How Do Siamese Cats Get Their Coat Coloration?

image: https://upload.wikimedia.org/wikipedia/commons/f/fa/Female_siamese_cat.jpg

TEACHER EDITION

Lesson Set: How Do Siamese Cats Get Their Coat Coloration?

OVERVIEW

Purpose

The purpose of these lessons are for students to further explore protein structure and function and to learn how proteins lead to observable traits.

Sequencing

This lesson set is designed to be taught prior to the introduction of the central dogma (DNA -> RNA -> protein) and the details of transcription and translation.

This lesson set is designed to be taught after the introduction of protein functions and cellular specialization. Students should know some examples of protein functions, that proteins do the work of the cell, that somatic cells in our body contain the same DNA, and that specialized cells express different genes to create different proteins specific for the function of the specialized cell.

Description

This learning set is centered around the Driving Question (DQ) "How do Siamese cats get their coat coloration?" Students will use this example to see how proteins can lead to observable traits. In the first lesson, Students will use paper models to show how enzyme structure in the active site relates to function. Students will use computer models in the second activity to show how proteins interact with other molecules in 3D. In the third activity, Students will experiment with Jell-O and fruit juices to show enzymes in action. In the fourth activity, Students will look at different molecular motor proteins and learn how their structure and function relate. In the fifth activity, Students explore how proteins synthesize melanin and pigments lead to observable traits. At the end of this learning set, students will be able to explain how the enzyme tyrosinase causes the coat coloration of Siamese cats.

NGSS Standards & Performance Expectations

- HS-LS1 From Molecules to Organisms: Structures and Processes
  - HS-LS1-1. Construct an explanation based on evidence for how the structure of DNA determines the structure of proteins which carry out the essential functions of life through systems of specialized cells.
- HS-LS3 Heredity: Inheritance and Variation of Traits
  - HS-LS3-1. Heredity: Ask questions to clarify relationships about the role of DNA and chromosomes in coding the instructions for characteristic traits passed from parents to offspring

NGSS Science and Engineering Practices (SEP)

- Developing and Using Models
  - Develop and use a model based on evidence to illustrate the relationship between systems or between components of a system. (HS-LS1-2)
  - Initial models - day 1, revised models - day 5, final models - day 7
- Constructing Explanations and Designing Solutions

- Construct an explanation based on valid and reliable evidence obtained from a variety of sources (including students' own investigations, models, theories, simulations, peer review) and the assumption that theories and laws that describe the natural world operate today as they did in the past and will continue to do so in the future. (HS-LS1-1)
- Jell-O explanation- day 4, myosin protein explanation - day 5, catechol oxidase explanation - day 6

NGSS Disciplinary Core Ideas (DCIs)

- LS1.A: Structure and Function
  - All cells contain genetic information in the form of DNA molecules. Genes are regions in the DNA that contain the instructions that code for the formation of proteins, which carry out most of the work of cells. (HS-LS1-1, HS-LS3-1)
  - Models for enzyme active site structure/function - day 1, computer animation - day 2, Gleevec treatment for CML - day 3-4, molecular motor animations - day 5, heat/acid denaturation of catechol oxidase - day 6-7
- LS3.A: Inheritance of Traits
  - Each chromosome consists of a single very long DNA molecule, and each gene on the chromosome is a particular segment of that DNA. The instructions for forming species' characteristics are carried in DNA. All cells in an organism have the same genetic content, but the genes used (expressed) by the cell may be regulated in different ways. Not all DNA codes for a protein; some segments of DNA are involved in regulatory or structural functions, and some have no as-yet known functions. (HS-LS3-1)
  - Mutation in Siamese cats - day 6

NGSS Crosscutting Concepts

- Structure and Function
  - Investigating or designing new systems or structures requires a detailed examination of the properties of different materials, the structure of different components, and connections of components to reveal its function and/or solve a problem. (HS-LS1-1)
  - Structure function paper modes - day 1, computer animations - days 2 & 5, readings - day 3-4, experimentation day 6-7, culminating in explanatory model using structure/function - day 7

Common Core State Standards Connections

- ELA/Literacy
  - WHST.9-12.5: Develop and strengthen writing as needed by planning, revising, editing, rewriting, or trying a new approach, focusing on addressing what is most significant for a specific purpose and audience
  - WHST.9-12.7: Conduct short as well as more sustained research projects to answer a question (including a self-generated question) or solve a problem; narrow or broaden the inquiry when appropriate; synthesize multiple sources on the subject, demonstrating understanding of the subject matter under investigation

- Students revise their models in light of new data and information, adding explanatory processes, culminating in a final explanatory model

Learning Goals

Students will describe structure-function relationships in proteins.
Students will explain how proteins lead to characteristics (observable traits) of an organism.
Students will explain how organisms make proteins to drive life processes such as movement.

Preparation

Activity 1

- Make copies of enzymes/substrates (optional - laminate copies), cut them out
- Make packets containing one each of enzymes (E1-4) and substrates (S1-9) and put in envelopes for students - each student (or group) needs one packet

Activity 3 (Jell-O experiment)

- Prepare pureed FRESH fruit with juice filtered from pulp: pineapple, apple, orange, kiwi fruit
- Juice from concentrate (thawed): pineapple, apple, orange, kiwi (if able to find)
- Mix up meat tenderizer solutions (2 tablespoons tenderizer in 1 cup warm water)
- Prepare gelatin mixture using only half the amounts of boiling and cold water

Activity 5 (catechol experiment)

- If using potatoes and catechol
  - Prepare pureed potato extract using a blender or mortar and pestle
  - Heat 1/3 of it to denature proteins, chill 1/3 of it, keep other 1/3 at room temp.
- If using apples and lemon juice
  - Cut apples into quarters
  - Dip two quarters in lemon juice, put one in refrigerator and one at room temp. in baggies
  - Keep two quarters out of lemon juice, put one in refrigerator and one at room temp. in baggies

Time

Approx. 6-9 class periods, depending on doing readers in/out of class time

Materials

Introduction/Jumpstart

- Jumpstart sheet

Activity 1

- Activity Sheet 1
- Enzyme/substrate packets

Activity 2

- Activity Sheet 2
- Computers with access to internet

Activity 3

- Activity Sheet 3

- Prepared gelatin mixture
- Prepared fruit juices
- Prepared tenderizer solutions
- Measuring cups
- Test tube racks (one per group)
- 10 test tubes or 10 15 mL conical vials per group
- Pipettes for each fruit juice/tenderizer
- Refrigerator
- Tape to label test tube racks

Activity 4

- Activity Sheet 4
- Computers with access to internet or one computer with projector do view as a class

Activity 5

- Activity Sheet 5
- If doing potato/catechol experiment
  - Prepared potato extract
  - Catechol solution (poisonous!)
  - Test tube racks (one per group)
  - 7 test tubes per group
  - Pipettes for each solution
  - Beaker and hot plate for heating potato extract
  - Beaker and ice for chilling potato extract
- If doing apple/lemon juice experiment
  - 2+ apples
  - Knife
  - Lemon juice
  - 4+ baggies
  - Refrigerator
  - Marker for labeling baggies

INSTRUCTIONAL SEQUENCE

Teaching Strategy: Student Discussions

- Questions are provided to guide the discussion and should not be used as a checklist or exact sequence. Let the natural conversation and discussion flow.
- The goal is not to hunt for the "correct answer" but to engage students in a discussion and to listen to ideas and questions students have.
- In order to promote more student discussions in the classroom, we are trying to move away from the traditional "IRE" - initiate, respond, evaluate style of teaching.

Introducing the learning set

Give students the "How do we get observable traits?" jumpstart worksheet to get them thinking about how proteins could lead to observable traits. This learning set centers around the DQ "How do Siamese cats get their coat coloration?" This sheet provides several examples of how Siamese cat colorations can be altered with temperature,

generating student interest in the problem. At the end of the sheet, students will make their initial models of how they think Siamese cats get their coloration.

Introducing the lesson

Have students think about what they learned previously about proteins in cells. Engage students in a discussion of what they have previously learned about proteins in cells. Some topics that may come up are different types of proteins, what proteins do, what DNA is in cells, types of cells that have different proteins, etc. Guide students to thinking about how enzymes function and why enzymes are important.

Sample questions:

- Do all cells have the same DNA to make the same proteins?
  yes
- Do all cells have the same proteins?
  no
- What are proteins?
  string of amino acids folded up that does a function in a cell
- Where are proteins found?
  in cells, they are a major component of cells
- What do proteins do?
  perform structural functions, help cells move, help cells keep their shape, receive signals, do chemistry, etc.
- How do you think proteins do chemistry/catalyze reactions?
  various responses, just want ideas
- What are the proteins called that do chemistry/catalyze reactions?
  enzymes
- Why do you think enzymes are important?
  various responses, just want ideas

Activity 1

Purpose: to further investigate proteins/enzymes and how their structure relates to their function

Teaching Background: Proteins

- Proteins are further discussed in this lesson in more detail.
- Research has shown the importance of proteins is not emphasized enough for students to understand how proteins lead to observable traits.
- At this point students will understand that proteins are made of amino acids, have many different functions inside of cells, and do the majority of the work inside of cells.
- Students will learn different structures and functions of proteins in more detail in this lesson and eventually how proteins lead to observable traits.

Engage students in a discussion of what they have previously learned about proteins and enzymes. Some topics that may come up are different types of proteins, what

proteins do, what an enzyme is, why they are important, etc. Guide students to thinking about how enzymes function and why enzymes are important.

Sample questions:

- What is an enzyme?
  protein that catalyzes a reaction
- Why are they important?
  various responses
- Do you know some examples of enzymes?
  various responses

Carrying out Activity 1

Prior to the activity, the teacher needs to prepare enzyme/substrate packets for the students. Each student or small group of students should receive a packet containing enzymes E1-4 and substrates S1-9. These should be cut out so students may manipulate them. They can be laminated (optional).

Students will first predict what type of cell they would expect an enzyme that breaks down food to be in. The will then work in groups to draw a picture of what they think an enzyme that breaks down food looks like. Students should focus on labeling important things and explaining how their enzyme breaks down food.

Students will then manipulate the enzymes and sugars/substrates, fill in the chart to see which substrates fit, and answer the questions about the enzymes and their sugar substrates. Students will move on to the "Making Sense" part of the activity where they will relate structure of the enzyme active site to the function of the protein.

Wrapping up Activity 1

Engage students in a discussion of what they learned about enzymes. Some topics that may come up are different kinds of enzymes, shapes of enzymes, active sites in enzymes, different substrates for enzymes, changing shape of enzymes, etc. Guide students to thinking about how enzymes function and why enzymes are important.

Sample questions:

- What did you notice about the notches in the enzymes?
  they had different shapes
- What are the notches called?
  active sites
- What do the active sites of enzymes do?
  form the binding site for substrates
- Why do different enzymes have different shaped active sites?
  they catalyze different reactions
- What do you think would happen if the active site was a different shape?
  various responses

Add words to vocabulary wall:

enzyme
substrate
active site
catalyze

Reading 1
Purpose: to show students an example of an enzyme and how it functions in human cells

Students may do this reading in class or as homework.

Wrapping up Reading 1
Engage students in a discussion of what they learned about the enzyme lactase. Some topics that may come up are different types of enzymes, what lactase does, the substrate of lactase, what lactase looks like, how our body breaks down lactose, what lactose intolerance is, if people can eat ice cream with lactose intolerance, why the lactase gene usually shuts off after the age of 4, how genes shut off, etc. Guide students to thinking about how enzymes function and why enzymes are important in the body. If there is time/interest, watch a short video about lactase persistence.

HHMI Video about lactase persistence: http://www.hhmi.org/biointeractive/making-fittest-got-lactase-co-evolution-genes-and-culture

Sample questions:

- What is lactose?
  a complex sugar (disaccharide) made up of galactose and glucose, milk sugar
- Where is it found?
  in dairy products
- Can your body use lactose as energy?
  not until it is broken down
- How does your body break down lactose?
  the enzyme lactase breaks it down into glucose and galactose
- What is lactose intolerance?
  when someone cannot digest lactose; get cramps, nausea, diarrhea when consume lactose
- What is lactose intolerance caused by?
  when your body no longer produces the lactase enzyme
- When does that happen?
  usually happens after age of 4, some people never have gene turned off (due to mutation) so they can ingest lactose for lifetime
- What happens when someone who is lactose intolerant ingests lactose?
  bacteria in the gut utilize it for food, producing gas and the symptoms described earlier
- What is LACTAID?
  purified lactose enzymes
- How do you get purified enzymes/proteins?

insert genes for proteins inside of bacteria/yeast/fungi to make them produce that protein (turn them into little factories), then they can be lysed to harvest the protein and purified from the other stuff inside the cells

- Can lactose intolerant people ingest dairy?
  LACTAID contains the enzyme lactase which will digest the lactose that your body cannot, some milks and stuff are pre-treated with lactase to break down lactose
- What do you think the enzyme lactase looks like?
  various responses

Activity 2

Purpose: to further investigate enzymes and how their structure relates to their function

Engage students in a discussion of what they learned about enzymes. Some topics that may come up are different types of enzymes, what enzymes do, what happens after an enzyme catalyzes a reaction, if reactions can be sped up or slowed down, if enzymes look different, if enzymes do more than one thing, etc. Guide students to thinking about how enzymes function and why enzymes are important in the body.

Sample questions:

- What are enzymes?
  proteins that catalyze a reaction
- Can enzymes catalyze more than one reaction?
  can catalyze one reaction, but do that reaction multiple times
- Do you think an enzyme looks different after it catalyzes a reaction?
  various responses
- What do you think would happen if an enzyme did change after it catalyzed a reaction?
  various responses
- Can you think of any ways to change the structure of an enzyme?
  various responses
- Can you think of any ways to speed up or slow down a reaction catalyzed by an enzyme?
  various responses

Carrying out Activity 2

Students or student groups will need computers with internet access for the tutorial about enzymes. Students will step through the tutorial, answering questions along the way. Students will then move on to the “Making Sense” part where they will apply what they learned in the activity to new situations. They will also be asked to think about what they have learned and build upon their explanation of what happens with the Siamese cat (DQ).

Wrapping up Activity 2

Engage students in a discussion of what they learned about enzymes. Some topics that may come up are different types of enzymes, how enzymes are useful, how enzymes

can denature/change shapes, what happens when enzymes change shapes, why enzymes should be kept cold, what happens when enzymes are warmed up, etc. Guide students to thinking about how enzymes function and why enzymes are important in the body.

Sample questions:

- Why are enzymes useful?
  they catalyze reactions and make them go faster
- What are some different things that can change shapes of enzymes?
  heat, pH, etc.
- How do these change the shapes?
  they denature the enzymes and make them long strings of amino acids
- What would happen if you added more enzymes to a reaction?
  it would go faster
- Why should enzymes be kept cold?
  heat denatures enzymes and makes them not work
- What would happen to insulin if it were left at room temperature for hours?
  it would denature and wouldn't work anymore

Add word to vocabulary wall:

denature

Reading 2

Purpose: to show students another example of an enzyme and how it functions in cells

Students may do this reading in class or as homework.

