR or DIFFERENT?



Learning Set 5: Are We More SIMILAR or DIDDERENT?

Content Standard	Inquiry Standard	LS5 Learning Performance
Constituents of a genome - A genome consists of all of the DNA found inside a single cell or virus. The genome contains all the genes required to build, maintain and propagate the cell, or a multicellular organism. For humans the genome includes all the DNA within both 23 pairs of chromosomes within the nucleus and the DNA in the mitochondria. The human genome consists of about 3 billion base pairs and is estimated to have 25,000 genes. Most of the genome is noncoding DNA, while only a small fraction is protein coding. The non-coding DNA includes some small parts that are highly variable DNA, which can be used to identify people. The genomes of any two humans are highly similar (99.9% identical to be exact). (Written by Aaron Rogat with the help of genomic experts)	Identify questions and concepts that guide scientific investigations . (NRC, 1996, A:1A/9-12)	Students compare genome sections of two different humans, and a human and a chimpanzee, and determine how similar we all are to each other.
	Formulate and revise scientific explanations and models using logic and evidence. (NRC, 1996, A:1D/ 9-12.).	Students create concept maps to visually represent a specific phenomena (skin color, lactose intolerance, FH, or sickle cell) over time.
Heritable material - The information passed from parents to offspring is coded in DNA molecules. (AAAS, pg. 108, 58:9-12#3)		Students explain the gene-environment interaction for a specific phenomenon.

Learning Set 5: Are We More Similar or Different?

Overview

Purpose
The purpose of this unit is to help students understand what a genome is and how similar any two people are to each other on the genetic level.

Description
Lesson 1
- Students review science content presented previously in the unit. They examine an ethical dilemma. Students explore what chromosomes are in, what is in chromosomes, and how many we have in order to understand what the genome is.

Lesson 2
- In this lesson students first spend time exploring the previously learned phenomena (skin color, lactose intolerance, FH, and sickle cell) and discussing the gene-environment interaction. They then create concept maps as they review one of the phenomena to prepare them for their final product.

Learning Goals
The learning goals addressed in this Learning Set are darkened.

National Standards
- Heritable material - The information passed from parents to offspring is coded in DNA molecules. (AAAS, pg. 108, 58:9-12#3)

Michigan Standards
- B2.4A Explain that living things can be classified based on structural, embryological, and molecular (relatedness of DNA sequence) evidence.
- B2.4d Analyze the relationships among organisms based on their shared physical, biochemical, genetic, and cellular characteristics and functional processes.
- B4.1 Genetics and Inherited Traits - Hereditary information is contained in genes, located in the chromosomes of each cell. Cells contain many thousands of different genes. One or many genes can determine an inherited trait of an individual, and a single gene can influence more than one trait. Before a cell divides, this genetic information must be copied and apportioned evenly into the daughter cells.
- B4.2B Recognize that every species has its own characteristic DNA sequence.
  - B4.4x Genetic Variation - Genetic variation is essential to biodiversity and the stability of a population. Genetic variation is ensured by the formation of gametes and their combination to form a zygote. Opportunities for genetic variation also occur during cell division when chromosomes exchange genetic material causing

permanent changes in the DNA sequences of the chromosomes. Random mutations in DNA structure caused by the environment are another source of genetic

Prior Knowledge

- Students should be familiar with the nucleus of a cell and the mitochondria and chloroplasts and the function of these organelles. They should know mitochondria are found in both plants and animals, but not bacteria. In addition students should know chloroplasts are not found in animal cells and typically are in plant cells.

Student Conceptual Challenges

- Some students think that DNA is everywhere in the cells of animals like the cytoplasm (not just in the nucleus).
- Students frequently confuse chromosomes and genes. Some misidentify genes as chromosomes

Time
2 days

Lesson 1: How similar or different are our genomes?

OVERVIEW

Purpose
In this lesson, students learn what makes up the genome, understand how big the human genome is, and understand what some general characteristics of the genome are (very little of it is actually protein coding DNA, regions in between DNA are the variable regions which do not code for DNA).

Connections
Students have spent the entire unit progressing from the macro level to the molecular level to answer the question of how similar or different we are. They have already learned about cells, DNA, genes, and the connection to proteins and our traits. This lesson helps students combine this knowledge while they learn about the human genome and again see just how similar we all are. It provides a good review of the science content. The lesson that follows provides a review of the phenomena covered in the unit.

Description
Students review science content presented previously in the unit. They examine an ethical dilemma. Students explore what chromosomes are in, what is in chromosomes, and how many we have in order to understand what the genome is.

Safety Guidelines
None applicable

Learning Performance
Students compare genome sections of two different humans, and a human and a chimpanzee, and

determine just how similar we all are to each other.

Time
1 day

PREPARATION

Materials
Student Readers
Slides 1-4
Genome section copies (1 of each for each group)
Calculators if necessary
Computer & projector (optional)

INSTRUCTIONAL SEQUENCE

Introducing Activity 5.1a: Introduction to the Human Genome Project
Ask students to think back to LS2 when they first learned about ethical dilemmas to help them prepare for their DNA Night projects. *Ask: What is an ethical dilemma? What are some examples of ethical dilemmas that we have learned about?* Review student answers and ideas about ethical dilemmas. Spend a little time on some of the ethical dilemmas the students themselves come up with. Ask them to elaborate: *Why is that considered an ethical dilemma?*

Tell them they will read a brief scenario that presents an ethical dilemma and ask their opinion on that dilemma.

Carrying Out Activity 5.1a:
Have students read "Priya Should Find Out If She Inherited a Fatal Disease (or should she?)" and answer the questions that follow in the Student Reader on page 162-163. They should do this individually. Once students have had time to do this, briefly discuss as a class students' responses to the first follow-up questions: *Would you choose to get tested? Would you want to find out if you had the disease or not? Why?* Allow all students who want to share their ideas to speak.

Help students make connections with previously learned material:
This lesson incorporates a lot of content that students have previously learned. As you go through the lesson, try to get students to make connections between the current material and previous material. Encourage students to find the answers to the questions you ask by looking back to the work they have done in their readers (these places have been indicated throughout the lesson to help you).

For example, as you review the Priya reading follow-up question 2 with students, discuss what students have previously learned about how our DNA contains codes, or sets of instructions, (called genes) for the proteins that do very important things in our bodies, such as give us specific traits (LS3, Lesson 2-3). We learned that there was a protein that dictated how dark our

skin would be (tyrosinase) (LS2, Lesson 3). There was a protein that dictated whether we would be lactose tolerant, or intolerant (lactase), etc. (LS2, Lesson 4).

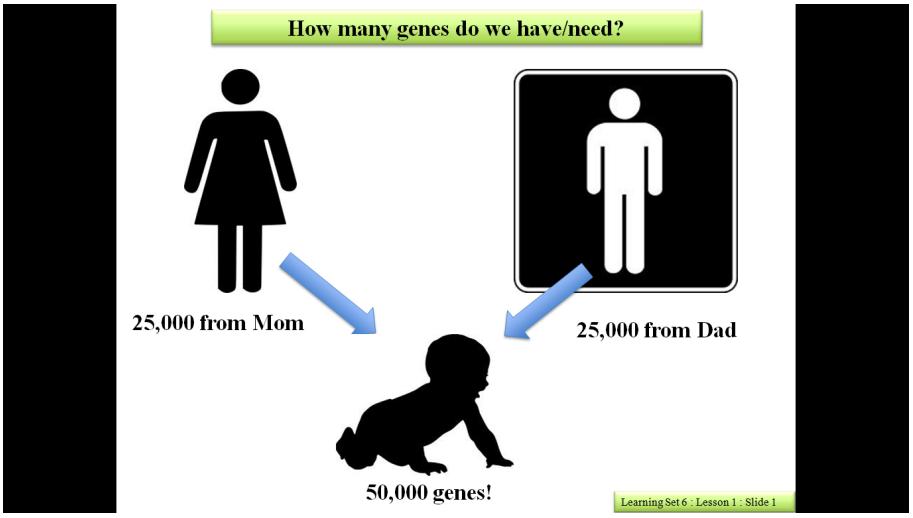
Teacher Note: Genes & Diseases

Students may or may not still think at this point that having the gene for a disease means you will get the disease. This may be an argument a student proposes when discussing follow-up question 1. Remind students that we also learned that just because someone has the gene for a specific protein in their DNA, it does not mean that the person will have the specific trait or disease—there are other factors involved with whether or not the gene will be expressed. We saw in LS5, Lesson 1, when we looked at Jason's family, the gene for the lactase protein was turned on or off to varying degrees and therefore his family had varying degrees of lactose intolerance. Similarly, we saw in LS4 that someone with the gene for sickle cell did not necessarily have sickle cell disease, rather they may experience some symptoms during certain types of weather. Point out that gene expression depends upon a number of factors including both genetic and environmental, so a test like what Priya would take to detect the Huntington's trait does not necessarily mean she will get the disease. Ask the students if fact this changes their opinion about whether they would get the test if they were Priya? And why or why not?

Promote discussion about proteins & genes:
Ask students: What do our genes do? (Why would Priya need to find out if she had the Huntington's gene?) Genes code for proteins, which determine what traits we will have. Priya would want to know if she had the Huntington's gene, which would code for either a functioning or defective gene that could tell her whether or not she was likely to get Huntington's.

Ask: Why are proteins important to us? (Because they do many different activities in our cells, see LS2, Lesson 1 for more details).

Ask: How many different genes do you think you need to make all the proteins you need to keep your body running? (It is unlikely students will know this answer. Take all student guesses.)



Show Slide 1. Inform students that we have about 25,000 genes on a single set (one set from one parent, so 23 chromosomes) of chromosomes. There are about 50,000 genes total in each cell

(from both parents, all 46 chromosomes). That is more genes than there are seats at Comerica Field, or most other Major League Baseball parks. That is a lot of genes, but maybe not too many when you think of how complex humans are.

Ask: If scientists want to understand more about humans (which they do), how many of all those genes do you think they need to study? Get students to realize that it is important for scientists to study all of the genes in our DNA. Studying all of the genes in our DNA and figuring out what they do (what proteins they code for) in our bodies, will help us better understand the human race, especially genetic diseases past and present.

Ask: In the case of Priya, how do you think scientists know where to find the right gene that will tell Priya whether or not she is likely to get Huntington's? What would they have to know about our DNA and our genes? Accept all reasonable responses from students. Guide students' thinking so that they suggest that scientists would need to know where all the genes are located in our DNA sequence. In other words, they would need a "map" of our genes, so they would know where to look if they needed to find a specific gene.

Explain to the students that scientists have been working on creating this "map" of our genes, and the genes of other organisms. All of the genes are organized into what is known as a **genome**. If scientists want to study our genes, they need to know how they are organized (in other words, they need to know the human genome).

Have students read about the Human Genome Project in their Reader (or watch the video, see below). They should answer the questions independently, then review in small groups and as a class. The key ideas that students should take away about the Human Genome Project are:

- The genome is a complete set of our genes (a "book of instructions").
- The Human Genome Project aims to map out all of our genes.
- It is important for a number of reasons (previously discussed with students) for scientists to have a "map" of all of our genes.