Teaching Background: Enzymes

- Several examples of enzymes and proteins are given during this unit.
- Students may start to think that enzymes only break down sugars (several examples of this in the unit) and this is not correct.
- The teacher may wish to create a chart to post in the front of the room (or students keep sheets) with the name of the protein, if it is an enzyme (y/n), and then function to keep track of the proteins and enzymes discussed in class.

Wrapping up Reading 2

Engage students in a discussion of what they learned about the enzyme cellulase. Some topics that may come up are what wood is made of, why plants grow tall without a skeleton, what cell walls are made of, what cellulose is, how termites digest cellulose, why humans/mammals can't digest cellulose, what happens when we eat cellulose, etc. Guide students to thinking about how enzymes function and why enzymes are important in the body.

Sample questions:

- What is wood made of?
  plant cells, mainly xylem, cellulose

- What is xylem?
  the cells of the plant that carry water from the roots to the top of the tree/leaves
- Why can plants grow tall when they don't have a skeleton?
  they have cell walls that are hard and provide support
- What are the cell walls made of?
  mainly cellulose
- What is cellulose?
  a complex sugar made of long chains of glucose molecules hooked together
- Can mammals digest cellulose?
  no, we can't break cellulose down
- How can termites eat wood?
  they can digest cellulose, which makes up 40-50% of wood
- How do they digest cellulose?
  the enzyme cellulase breaks cellulose down into glucose molecules
- What happens when humans ingest cellulose?
  it is fiber or roughage for our body

Activity 3

Purpose: to test for the presence and specificity of enzymes in fruits

Engage students in a discussion of what they know about enzymes and their function. Also, show students a Jell-O box and let them see that it says not to add fresh pineapple to the Jell-O. Ask the students about this. Some topics that may come up are different types of enzymes, where enzymes are found, if there are enzymes in plants and fruit, what happens when you add pineapple to Jell-O, what would happen if the pineapple was not fresh, what Jell-O is made of, etc. Guide students to thinking about how enzymes function and where they're found.

Sample questions:

- Where can you find enzymes?
  in cells
- Are there enzymes in plants?
  yes
- What kind of enzymes?
  various responses
- Are there enzymes in fruit?
  yes
- Have you ever seen the back of a box of Jello tell you not to add fresh pineapple to the Jell-O?
  various responses, hopefully some yes (show students a box)
- Why do you think it tells you not to do that?
  various responses
- What do you think happens when you add fresh pineapple to Jello?
  it won't set up
- Why would that be?
  various responses

- What is gelatin/Jell-O?
  a solid substance derived from collagen inside of animal's skin and bones; mainly collagen (a protein)
- What do you think the fruit would do to the Jell-O?
  various responses

Carrying out Activity 3
Activity adapted from: http://www.accessexcellence.org/AE/AEPC/WWC/1991/enzymes.php

*Care should be taken to avoid burns on the hot Jell-O
*Students should be instructed NEVER to taste anything in the laboratory
*Be aware of any dietary restrictions (kosher/halal Jell-O)

Several solutions need to be made prior to the laboratory:

- Fruit juice
  pureed FRESH fruit with juice filtered out from pulp (orange, apple, pineapple, kiwi)
  frozen juice concentrate, thawed (apple, orange, pineapple)
  testing 4 different fruits: pineapple, kiwi, apple, orange - fresh and concentrated for each
  *note - lab is written for 3 concentrates and 4 fresh juices, if you are able to find concentrated kiwi fruit, you may use it as well; modify the charts for 11 samples and give students 11 test tubes
  need enough juice for each group to use 3 mL of each juice
- Gelatin mixture
  prepare gelatin mixture using only half the amounts of boiling and cold water
  stir until dissolved
  need enough gelatin mixture for each group to use 100 mL total (10 x 10 mL) or 110 mL total (11 x 10 mL) if doing 11 samples
- Meat tenderizer solution
  2 tablespoons tenderizer in 1 cup warm water, stir until dissolved (may not completely dissolve)
  two different meat tenderizers
  need enough solution for each group to use 3 mL per tenderizer

Laboratory stations should also be set up with 10 test tubes per group with a rack (11 if also using kiwi from concentrate), tape for labeling rack, pipettes for each fruit juice (do NOT cross-contaminate between juices), pipettes for the gelatin mixture and meat tenderizer (do NOT cross-contaminate), and distilled water.

Students will first answer the questions at the beginning of the lab and make their predictions about what will happen to the Jell-O when different additives (fruit juice, meat tenderizer, water) are added. Students should be reminded to have a control (water) in their experiment (so they will have water, 2 different meat tenderizers, and 7 juices for 10 samples total). Students will then label their test tubes 1-10 and their rack

with their names. Students will place 10 mL of the Jell-O/gelatin mixture into each test tube.

They will then place 3 mL of each test liquid into each tube and record which additive they put in each numbered tube. Students should be reminded and watched so that they do not mix the pipettes between the juices/liquids. Students will then cover each test tube with their thumb and invert to mix the liquids, being careful not to contaminate the solutions.

The racks of test tubes will then be placed in the refrigerator overnight to solidify. The next day, students will look at their test tubes and record their observations. They will then move on to the "Making Sense" section where they will answer questions about their control, and the results of their experiment. The students will also be asked to apply their knowledge in new situations and relate their findings to what they have previously learned about heat denaturing.

* An extension activity could be to boil fresh pineapple juice and test this as well to see how heat inactivates enzymes

Wrapping up Activity 3

Engage students in a discussion of what they learned about enzymes and fruit. Some topics that may come up are what enzymes are present in the fruit, why the apple and orange juice let the Jell-O set up, why the fresh pineapple/kiwi juices made the Jell-O stay liquid, why the pineapple/kiwi juices from concentrate made the Jell-O set up, what is in meat tenderizers, what meat tenderizers do, why people in pineapple processing plants wear gloves and masks, what happens when enzymes are warmed up, etc. Guide students to thinking about how enzymes function and why enzymes are important.

Sample questions:

- Which test tube was your control?
  the one with the water and gelatin/Jell-O
- Which of the additives made the Jello stay liquid?
  answers may vary but should include pineapple (fresh), kiwi (fresh), meat tenderizers
- Which of the additives made the Jell-O solidify?
  answers may vary but should include water, orange, apple, pineapple (from concentrate), kiwi (from concentrate)
- Why do you think the fresh pineapple juice made the Jello stay liquid?
  it has proteins/enzymes that break down the collagen
- Why do you think the pineapple juice from concentrate made the Jello solidify?
  the concentrate solution was heated and the enzymes denatured so could no longer function to break down collagen
- Why do you think the apple/orange juice did not effect the Jello?
  it does not have proteins/enzymes that break down collagen
- Why do you think people in pineapple processing plants wear gloves and masks?

so they don't breathe in or touch the enzymes which break down the collagen - it would destroy their skin/lung tissues

- What do you think would happen if you heated the fresh pineapple juice before you added it to the Jell-O?
  the proteins/enzymes may denature and not work anymore so the Jello would solidify - would act like pineapple juice from concentrate

Reading 3

Purpose: to show students how scientists know what proteins look like

Students may do this reading in class or as homework.

Wrapping up Reading 3

Engage students in a discussion of what they learned about how scientists "see" protein structures. Some topics that may come up are size of proteins, what proteins look like, how scientists "see" proteins, why you want to know the structures, why you can't use a microscope to see proteins, what x-ray crystallography is, how molecules can inhibit enzyme functions, what the BCR-ABL mutant protein is, how Gleevec works, etc. Guide students to thinking about how knowing protein structures helps determine functions.

* Extension: visit www.insidecancer.org, diagnosis & treatment, targeted activators, Gleevec & Chronic Myeloid Leukemia to view short videos about CML and Gleevec

Sample questions:

- How big are proteins?
  1-100 nm
- What do proteins look like?
  some globular, some have domains/pieces sticking off, shapes vary
- Can scientists use microscopes to look at proteins?
  not really
- How do scientists know what proteins look like?
  mainly by using x-ray crystallography
- Why do scientists want to know what proteins look like?
  structure and function relationships
- What can you do knowing the structure of proteins?
  design drug targets, predict functions, look at how other proteins could bind
- What is a chromosome translocation?
  when two chromosomes break and then swap pieces and fuse back together
- What is the Philadelphia chromosome?
  a mutant chromosome formed from a chromosome 9 and 22 translocation
- Why is this translocation particularly bad?
  breaks are in the middle of genes, the silencing domain from ABL1 is broken off; ABL1 gene gets fused to BCR gene and this makes a mutant protein where ABL1 is always on
- What is the normal function of ABL1?
  signals cells to grow and divide

- How does this mutation help cause CML cancer?
  the protein to signal cells to grow and divide is always on, so cells grow and divide more, which can help lead to cancer
- What is Gleevec?
  a small molecule that binds to the active site of the mutant BCR-ABL protein
- How does it help treat CML?
  it fits into the active site of BCR-ABL so that it can't signal the cell to grow and divide
- How does knowing the structure of the BCR-ABL protein help?
  you can design a small molecule to fit the mutant active site

Activity 4

Purpose: to further investigate proteins and how their structure relates to their function

Teaching Background: Chemistry

- This activity is a bit rich in chemistry (ATP hydrolysis, ADP exchange, proton pumps) which may be a problem for students since most have not yet had chemistry.
- The activity may be modified to fit the needs of your students and class.
- The activity could be done all together as a class (recommended), questions dealing with ATP/ADP could be omitted from the worksheets, or the animations/videos could just be watched to simply provide more examples of protein functions for students.

Engage students in a discussion of what they know about enzymes. Some topics that may come up are how structure relates to function, how scientists know structures of proteins, what kinds of proteins are in cells, if students have heard of molecular motors (such as myosin, kinesin), what they think molecular motors do, etc. Guide students to thinking about how enzymes function and why structure of proteins is important for function.

Sample questions:

- Why is it important to know the structure of proteins?
  structure and function go hand-in-hand
- What are some examples of proteins you find in cells?
  various answers
- What do those proteins do in cells?
  various answers
- Have you heard of molecular motors?
  various answers, probably "no"
- What do you think molecular motors do?
  various answers

Carrying out Activity 4

Students will first watch the video "The Inner Life of a Cell" as a class to view a molecular motor (kinesin) pulling a vesicle inside of the cell and will predict how they think it is able to move like that. Two versions of the video are on the student sheet: one with music and one with narration. Teachers may wish to introduce the activity with

the version with music and get student ideas, then later in the activity show the version with narration. It is up to the teacher which version to show to the class.

Music: http://www.studiodaily.com/2006/07/cellular-visions-the-inner-life-of-a-cell/
Narration: http://multimedia.mcb.harvard.edu/anim_innerlife.html

Teaching Background: Proteins

- Proteins are further discussed in this activity in more detail.
- Research has shown the importance of emphasizing different functions of actual proteins in cells to give students more examples of what proteins do in cells.
- Students will learn different structures and functions of proteins in more detail in this activity

Students will then watch short videos on kinesin and myosin (from this website: http://www.molecularmovies.com/showcase/#Cytoskeleton%20/%20Molecular%20Motors) and answer questions about those molecular motors and how they work.

This activity may be done individually with students (or groups of students) sharing a computer or may be done as a class. It is up to teacher discretion because this lesson is fairly heavy in chemistry and most students have not yet had chemistry, but it is recommended that this be done together as a class to be able to talk through the examples of motor proteins. If done as a class, the teacher only needs a computer with access to the internet and a projector and sound and students will not need computers.

Students will then move on to the "Making Sense" portion where they will answer questions asking about why these proteins are called "motors" and why they are important. Students will also be asked to apply their knowledge of myosin and predict how a mutation in cardiac myosin could cause an enlarged heart and sudden death. Students will also be asked if they think proteins can cause observable traits and will be asked to create a revised model of how they think Siamese cats get their coloration.

<u>Wrapping up Activity 4</u>
Engage students in a discussion of what they learned about molecular motors. Some topics that may come up are different types of enzymes in the body, what kinesin does, how proteins move, how kinesin and myosin "walk," how ATP/ADP exchange works, what ATP and ADP are, why ATP/ADP exchange causes changes, how structure relates to function, how a mutation in a protein could cause something bad to happen, if a mutation in a protein could cause a disease or a trait that you could see, etc. Guide students to thinking about how enzymes function and why structure of proteins is important.

Sample questions:

- What is kinesin?
  a motor protein that pulls organelles along microtubule "tracks" in the cell
- How does kinesin work?

motor head binds to microtubule, ADP is released, ATP binds and triggers neck linker to zipper on to catalytic core, this throws second motor head in front of first motor head, the attached trailing head then hydrolyzes ATP to ADP + Pi and the front head releases ADP and ATP binds, cycle repeats for kinesin to "walk" along the microtubule track

- How does its structure relate to its function?
  has two motor heads which bind and "walk" along the microtuble track, have a long region to bind to an organelle
- What is myosin?
  a protein that is involved in muscle contraction
- How does myosin work?
  catalytic core contain ADP + phosphate, bind to actin, phosphate released, core binds tighter and changes conformation to pull actin, then ADP released, ATP binds, myosin head detaches from filament, then ATP hydrolyzed which changes conformation back to relaxed state
- Are these proteins molecular motors?
  yes
- Why?
  various answers, they use energy to move, they do the same things over and over, etc.
- How could a mutation in cardiac myosin cause an enlarged heart and sudden death?
  various answers, example: myosin would not be able to contract the heart muscle as well so it would not be able to pump blood throughout the body
- Can proteins cause observable traits?
  various answers
- Why or why not?
  various answers

Reading 4

Purpose: to further investigate proteins and how they lead to traits

Students may do this reading in class or as homework.

Wrapping up Reading 4

Engage students in a discussion of what they learned about blood type. Some topics that may come up are what antigens are, what the difference is between Type A and Type B blood, what the difference is between type AB and Type O, what antibodies people with certain blood types have, what the Rh factor is, what the Rh factor does, what Rh disease is, how Rh disease is prevented, what types of blood people with certain blood types can receive, why Type O- is the universal donor, why Type AB+ is the universal receiver, what immune rejection is, etc. Guide students to thinking about how proteins are important for blood types.

Sample questions:

- What are antigens?

antibody generators, proteins or short sequences of proteins that antibodies can bind

- What is the difference between Type A and Type B blood?
  Type A has A antigens on the red blood cells; Type B has B antigens on the red blood cells
- What is the difference between Type AB and Type O blood?
  Type AB has both A and B antigens on the red blood cells; Type O has neither A nor B antigens on the red blood cells
- What antibodies does someone who has Type B blood have?
  type A antibodies
- Why are some blood types positive and some types negative?
  positive refers to Rh factor positive, they contain an additional Rh antigen; negative means they do not have the Rh antigen
- When does one get Rh disease?
  when an Rh- mother is pregnant with an Rh+ child and the baby's blood mixes with the mothers; normally occurs in second or subsequent Rh incompatible pregnancies
- What causes Rh disease?
  the baby's blood mixes with the mother's blood and she begins to produce antibodies against the D/Rh antigen to attack the foreign blood cells
- What can happen to the baby if the Rh disease is not treated?
  baby can develop anemia (fewer RBCs/hemoglobin) or be stillborn in severe cases
- How is Rh disease treated/prevented?
  Rh- mothers get a shot of antibodies against the Rh/D antigen at 28 weeks gestation to attack any of the baby's Rh+ blood cells before they are discovered by the mother's immune system and she begins to raise antibodies against them
- What blood types can someone who is type B positive receive?
  Types B+, B-, O+, O-
- What blood types can someone who is type O positive receive?
  Types O+, O-
- Why is Type O negative the universal donor?
  the red blood cells do not contain any A or B or Rh antigens
- What blood type is the universal acceptor and why?
  Type AB+ because their red blood cells contain A, B, and Rh antigens, so they do not have those antibodies; there are no A, B, or Rh antibodies to attack the different red blood cells

Add words to vocabulary wall:

antigen
immune rejection

Activity 5

Purpose: to show how proteins lead to observable traits
Activity adapted from: http://www.science-projects.com/Tyrosinase.htm

Carrying out Activity 5
Students must first read the pre-lab for the necessary background information and answer the pre-lab questions (done in class or as homework the night before).

**Reading 5 may be done in class or as homework between pre-lab and the actual laboratory portion of Activity 5. This reading should help students understand the laboratory and should help students begin to connect the laboratory to the DQ Siamese cat example. (more on Reading 5 after Activity 5 break-down)

Teaching Background: Skin color
- Catechol oxidase and tyrosinase are discussed in this lab as examples of how proteins lead to observable traits.
- Students should be told that skin color is a result of several different genes and is not just a result of the production of melanin.

Engage students in a discussion of what they learned about enzymes. Some topics that may come up are what catechol oxidase is and what it does, where catechol is found, what benzoquinone is, what happens to an apple if you cut it up and sit it out on the table, what happens to benzoquinone in cells, what melanin is, where you can find melanin, what an albino is, how much melanin an albino has, why the siamese cat is colored the way he is, etc. Guide students to thinking about how enzymes function and why enzymes are important in the body.

Sample questions:
- What is catechol oxidase and what does it do?
  a protein enzyme that reacts catechol with oxygen to yield benzoquinone and water
- Where is catechol found?
  in plant cells
- What is benzoquinone?
  a pigment that is a brown/black color
- What would happen to a pear if you cut it up and let it sit in a bowl on the table?
  it would turn brown because the catechol in the cells reacts with the oxygen to form benzoquinone; benzoquinone is a pigment that is responsible for the brownish color
- What happens to benzoquinone in cells?
  it gets converted to melanin
- What is melanin and where can you find it in your body?
  a pigment, mainly in your skin - responsible for skin color; some is found in hair, iris of eyes
- How much melanin would someone have who has dark skin?
  a lot
- Have you heard of an albino before?
  various responses, most yes
- What is an albino?
  someone (or something) that is very pale and has no pigments in their skin

- How much melanin would someone have who is an albino?
  none
- Look at the picture of a Siamese cat. What patterns in coat color do you notice?
  various responses - dark tail, face, ears, legs; light body color
- Why do you think Siamese cats are colored the way they are?
  various responses, maybe something about melanin

Several solutions need to be made prior to the laboratory:

- Potato extract
  pureed fresh potato, by blender or by mortar and pestle
  need enough juice for each group to use approximately 7 mL total (7 x 1 mL)
- Heated potato extract
  take 1/3 of the potato extract and heat in a beaker with stirring on a hot plate
  keep it hot for at least 10 minutes to try to denature the catechol oxidase enzymes
- Chilled potato extract
  take 1/3 of the potato extract and chill in a beaker on ice to 0-5 °C

Laboratory stations should also be set up with 7 test tubes per group with a rack, pipettes for each potato extract (do NOT cross-contaminate between extracts) and distilled water.

Students will first answer the questions at the beginning of the lab and make their predictions about what will happen to the tubes (where they think benzoquinone will form, dark color).

After answering these questions, students will set up their experiment. Students will label their test tubes 1-7 and add 5 mL distilled water to each tube. Students will then add 10 drops of catechol in tubes 1, 2, 4, and 6; 10 drops of distilled water in tubes 1, 3, 5, and 7; 10 drops of room temperature potato extract into tubes 2 and 3; 10 drops of heated potato extract into tubes 4 and 5; and 10 drops of chilled potato extract into tubes 6 and 7.

Students should be warned that **catechol is a poison** and that they are not to make contact with the solutions. They are also to wash their hands thoroughly after the experiment.

Students will then record their observations in the data table for each of the tubes. They will then analyze their data to conclude in which tubes benzoquinone was produced.

Alternative to using catechol and potato extracts: If desired, instead of using catechol and potato extracts, **this lab can be done with an apple and lemon juice**. An apple should be quartered prior to the laboratory. Two of the quarters should be dipped immediately in lemon juice and put in baggies. One of each of the quarters (lemon juice/no juice) should be kept at room temperature in baggies. One of each of the quarters (lemon juice/no juice) should be placed in the refrigerator in baggies. This

should be done at least 30 minutes prior to the laboratory. The same fruit pieces may be used for all classes throughout the day (return refrigerated apples to fridge when not making observations). Instead of having students use the data table on their sheets, the experimental set up should be described and students should predict what will happen to the apple pieces (brown/not brown). Students should be asked to explain what the purpose of lemon juice is. Most students will know that lemon juice prevents browning, but push students to explain that lemon juice is an acid and that acids can cause proteins to denature. Therefore, lemon juice is denaturing the catechol oxidase that is naturally found in the apple so it cannot perform its function. Then show the students the apple slices and let them make observations. The apples dipped in lemon juice should have less brown than the other slices. The apples kept cool (slowed the enzymes down) should have less brown than their respective slices.

Students will then move on to the "Making Sense" portion of the lab where they will answer questions about the laboratory and connect their observations from the lab to the Siamese cat example. Students will then make their final model of how the Siamese cat gets its coloration.

Wrapping up Activity 5

Engage students in a discussion of what they learned about enzymes. Some topics that may come up are what happened when they heated/cooled the potato extract, which tubes were controls, what parts of the Siamese cat are the warmest, what the mutation in the Siamese cat's tyrosinase enzyme does, why Siamese cats have the coat pattern they do, what would happen if you left a Siamese cat outside all winter, what would happen if you put boots on a Siamese cat, if proteins can lead to visible traits, etc. Guide students to thinking about how enzymes function and why enzymes are important in the body.

Sample questions:

- Which tube(s) was/were your control tubes? Why?
  tubes 1 (water plus catechol) and 3, 5, 7 (water plus potato extracts)
- What happened when you heated the potato extract? Why?
  the catechol oxidase enzymes denatured; reaction will not work
- What happened when you chilled the potato extract? Why?
  catechol oxidase enzymes would move slower because they were cold; reaction will not go as fast
- Look back at the picture of the Siamese cat in the Prediction section. What parts of the cat's body would be the warmest? What parts would be the coolest?
  warmest - body, coolest - ears, tail, nose, feet, extremities
- Do you notice a pattern between the cat's coat color and the temperature of the body areas?
  lighter color where warm, darker color where cooler
- Siamese cats have a mutation that causes their tyrosinase enzyme to be especially sensitive to heat. What does this mean?
  heat sensitive means that a little bit of heat will denature the enzyme as opposed to the normal high amount of heat it takes

- Why do Siamese cats have the color coat pattern they do?
  the tyrosinase is heat sensitive so in the areas that are warm (like the body), the enzyme denatures and does not make dopaquinone to make melanin so the body is light in color; in the areas that are cooler (like the tail and ears), the enzyme does not denature, so it does make dopaquinone to make melanin so the ears and tail are darker in color because melanin is present
- What would happen if you left a Siamese cat outside all winter? Why?
  the cat would be colder, so it would be darker all over (enzyme would not denature as much)
- What would happen if you put boots on the feet of a Siamese cat? Why?
  the feet would be warmer, so the enzyme would denature in the feet so the feet would be lighter in color
- Can proteins lead to visible traits? Why or why not?
  various responses, hopefully a lot of yes

Reading 5

Purpose: to further investigate melanin and how it leads to albinism

Students may do this reading in class or as homework (ideally between Activity 5 pre-lab and laboratory).

Wrapping up Reading 5

Engage students in a discussion of what they learned about melanin and albinism. Some topics that may come up are what albinism is, why albino animals look very white, what pigments are, where pigments are found, why we tan, how we tan, the difference between albino and albinoid, what enzymes make melanin, what tyrosine is, what dopaquinone is, what happens when tyrosinase is mutated, how this mutation causes albinism, the difference between oculocutaneous and ocular albinism, what happens to animals and humans with albinism, how this relates to the Siamese cat, etc. Guide students to thinking about how proteins are important for giving observable traits.

Sample questions:

- What are pigments and where are they found?
  molecules that give coloration, found in leaves, skin, hair, fur, eyes, etc.
- Why do we tan?
  to protect out skin from the harmful UV rays from the sun
- How do we tan?
  the UV rays cause skin cells to make more enzymes that produce melanin to make more melanin to make our skin darker
- What is the difference between albino and albinoid?
  albino is a complete lack of melanin and albinoid is less melanin that a normal person should have
- What enzymes make melanin?
  the main enzyme is tyrosinase (similar to catechol oxidase)
- What is tyrosine?
  an amino acid that can be converted to melanin

- What is dopaquinone?
  the product of the tyrosinase reaction; can be put together with other molecules to make various forms of melanin
- What happens when tyrosinase is mutated?
  tyrosine cannot be converted to dopaquinone so melanin cannot be formed, you get a light color/no color instead of a dark color
- How does this mutation cause albinism?
  the enzyme cannot function properly so it cannot make dopaquinone to make melanin
- What is the difference between oculocutaneous and ocular albinism?
  ocular - eyes only, oculocutaneous - skin, hair/feathers/fur, eyes
- What happens to animals with albinism?
  animals cannot hide as well so they have a shortened lifespan; humans are more susceptible to sunburn and skin cancers
- How does this relate to the Siamese cat example?
  various responses, maybe students will begin to connect the color on the cat with the enzyme tyrosinase and may come up with some explanation saying the enzyme is present in the ears/tail/face/feet but not on the body

Teacher Supplemental Sheets

The two sheets on the following pages are supplemental sheets teachers may wish to use in their classroom. These are optional.

Words to Know Organizer

Graphic organizer for students to keep track of vocabulary words.
Contains column for word, definition, and example.
May be modified to suit needs of students.

List of Proteins

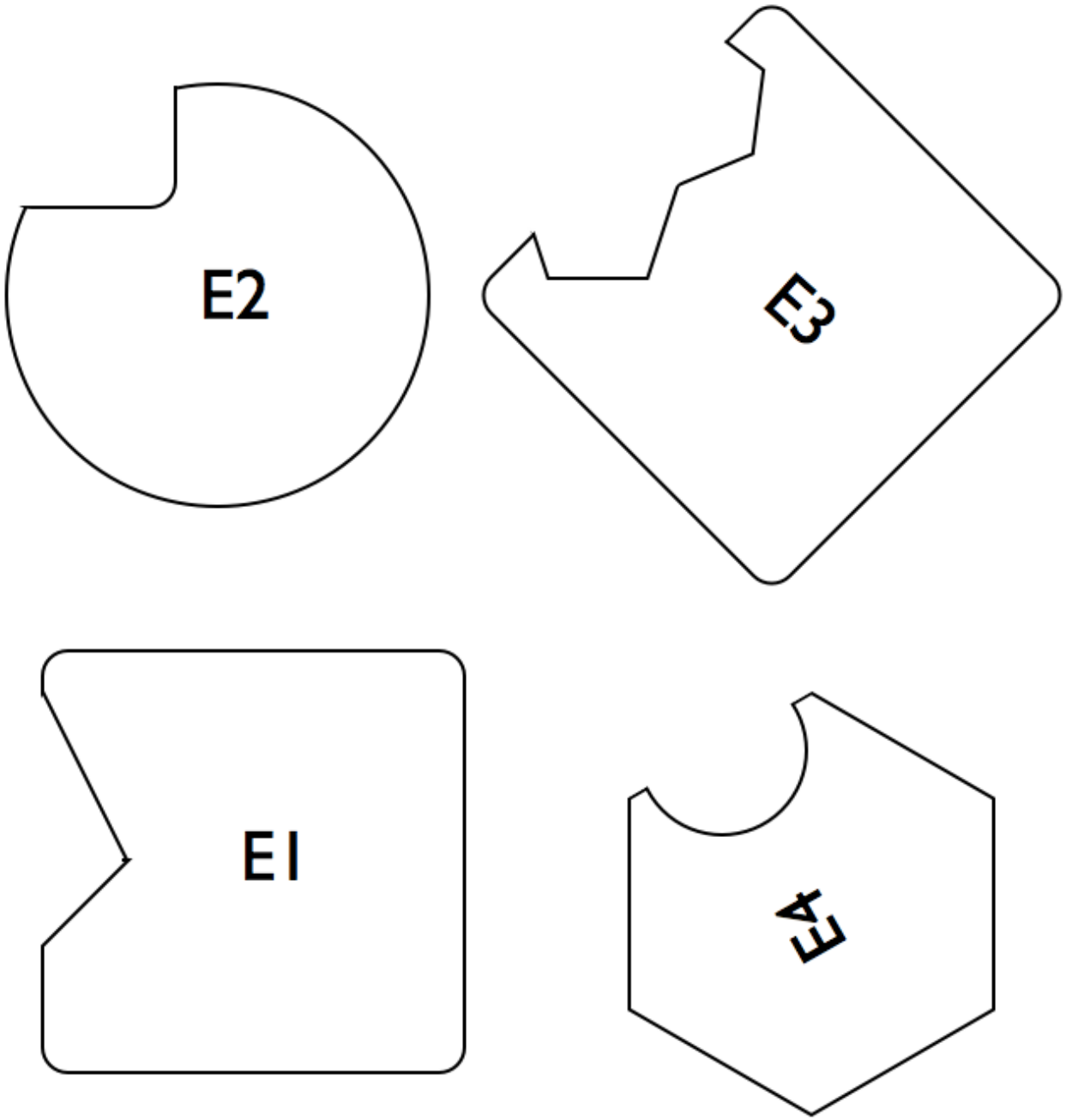
Graphic organizer for classroom to keep track of proteins discussed.
Contains column for protein, if an enzyme (y/n), and function.
May be modified to suit needs of students.
Helps students keep track of proteins and their functions that are discussed repeatedly.
Helps them see that not all enzymes break down sugars.
This chart may also be used prior to this unit and throughout the year.