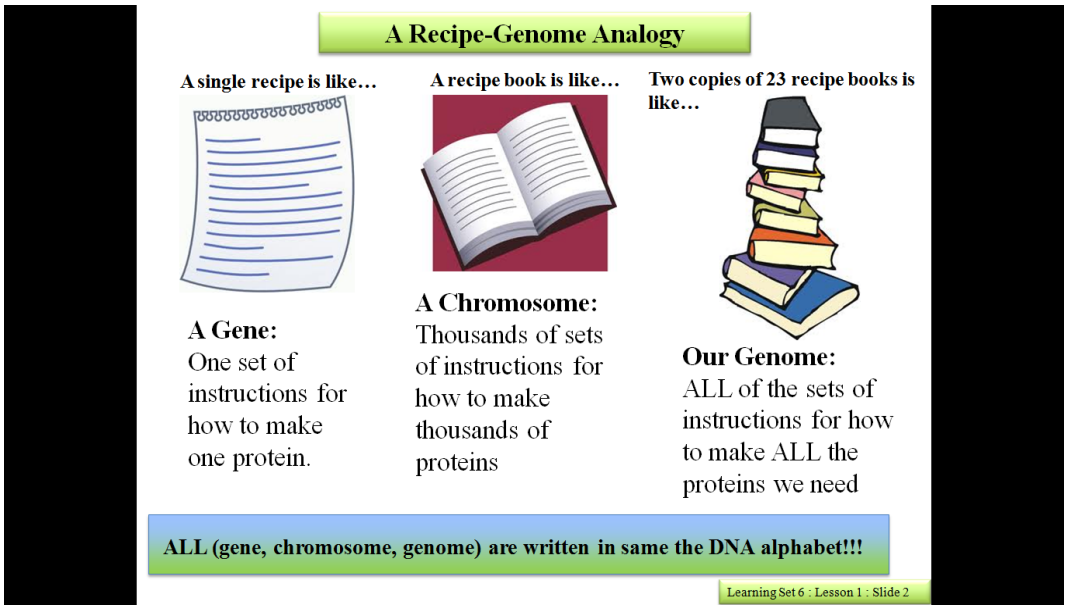
Teacher Note: Genome Project Video

If you access to the internet, and computer, and projector you can have students watch an excerpt (about the first 15 minutes or so) from the NOVA video "Cracking the Code of Life" here: http://www.pbs.org/wgbh/nova/body/cracking-the-code-of-life.html instead of reading about the human genome project. Students should still answer the questions about the project and discuss.

A Recipe-Genome Analogy:

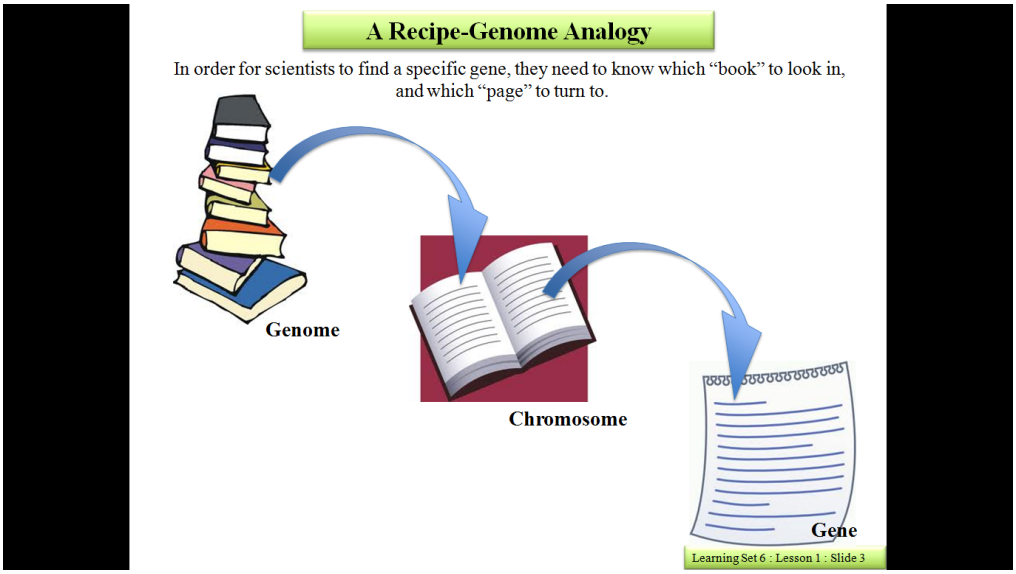
As you review the reading and/or video with students you should discuss the recipe-genome analogy. Explain to students that if we looked at all the DNA in any one cell of our body we would find all the genes (or instructions) for making all the proteins in all the cells of our bodies. All DNA that is contained within one cell has all the information necessary to make a human being. In other words: all the DNA found in a cell contains the blueprint to make a human being.

As you discussed with students earlier, all DNA is organized in a special way: Our **genome**. Show students Slide 2.



Explain the Recipe-Genome analogy: A recipe written on a single sheet of paper is like a gene. A single recipe contains instructions for making a single food dish. This is like a gene which contains instructions for making a single protein. If we took those recipes or sets of directions and started binding a bunch of them together, we would have a recipe book. Similarly, if we took all of the genes and bunched them together we would have a chromosome. We need the directions in two copies of 23 different books (two copies of 23 different chromosomes) to make a human. This is how our genes are organized at the most basic level.

Remind students that in order to be able to find specific genes. We need to know what book to look in (which chromosome) and what page (which gene). Show Slide 3.



Concluding Activity 5.1a:

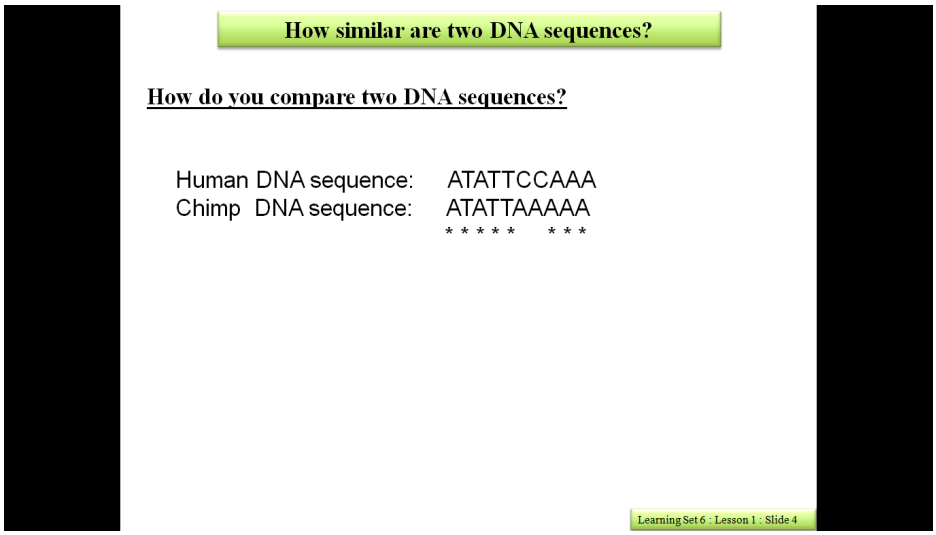
Because scientists need to know what "page" of what "book" to look in, it's important for scientists to have all the "books!!!"

Before moving on to the next activity have students answer the following check-in question in their Readers: *How would knowing the human genome help answer the driving question?*

Activity 5.1b:
Introducing Activity 5.1b: Genome Comparison
Return to the driving question "How similar or different are we from each other?" and *ask students: Given what you know about the genome, what must you do to understand how similar two people are at the genetic level or how similar two organisms are?* Students should realize the need to compare entire genomes. (A continuation of the conclusion to Activity 5.1a).

Carrying Out Activity 5.1b:
Tell students that in this activity we are going to finally get down to the answer to our driving question and figure out just how similar or different we all are from each other. We will be looking at pieces of human genomes and chimpanzee genomes to determine how similar two humans are to each other, as well as how similar a human is to a chimp.

Ask students: *How would you go about determining how similar two peoples' DNA sequences are?* (Students should suggest that you would have to compare the DNA bases side by side to see if there are differences in the bases.)



Show Slide 4. Explain to students how to compare DNA sequences using the example shown in the slide. Point out that this is an extremely small segment of the entire genome for a human and a chimp. Hold up a piece of the genome they will be using in the activity so they can see just how many bases they'll be going through (and this, too, is just a small part of the genome as well!!!) Show them the asterisks underneath, and explain that when the asterisk is present, the bases are the same, when it's absent, the bases are different.

Explain that we could try to align the entire genomic sequence of two individuals or two different species to find how similar they are at the DNA level, but this is a lot of data (3 billion base pairs for the human genome) and requires several computers. You can certainly go base by base and check each one to see where the differences lie, but this would take a huge amount of time. Today we've got an easier way to help us spot differences in DNA bases. First of all, we will only be looking at a small portion of the genomes. Second, we have got printouts with the asterisks underneath (just like we saw in the slide)—remember, they are present when the bases are the same, and absent when they are different. This makes it easier to spot the differences.

Before beginning the activity, have students complete predictions in their student reader about how similar two humans' genomes will be and how similar human and chimpanzee genome will be. Their claim should be in the form of a percentage. Based on what you just went over with them about how they will be comparing genomes (side by side), guide them to see that their evidence will be something having to do with how many bases are similar or different. Their reasoning should come from what they have previously learned about DNA. Samples have been completed in the Annotated Student Reader for you.

Break students up into groups and give each group the DNA sequences comparing two humans. The directions for how to calculate the % of identical bases are written in their Student Readers, but help them as needed to understand the following points:

- They were handed out 10 pages worth of the genomes, but this is still such a small portion of the actual genome (3 billion bases for humans!)
- We are not looking at both strands of DNA, we are just looking at one strand and we are comparing it to the same strand of another person. There are 60 bases on each line for each human/chimp. When students need to total the number of bases on an entire page, help them remember to total the number of bases for each individual on the page, NOT for both individuals on the page. The base totals for each page are provided below.
- Remind groups to divide the task by giving each student in the group a few pages to work on. They can then all combine their numbers to get the total number of identical bases.
- Assist students with calculations as needed.
- The numbers on the right indicate what pair of bases the last letter on the line is.
- Some of this sequence is a gene, some of it is not. Cells would be able to tell the difference, but human eyes cannot.

Two Humans:

Page beginning with base #…	Base differences on page	Total bases on page	Total identical bases per page
1670/1737	1	900	899
2570/2637	1	840	839
3410/3477	5	900	895
4310/4377	3	840	837
5150/5217	4	900	896
6050/6117	1	780	779
6890/6957	2	900	898
7790/7857	4	780	776
8570/8637	4	960	956

9530/9597	3	780	777

Total bases on all pages: 8580
Total identical bases on all pages: 8552
% identical bases: 99.67%

Once they have completed comparing two human genomes collect all the sequences (so students do not get confused) and pass out the human and chimp DNA sequences. Have them repeat the process.

Teacher Note: Timing

This lesson is meant to be completed in a single class period. If you do not have enough time to have all groups complete the comparison for two humans and human and chimp, have half the class compare humans, and the other half compare the human and chimp DNA sequences. Then have all the groups share their findings with each other.

Human & Chimp:

Page beginning with base #…	Base differences on page	Total bases on page	Total identical bases per page
3479/2897	82	840	758
4319/3737	76	900	824
5219/4637	62	900	838
6119/5536	69	780	711
6959/6376	73	900	827
7859/7276	74	780	706
8638/8056	88	960	872
9598/9016	73	780	707
10378/9796	77	960	883
11338/10756	72	780	708

Total bases on all pages: 8580
Total identical bases on all pages: 7834
% identical bases: 91.31% (NOTE: this percentage is lower than the actual percent similarity between humans and chimps, which is closer to 95%. This could be due to the fact that we are not looking at the entire genomes.)

Concluding Activity 6.1b:
Have students answer the follow-up questions, then guide a discussion of their answers.

As the discussion takes place, remind students of the following:

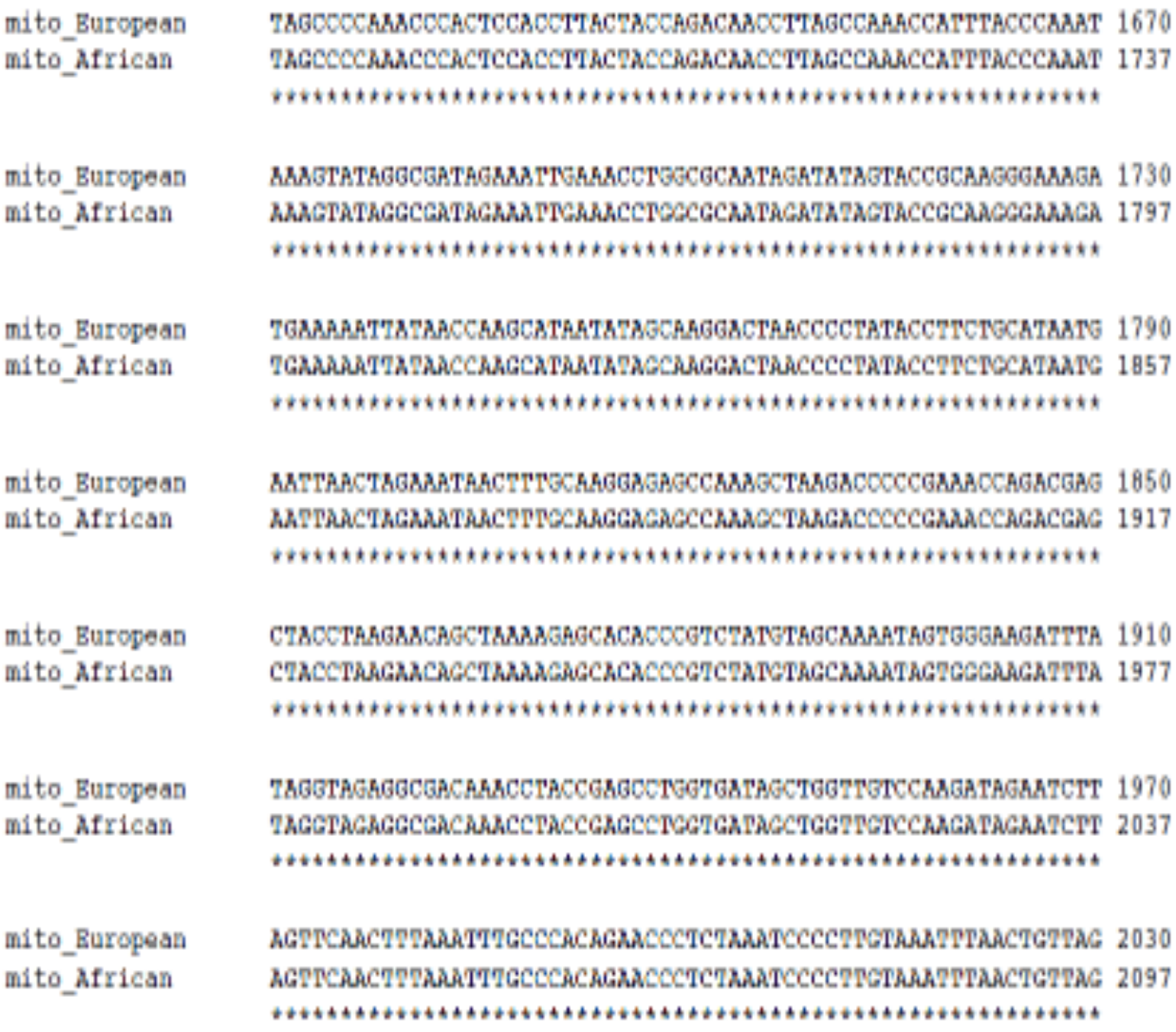
- The DNA sequences we looked at thin this activity is just one part of the entire genome (and a small one at that)
- Thus, we have to look at our entire genome to understand just how similar or different we are.
- Scientists are doing this now. They have determined, and are currently determining, the DNA sequence of the entire genome of many organisms—from mice, human, dogs and

pigs, to flies, worms, mold, corn, and soybeans (note, this is just a small list of all the organisms whose genomes have been sequenced and the list grows every day).

- The students compare small pieces of DNA sequences of humans and a chimp. Scientists, on the other hand, have compared the whole genomes of humans and a number of different organisms and here is what they have found:
    - The genome of any two humans are in the world are 99.9% identical. This includes both genes and non-gene regions. Explain that even though a 0.1% difference is a small number it translates into 3 million base pair differences because the human genome is 3 billion base pairs; therefore, we can still find unique differences between people.
    - The chimpanzee and a human genomes are 95% identical. This includes both gene and non-gene regions, but this is still 40 million base pair differences. However, if just look at the protein coding regions of DNA, we find they are 99% identical.
    - On average the mouse and human gene coding regions are 85% identical. Some genes are as low as 60% but some are as high as 99%; there is much less similarity in non-gene regions.
    - Some gene regions in flies are as much as 90% identical to those in humans. However, the overall genomes of flies and humans are much less similar than mice and humans.

Concluding Lesson 5.1

Ask students to consider the genome project findings in light of the driving question. Ask students how this lesson about the human genome changes their thinking about how similar we are biologically? Students write a scientific explanation about this in their Readers.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mito_African TAGCCCCAAACCCACTCCACCTTACTACCAGACAACCTTAGCCAAACCATTTACCCAAAT 1737
mito_European AAAGTATAGGCGATAGAAATTGAAACCTGGCGCAATAGATATAGTACCGCAAGGGAAAGA 1730
mito_African AAAGTATAGGCGATAGAAATTGAAACCTGGCGCAATAGATATAGTACCGCAAGGGAAAGA 1797
mito_European TGAAAAATTATAACCAAGCATAATATAGCAAGGACTAACCCCTATACCTTCTGCATAATG 1790
mito_African TGAAAAATTATAACCAAGCATAATATAGCAAGGACTAACCCCTATACCTTCTGCATAATG 1857
mito_European AATTAACTAGAAATAACTTTGCAAGGAGAGCCAAAGCTAAGACCCCCGAAACCAGACGAG 1850
mito_African AATTAACTAGAAATAACTTTGCAAGGAGAGCCAAAGCTAAGACCCCCGAAACCAGACGAG 1917
mito_European CTACCTAAGAACAGCTAAAAGAGCACACCCGTCTATGTAGCAAAATAGTGGGAAGATTTA 1910
mito_African CTACCTAAGAACAGCTAAAAGAGCACACCCGTCTATGTAGCAAAATAGTGGGAAGATTTA 1977
mito_European TAGGTAGAGGCGACAAACCTACCGAGCCTGGTGATAGCTGGTTGTCCAAGATAGAATCTT 1970
mito_African TAGGTAGAGGCGACAAACCTACCGAGCCTGGTGATAGCTGGTTGTCCAAGATAGAATCTT 2037
mito_European AGTTCAACTTTAAATTTGCCCACAGAACCCTCTAAATCCCCTTGTAAATTTAACTGTTAG 2030
mito_African AGTTCAACTTTAAATTTGCCCACAGAACCCTCTAAATCCCCTTGTAAATTTAACTGTTAG 2097


mito_European CTAACCGTGCAAAGGTAGCATAATCACTTGTTCCTTAAATAGGGACCTGTATGAATGGCT 2570
mito_African CTAACCGTGCAAAGGTAGCATAATCACTTGTTCCTTAAATAGGGACCTGTATGAATGGCT 2637
mito_European CCACCACGCTTCAGCTGTCTCTTACTTTTAACCAGTGAAATTGACCTGCCCGTGAAGAGG 2630
mito_African CCACGAGGGTTCAGCTGTCTCTTACTTTTAACCAGTGAAATTGACCTGCCCGTGAAGAGG 2697
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mito_African CGGGCATGACACAGCAAGACGAGAAGACCCTATGGAGCTTTAATTTATTAATGCAAACAA 2757
mito_European TACCTAACAAACCCACAGGTCCTAAACTACCAAACCTGCATTAAAAATTTCGGTTGGGGC 2750
mito_African TACCTAACAAAGCCACAGGTCCTAAACTACCAAACCTGCATTAAAAATTTCGGTTGGGGC 2817
mito_European CACCTCGGAGCAGAACCCAACCTCCGAGCAGTACATGCTAAGACTTCACCAGTCAAAGCG 2010
mito_African GACCTCGGAGCAGAACCCAACCTCCGAGCAGTACATGCTAAGACTTCACCAGTCAAAGCG 2877
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mito_African       CTAGGAGGCCTACCCCCGCTAACCGGCTTTTTGCCCAAATGGGCCATTATCGAAGAATTC 5277
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mito_African       CTCTAAGATTAAAAATGCCCTAGCCCACTTCTTACCACAAGGCACACCTACACCCCTTAT 8937
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mito_European      CGCCAACTACTTATTATCCAAACCATCACCCTACTCATTCAACCAATACCCCTCCCCCT 8930
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mito_African        CTAGGAGGGCACTGGCCCCCAACAGGCATCACCCCGCTAAATCCCCTAGAAGTCCCACTC 9597
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mito_chimp      CATTGTAGGTCCTTACGGGCTATTACAGCCCTTCGCTGACGCCATAAAACTCTTCACTAA 2897
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mito_chimp      AGAACCCTTAAAACCCTCCACTTCAACCATTACCCTCTACATCACCGCCCCAACCCTAGC 2957
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mito_human      TCTCACCATCGCTCTTCTACTATGAACCCCCCTCCCCATACCCAACCCCCTGGTCAACCT 3599
mito_chimp      CCTCACCATTGCCCTCTTACTATGAACCCCCCTCCCCATACCCAACCCCCTAGTCAATCT 3017
                 ******** ** **  ********************************** ***** **