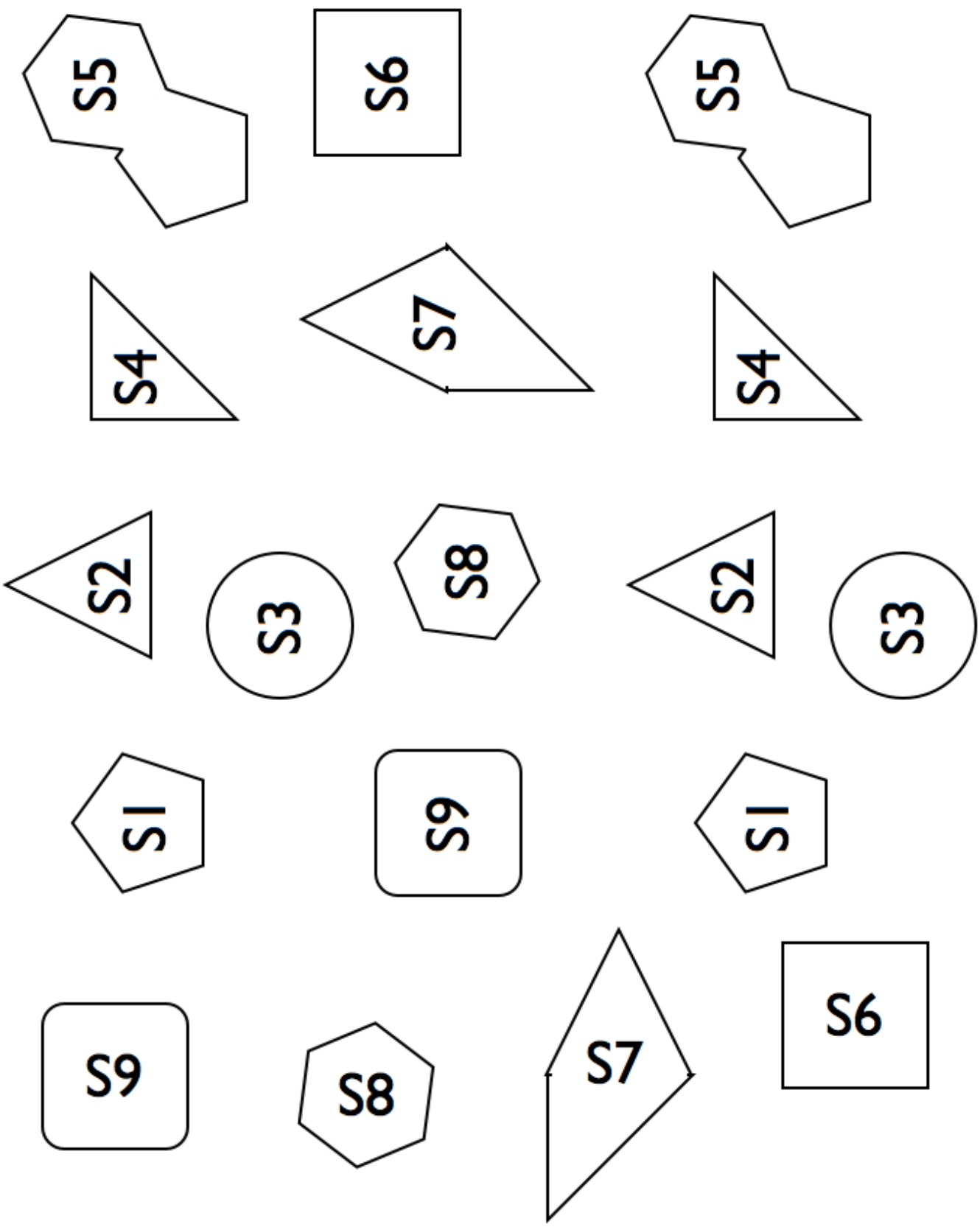
Words to Know

Word	Definition	Example

List of Proteins

Protein	Enzyme (y/n)	Function


E2
E3
E1
E4


S5
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S3
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S9
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S7
S6

TEACHER EDITION - ANSWER KEY

JUMPSTART: HOW DO WE GET OBSERVABLE TRAITS?

1. Look at the picture of a Siamese cat on the right. What patterns in coat color do you notice?

dark head, tail, feet
light colored body

Siamese cat,https://www.flickr.com/photos/sonstroem/18314863075/in/photostream/

2. Why do you think Siamese cats are colored the way they are?

looking for ideas

3. Do you think cells and/or proteins are involved in the coat coloring? Why or why not?

maybe yes, most will not know how

4. A Siamese cat named Boots does not like the snowy cold weather in the winter. His owners decided to put some shoes on his feet so that they would not get cold and wet when he went outside in the snow. One day after Boots had been outside for several hours, he came inside and the owners took off his shoes. They were shocked to see that Boots' feet had turned white! How could this happen?

just want students to think and just want ideas

5. Boots' owners have another Siamese cat named Snowball. Even though they are brothers, Snowball is just the opposite of Boots - he loves cold weather and the snow. Snowball often plays and sleeps outside all winter long. After a few months of being outside during the winter, his owners noticed that Snowball was getting darker. His white body was turning dark like his paws! How could this happen?

just want students to think and just want ideas

6. Create your initial model of how Siamese cats get their coat coloration and pattern.

just want student ideas, look for labeling and explanations

ACTIVITY 1: WHAT ARE ENZYMES?

PURPOSE

In earlier lessons, we learned that different cells contain different proteins. This activity further investigates proteins and how their structure relates to their function.

PREDICTION

1. In previous lessons, you learned that specialized cells contain different proteins. In what kind of cell do you think you would find a protein or enzyme that breaks down food?

would be found where food gets broken down - in intestines or stomach or mouth

2. Think about enzymes that break down food. What do you think they look like? **Draw a picture** of what your group thinks they look like. **Label important things** you think that it would have. How does the enzyme break down food?

should look for drawing and labeling

TEACHER EDITION - ANSWER KEY

PROCEDURE

3. Get an enzyme packet from your teacher. What observations can you make about the enzymes?

they all are different shapes, they have different shaped notches (active sites)

4. What do you think the notches in the enzymes are used for?

for putting substrates in and breaking things down

5. The notches in the enzymes are called **active sites**. Why do you think the active sites for each enzyme are different shapes?

so that they can break down specific substrates

6. Try to fit the different sugars (S) into the active sites in the enzymes (E). Some active sites may need two sugars together to fill it. Place an "X" in the boxes where the sugars fit the active sites of the enzymes.

	S1	S2	S3	S4	S5	S6	S7	S8	S9
E1		X		X			X		
E2									X
E3	X				X			X	
E4			X						

7. What observations can you make about the sugars and the active sites?

only certain shaped ones fit, the enzymes are specific to certain substrates

8. Why is it important that the enzyme active sites are different shapes?

enzymes are proteins, so different enzymes have different functions - need to be shaped a certain way to do your function - breaking down a certain sugar

MAKING SENSE

9. What is an active site?

a "notch" or crevice in the enzyme where the substrate binds

10. Why do enzymes have an active site?

to have a binding site for substrates

11. Why do different enzymes have different active sites?

they catalyze different reactions, so they must be specific to certain substrates

12. What do you think would happen if the shape of an active site on a protein enzyme changed?

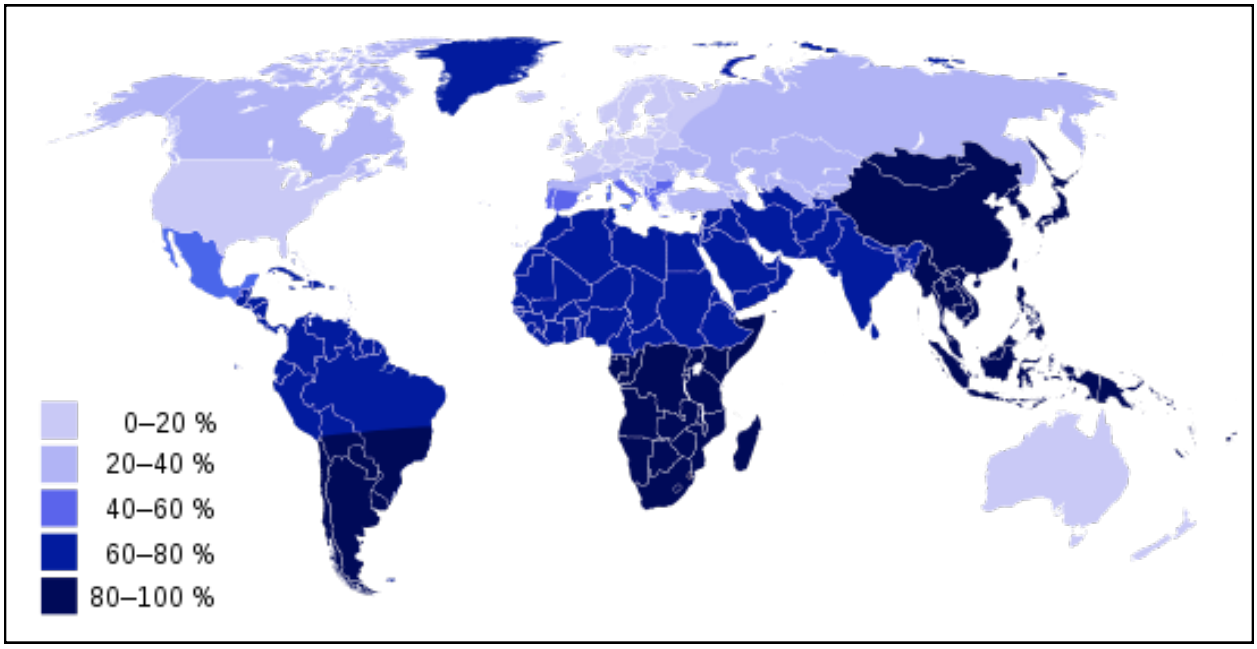
the enzyme would no longer be able to catalyze the reaction because the substrate would not fit properly

READING 1: HOW DO YOU GET LACTOSE INTOLERANCE?

JUMPSTART

Have you heard of someone having lactose intolerance? Are you or someone you know not able to drink milk or have dairy products? When someone with lactose intolerance ingests dairy, they feel sick and may have nausea, cramping, bloating, and diarrhea. Their body is simply unable to tolerate consumption of dairy products.

Below is a world map showing the percentage of people having lactose intolerance in countries across the world. Light colored nations have a low percentage of lactose intolerance (more people that can ingest dairy) while dark colored nations have a high percentage of lactose intolerance (more people that cannot ingest dairy).



World lactose intolerance, https://commons.wikimedia.org/wiki/File:Laktoseintoleranz-1.svg

1. What observations can you make from the map?

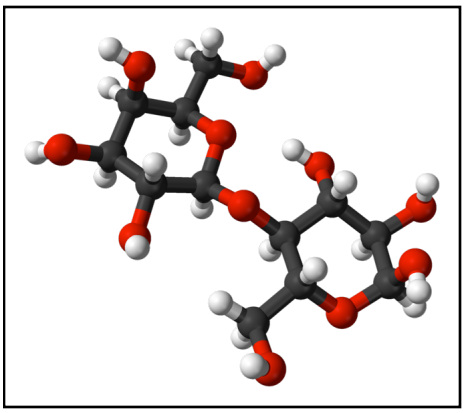
US, Canada, Russia, Australia, Europe have low levels of lactose intolerance
South America, Asia, south Africa have high levels of lactose intolerance

2. What inferences can you make from your observations?

just want ideas, some students may see correlation between wealth or domestication of animals as giving less lactose intolerance

What is Lactose?

Lactose is a sugar found in dairy products. This sugar is named so because "lac" is Latin for milk and the -ose ending is used to name sugars. So lactose is milk sugar. Lactose makes up about 2-8% of milk. Lactose is a complex sugar: a **disaccharide**. This means it is made up of two smaller sugars put together. The picture on the right shows how lactose is made of galactose (one of the rings) and glucose (the other ring) hooked together.



Lactose, http://en.wikipedia.org/wiki/File:Alpha-lactose-from-xtal-3D-balls.png

How Does Our Body Process Lactose?

Humans cannot use complex sugars like lactose for energy until they are broken down. Our bodies produce an enzyme called **lactase** which is able to break down lactose molecules. It is easy to remember that lactase breaks down lactose because enzymes end in -ase, so lactase is the enzyme that breaks down the lactose sugar.

In class, you learned that enzymes have specific **substrates** (or molecules they bind). Therefore, lactose is the substrate for lactase. The cells in your intestines make the protein enzyme lactase and secrete it out into the space in your intestines where the food goes through. When you consume dairy, the lactase enzymes in your intestines bind to lactose molecules and cleave them apart. Now, since lactose is broken up into simple sugars, your cells can take in the galactose and glucose and use them for energy.

3. What is lactose and where is it found?

a complex sugar (disaccharide) made up of galactose and glucose, milk sugar found in dairy products

4. How does your body digest lactose?

the enzyme lactase breaks lactose up into the simple sugars of galactose and glucose, which our cells can then take in and use for energy

What is Lactose Intolerance?

People who are lactose intolerant do not make the enzyme lactase. If they do not have that enzyme, any lactose they consume is unable to be taken up by their cells to use as energy. Remember, the cells can only take up simple sugars and lactose is a complex sugar until it is broken down by lactase.

So what happens when someone who is lactose intolerant consumes dairy? If the person's cells do not make any lactase enzyme, the lactose cannot be broken down. If

the lactose is not broken down, then the person's cells can't absorb the sugars to use as energy. The lactose then becomes food for something else: your gut bacteria! Your body contains trillions of bacteria in your intestines to help you digest food. If your body does not break down lactose, your gut bacteria will!

If someone has the lactase enzyme, lactose is broken down in the small intestine. However, most of your gut bacteria live in your large intestine. Therefore, if someone does not make the lactase enzyme, lactose passes through the small intestine and into the large intestine. When the lactose makes it into the large intestine, the gut bacteria break it down and use it for food, releasing gases in the process. This is what produces the nausea, cramping, bloating, and diarrhea after a person who is lactose intolerant consumes dairy.

5. What does "lactose intolerance" mean?

not being able to break lactose down into the two simple sugars, being "intolerant" to lactose, not being able to digest lactose

6. What happens to lactose when a lactose intolerant person consumes dairy products?

they are unable to break it down, so bacteria in the gut use it for food, producing gas and nausea, cramping, bloating, and diarrhea

Can Someone Who is Lactose Intolerant Ever Have Ice Cream?

Fortunately, someone who is lactose intolerant does not have to live their life without ice cream! Scientists can insert the gene that codes for the lactase protein inside of bacteria, yeast, or fungi. When they do this, they turn that organism into a "lactase factory" - these organisms produce large amounts of the lactase enzyme. They can then lyse the single celled organisms and purify out all the lactase protein enzymes, giving them large amounts of purified lactase. This is also how insulin for diabetics is made - bacteria are turned into insulin factories.