mito_human      CAACCTAGGCCTCCTATTTATTCTAGCCACCTCTAGCCTAGCCGTTTACTCAATCCTCTG 3659
mito_chimp      TAACTTAGGCCTCCTATTTATTCTAGCCACCTCCAGCCTAGCCGTTTACTCAATCCTCTG 3077
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mito_human      ATCAGGGTGAGCATCAAACTCAAACTACGCCCTGATCGGCGCACTGCGAGCAGTAGCCCA 3719
mito_chimp      ATCAGGGTGAGCATCAAACTCGAACTACGCCTTAATCGGTGCACTACGAGCAGTAGCCCA 3137
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mito_human      AACAATCTCATATGAAGTCACCCTAGCCATCATTCTACTATCAACATTACTAATAAGTGG 3779
mito_chimp      AACAATCTCATACGAAGTCACTCTAGCCATTATCCTACTGTCAACGCTACTAATAAGTGG 3197
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mito_human      CTCCTTTAACCTCTCCACCCTTATCACAACACAAGAACACCTCTGATTACTCCTGCCATC 3839
mito_chimp      CTCCTTCAATCTCTCTACCCTTGTCACAACACAAGAGCACCTCTGACTAATCCTGCCAAC 3257
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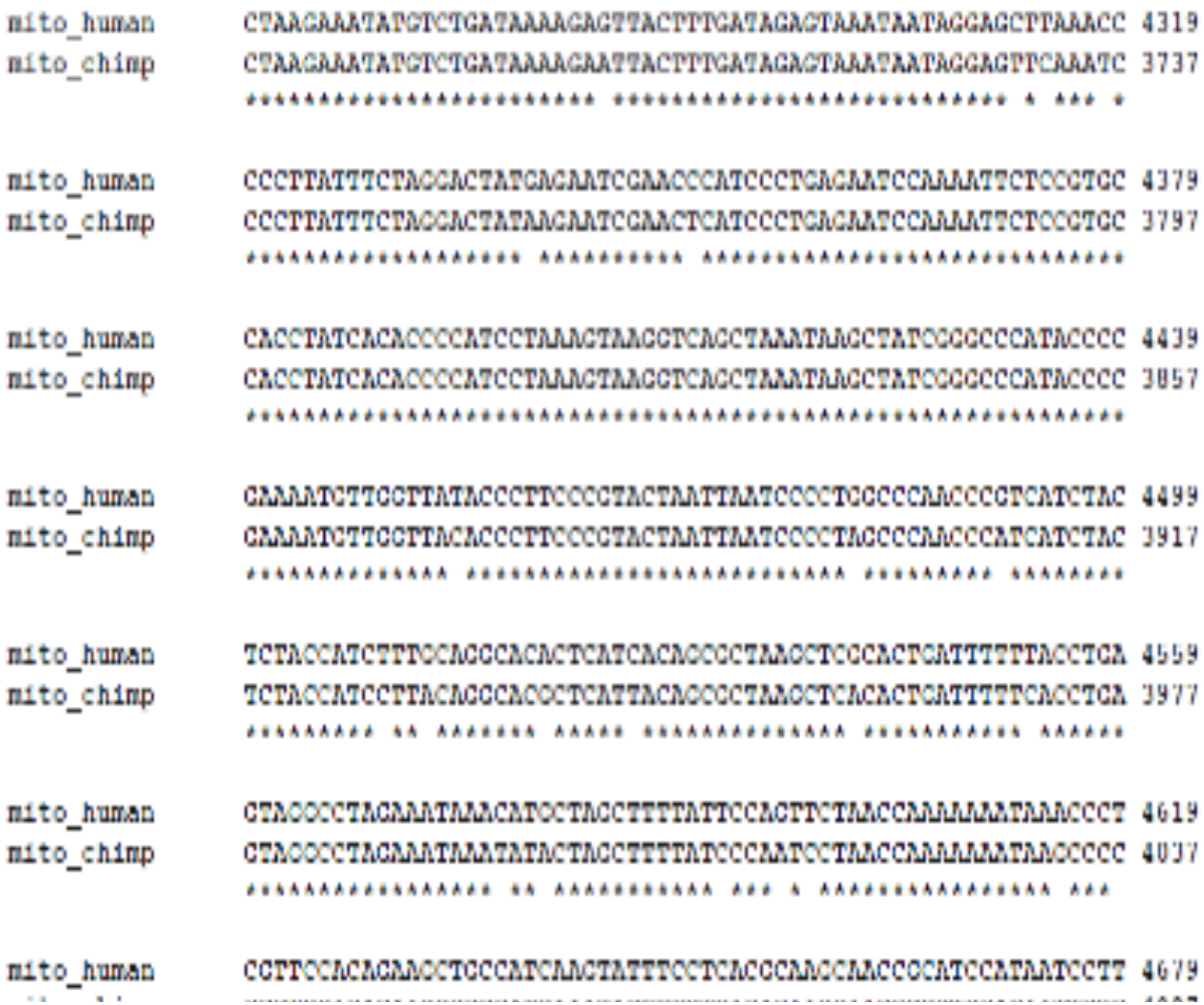
mito_human CTAAGAAATATGTCTGATAAAAGAGTTACTTTGATAGAGTAAATAATAGGAGCTTAAACC 4319
mito_chimp CTAAGAAATATGTCTGATAAAAGAATTACTTTGATAGAGTAAATAATAGGAGTTCAAATC 3737
mito_human CCCTTATTTCTACGACTATGAGAATCGAACCCATCCCTGAGAATCCAAAATTCTCCGTGC 4379
mito_chimp CCCTTATTTCTACGACTATAAGAATCGAACTCATCCCTGAGAATCCAAAATTCTCCGTGC 3797
mito_human CACCTATCACACCCCATCCTAAAGTAAGGTCAGCTAAATAAGCTATCGGGCCCATACCCC 4439
mito_chimp CACCTATCACACCCCATCCTAAAGTAAGGTCAGCTAAATAAGCTATCGGGCCCATACCCC 3857
mito_human CAAAATGTTGGTTATACCCTTCCCGTACTAATTAATCCCCTGCCCCAACCCCGTCATCTAC 4499
mito_chimp CAAAATGTTGGTTACACCCTTCCCGTACTAATTAATCCCCTACCCCAACCCATCATCTAC 3917
mito_human TCTACCATCTTTGCAGGCACACTCATCACAGCCCTAAGCTCCCACTGATTTTTTACCTGA 4559
mito_chimp TCTACCATCCTTACAGGCACGCTCATTACAGCCCTAAGCTCACACTGATTTTTCACCTGA 3977
mito_human CTAGCCCTACAAATAAACATGCTAGCTTTTATTCCAGTTCTAACCAAAAAAATAAACCCT 4619
mito_chimp CTAGCCCTACAAATAAATATACTAGCTTTTATCCCAATCCTAACCAAAAAAATAAGCCCC 4037
mito_human CGTTCCACAGAAGCTGCCATCAAGTATTTCCTCACGCAAGCAACCGCATCCATAATCCTT 4679


mito_human TCTCGCACCTGAAACAAGCTAACATGACTAACACCCTTAATTCCATCCACCCTCCTCTCC 5219
mito_chimp TCTCGCACCTGAAACAAGCTAACATGATTAACTCCCCTAATTCCATCCACCCTCCTCTCC 4637
mito_human CTAGGAGGCCTGCCCCCGCTAACCGGCTTTTTGCCCAAATGGGCCATTATCGAAGAATTC 5279
mito_chimp CTAGGAGGCCTACCCCCACTAACTGGCTTCTTACCCAAATGAGTTATCATCGAAGAATTC 4697
mito_human ACAAAAAACAATAGCCTCATCATCCCCACCATCATAGCCACCATCACCCTCCTTAACCTC 5339
mito_chimp ACAAAAAATAATAGCCTCATCATCCCCACCATCATAGCCATCATCACTCTCCTTAACCTC 4757
mito_human TACTTCTACCTACGCCTAATCTACTCCACCTCAATCACACTACTCCCCATATCTAACAAC 5399
mito_chimp TATTTCTACCTACGCCTAATCTACTCCACCTCAATTACACTACTTCCCATATCTAATAAC 4817
mito_human GTAAAAATAAAATGACAGTTTGAACATACAAAACCCACCCCATTCCTCCCCACACTCATC 5459
mito_chimp GTAAAAATAAAATGACAATTCGAACATACAAAACCCACCCCCTTCCTCCCTACACTCATC 4877
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mito_chimp ACCCTTACCACACTGCTTCTACCCATCTCCCCCTTCATACTAATAATCTTATAGAAATTT 4937
mito_human AGGTTAAATACAGACCAAGAGCCTTCAAAGCCCTCAGTAAGTTGCAATACTTAATTTCTG 5579
mito_chimp AGGTTAAGCACAGACCAAGAGCCTTCAAAGCCCTCAGCAAGTTACAATACTTAATTTCTG 4997

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mito_human      ATCTACAACGTTATCGTCACAGCCCATGCATTTGTAATAATCTTCTTCATAGTAATACCC 6119
mito_chimp      ATCTACAATGTCATCGTCACAGCCCATGCATTCGTAATAATCTTCTTCATAGTAATGCCT 5536
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mito_human      ATCATAATCGGAGGCTTTGGCAACTGACTAGTTCCCCTAATAATCGGTGCCCCCGATATG 6179
mito_chimp      ATTATAATCGGAGGCTTTGGCAACTGGCTAGTTCCCTTGATAATTGGTGCCCCCGACATG 5596
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mito_human      GCGTTTCCCCGCATAAACAACATAAGCTTCTGACTCTTACCTCCCTCTCTCCTACTCCTG 6239
mito_chimp      GCATTCCCCCGCATAAACAACATAAGCTTCTGGCTCCTGCCCCCTTCTCTCCTACTTCTA 5656
                ** ** ***************************** *** * ** ** *********** **

mito_human      CTCGCATCTGCTATAGTGGAGGCCGGAGCAGGAACAGGTTGAACAGTCTACCCTCCCTTA 6299
mito_chimp      CTTGCATCTGCCATAGTAGAAGCCGGCGCGGGAACAGGTTGAACAGTCTACCCTCCCTTA 5716
                ** ******** ***** ** ***** ** ********************************

mito_human      GCAGGGAACTACTCCCACCCTGGAGCCTCCGTAGACCTAACCATCTTCTCCTTACACCTA 6359
mito_chimp      GCGGGAAACTACTCGCATCCTGGAGCCTCCGTAGACCTAACCATCTTCTCCTTACATCTG 5776
                ** ** ******** ** ****************************************** **

mito_human      GCAGGTGTCTCCTCTATCTTAGGGGCCATCAATTTCATCACAACAATTATCAATATAAAA 6419
mito_chimp      GCAGGCATCTCCTCTATCCTAGGAGCCATTAACTTCATCACAACAATTATTAATATAAAA 5836
                *****  *********** **** ***** ** ***************** *********

mito_human      CCCCCTGCCATAACCCAATACCAAACGCCCCTCTTCGTCTGATCCGTCCTAATCACAGCA 6479
mito_chimp      CCTCCTGCCATGACCCAATACCAAACACCCCTCTTCGTCTGATCCGTCCTAATCACAGCA 5896
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mito_human      GTCCTACTTCTCCTATCTCTCCCAGTCCTAGCTGCTGGCATCACTATACTACTAACAGAC 6539
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mito_human      AAATGATCTGCTGCAGTGCTCTGAGCCCTAGGATTCATCTTTCTTTTCACCGTAGGTGGC 6959
mito_chimp      AAATGATCTGCCGCAGTACTCTGAGCCCTAGGGTTTATCTTTCTCTTCACCGTAGGTGGC 6376
                *********** ***** ************** ** ******** ***************

mito_human      CTGACTGGCATTGTATTAGCAAACTCATCACTAGACATCGTACTACACGACACGTACTAC 7019
mito_chimp      CTAACCGGCATTGTACTAGCAAACTCATCATTAGACATCGTGCTACACGACACATACTAC 6436
                ** ** ********* ************** ********** *********** ******

mito_human      GTTGTAGCCCACTTCCACTATGTCCTATCAATAGGAGCTGTATTTGCCATCATAGGAGGC 7079
mito_chimp      GTCGTAGCCCACTTCCACTACGTTCTATCAATAGGAGCTGTATTCGCCATCATAGGAGGC 6496
                ** ****************** ** ********************* ***************

mito_human      TTCATTCACTGATTTCCCCTATTCTCAGGCTACACCCTAGACCAAACCTACGCCAAAATC 7139
mito_chimp      TTCATTCACTGATTCCCCCTATTCTCAGGCTATACCCTAGACCAAACCTATGCCAAAATC 6556
                ************** ****************** ****************** *********

mito_human      CATTTCACTATCATATTCATCGGCGTAAATCTAACTTTCTTCCCACAACACTTTCTCGGC 7199
mito_chimp      CAATTTGCCATCATGTTCATTGGCGTAAACCTAACCTTCTTCCCACAGCACTTCCTTGGC 6616
                ** **  * ***** ***** ******** ***** *********** ***** ** ***

mito_human      CTATCCGGAATGCCCCGACGTTACTCGGACTACCCCGATGCATACACCACATGAAACATC 7259
mito_chimp      CTATCTGGGATGCCCCGACGTTACTCGGACTACCCCGATGCATACACCACATGAAATGTC 6676
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mito_human      TCCTAGTCCTCATCGCCCTCCCATCCCTACGCATCCTTTACATAACAGACGAGGTCAACG 7859
mito_chimp      TCCTAGTCCTTATTGCCCTACCATCCCTGCGTATCCTTTACATAACAGACGAGGTCAACG 7276
                ********** ** ***** ******** ** ******************************

mito_human      ATCCCTCCCTTACCATCAAATCAATTGGCCACCAATGGTACTGAACCTACGAGTACACCG 7919
mito_chimp      ACCCCTCCTTTACTATTAAATCAATCGGCCATCAATGATATTGAACCTACGAATACACCG 7336
                * ****** **** ** ******** ***** ***** ** ********** *******