Purified lactase enzymes can then be added to milk and other dairy products to break down the lactose for people who are lactose intolerant. These products would no longer contain the complex sugar lactose but the simple sugars galactose and glucose instead. Dairy products treated with purified lactase enzymes are then safe for lactose intolerant people to consume without the worries of intestinal issues. Additionally, some pharmaceutical companies have made capsules containing the purified lactase protein enzyme (such as LACTAID®) for people to eat prior to consuming normal untreated dairy products. So

even though people who are lactose intolerant don't produce the lactase enzyme in their bodies, when they eat a LACTAID® capsule, they are eating the purified protein enzyme which can then function to break down the lactose they are about to consume.

7. What is LACTAID® and how does it work?

a capsule of purified lactase enzyme; it replaces the lactase enzyme in your body and breaks down lactose in food into galactose and glucose

How Do You Become Lactose Intolerant?

It is actually normal for mammals (including humans) to develop lactose intolerance as you age. When you were a baby, you drank a lot of milk. But then as you grew up, you relied on other foods to get your nutrients such as bread, meat, fruits, and vegetables. You have probably heard the expression "if you don't use it, you lose it." Your body is programmed to stop the production of the protein enzyme lactase at the end of the weaning period (or length of time you drink your mother's milk) because it is no longer necessary - you can eat many other things for your nutrients when you are older, but must rely only on milk when you are a baby. This is another example of how cells produce only the specialized proteins they need for their function.

8. How does a person become lactose intolerant?

your body stops producing the lactase enzyme

Why Isn't Everyone Lactose Intolerant?

You may have noticed that South America and parts of Africa and Asia show large percentages of the population with lactose intolerance while the United States, Europe, Russia, and Australia show large percentages of the population without lactose intolerance. Why is this?

The ability to continue producing the lactase enzyme appears to be a recent adaptation to dairy consumption. People who acquired a mutation that stopped lactase from being turned off (thus, lactase production never stopped) are able to continue to consume dairy products without intestinal difficulties. In countries such as the US, animals are domesticated and their milk is often consumed by humans. Because dairy has been widely available in countries that have domesticated animals, people who are able to keep producing the lactase enzyme in these countries are able to keep getting nutrients from dairy sources as well. Over time, this trait was selected for and thus, a large population in the country was able to continue consuming dairy products. In countries that do not consume dairy in adulthood, this trait was not selected for, so many people develop lactose intolerance.

9. What would you expect to happen if people in the US stopped drinking milk?

would probably see an increase in lactose intolerance

10. Do you think more or less people in the world will be lactose intolerant 100 years from now? Why?

will probably see a decrease of lactose intolerance because world is becoming more industrialized and able to afford/produce milk to consume

QUESTIONS TO CONSIDER

11. Why is lactase important in the body?

breaks down lactose into simple sugars to be able to use them for energy; allows you to obtain nutrients from dairy products

12. Why doesn't the enzyme that breaks down sucrose (another disaccharide) just break down lactose in people who are lactose intolerant?

because each enzyme is structured for a certain function - the active site of sucrase fits sucrose and not lactose, so it cannot break it down

ACTIVITY 2: WHY ARE ENZYMES IMPORTANT?

PURPOSE

This activity further investigates enzymes and how their structure relates to their function.

PROCEDURE

Go to the following website and start the animation All About Enzymes:

- http://www.learnerstv.com/animation/animation.php?ani=324&cat=Biology

1. Why is it important that enzymes are not changed after they help a reaction?

so that the same molecule can be used over and over again to catalyze many reactions

2. What are some things that can affect the shape and function of an enzyme?

high temperatures, extreme pH

3. How do you think these things change the shape of an enzyme?

by denaturing or "unraveling" the protein

4. Click on "Why Enzymes?" and view the reaction **without** the enzyme. What happens?

the two sugars collided a lot but did not make a bond together

4. View the reaction again, this time **with** the enzyme. What happens this time?

the sugars attached to the enzyme and got bonded together

5. Why do you think the reaction was different with and without the enzyme?

the enzyme held the sugars in place/in the proper orientation for them to bond together

6. Return to the Enzyme Menu and view **Specificness**. What happens when the green enzyme tries to break apart the double sugar molecule? What about the yellow enzyme? Why is there a difference?

the double sugar molecule does not fit in the green enzyme, so it does not get broken down; it fits in the yellow enzyme and gets broken down; the shape of the active sites is the difference between the two

7. Return to the Enzyme Menu and view **Reusing Enzymes**. Why is it helpful that enzymes can be reused?

they can be reused to form polymers (or chains) of things; also so that you don't need to make many enzymes if one can be reused

8. Return to the Enzyme Menu and view **Denaturing**. How does heat make the enzyme not work anymore?

heat changes the shape of the enzyme (or denatures it) so that the substrate can no longer bind or fit in the active site

Making Sense

9. What would happen to a reaction if you added more enzymes to it?

the reaction would go quicker or speed up

10. Diabetic patients can be given purified insulin (a protein) to help them regulate their blood sugar. One patient reads that his insulin must be kept in the refrigerator. Why is this?

at room temperature, the protein denatures and is not able to function anymore; it must be kept cold to keep its shape and activity

11. What do you think would happen to the insulin if it were left out on a table for a few hours?

the enzyme would denature and wouldn't be able to function anymore

12. Look again at the picture of the Siamese cat on the right. Do you think an enzyme could be responsible for the coat color of the cat? Why or why not?

some students may start to put body temperature/heat together with enzyme denaturing to see that an enzyme could be responsible

Siamese cat,https://www.flickr.com/photos/sonstroem/18314863075/in/photostream/

13. What did you learn from this lesson that you may be able to apply to your model of how the Siamese cat gets its coloration?

some students may start to put body temperature/heat together with enzyme denaturing to see that an enzyme could be responsible

READING 2: WHY CAN'T A WOODCHUCK EAT WOOD?

JUMPSTART

Woodchucks have it rough. Not only do they have a tongue twister saying that they can't chuck wood, but they also are unable to eat wood. You have probably heard of termites. Termites are a common pest that can destroy houses by eating the wood. Look at the following pictures of a woodchuck (left) and a termite (right).

Woodchuck, https://commons.wikimedia.org/wiki/File:Woodchuck_offspring_in_our_yard_%285825855337%29.jpg

Termite, https://commons.wikimedia.org/wiki/File:Workertermite1.jpg

1. Why do you think a woodchuck can't eat wood but a termite can?

just want answers, maybe something to do with an enzyme/protein that one has while the other does not

WHAT IS WOOD MADE OF?

You know that wood comes from trees. But what exactly is wood? Wood is **xylem** in the stems or trunks of trees. Xylem transports water and minerals from the soil up the tree and to the leaves and other growing areas. It is the part of the tree inside the bark. If you have ever taken the bark off a tree, cut down a tree, or looked at a slice of a tree (right) you can see that the majority of a tree's stem or trunk is made of xylem.

Tree cross section, https://commons.wikimedia.org/wiki/File:Taxus_wood.jpg

WHAT IS XYLEM MADE OF?

Xylem is actually just a fancy name for the plant cells that transport water and minerals up from the roots to the leaves. You learned before that plants are made up of

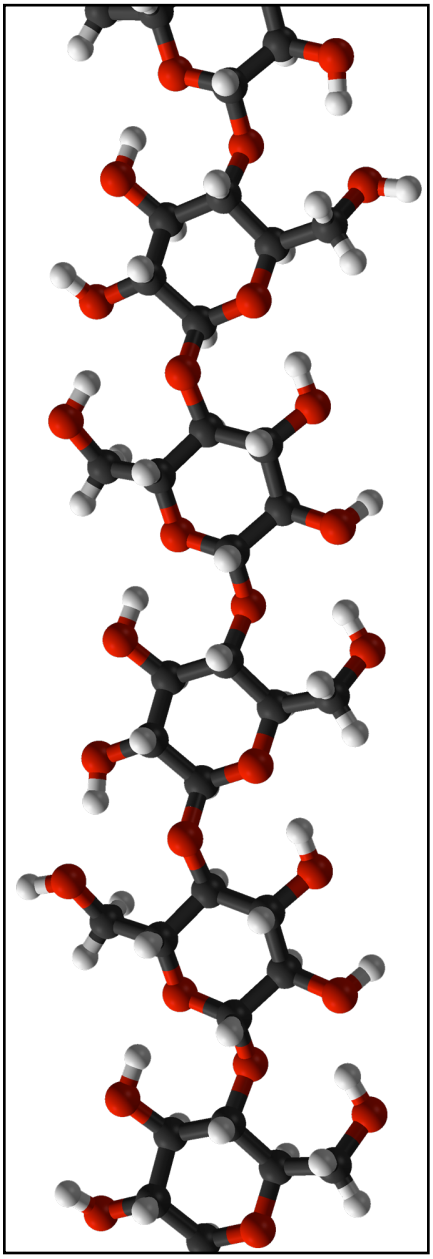
cells just like we are. However, plants contain some special things like chloroplasts to make sugar from sunlight, water, and carbon dioxide and cell walls to support and protect the plant's cells. Because plants don't have a skeleton, they need strong cell walls to hold the plant up. Think about trees compared to other plants. Are trees stronger and harder than other green plants? Which do you think contains thicker cell walls?

2. What is wood made of?

plant cells, mainly xylem, cellulose

3. Why are cell walls important?

they provide structural support for the plants



Cellulose, https://commons.wikimedia.org/wiki/File:Cellulose-Ibeta-from-xtal-2002-3D-balls.png

What are Cell Walls Made Of?

Cell walls in plants are composed mainly of **cellulose**. The last reading you did was about lactose. Do you remember that the -ose in lactose meant sugar? What do you think cellulose is? Like its name suggests, cellulose is a sugar found in cells! Cellulose is similar to lactose because it is another complex sugar. But it is a lot more complex than lactose! Cellulose is actually made of several hundred to over ten thousand glucose molecules hooked together (above). Cellulose forms long chains and these long strong chains make up the strong cell wall to hold a plant up. With the world having so many plants, cellulose is the most common organic compound found on Earth! Just cellulose by itself makes up almost half (40-50%) of wood.

4. What is cellulose and where is it found in plant cells?

a complex sugar made of long chains of glucose molecules hooked together, it is found in the cell walls

How Can Termites Eat Wood?

Like humans and lactose, termites must first break down the complex sugars to be able to use them for energy. If lactase was the enzyme that breaks down lactose, what do you think the enzyme that breaks down cellulose would be? Termites produce **cellulase** enzymes in their digestive system to break down the wood that they eat. Cellulase breaks down the long chains of cellulose (a complex sugar) into simple sugar molecules of glucose. Once the cellulose is broken down into glucose, the termite's cells can absorb the simple sugar to use it for energy.

5. How do termites digest cellulose?

an enzyme called cellulase breaks cellulose down into the monomeric units of glucose where it can then be digested

Why Can't Woodchucks Eat Wood?

Most mammals (including humans and woodchucks) do not produce the cellulase enzyme. This is very similar to the previous reading about lactose intolerance where a person who does not make the enzyme lactase cannot break down the complex lactase sugar. Since mammals do not make the enzyme cellulase, they are unable to break the complex sugar cellulose down into simple sugar molecules of glucose to use as energy.

What Happens If You Eat Cellulose?

You don't sit down with a pile of sticks to eat for lunch. First of all, wood is hard to chew and it doesn't really taste good. But most importantly you can't digest the cellulose in wood. Plants are a part of a healthy diet though (broccoli, asparagus, lettuce, etc.) and do contain a lot of cellulose. So what happens when you eat broccoli? You may have heard of **dietary fiber** (or roughage). Dietary fiber is the part of plants that your body cannot break down, such as cellulose. Dietary fiber is an important part of your diet and helps to keep your digestive system healthy by softening stool and shortening the amount of time it takes for digested food to move through your system. So although you cannot break down cellulose, it is an important part of a healthy diet.

6. Why can't humans digest cellulose?

most mammals don't make the cellulase enzyme to break down cellulose into smaller components

7. What happens when humans ingest cellulose?

it passes through our body as dietary fiber because we cannot break it down

ACTIVITY 3: CAN I SEE ENZYMES IN ACTI0N?

PURPOSE

This experiment tests for the presence and specificity of enzymes in fruits.

PREDICTION

1. What is Jell-O made of?

mainly collagen (a protein)

2. Why do you think there is a warning in the directions not to add fresh pineapple to Jell-O?

some may say that it will not set up if you add fresh pineapple to it

3. What do you think is different about pineapple compared to other fruit?

just want ideas, maybe something about different proteins or enzymes in the pineapple compared to the other fruit

4. List the different liquids you will add to the Jello in the chart below. Then predict what will happen to the Jell-O when you add each different liquid.

Liquid Added	Prediction for Jello
students need: *water (control)* *2 different meat tenderizers* *4 different juices (pineapple, kiwi, apple, orange), each from both concentrate and fresh* **note, if you are able to find concentrated kiwi, have students add an extra line on chart and they will need 11 tubes*	*should make prediction for each sample - will it set up or not*

PROCEDURE

PART I

5. Number your test tubes from 1-10.

6. Add 10 mL of the Jell-O mixture to each test tube. Be careful - it will be HOT!

7. Place 3 mL of each test liquid into each tube. Use one pipette for each liquid and **do not mix pipettes between liquids!** Record which liquid went in which test tube in the following table.

Test Tube Number	Test Liquid Added
1	
2	
3	
4	
5	
6	
7	
8	
9	
10	

students should record liquid added to each test tube

8. Cover the tube with your thumb and shake well to mix the test liquid and Jello.

9. Refrigerate test tubes overnight.

10. Why was it important to use one pipette for each liquid and not to mix pipettes?

to not cross-contaminate the liquids/juices

11. Do you expect to see any differences between the fresh juice and juice from concentrate? Why or why not?

just want student ideas, probably yes, maybe something about the concentrate being heated so the enzymes will be denatured

PART II

12. On day 2, check the contents of each test tube. Record your observations on the table below.

Test Tube Number	Observations
1	
2	
3	
4	*students should record observations; did the Jell-O set up or not? any other observations (color, thickness, etc.)*
5	
6	
7	
8	
9	
10	

MAKING SENSE

13. Which tube was your control and why?

the tube that contained the water, it did not contain any additives

14. Which liquids gave you positive results (Jell-O still liquid)?

pineapple (fresh), kiwi (fresh), meat tenderizers (answers will vary)

15. Which liquids gave you negative results (Jell-O solid)?

water, orange (both), apple (both), pineapple (concentrate), kiwi (concentrate) (answers will vary)

16. Were there any differences between the fresh juice and juice from concentrate?

answers will vary, hopefully between the pineapple and kiwi juices (concentrate - Jello set up, fresh - Jell-O still liquid)

17. Why do you think there were these differences?

juice from concentrate is usually pasteurized/heated, so the enzymes that break down collagen were denatured and could not function anymore; fresh - enzymes working

18. What enzymes do the meat tenderizers contain?

answers will vary, mainly proteases

19. Why are these used to tenderize meat?

these tenderizers contain enzymes that break down proteins in meat, when they break down the proteins, the meat gets softer

20. Imagine that you ran out of meat tenderizer at home. What else could you use for meat tenderizer? Why would you add this?

could use fresh pineapple juice (or other juices found in experiment to give positive results), would use this because it has enzymes to break down protein

21. Other than good hygiene, can you think of a reason why pineapple processors are required to wear gloves and surgical masks when they process pineapple?

so they don't breathe in or touch the enzymes which break down the collagen - it would destroy their skin/lung tissues

22. What do you think would happen if you heated the pineapple juice before adding it to the Jell-O mixture? Why?

the proteins/enzymes would denature and not work, so the Jello would solidify; would act like the pineapple juice from concentrate

READING 3: HOW DO WE KNOW WHAT PROTEINS LOOK LIKE?

JUMPSTART

You know that cells are so small that they cannot be seen with the naked eye. In class, you observed different types of cells using light microscopes. There are several different types of microscopes. Three types of microscopes are listed below along with their **resolution** (size of smallest thing they can image) and sample preparation guides.

Microscope	Resolution	Sample Preparation
Light	200 nm	may need to stain sample to view it
Scanning Electron	1-5 nm	must be electrically conductive or coated with a metal
Transmission Electron	0.05 nm	must be able to withstand a vacuum so need to be "fixed" by plastic embedding

1. What is the smallest thing you could see with a light microscope?

something 200 nm or larger

2. If proteins are 1-100 nm large, which microscope(s) would you use to view proteins?

scanning electron or transmission electron microscope

WHY ARE PROTEINS SO HARD TO VIEW?

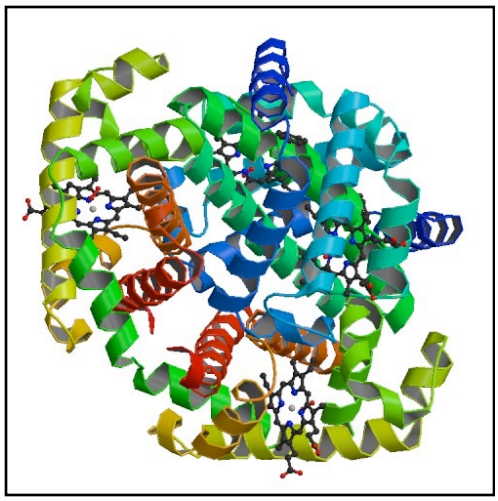
Have you seen the head of a pin? It is very tiny - about 2 mm large. The cells in your body are about 10 µm large, or 200 times smaller than the head of a pin. Proteins are even smaller. They are 1-100 nm large, or at least 20,000 times smaller than the head of a pin. That's tiny!

Not only are proteins super small, but they are also extremely active. You learned before that proteins zip around your cells doing chemistry, performing structural functions, helping them move, helping them keep their shape, receiving signals, and lots of other things. Have you ever tried to take a picture of a child or animal moving around? It's very difficult to get a clear picture. Now imagine you were trying to take a picture of something moving around, only that thing is 20,000 times smaller than the head of a pin. It's almost impossible! This is why it has taken scientists years to get pictures of proteins and why we still don't know what many proteins look like.

3. How big are proteins?

proteins are 1-100 nm big, or 20,000 times smaller than the head of a pin

What Do Proteins Look Like?



Hemoglobin, http://www.rcsb.org/pdb/explore/images.do?structureId=2DN1

Proteins come in all sorts of shapes and sizes. In class, you learned that certain types of cells had certain shapes because that helped with their function. The structure and function of proteins go hand-in-hand as well. The majority of proteins are **globular** in shape. Like the name suggests, the protein is a big glob or ball. Other proteins have different shapes because they perform specific functions. Look at the structure of hemoglobin on the right. In a previous lesson, you learned that proteins are made up of amino acids. These amino acids are attached together to make a long chain of amino acids. This is called the primary structure of the protein. The chains then fold into a secondary structure of **α-helices** or **β-sheets** to make a unique shape for the protein. In the hemoglobin shown on the right, the chain is folded into many α-helices that look like springs. The α-helices are then further folded into a globular shape to make the shape of the protein. β-sheets happen when parts of the amino acid chain run parallel to each other.

4. Describe the two different types of secondary structures in proteins.

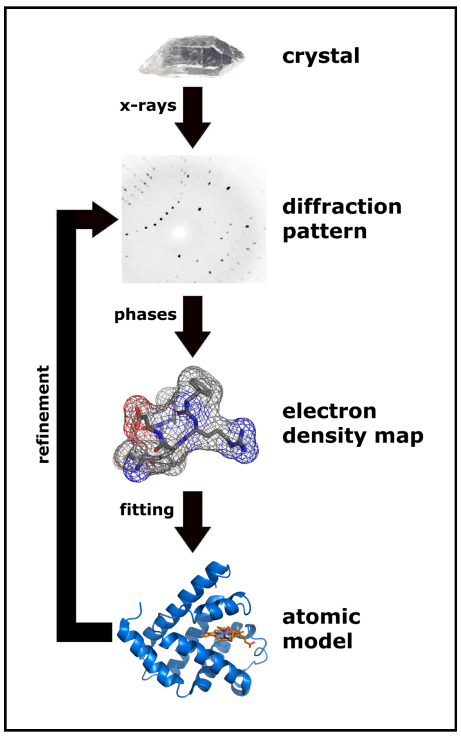
α-helices - make a coil or look like a spring; β-sheets - parts of the chain run parallel to each other to form sheets

How Do You Image Proteins?

Which kind of microscope did you think would be best to use to image proteins in the Jumpstart? Actually, none of these options for microscopes are very good for imaging proteins, so scientists use instruments other than microscopes to image proteins. The main way scientists image proteins is by using **X-ray crystallography**. Like the name sounds, scientists make protein crystals and shoot x-rays through the crystals. X-ray crystallography is an extremely time consuming and complicated technique. It often takes years for scientists to make the proper protein crystals and then to interpret the data to get the structure of the protein.

How Does X-Ray Crystallography Work?

If scientists want to get the structure of a certain protein, they must first purify it. Protein purification can be complex and time consuming. Some proteins are easy to purify while scientists have not yet been able to purify others despite years of trying. Once you have pure protein, you must then **crystallize** it. Protein crystallization is when you make a solid out of the protein with the proteins arranged in an orderly repeating pattern. You are already familiar with one type of crystal - table salt. Have you ever



X-ray crystallography, https://en.wikipedia.org/wiki/File:X_ray_diffraction.png

looked closely at table salt? Did you notice that the grains were little cubes? When you crystallize table salt, the atoms arrange themselves in an orderly repeating cubic pattern. Protein crystallization is another time consuming process that can take scientists years.

Once you finally have your protein in a crystal in an orderly repeating pattern, you can then shoot x-rays through the crystal (see diagram on left). The x-rays go through the crystal and scatter, producing a **diffraction pattern**. This pattern is a series of dots produces by the light scattering through the protein crystal. Interpreting the pattern of dots can also take years! Eventually though, scientists end up with a model of what the protein looks like. As you can tell, it takes a very long time to be able to get a good image or structure of a protein.

5. How do scientists know what proteins look like?

they use x-ray crystallography - first must purify protein, then make crystal, then shoot x-rays at it and then interpret the diffraction pattern

What Can You Use the Structures For?

So after you spent all that time finding the structure of a protein, what do you do with it? Protein structures are extremely useful for scientists. As you read previously, the structure and function of proteins go hand-in-hand: a piece that sticks off a protein may attach to something else. Scientists can also use the protein structures to see how proteins bind to each other. They can use computer programs that try to fit the proteins together to see what parts of the proteins touch each other. A lot of diseases are caused by changes in the proteins that make them not able to bind to other proteins correctly. Scientists can use the protein structures to better understand these diseases.

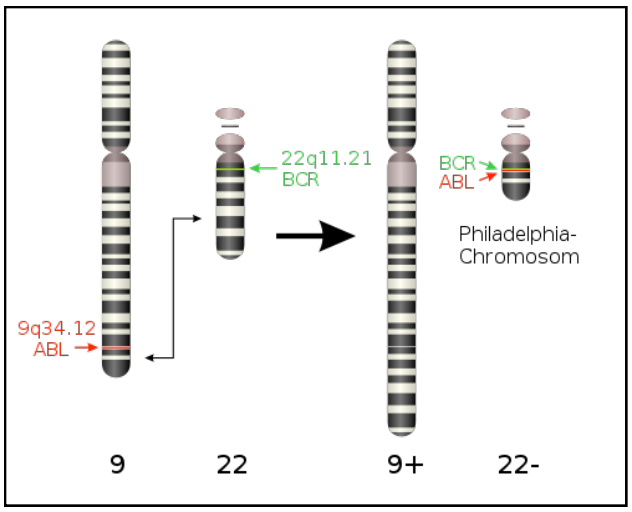
Another neat application of protein structures is drug design. Drug companies use the structures of enzymes to figure out the shape of their active sites, or where the substrates or targets bind. When they know what shape the active site is, they can design small molecules (or drug targets) to fit inside of that active site to **inhibit** its activity. If you had an enzyme that made cholesterol, you could design a drug target to fit inside the active site and stop it from making cholesterol. This drug could then be useful for patients with high cholesterol. So even though it may take many years to get the structure or image of a protein, the structures are extremely useful!

6. What can you do knowing the structure of proteins?

try to figure out the function of the protein, see how proteins bind each other, design drugs targets to inhibit enzymes

How Have Scientists Used Protein Structures?

One of the biggest success stories that involves protein structures is the development of the drug Gleevec to treat chronic myelogenous leukemia (CML). One of the mutations that causes CML is a chromosome translocation. Chromosomes 9 and 22 both break and swap their pieces. This is a particularly nasty mutation because the breaks on both chromosomes occur right in the middle of genes. So when the new chromosomes are formed, the one dubbed the "Philadelphia chromosome" contains a new mutant gene that contains half of the gene *ABL1* from chromosome 9 and *BCR* from chromosome 22. And, since genes code for proteins, this new mutant gene codes for a new mutant protein.



CML chromosome translocation, http://en.wikipedia.org/wiki/File:Philadelphia_Chromosom.svg

ABL1 is another example of an enzyme. It doesn't break down sugars like the other enzymes you have studied; it signals cells to divide. Normally, this enzyme has another section attached (the silencing portion) that keeps it turned off until it is needed. But in CML, the chromosome break divides the active portion of the gene from the silencing portion. The active portion of the gene is then attached to the *BCR* gene. Scientists don't know the exact function of the normal BCR protein, but when a section of it is attached to the ABL1 enzyme, it forms the mutant BCR-ABL protein enzyme. This enzyme is always active (because the silencing portion was removed and replaced) and is always signaling the cells to grow and divide. You learned in a previous unit that cancer cells express more proteins telling them to grow and divide, so this is another example of how pro-growth proteins can lead to cancer.

7. How does a chromosome translocation help cause CML?

translocation swaps pieces of genes and makes new Philadelphia chromosome that has fusion gene BCR-ABL, this codes for a mutant protein that is always signaling cells to grow and divide

Because this mutant enzyme causes such devastating effects to cells, scientists have studied the structure of the mutant BCR-ABL protein to see if they could design a drug target to inhibit this enzyme. If they were able to inhibit this mutant enzyme (and not other normal ABL1 enzymes), they would be able to essentially "correct" these mutated cells and potentially stop them from turning into cancerous cells.

BCR-ABL enzyme with Gleevec, http://en.wikipedia.org/wiki/File:Bcr_abl_STI_1IEP.png

The drug Gleevec was the first drug to actually alter the progression of CML cancers. The picture on the right shows Gleevec binding to the BCR-ABL active site. The binding of Gleevec prevents the enzyme from being able to signal cells to divide. Because of the initial success of Gleevec, TIME Magazine actually called this drug "the magic bullet" to cure cancer. Indeed, Gleevec has been successful in helping treat CML, however some people have developed Gleevec resistance. Scientists have since made other drugs that fit the active site of the mutant BCR-ABL protein using the protein structure to try to inhibit it to stop the progression of CML cancers.

Want To Learn More About Gleevec & CML?

Visit www.insidecancer.org, diagnosis & treatment, targeted activators, Gleevec & Chronic Myeloid Leukemia to view short videos about CML and Gleevec

Questions to Consider

8. Why is it important to find structures of proteins?

knowing the structures of proteins provides them with lots of useful information about the protein, its function, and possible drug targets for the protein

9. If scientists discovered a protein looked similar to another protein, do you think they would have a similar function? _____ Why or why not?

yes, they probably would; things that look alike probably have similar functions because structure and function go hand-in-hand

ACTIVITY 4: ARE SOME PROTEINS MICRO-MACHINES?

PURPOSE

This activity further investigates proteins and how their structure relates to their function.

PREDICTION

Your teacher is going to show you a video called "The Inner Life of the Cell." Pay special attention to the motor protein called kinesin that is carrying a vesicle.

http://www.studiodaily.com/2006/07/cellular-visions-the-inner-life-of-a-cell (music only)
http://multimedia.mcb.harvard.edu/anim_innerlife.html (narrated)

1. How do you think kinesin is able to move like that?

just want student ideas

PROCEDURE

PART I (http://www.molecularmovies.com/showcase/#Cytoskeleton%20/%20Molecular%20Motors), scroll down to Kinesin Mechanism

2. Watch the short video on kinesin. What is kinesin?

motor protein that pulls organelles along microtubule "tracks" in the cell

3. What happens to kinesin when ADP is released and ATP binds?

motor head binds to microtubule, ATP binding triggers neck linker to zipper on catalytic core, this throws second motor head in front of first motor head

4. What happens to kinesin when ATP is broken down to ADP plus phosphate?

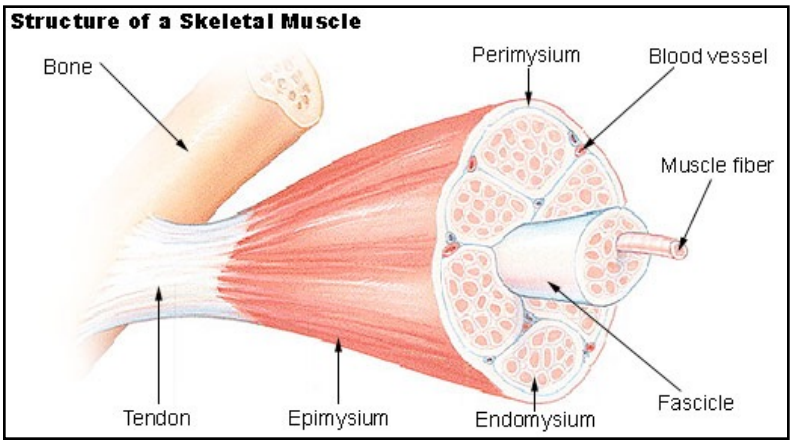
attached trailing head breaks ATP down and releases from microtubule

5. How does the structure of kinesin relate to its function?

has two motor heads which bind and "walk" along the microtubule track, have a long region to bind to an organelle

PART II

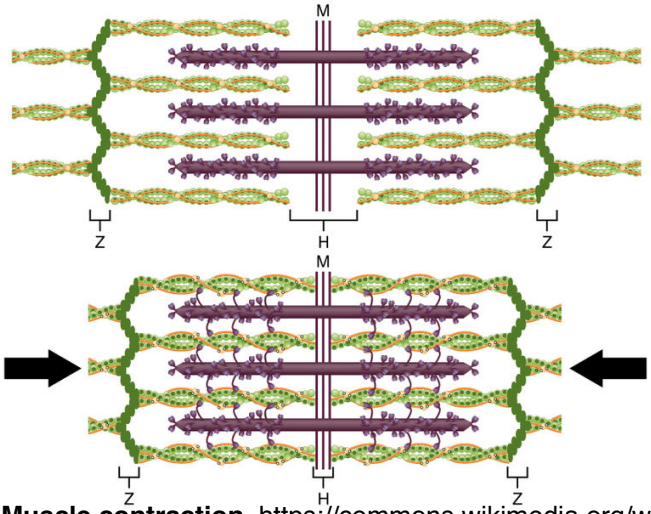
We are now going to be looking at proteins involved in muscle contraction. Look at the picture on the right of the structure of muscles. Muscle cells are combined into bundles. Inside the cells, they contain the proteins actin and myosin.