mito_human      ACTACGGCGGACTAATCTTCAACTCCTACATACTTCCCCCATTATTCCTAGAACCAGGCG 7979
mito_chimp      ACTACGGCGGGCTAATCTTCAACTCCTACATACTCCCCCCATTATTCTAGAACCAGGTG 7396
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mito_human      ACCTGCGACTCCTTGACGTTGACAATCGAGTAGTACTCCCGATTGAAGCCCCCATTCGTA 8039
mito_chimp      ATCTACGACTCCTTGACGTTGATAACCGAGTGGTCCTCCCAGTTGAAGCCCCCGTTCGTA 7456
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mito_human      TAATAATTACATCACAAGACGTCTTGCACTCATGAGCTGTCCCCACATTAGGCTTAAAAA 8099
mito_chimp      TAATAATTACATCACAAGATGTTCTACACTCATGAGCTGTTCCCACATTAGGCCTAAAAA 7516
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mito_human      CAGATGCAATTCCCGGACGTCTAAACCAAACCACTTTCACCGCTACACGACCGGGGGTAT 8159
mito_chimp      CAGACGCAATTCCCGGACGCCTAAACCAAACCACTTTCACCGCCACACGACCAGGAGTAT 7576
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mito_human      ACTACGGTCAATGCTCTGAAATCTGTGGAGCAAACCACAGTTTCATGCCCATCGTCCTAG 8219
mito_chimp      ACTACGGCCAATGCTCAGAAATCTGTGGAGCAAACCACAGTTTTATACCCATCGTCCTAG 7636
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mito_human      CCGCCGCAGTACTGATCATTCTATTTCCCCCTCTATTGATCCCCACCTCCAAATATCTCA 8638
mito_chimp      CCGCCGCAGTACTAATCATTCTATTCCCCCCTCTACTGGTCCCCACTTCTAAACATCTCA 8056
                ************** *********** ********* ** ******* ** *** ******

mito_human      TCAACAACCGACTAATCACCACCCAACAATGACTAATCAAACTAACCTCAAAACAAATGA 8698
mito_chimp      TCAACAACCGACTAATTACCACCCAACAATGACTAATTCAACTGACCTCAAAACAAATAA 8116
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mito_human      TAACCATACACAACACTAAAGGACGAACCTGATCTCTTATACTAGTATCCTTAATCATTT 8758
mito_chimp      TAACTATACACAGCACTAAAGGACGAACCTGATCTCTCATACTAGTATCCTTAATCATTT 8176
                **** ******* ************************* ************************

mito_human      TTATTGCCACAACTAACCTCCTCGGACTCCTGCCTCACTCATTTACACCAACCACCCAAC 8818
mito_chimp      TTATTACCACAACCAATCTTCTTGGGCTTCTACCCCACTCATTCACACCAACCACCCAAC 8236
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mito_human      TATCTATAAACCTAGCCATGGCCATCCCCTTATGAGCGGGCACAGTGATTATAGGCTTTC 8878
mito_chimp      TATCTATAAACCTAGCCATGGCTATCCCCCTATGAGCAGGCGCAGTAGTCATAGGCTTTC 8296
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mito_human      GCTCTAAGATTAAAAATGCCCTAGCCCACTTCTTACCACAAGGCACACCTACACCCCTTA 8938
mito_chimp      GCTTTAAGACTAAAAATGCCCTAGCCCACTTCTTACCGCAAGGCACACCTACACCCCTTA 8356
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mito_human      ATTAGGAGGGCACTGGCCCCCAACAGGCATCACCCCGCTAAATCCCCTAGAAGTCCCACT 9598
mito_chimp      GCTAGGAGGACACTGGCCCCCAACAGGTATTACCCCACTAAATCCCCTAGAAGTCCCACT 9016
                  ******* ****************** ** ***** ************************

mito_human      CCTAAACACATCCGTATTACTCGCATCAGGAGTATCAATCACCTGAGCTCACCATAGTCT 9658
mito_chimp      CCTAAACACATCTGTATTACTCGCATCAGGAGTATCAATTACTTGAGCCCATCACAGCTT 9076
                ************ ***************************** ** ***** ** ** **  *

mito_human      AATAGAAAACAACCGAAACCAAATAATTCAAGCACTGCTTATTACAATTTTACTGGGTCT 9718
mito_chimp      AATAGAAAATAACCGAAACCAAATAATTCAAGCACTGCTTATTACGATTCTACTAGGTCT 9136
                ********* ************************************* *** **** *****

mito_human      CTATTTTACCCTCCTACAAGCCTCAGAGTACTTCGAGTCTCCCTTCACCATTTCCGACGG 9778
mito_chimp      TTATTTTACCCTCCTACAAGCCTCAGAATATTTCGAATCCCCTTTTACCATTTCCGATGG 9196
                 ***************************** ** ***** ** ** ** *********** **

mito_human      CATCTACGGCTCAACATTTTTTGTAGCCACAGGCTTCCACGGACTTCACGTCATTATTGG 9838
mito_chimp      CATCTACGGCTCAACATTCTTTGTAGCCACAGGCTTCCACGGACTCCACGTCATTATTGG 9256
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mito_human      CTCAACTTTCCTCACTATCTGCTTCATCCGCCAACTAATATTTCACTTTACATCCAAACA 9898
mito_chimp      ATCAACTTTCCTCACTATCTGCCTCATCCGCCAACTAATATTTCACTTCACATCCAAACA 9316
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mito_human      TCACTTTGGCTTCGAAGCCGCCGCCTGATACTGGCATTTTGTAGATGTGGTTTGACTATT 9958
mito_chimp      TCACTTCGGCTTTCAAGCCGCCGCCTGATACTGACACTTCGTAGATGTAGTCTGACTATT 9376
                ****** *****  ******************** ** ** ******** ** ********

mito_human      TCTGTATGTCTCCATCTATTGATGAGGGTCTTACTCTTTTAGTATAAATAGTACCGTTAA 10018
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mito_human      AGTTATGTCATCCCTCTTATTAATCATCATCCTAGCCCTAAGTCTGGCCTATGAGTGACT 10378
mito_chimp      AGTCACATCATCCCTCTTATTAATTACTATCCTAGCCCTAAGCCTCGCCTACGAATGATT 9796
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mito_human      ACAAAAAGGATTAGACTGAACCGAATTGGTATATAGTTTAAACAAAACGAATGATTTCGA 10438
mito_chimp      ACAAAAAGGGTTAGACTGAACCGAATTGGTATATAGTTTAAATAAAACGAATGATTTCGA 9856
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mito_human      CTCATTAAATTATGATAATCATATTTACCAAATGCCCCTCATTTACATAAATATTATACT 10498
mito_chimp      CTCATTAAATTATGATAATCATATTTACCAAATGCCCCTTATTTATATAAATATTATACT 9916
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mito_human      AGCATTTACCATCTCACTTCTAGGAATACTAGTATATCGCTCACACCTCATATCCTCCCT 10558
mito_chimp      AGCATTTACCATCTCACTTCTAGGAATACTAGTATATCGCTCACACCTAATATCTTCCCT 9976
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mito_human      ACTATGCCTAGAAGGAATAATACTATCGCTGTTCATTATAGCTACTCTCATAACCCTCAA 10618
mito_chimp      ACTATGCCTAGAAGGAATAATACTATCACTGTTCATCATAGCCACCCTCATAACCCTCAA 10036
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mito_human      CACCCACTCCCTCTTAGCCAATATTGTGCCTATTGCCATACTAGTCTTTGCCGCCTGCGA 10678
mito_chimp      TACTCACTCCCTCTTAGCCAATATTGTACCCATCACCATACTAGTCTTTGCTGCCTGCGA 10096
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mito_human      CTAAACATTCTACTACTCACTCTCACTGCCCAAGAACTATCAAACTCCTGAGCCAATAAC 11338
mito_chimp      CTAAATATCCTATTACTCACTCTTACAACCCAAGAACTATCAAACACCTGAGCCAACAAC 10756
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mito_human      TTAATATGACTAGCTTACACAATAGCTTTTATAGTAAAGATACCTCTTTACGGACTCCAC 11398
mito_chimp      TTAATATGACTAGCGTACACGATGGCTTTCATGGTAAAAATACCCCTTTACGGACTCCAC 10816
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mito_human      TTATGACTCCCTAAAGCCCATGTCGAAGCCCCCATCGCTGGGTCAATAGTACTTGCCGCA 11458
mito_chimp      CTATGACTCCCTAAAGCCCATGTCGAAGCCCCTATTGCCGGGTCAATGGTACTTGCTGCA 10876
                 ********************************** ** ** ******** ******** ***

mito_human      GTACTCTTAAAACTAGGCGGCTATGGTATAATACGCCTCACACTCATTCTCAACCCCCTG 11518
mito_chimp      GTACTCTTAAAATTAGGTGGCTATGGCATAATACGCCTCACACTCATCCTCAACCCCCTA 10936
                ************ **** ******** ******************** ***********

mito_human      ACAAAACACATAGCCTACCCCTTCCTTGTACTATCCCTATGAGGCATAATTATAACAAGC 11578
mito_chimp      ACAAAACATATAGCCTATCCCTTCCTCATGTTGTCCTTATGAGGTATAATCATAACAAGC 10996
                ******** ******** ********  *  * *** ******* ***** *********

mito_human      TCCATCTGCCTACGACAAACAGACCTAAAATCGCTCATTGCATACTCTTCAATCAGCCAC 11638
mito_chimp      TCCATCTGCCTGCGACAAACAGACCTAAAATCGCTCATTGCATACCCTTCAGTCAGCCAC 11056
                *********** ********************************** ***** ********

mito_human      ATAGCCCTCGTAGTAACAGCCATTCTCATCCAAACCCCCTGAAGCTTCACCGGCGCAGTC 11698
mito_chimp      ATAGCCCTCGTAGTAACAGCCATTCTCATCCAAACCCCCTGAAGCTTCACCGGCGCAATT 11116
                ************************************************************ *

mito_human      ATTCTCATAATCGCCCACGGGCTTACATCCTCATTACTATTCTGCCTAGCAAACTCAAAC 11758
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Lesson 2: How does the environment affect how SIMILAR or DIFFERENT we are?

OVERVIEW

Purpose
Students review previous phenomena and particularly consider how the environment in which they live can affect them genetically. Sometimes our environment can *change* our genes (cause mutations) and these changes can be passed down from one generation to the next. Other times, the environment affects what genes get turned "on and off."

Connections
In previous Learning Sets students learned about four different phenomena: skin color, lactose intolerance, FH, and sickle cell anemia. In LS6 Lesson 2 students explored lactose intolerance specifically and learned about how genes can be turned on and off. The activities in this lesson encourage students to think more about how the environment can affect our genes, and provide the opportunities for students to review one of the phenomena in more detail in preparation for their final projects for DNA Night.

Description
In this lesson students first spend time exploring the previously learned phenomena (skin color, lactose intolerance, FH, and sickle cell) and discussing the gene-environment interaction. They then create concept maps as they review one of the phenomena to prepare them for their final product.

Safety Guidelines
None applicable

Learning Performance
Students create concept maps to visually represent a specific phenomena (skin color, lactose intolerance, FH, or sickle cell) over time.
Students create a macro-molecular chart for a specific phenomenon.
Students explain the gene-environment interaction for a specific phenomenon.

Time
2 days

PREPARATION

Materials
Student Readers pp:
Slide 1-6 (LS5, Lesson 2)
Chart paper

Markers
Post-its
Tape

PRIOR TO THIS LESSON: Ask students to write on a sheet of scrap paper a ranking of their interest in each of the phenomena (skin color, lactose intolerance, FH, and sickle cell), with one being the most interesting to them and four being the least interesting to them. Use these rankings to form small groups for them to work with on this lesson and the final project. There should be at least one group for each phenomenon in the class.

INSTRUCTIONAL SEQUENCE

Introducing Activity 5.2a:
Review with students their findings from the previous lesson:

- What did you find was the cause of Jason's lactose intolerance? Ask students to provide evidence from the previous lesson to support their answer. (*Jason was lactose intolerant because his DNA does not contain the appropriate "switch" to make the RNA that will make the lactase protein)*
- What was the "switch" that enabled Maya, Chelsea, and Mom to make lactase, but not allow Jason to make lactase? Where is this "switch" located? *(Those that can make lactase have T-A as the third base-pair in the appropriate part of their DNA. Jason has C-G instead of T-A, which does not allow him to make the RNA that will make lactase.)* (*In their DNA, specifically, the DNA sequence BEFORE the gene that codes for the production of lactase. Jason's DNA is normal, without any mutation, the mutation in lactose tolerant people is the switch that turns the gene on or off)*
- Do you think that Jason's genome more similar or different from the rest of his family? *Accept all answers. Ask students to give evidence to support their answer from what they know about the humane genome*

Carrying Out Activity 5.2a: Gene-Environment Interaction
In this activity you want students to get a firm grasp on the ways the environment can interact with our genes. Show LS5 Lesson 2 Slide 1 which displays the four phenomena we've studied (and which they will choose from for their final projects).

Inform students of the groups you've previously created (in the slide) and have them sit with their groups. Tell students that even though we've all studied all of the phenomena already, each group will become the expert on how the environment interacts with our genes for their phenomenon and will be teaching the rest of us. The information they collect during this activity will be added to their concept map in the next activity.

Direct students to Activity 5.2a in their reader for directions on completing the activity.

Activity 5.2a

Directions: (also included in Student Reader)

1) Use the readings related to your phenomenon to answer the following questions. The readings for each of the phenomena are:

Skin Color: LS1, How cells affect skin color LS1, Skin color adaptation LS2, What happened to Sammy Sosa? LS3, Fish research helps uncover genetics of human skin color
Lactose Intolerance: LS2, Don't Pass the Milk Please LS2, New Spoof of Milk Mustache Ad Spotlights Lactose Intolerance
Familial hypercholesterolemia: LS3, The Medical Case: Familial Hypercholesterolemia LS3, The Medical Case: Familial Hypercholesterolemia, part 2 LS3, Genomics Medical Journal
Sickle cell: LS4, Sudden Death and Sickle Cell Trait: How Knowing Your Genes Can Save Your Life LS4, Sickle Cell Disease: The crooked red blood cells LS4, Are All Mutations Bad? A Mutation Story

2) Use the readings identified above to help you identify the following characteristics of your phenomenon from the macro world to the molecular world:
    a. The phenomenon
    b. Possible biological physical traits displayed by individuals experiencing this phenomenon
    c. Organ involved
    d. Type of cells involved
    e. Protein
    f. Gene expression: What does the gene tell the protein to do? And, what happens if the gene has a mutation or the protein is malfunctioning in some way?
    g. Gene-environment interaction
3) Complete your section of the table and be prepared to share out your findings with the rest of your class. (A sample phenomenon table has been provided for the teacher).

Teacher Note:

If you have time and think it would be worthwhile for your class you could have each group put their answers on chart paper and hang it up for other groups to copy.
A slide has been included in the powerpoint for this Learning Set which you could fill in also as students present, if you are comfortable doing so (LS6, Lesson 2, Slides2-5).

4) As your classmates share out the characteristics of their phenomenon, enter the details into the table in your reader.

Genomics Unit Phenomena

Macro

Molecular

Phenomenon	**Skin color**	**Lactose intolerance**	**Familial hypercholesterolemia**	**Sickle cell**
Possible Traits	A variety of skin colors	Either no external "symptoms" or gas, bloating, stomach cramps	No symptoms or bulges on arms, knees, elbows, & toes from fatty deposits; obesity	Sickle-shaped vs. round red blood cells, pain, fever, swelling, and tissue damage that can lead to death
Organ	Skin	Small intestine	Liver	Circulatory system
Cell type	Skin cells	Small intestine cells	Mostly liver cells	Red blood cells
Protein	Tyrosinase	Lactase	LDL Receptor	Hemoglobin
Gene expression	Tyrosinase produces more melanin which leads to darker skin colors	If lactase is still being produced in the small intestine it breaks down lactose (person can digest milk). Without lactase being made in the small intestine the body does not digest lactose (person cannot digest milk)	LDL receptor binds to cholesterol to bring it from the blood into the cell to be used. Gene mutation causes error in LDL receptor protein which results in body's inability to remove cholesterol from the blood and use it in cells	Hemoglobin A (alpha, normal) carries oxygen through the blood to different parts of the body. Hemoglobin S (beta, sickle shaped) is unable to carry oxygen around the body, gets caught in arteries because of its shape
Environment interaction	Melanin acts as a natural sunscreen (darker people are more naturally protected against the sun's UV light). Lighter people are at greater risk for UV light to damage their	People began dairy farming 1000 years ago in certain parts of the world and developed the ability to drink milk into adulthood (a genetic mutation). Lactose intolerant people can take a pill	Lifestyle/diet (Chinese people from Canada had a diet more like Westerners and filled with fat than Chinese people from China with similar LDL receptor problems.)	Found mostly in peoples originating from tropical climates because the sickle cell gene provides a resistance to malaria. Strenuous exercise (where a lot of oxygen is required) can cause people

	DNA (cause cancer). People can tan/burn in the sun during different times of year (seasonal effect)	that helps their body break down lactose.		with only 1 sickle cell trait to exhibit symptoms of sickle cell

Teacher Note: Circulatory System

It might not be immediately clear to students what organ is involved with sickle cell. Help them understand that it is our entire circulatory system that is the organ involved. Veins and arteries (through which blood flows) are part of an organ called the Circulatory System which is responsible for pumping and channeling blood to and from the body and lungs with heart, blood and blood vessels. Veins themselves are not considered an organ because they are a grouping of different tissues like a organ.

Concluding Activity 5.2a:

After student groups have completed the table for their phenomenon have them share their results with their class. Walk around and make sure all students are correctly completing the rest of the table. If there is more than one group for a phenomenon have them share out together and add to each other's details.

Have students individually complete the Check for Understanding:

Check For Understanding:

Write a scientific explanation: How can the environment influence our genes?

A sample response for lactose intolerance:
Claim: *Lactose intolerance is genetically normal, and due to environmental factors people developed the ability to digest lactose.*
Evidence: *The reading from LS2 about "New Spoof of Milk Mustache Ad Spotlights Lactose Intolerance" points out that when peoples began dairy farming in Northern Europe 1000 years ago they continued to drink milk past infancy and developed a genetic tolerance.*
Reasoning: *The dairy farmers that drank milk into adulthood developed a mutation in their DNA that meant that their bodies still made lactase which allowed them to digest milk. This mutation has been passed down to their descendents.*

Introducing Activity 5.2b:

Tell students that to conclude the genomics unit and prepare them for their final project they will be creating concept maps for their phenomenon.

Review with students the idea of a concept map and how to make one. Solicit student ideas about this.

Teacher Background: Concept Maps

Students should realize that a concept map is a visual representation of ideas and how the ideas are related to each other. Words are placed on the map and are connected with lines. Also on the lines should be linking words which illustrate the relationship indicated by the line connecting the concepts. Other things can be added to the concept map as well to make it more complete, for example, definitions and examples, or diagrams. Students should also realize that there is no one right way to make a concept map. There are many "right" ways, as long as students can show why two or more words link together.

You will do a simple practice example with the class. If your students are very familiar with concept mapping you can skip the practice and move on to the rest of the lesson.

If you had students create a concept map during LS 1, Lesson 5, you only need to review this here.

Carrying Out Activity 5.2b: Concept Mapping the phenomena
Students will be working in the same groups from Activity 5.2a. They will work together to create a concept map about their same phenomenon (skin color, lactose intolerance, sickle cell, or FH).

This time, direct students to use all the materials (readings, answers to questions, activities) from their Readers to help them do this, especially using the information they collected for the previous activity. The idea is to review and synthesize the information.

Pass out chart paper, Post-its, and markers to each group. Tell them they will be presenting their final concept map to the class so they need to write neatly so their classmates can read and understand what's written.

Activity 5.2b

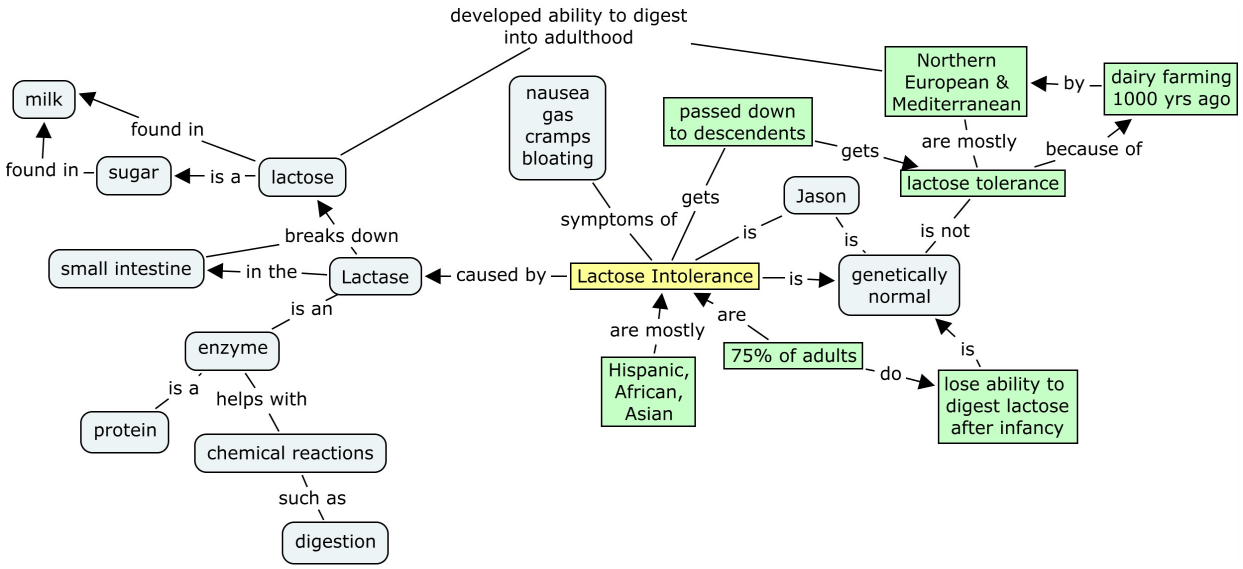
Directions: (also included in the student reader)

1) Begin by looking back through your student reader for information about your phenomenon. Identify key ideas (words or short phrases) about the phenomenon. Refer to the macro-molecular diagram to guide you. Be sure to include the key ideas from the previous activity. For example, a key idea for lactose intolerance might be "lactase."
2) Write these words/short phrases on Post-its (one word/phrase per Post-it).
3) Work as a group to move the words around the chart paper, trying different placements of words until your group comes to consensus on a general structure for your concept map.
4) Using the marker, begin connecting the words/phrases to each other. For every connecting line you draw you must also have connecting words to show the relationship.
5) Add in extra information as you see necessary. Extra information could include evidence from readings and activities we've done in class.
6) Tape down the Post-its so they do not fall off your chart paper when it is hung up.
7) Copy your group's final concept map in the appropriate place in your student reader.

Point out to students that one way to get started finding key ideas would be to take the key words identified for the different readings.

As students work, walk around and pay attention to the words they are using and how they are choosing to connect them. There is no one right way to do it, but you might want to be sure they include certain concepts. Remind them that this is to review all the science we have learned about different phenomena. They should include as much information as they can. Encourage students to make multiple links and add multiple details.

A possible (simple) sample for the phenomenon of lactose intolerance has been done below:



Wrapping Up Activity 5.2b:
Have students present their concept maps to the class. Encourage discussion about the maps and encourage students to ask questions about why students placed words where they did, or about how they connected concepts (e.g. Why did you connect x with y?) Encourage students to point out if something important seems to be missing, and have groups add this into their map with the help of their class. If there are groups that mapped the same phenomenon, have students contrast and compare the two concept maps that result.