Muscle diagram, https://commons.wikimedia.org/wiki/File:Illu_muscle_structure.jpg

6. Look at the picture of muscle contraction. Actin and myosin are both very long, but the myosin has bulbs on each end of the protein. According to the picture, what happens when muscles contract?

actin filaments move closer to each other; <u>neither protein shortens</u> - actin and myosin just overlap more when contracted



Muscle contraction, https://commons.wikimedia.org/wiki/File:1006_Sliding_Filament_Model_of_Muscle_Contraction.jpg

7. How do you think the bulbs on myosin help muscles contract?

just want ideas, maybe something about protein moving

8. Watch the short video on myosin (http://www.molecularmovies.com/showcase/#Cytoskeleton%20/%20Molecular%20Motors), scroll down to Myosin Mechanism.

What is myosin? Where is it found in the body?

a protein involved in muscle contraction, in the muscle cells

9. What happens when myosin releases phosphate and ADP?

catalytic core binds to actin, when phosphate released the core binds tighter an changes conformation to pull actin

10. What happens when ATP binds to myosin?

when ATP binds, myosin head detaches from filament

11. How does myosin contract your muscles?

myosin pulls on the filaments in the muscles, when it pulls on the filaments, the muscles shorten, or contract

MAKING SENSE

12. The proteins you studied are sometimes called "molecular motors." Why do you think they are called this?

use energy (ATP) to move inside the cell

13. Why are these motor proteins important?

they move things inside of the cell - kinesin moves vesicles from one part of the cell to another, myosin helps contract muscle cells so we can move our body

14. Familial Hypertrophic Cardiomyopathy (FHC) is a disease caused by a mutation to the cardiac myosin protein. The symptoms are an enlarged heart and sudden death. How could a mutation to cardiac myosin cause sudden death?

various answers, example - myosin would not be able to contract the heart muscle so it would not be able to pump blood through the body

15. Can proteins lead to visible traits? _____ Why or why not?

various answers and reasoning, hopefully a lot of "yes" - proteins can contract muscles and you can see muscle contraction

16. Was there anything you learned from this lesson that you may be able to apply to your model of how the Siamese cat gets its coloration?

various answers, maybe something about proteins

Siamese cat,https://www.flickr.com/photos/sonstroem/18314863075/in/photostream/

17. Create a revised model of how Siamese cats get their coat coloration and pattern. Be sure to include anything helpful you have learned so far in this unit.

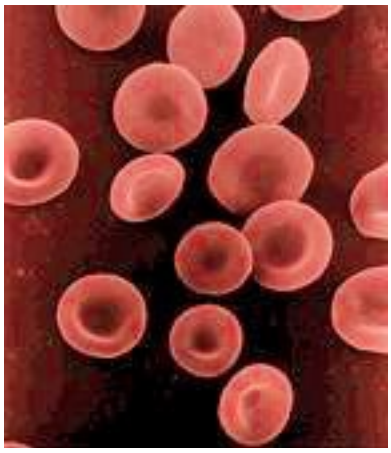
look for drawing and labeling and explanation that includes proteins

READING 4: WHY DO WE HAVE DIFFERENT BLOOD TYPES?

JUMPSTART

You have probably heard of people having different blood types. Can you name the different blood types? Do you know your own blood type?

There are four main blood types: A, B, AB, and O. There is also an additional factor that gives you a positive or negative. Have you seen hospital shows on TV where trauma doctors yell for "O neg." blood for patients? O negative blood is the "universal donor."



Red Blood Cells, https://commons.wikimedia.org/wiki/File:RBC_micrograph.jpg

1. Why do you think O negative is called the "universal donor"?

various answers, probably "can give it to anyone"

2. Why do you think this type of blood could be given to anyone?

various answers, just looking for initial student ideas

WHAT IS THE DIFFERENCE BETWEEN A, B, AND O BLOOD?

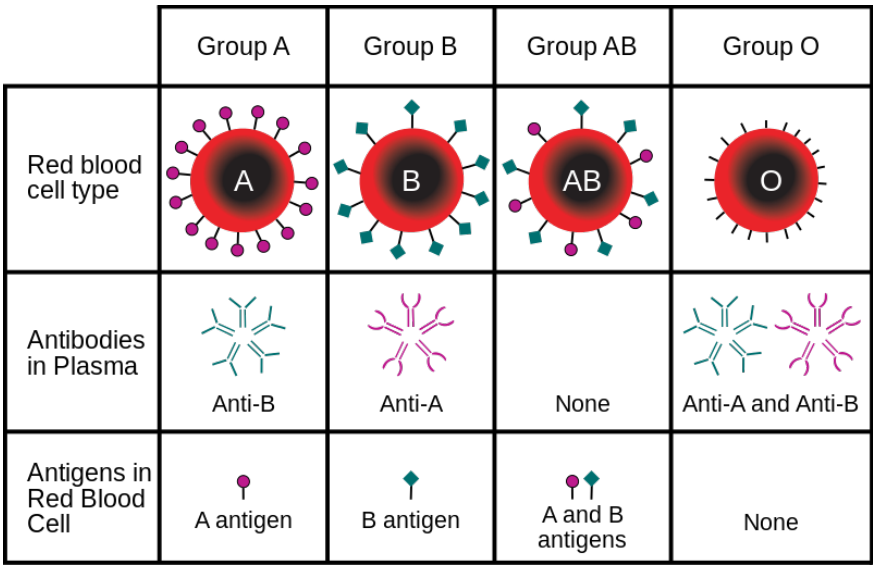
Your blood is made up of all kinds of different cells such as platelets, white blood cells, macrophages, red blood cells, and much more. Red blood cells are the cells that carry oxygen throughout your body. Everyone has red blood cells filled with hemoglobin proteins to carry oxygen, but there are also proteins on the surface of red blood cells. The different surface proteins on the red blood cells make up the different blood types.

Do you remember that cells can have different proteins sticking out of the cells to contact other cells or bind to other things? Some of these proteins are **antigens**. Antigens are so named because they are antibody generators. Therefore, antibodies bind to antigens, or proteins sticking out of the cells. Red blood cells can have two different protein antigens on their surface: A and B. This is where the A and B blood types come from.

A person whose red blood cells express the protein antigen A on the surface of their red blood cells would have blood type A. A person whose red blood cells express the protein antigen B on the surface of their red blood cells would have the blood type B.

These protein antigens are different in shape (see diagram on right) so that only antibodies specific to that antigen may bind to it.

People can also express <u>both</u> protein antigens A and B! These people have the fairly rare blood type AB because their red blood cells express both the A and B protein antigens on the surface of their red blood cells.



Antigens, https://commons.wikimedia.org/wiki/File:ABO_blood_type.svg

If people can express one or both of the protein antigens A and B, do you think someone can express <u>neither</u> of the protein antigens? Certainly! These people whose red blood cells do not produce either of the A or B protein antigens have the blood type O.

3. What are antigens?

antibody generators, proteins or short sequences of proteins that stick out of the cell so that antibodies can bind

4. What is the difference between Type A and Type B blood?

Type A has A antigens on red blood cells; Type B has B antigens on the red blood cells

5. What is the difference between Type AB and Type O blood?

Type AB has both A and B antigens on red blood cells; Type O has neither A nor B antigens on the red blood cells

What Happens When a Person with Type A Blood Gets Type B Blood?

To make things a little more complicated, people with different blood types also have different antibodies. The bottom part of the picture on this page shows the A antibody binding to the A surface molecules, or antigen. A antibodies bind to A antigens and B antibodies bind to B antigens.

You may have heard that antibodies bind to pathogens or bad things in your body. When antibodies bind to these pathogens, they are signaling that the pathogen needs to be destroyed by the body's immune system. If antibodies bind to antigens to signal for their destruction, do you think someone with Type A blood would have Type A antibodies?

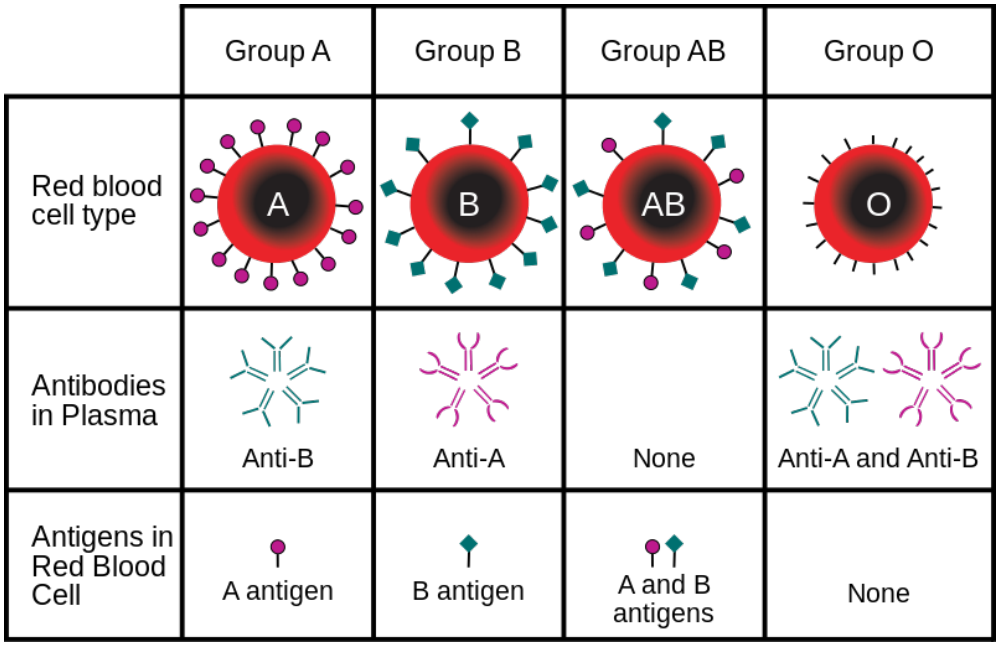
If a person has Type A blood, his or her red blood cells express the antigen A on the surface of the cell. If they had Type A antibodies, these antibodies would be able to bind to their red blood cells and would signal for their destruction. This would not be good! The person's body would be attacking itself and killing all its red blood cells! What do you think would happen if all the person's red blood cells were killed off?

6. What antibodies do you think a person with Type A blood would have?

___*not type A antibodies, students maybe guess type B or none*___

Because you wouldn't be able to transport oxygen throughout your body without your red blood cells, a person with Type A blood does not have Type A antibodies. However, that person does have Type B antibodies (see diagram on right). These Type B antibodies would be able to bind any red blood cells that express the Type B antigen. This makes sense because if you were Type A, you would want your body to get rid of any blood cells that were Type B because they would not be yours! All of your red blood cells are Type A, so any Type B ones would be foreign to your body and would not be good for you!

Similarly, someone with Type B blood would not have Type B antibodies (these antibodies would attack the body's own red blood cells). They would have Type A antibodies to mark any Type A red blood cells as foreign. What kind of antibodies do you think a person would have if they



Antigens, https://commons.wikimedia.org/wiki/File:ABO_blood_type.svg

contained both A and B antigens and were Type AB? Since these people have both antigens on their red blood cells, they would have neither antibody because both antibodies would mark their red blood cells as foreign. What about people with Type O blood? They have neither antigen on their red blood cells, so they have both antibodies.

So what would happen if you gave someone who has Type A blood Type B blood instead? If you remember from earlier, someone who has Type A blood has Type B antibodies. These antibodies would then bind to the Type B red blood cells and signal the person's immune system that they are foreign and need to be destroyed. This is called **immune rejection**. You have probably heard of this before but didn't know quite what it is. Your body rejects, or signals that the blood cells are foreign by tagging the foreign red blood cells with antibodies. The immune system then destroys the foreign red blood cells. This can also happen when a patient is transplanted with a new organ such as a liver. If the blood and tissue types do not match, the body will have antibodies against the foreign cells and will attack and reject the organ.

7. What antibodies does someone who is Type B have?

type A antibodies

8. What types of blood can someone who has Type A blood receive without rejecting it?

Type A and Type O

Where Does the Positive and Negative Come From?

Remember the Jumpstart asking you about hospital shows on TV where trauma doctors yell for "O neg." blood for patients? You just learned that Type O red blood cells do not contain A or B antigens on their surface. But what does the "neg." or negative mean?

Red blood cells also contain another type of protein on their surface - the **Rh factor**. The Rh blood group system is so named because the early experiments describing it were done with Rhesus monkey blood. The Rh blood group system actually consists of 50 different types of antigens, but the commonly used term "Rh factor" just refers to the presence or absence of the D antigen. Like Type A and Type B blood, if a person is Rh positive (Rh+), the person contains the Rh blood group system D antigen. Conversely, if a person is Rh negative (Rh-), the person does not contain the D antigen on red blood cells.

9. Why are some blood types positive and some types negative?

positive refers to Rh factor positive, they contain an additional Rh antigen, negative means they do not have the Rh antigen

The Rh factor can cause problems during pregnancy, leading to **Rh disease**. In mild cases, the fetus can have **anemia**. You have probably heard of anemia, but may not know that it is simply a lower than normal amount of red blood cells or not enough hemoglobin protein in the red blood cells. In severe cases of Rh disease, the baby may be stillborn. Rh disease typically occurs in second or subsequent pregnancies in an Rh- woman. If the father is Rh+, the baby has a chance of also being Rh+. During pregnancy, a small amount of the baby's blood can enter the mother's circulation. If the baby is Rh+ and the mother is Rh-, the mother will begin to produce antibodies against the D antigen. These antibodies are able to travel through the mother's bloodstream into the baby. If the antibody levels are high enough, they can then begin to attack the baby's red blood cells and cause the fetus to develop anemia or even worse. The main time that the baby's blood enters the mother's circulation is during birth. So, generally, the first Rh-incompatible pregnancy is not a problem because the mother begins to produce the antibodies after the birth of the baby. However, after the Rh+ baby's blood enters the mother's system during birth, any subsequent Rh+ children are at risk for developing Rh disease. Because of this, Rh disease becomes more severe with each additional Rh-incompatible pregnancy.