As students present their maps have them use what they have learned about the human genome to determine whether they believe that these differences in our characteristics mean that we are more similar or more different when we look at our genome? Have students use their concept maps as evidence for their answers.

Appendix

- Additional Ethical Dilemmas
- Reading Strategy Templates

How SIMILAR or DIFFERENT Are We From Each Other?

Ethical Discussion

Should Individuals Who Have "Drug Addiction Genes" Be Treated Differently?
From the Scholastic website article, The Role of Genes and Drug Addiction
http://teacher.scholastic.com/scholasticnews/indepth/headsup/intro/index.asp?article=genes

A major finding about the genetics of drug addiction was reported in 2004 by investigators at Duke University Medical Center. The researchers were able to identify a specific protein—PSD-95—that had a relationship to drug addiction. Mice that had low amounts of PSD-95 were much more sensitive to cocaine (than mice with normal amounts of PSD-95).

The researchers concluded that mice with normal amounts of PSD-95 were less likely to become addicted to cocaine (than mice with low amounts of PSD-95). According to Marc G. Caron, Ph.D., an investigator who was part of the research team, PSD-95 "likely plays a role in addiction to other drugs—including nicotine, alcohol, morphine, and heroin."

Consider the following scenario:

The case of Jacob puts the dangers of drugs in focus. Jacob began using OxyContin (a prescription drug for pain) at 18. Eventually Jacob moved from OxyContin to heroin. "If I'd never touched OxyContin, I wouldn't have done heroin," he claims. Before long, Jacob was selling OxyContin pills to help support his habit. (Selling prescription drugs makes you a drug dealer and subject to criminal prosecution.) One day Jacob didn't have money to buy heroin. Desperate, Jacob robbed the local liquor store. Fortunately, no one was hurt but Jacob was arrested. Now he faces criminal charges from robbery to drug dealing. The judge has ordered Jacob to go to rehab to help him with his addiction. Jacob's lawyer read about a "Drug Gene" and has asked Jacob to get tested to see if he is genetically sensitive to drug addiction, meaning if he has the "Drug Gene" his body would produce low levels of the PSD-95 protein.
You are asked by the judge in Jacob's case to act as an adviser. Your job is to discuss the topic of individuals that have these "Drug Genes" and to make recommendations about how Jacob's case should be handled once his genetic test comes back. Consider the following:

A) It is estimated that genes contribute about 60% of a persons' vulnerability to drugs, an individual's environment contributes the other 40%. That means drug gene sensitive people are not "doomed" if they have this "drug gene" but they might want to be aware of the gene and its potential dangers.
B) Testing every drug addict for the "Drug Gene" will cost millions of dollars
C) Addiction adds to crime rates and violence.
D) If an individual tests positive for the "Drug Gene", what is their responsibility as an individual? Should they go to jail? Should they be forced to get help? Should they be let go because it's a "genetic"problem?

How SIMILAR or DIFFERENT Are We From Each Other?

Use the ethical decision framework that follows to make a decision about what course of action the judge should take with Jacob if he is found to have the "Drug Gene." Should the results of Jacob's "Drug Gene" test affect what happens to Jacob? Should Jacob go to jail? Rehab? Counseling? Other?

Your class will now work together using ethics to try to make a recommendation to the judge about what action(s) he/she should take.

Ethical Decision-Making Framework

What do you think is the ethical problem?

Ethical Problem- Testing individuals' genes for sensitivity to drug addiction may mean some individuals get treated differently than those who do not have the drug sensitive gene.

Students need to discuss what course of action the judge should take if Jacob is found to have the "Drug Gene" that will be fair for all stakeholders.

What are relevant facts? (Consider what you read above and what you have learned about the "Drug Gene".)

- *The researchers were able to identify a specific protein—PSD-95—that had a relationship to drug addiction.*
- *Mice that had low amounts of PSD-95 were much more sensitive to cocaine (than mice with normal amounts of PSD-95).*
- *The researchers concluded that mice with normal amounts of PSD-95 were less likely to become addicted to cocaine (than mice with low amounts of PSD-95).*
- *PSD-95 "likely plays a role in addiction to other drugs—including nicotine, alcohol, morphine, and heroin."*
- *Jacob began using OxyContin (a prescription drug for pain) at 18. Eventually Jacob moved from OxyContin to heroin.*
- *Jacob began selling OxyContin so he could buy heroin*
- *Selling prescription drugs makes you a drug dealer and subject to criminal prosecution*
- *Desperate, Jacob robbed the local liquor store.*
- *No one was hurt but Jacob was arrested. Now he faces criminal charges from robbery to drug dealing.*

How SIMILAR or DIFFERENT Are We From Each Other?

- *It is estimated that genes contribute about 60% of a persons' vulnerability to drugs, an individual's environment contributes the other 40%. That means drug gene sensitive people are not "doomed" if they have this "drug gene" but they might want to be aware of the gene and its potential dangers.*
- *Testing every drug addict for the "Drug Gene" will cost millions of dollars*
- *Addiction adds to crime rates and violence.*

What are questions that are still unknown?

Answers will vary

Here are some potential actions the judge could take.

- Send Jacob to jail
- Send Jacob to rehab

List three more actions the judge could take:

Answers will vary

How SIMILAR or DIFFERENT Are We From Each Other?

What stakeholders should you consider?

Jacob
The Judge
The Community
The Victim of the robbery
Other people who have the "Drug Gene"
People who don't have the "Drug Gene"
Students may list others but these are the main stakeholders that should be considered

What stakeholder did your teacher assign you? _____

What do you think are the concerns of your stakeholder?

Answers will vary

What action does your stakeholder think the judge should take?

Answers will vary

Explain why your stakeholder has chosen that action:

Answers will vary

How SIMILAR or DIFFERENT Are We From Each Other?

Now as a whole class, fill out this chart with all the stakeholders and their actions.

Who are the stakeholders?	**What action is this stakeholder recommending?**

What action(s) do you recommend the judge should take? Why?
Answers will vary

Resources
Scholastic, The Role of Genes in Drug Addiction
http://teacher.scholastic.com/scholasticnews/indepth/headsup/intro/index.asp?article=genes

How SIMILAR or DIFFERENT Are We From Each Other?

Ethical Discussion

Should Employees Undergo Genetic Testing to See if They Are Sensitive to Certain Chemicals They Might be Exposed to on the Job?

Beryllium (**Be**) is found naturally in food and water, but high **Be** exposure is mostly caused by working with **Be** in factories where **Be** dust can be easily inhaled. Beryllium is used in such products as cell phones, aircraft engine parts and nuclear workers use them to make triggers for nuclear bombs.

Some people who are exposed to **Be** develop a disease called Chronic Beryllium Disease (CBD). CBD is a disease that is characterized by an accumulation of T cells in the lungs. T cells help the body fight infection. When there are too many T cells in the lungs they damage the lungs and cause shortness of breath and dry coughing.

Changes in a gene called, HLA DP (**h**uman **l**eukocyte **a**ntigen) causes people to be sensitive to exposure to **Be**. HLA DP has the instructions to make a protein that helps T cells do their job. When scientists looked at how the change in the HLA DP gene would affect the protein made, they discovered that people who are sensitive to **Be** have a different sequence of amino acids. Only a small portion (1-15%) of the population is **Be** sensitive.

What do you think is happening to the protein to cause some people to be sensitive to Be?

The protein is not folding in the same way anymore and since it is a different shape, it cannot do its job.
Students might have some other ideas about how Be is interacting with the protein. These ideas might be correct, but scientists are still trying to figure it out.

How SIMILAR or DIFFERENT Are We From Each Other?

Read the following article about contract workers in the California based Livermore Lab.

Beryllium Exposure Warning Arrives Too Late for Contract Workers at Livermore Lab
http://www.chronicberylliumdisease.com/news/nw_020808_contract_workers_livermore_lab_ptr.htm (edited)

February 8, 2008 — At Lawrence Livermore Labs in California, as many as 178 GSE Construction workers may have been exposed to the known carcinogen (cancer causing) beryllium, a toxic metal that can cause lung cancer and chronic beryllium disease. Results from a routine beryllium test revealed dangerously high levels of beryllium as early as July 2007. GSE contract workers may have been unknowingly exposed to beryllium and placed at risk of developing beryllium related diseases (CBD).

Normally, when exposures to **Be** becomes known, the policy is to test workers for beryllium sensitivity, to make sure the workers are not at risk of developing beryllium related diseases and to prevent further beryllium exposure.

Since the Livermore lab does not plan to get rid of the beryllium because it will cost millions of dollars, they have chosen to test all of the exposed workers to see if they have the gene for **Be** sensitivity. If the test comes back positive, how should the workers be treated?

They have asked you to advise them on how to treat all their workers fairly. Should the **Be** sensitive workers be fired? Should the **Be** sensitive workers get extra health insurance? Should **Be** sensitive workers be forced to wear protective gear? Should the company they work for help them find a different job?

Use the ethical decision framework that follows to make a decision about what course of action the Livermore lab should take.

How SIMILAR or DIFFERENT Are We From Each Other?

Ethical Decision-Making Framework

What do you think is the ethical problem?

Ethical Problem- Testing workers genes for sensitivity to certain chemicals may mean some people who are sensitive to certain chemicals at work get treated differently from those who are not sensitive.

Students need to discuss what the Livermore Lab should do to fairly address the issue of certain workers being sensitive to Be exposure and others not being sensitive to Be exposure.

How SIMILAR or DIFFERENT Are We From Each Other?

What are relevant facts? (Consider what you read above and what you have learned about beryllium sensitivity.)

- *Beryllium (Be) is found naturally in food and water,*
- *High Be exposure is mostly caused by working with Be in factories where Be dust can be easily inhaled.*
- *Beryllium is used in such products as cell phones, aircraft engine parts and nuclear workers use them to make triggers for nuclear bombs.*
- *Some people who are exposed to Be develop a disease called Chronic Beryllium Disease (CBD).*
- *CBD is a disease that is characterized by an accumulation of T cells in the lungs.*
- *T cells help the body fight infection.*
- *When there are too many T cells in the lungs they damage the lungs and cause shortness of breath and dry coughing.*
- *Changes in a gene called, HLA DP (human leukocyte antigen) causes people to be sensitive to exposure to Be.*
- *HLA DP has the instructions to make a protein that helps T cells do their job.*
- *Scientists discovered that people who are sensitive to Be have a different sequence of amino acids.*
- *Only a small portion (1-15%) of the population is Be sensitive.*
- *At Lawrence Livermore Labs in California, as many as 178 GSE Construction workers may have been exposed to the known carcinogen (cancer causing) beryllium, a toxic metal that can cause lung cancer and chronic beryllium disease.*
- *Results from a routine beryllium test revealed dangerously high levels of beryllium as early as July 2007.*
- *GSE contract workers may have been unknowingly exposed to beryllium and placed at risk of developing beryllium related diseases (CBD).*
- *Normally, when exposures to Be becomes known, the policy is to test workers for beryllium sensitivity, to make sure the workers are not at risk of developing beryllium related diseases and to prevent further beryllium exposure.*
- *The Livermore lab does not plan to get rid of the beryllium because it will cost millions of dollars*
- *All of the exposed workers will be tested to see if they have the gene for Be sensitivity*

How SIMILAR or DIFFERENT Are We From Each Other?

What are questions that are still unknown?

Answers will vary

Here are some potential actions the Livermore lab could take.

- Offer extra health care to the people who are sensitive
- Fire the workers who are sensitive
- Treat all workers the same (no one is fired and all workers get the same amount of health care and the same protective gear)

List three more actions the Livermore lab could take:

Answers will vary

What stakeholders should you consider?

The Be sensitive people (people who test positive for sensitivity to Be)
The Be non sensitive people (people who are not sensitive to Be)
Livermore Labs
Students may list others but these are the main stakeholders they should list

What stakeholder did your teacher assign you? _____

What do you think are the concerns of your stakeholder?

Answers will vary

How SIMILAR or DIFFERENT Are We From Each Other?

What action does your stakeholder think the Livermore lab should take?

Answers will vary

Explain why your stakeholder has chosen that action:

Answers will vary

Now as a whole class, fill out this chart with all the stakeholders and their actions.

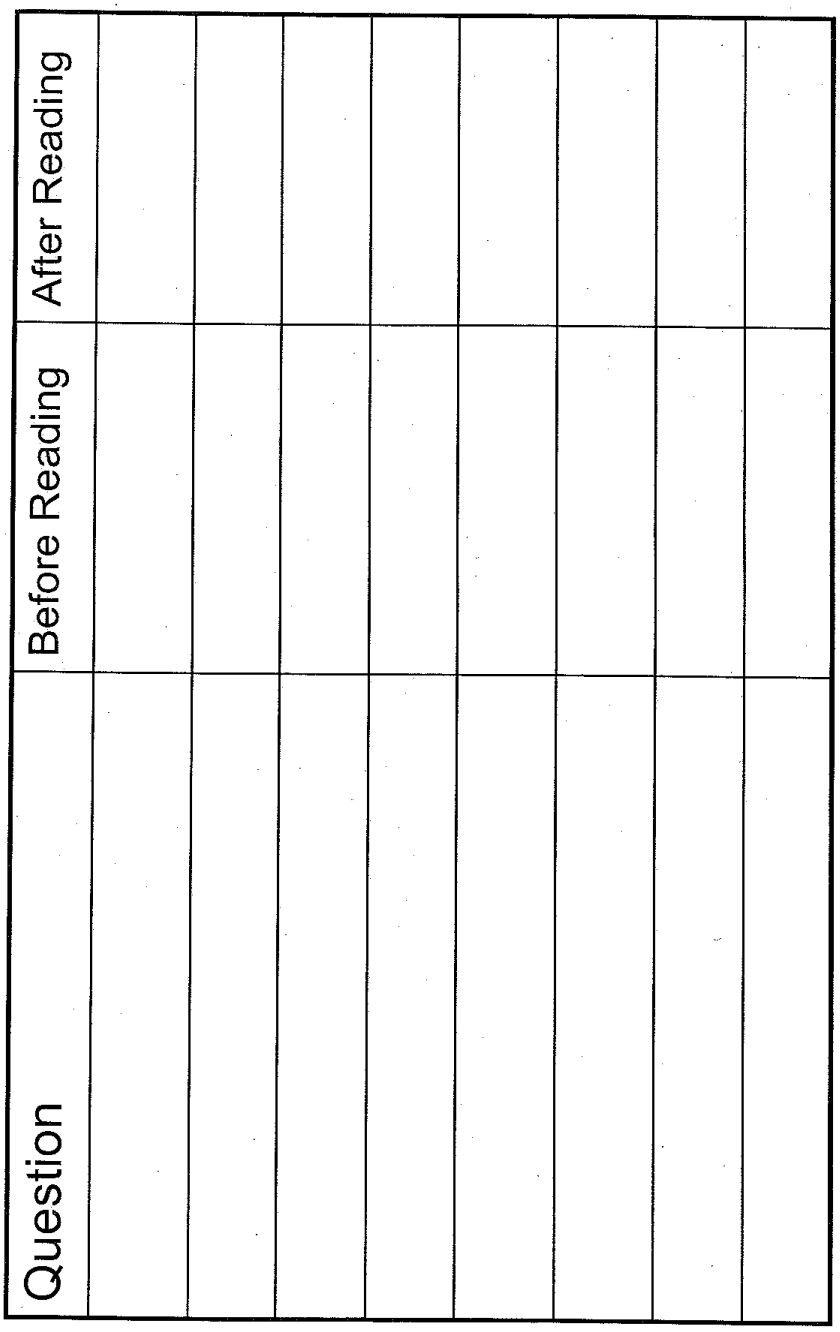
Who are the stakeholders?	**What action is this stakeholder recommending?**

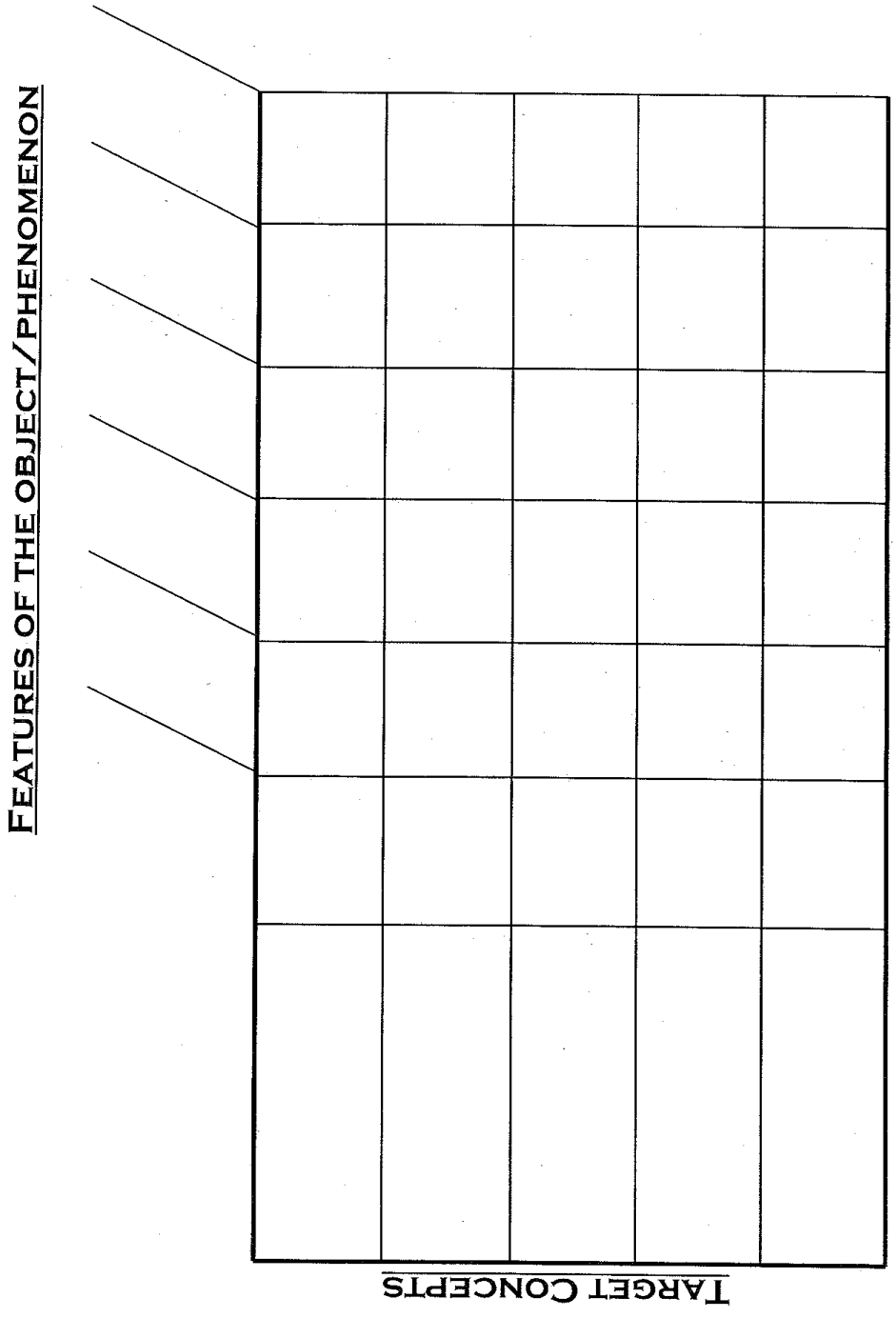
What action(s) do you recommend the Livermore labs take? Why?
Answers will vary

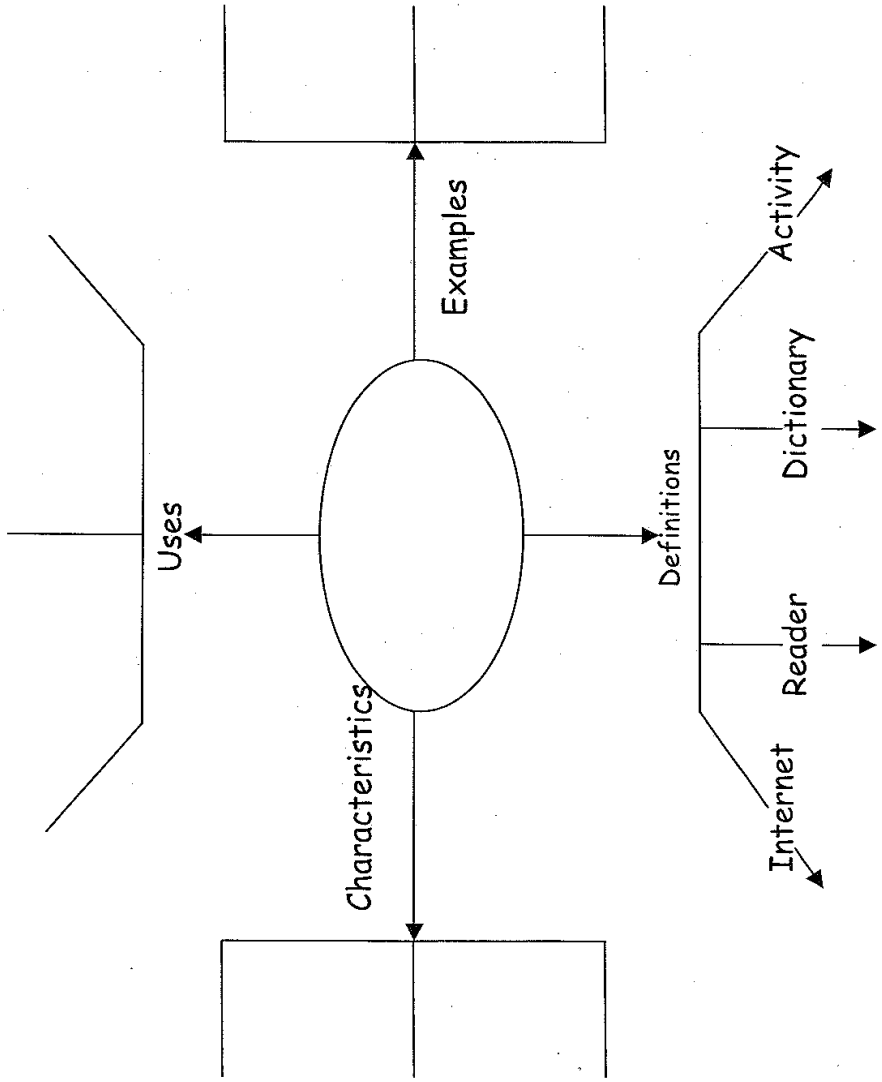
Resources
Canadian Center for Occupational Health and Safety, Beryllium Disease
http://www.ccohs.ca/oshanswers/diseases/beryllium.html

****Beryllium Network, Beryllium Exposure Warning Arrives Too Late for Contract Workers at Livermore Lab
http://www.chronicberylliumdisease.com/news/nw_020808_contract_workers_livermore_lab.htm

CDC Public Health Genomics, HLA-DPB1 and Chronic Beryllium Disease
http://www.cdc.gov/genomics/hugenet/reviews/beryllium.htm


Question
Before Reading
After Reading


FEATURES OF THE OBJECT/PHENOMENON
TARGET CONCEPTS


Examples
Uses
Definitions
Activity
Dictionary
Reader
Internet
Characteristics