Rh disease used to kill 10,000 babies each year in the United States alone. However, most Rh disease can now be prevented. Now, nearly all Rh- mothers are given an injection of antibodies against the D antigen at 28 weeks gestation. These antibodies are injected into the mother so that they are able to find and destroy any of the baby's Rh+ red blood cells that entered the mother's blood before the mother's immune system can discover them and begin making her own antibodies. The injected antibodies only last about 4-6 weeks in the mother's blood, so the immunity typically wears off shortly after the baby is born.

10. How does Rh disease occur?

an Rh- mother is pregnant with an Rh+ fetus, the fetus' blood enters the mother's system and her body makes antibodies against D antigen, they attack the baby's RBC's

11. How do doctors prevent Rh disease?

give the mother a shot of antibodies against D antigen to find any of baby's blood cells in the mother before her immune system finds them

Why is O- the "Universal Donor"?

Let's put together what we have just learned about blood types and the Rh factors. What different antigens does Type O blood have on its red blood cells? They have none. What about red blood cells that are Rh-? They have no Rh antigen as well. Can antibodies bind to red blood cells with no antigens? No - you need antigens for antibodies to bind.

So what happens when someone with Type A blood gets Type O blood? That person has type A antigens on his or her red blood cells, so what antibodies does that person have? That person would have type B antibodies to attack any red blood cells that have antigen B. What antigens does Type O red blood cells have? They have none! So do the antibodies in the person attack the Type O blood? No, because Type O red blood cells do not contain any antigens for the Type B antibodies to bind. The same is true for the Rh factor. O- red blood cells do not contain any Rh factor antigens, so the antibodies cannot bind to them.

Type O- blood has red blood cells with no antigens for the A, B, or Rh antibodies to bind. Because none of the antibodies can bind to the red blood cells, this blood may be given to anyone because it cannot be attacked by antibodies. This is why Type O- blood is called the universal donor.

12. What blood types can someone who is type B positive receive?

Types B+, B-, O+, O-

13. What blood types can someone who is type O positive receive?

Types O+, O-

14. Why is Type O negative the universal donor?

the red blood cells do not contain any A or B or Rh antigens

Is There a "Universal Acceptor"?

If Type O- is the universal donor, what would the universal acceptor be? The universal acceptor means that someone with that blood type can accept any type of blood.

15. What blood type is the universal acceptor and why?

Type AB+ because their red blood cells contain A, B, and Rh antigens, so they do not have those antibodies to attack the different red blood cells

The universal acceptor would probably have the exact opposite blood type as the universal donor. That person would be able to accept any type of blood, so would the person have any A, B, or Rh antibodies? What blood type has no A or B antibodies? Someone with both A and B antigens, or someone with the blood type AB. What about the blood type that has no Rh antibodies? Someone with the Rh antigen (or Rh+) would have no Rh antibodies. So someone with the blood type AB+ would be able to accept any type of blood because they do not have the antibodies to attack the red blood cells. Someone with type AB+ blood is the universal acceptor.

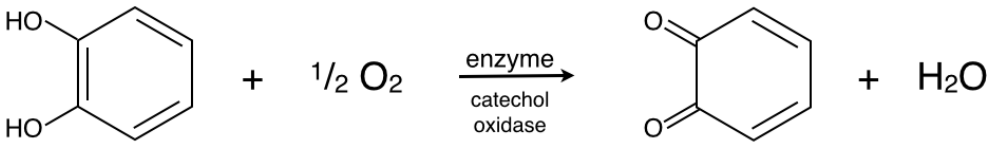
ACTIVITY 5: CAN PROTEINS MAKE TRAITS THAT WE CAN SEE?

PURPOSE

This activity shows how proteins can lead to observable traits.

PRE-LAB

In a previous lesson, you did experiments with enzymes and Jell-O and you also read about different enzymes. Enzymes are special proteins that catalyze chemical reactions such as breaking down sugars, breaking down collagen, and signaling cells to grow, among many other activities. In this lab, we will be doing another experiment with an enzyme. The enzyme you will be using is called catechol oxidase. Let's look at the name "catechol oxidase" to give us clues to what this enzyme does. If the -ase tells you that it is an enzyme, what do you think the oxid- tells you? Like the name suggests, "oxidase" means an enzyme that **oxidizes** (or removes hydrogens from) a molecule. What about the "catechol" in its name? Could it be the **substrate**? Catechol is indeed the substrate, so the name "catechol oxidase" tells you that it is an enzyme that oxidizes catechol. The reaction is shown below:



catechol (light) benzoquinone (dark)

You have probably seen this reaction take place, but just didn't know it. What happens when you take a few bites out of an apple and let it sit on the table? Does the apple turn brown where it was exposed to the air? When you see this, you just saw catechol oxidase in action. Catechol is a compound found in plant cells. The enzyme catechol oxidase is also found in plant cells. The left side of the equation shows the **reactants**: catechol and oxygen. When you bite into an apple and break the skin, you expose the catechol to air. Since both products are now present, the enzyme can now function and the reaction takes place. It makes the **products** (right side of the arrow): benzoquinone and water. If the apple turns brown, what do you think benzoquinone is? Benzoquinone is a **pigment**, or molecule that has coloring. This is why your apple turns brown - a pigment is formed as a product from the reaction. Your apple was light colored before the catechol was oxidized, but then turns dark after the reaction when benzoquinone is formed.

In organisms, after benzoquinone is formed, it is then converted to **melanin**. Melanin is another type of pigment. You should be familiar with melanin as well because this is the pigment that gives our skin color. Someone with a lot of melanin has darker skin while someone with less melanin has lighter skin.

TEACHER EDITION - ANSWER KEY

1. What is catechol oxidase and what does it do?

a protein enzyme that reacts catechol with oxygen to yield benzoquinone and water

2. Where is catechol found?

in plant cells

3. What would happen to a pear if you cut it up and let it sit in a bowl on the table? Describe it at a molecular level.

it would turn brown because the catechol in the cells reacts with the oxygen to form benzoquinone, benzoquinone is a pigment that is responsible for the brownish color

PREDICTION

4. Look at the picture of a Siamese cat on the right. Do you think an enzyme could be responsible for the coat color of the cat? Why or why not?

answers will vary, hopefully yes and students will begin to connect coloration to enzymatic activity

5. What could you take from this pre-lab and apply to your model of how the Siamese cat gets its coloration?

answers will vary, hopefully something about pigments (melanin) and enzymes

Siamese cat,https://www.flickr.com/photos/sonstroem/18314863075/in/photostream/

READING 5: WHAT MAKES A SQUIRREL ALBINO?

JUMPSTART

Have you seen an albino squirrel before? There are many different kinds of squirrels at the University of Texas at Austin and there is a long standing legend that seeing an albino squirrel before a test is good luck!

In 2001, students even created the Albino Squirrel Preservation Society to celebrate this legend and to foster compassion and goodwill towards albino squirrels.

1. What do you think makes a squirrel albino?

Albino squirrel, https://commons.wikimedia.org/wiki/File:Rare_White_Albino_Squirrel.jpg

various answers, probably something about lacking pigmentation

HOW DO WE GET OUR COLORING?

You have probably heard of pigments or pigmentation as things that give certain colors. Plants and animals have **pigments**, or molecules, that give coloration to leaves, fur, hair, and skin. Trees express certain red, orange, and yellow pigments in their leaves in the fall to turn them bright colors. Red foxes have red pigments in their fur to make it red. Humans also have pigments in their hair, skin, and eyes to give them coloration. The main pigment found in most organisms is **melanin**. Melanin is responsible for making our skin and hair dark. There are different forms of melanin which give slightly different colors. The most common melanin is brownish-black and is responsible for dark skin color and dark hair. Another form is a redish-brown color and is responsible for red hair and freckles.

2. What are pigments and where are they found?

pigments are molecules that give coloration to organisms; they are found in leaves, fur, hair, skin, etc.

HOW DO WE TAN?

In a previous unit, you learned that specialized cells become specialized by expressing certain proteins specific to their function. Melanin is made by protein enzymes from the amino acid tyrosine. These enzymes that produce melanin are proteins, so they are

expressed by only certain types of cells. Your muscles don't need to be colored, so the enzymes to produce melanin are not expressed in your muscles. However, your skin helps protect you from damaging sun rays, so being a darker color helps protect your body.

You should also remember that the amounts or levels of proteins can vary inside of cells. Someone who has dark skin has more protein enzymes to produce melanin inside of their skin cells than someone who has light skin. When we go outside, we are exposed to UV radiation from the sun. This radiation causes skin cells to start producing more enzymes that make melanin. The more melanin the skin cells produce, the darker the skin cells become. This is how we are able to tan.

3. How do we tan?

UV rays cause skin cells to produce more enzymes that make melanin, they make more melanin which causes brown coloration of the skin

4. What do you think albinism is caused by?

producing less or no melanin

What Causes Albinism?

If tanning is caused by producing more enzymes that make melanin, you probably said that albinism is caused by producing less or no enzymes to make melanin or having no melanin. This is indeed correct. Organisms that have a complete absence of melanin are called an **albino** while organisms with a lesser amount of melanin than normal are described as an **albinoid**.

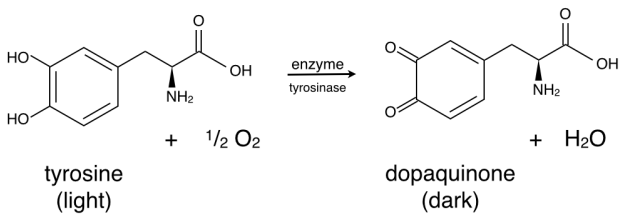
So how do organisms have a complete absence of melanin? You learned earlier that melanin is made by enzymes from the amino acid tyrosine. The first step to synthesize melanin is done by the enzyme tyrosinase. Tyrosinase oxidizes tyrosine to convert it to a dopaquinone. Dopaquinone can then combine with other molecules to make the different forms of melanin.

5. Draw how melanin is synthesized, starting with tyrosine:

tyrosinase
tyrosine ----------> dopaquinone +other molecules --> different forms of melanin

Look at your drawing of how melanin is synthesized. If albinos have no melanin, something must be going wrong in the pathway to synthesize melanin. Most albinism is caused by the absence or a defect in one of the enzymes that synthesize melanin. One of the most common causes of albinism is caused by a mutation to the tyrosinase gene

which results in a non-functional tyrosinase protein. Put your finger over the arrow between tyrosine and dopaquinone in your drawing. If the tyrosinase enzyme is not functional, this reaction cannot occur. Everything to the right of your finger will not be able to be made. Dopaquinone cannot be made, and if it cannot be made, then the product of melanin further down the pathway cannot be made either either.



tyrosine (light) — dopaquinone (dark)

6. How does a mutation to the tyrosinase gene cause albinism?

mutation to gene changes the tyrosinase protein enzyme made, it cannot function properly; it cannot make dopaquinone from tyrosine, which then cannot be used to make melanin, with no melanin, you have no coloration

Are All Albinos White?

There are varying levels of albinism in organisms. The albino squirrel on the first page had white fur and red eyes. The albino freshwater snail on this page is very red all over its entire body. This is because these freshwater snails contain hemoglobin to carry oxygen throughout its body. When hemoglobin has oxygen bound, it is bright red. Since the snail is an albino and does not have any melanin, the bright red hemoglobin shows through the body and is easy to see.

Albino freshwater snail, http://en.wikipedia.org/wiki/File:Biomphalaria_glabrata.jpg

There are two main categories of albinism in humans: oculocutaneous albinism and ocular albinism. The word “ocular” means eyes and “cutaneous” means skin. Someone with ocular albinism, therefore, is lacking pigment only in their eyes. Someone with oculocutaneous albinism is lacking pigment in their eyes, skin, and hair. In non-humans oculocutaneous albinism results in lack of melanin in the fur, scales, or feathers. Animals that are albino lack the normal coloration of their species. Although it is not so much a worry in humans, many animals use their coloration to hide from predators. Albino animals in nature are unable to camouflage or hide from predators, so they generally have a shorter life span than other non-albino animals. In humans, lack of skin pigmentation makes a person more susceptible to sunburn and skin cancers.

7. What are some problems with being an albino (human and non-human)?

non-human - unable to hide from predators so have shorter lifespan
humans - more susceptible to sunburn and skin cancers

ACTIVITY 5: PROCEDURE

PART I

6. In this lab, you will be converting catechol to benzoquinone. You will mix catechol with potato extract. What does the potato extract supply to the reaction?

catechol oxidase (the enzyme)

7. What happens to enzymes when they are heated?

they denature and are no longer able to function

8. What do you think will happen if you heat the potato extract?

the heat will denature the catechol oxidase enzyme and it will no longer be able to function

9. The following table is the layout of your experiment:

Tube	Distilled Water	Catechol	Distilled Water	Potato Extract	Heated Potato Extract	Chilled Potato Extract
1	5 mL	10 drops	10 drops	-	-	-
2	5 mL	10 drops	-	10 drops	-	-
3	5 mL	-	10 drops	10 drops	-	-
4	5 mL	10 drops	-	-	10 drops	-
5	5 mL	-	10 drops	-	10 drops	-
6	5 mL	10 drops	-	-	-	10 drops
7	5 mL	-	10 drops	-	-	10 drops

In which tubes do you think benzoquinone will form (indicated by a dark color)? Why?

just want a guess, hopefully they will say 2 & 6 because they contain both catechol and functional catechol oxidase (from the potato extract)

PART II

10. Label your test tubes 1-7.

11. Add 5 mL of distilled water to each test tube.

12. Carefully add 10 drops of catechol in tubes 1, 2, 4, and 6.
    (!!!) Catechol is a poison! Avoid contact with all solutions and wear gloves. Wash your hands thoroughly after the experiment.

13. Add 10 drops of distilled water in tubes 1, 3, 5, and 7.

14. Add 10 drops of room temperature potato extract into tubes 2 and 3.

15. Add 10 drops of heated potato extract into tubes 4 and 5.

16. Add 10 drops of chilled potato extract into tubes 6 and 7.

17. Record your observations in the table. Include rough time it took for color change.

Tube	Observations
1	*want observations including color and time it took for it to change color (not necessarily exact time, just "fast" or "slow" will work)*
2	
3	
4	
5	
6	
7	

18. In which tubes did benzoquinone form?

answers will vary based on experiment - tubes 2 & 6 should work

19. How did your results compare to your predictions in Part I?

answers will vary

Making Sense

20. Which tube(s) was/were your control tube(s)? Why?

Tube 1 (no catechol oxidase), 3 & 5 & 7 (no catechol)

21. What happened when you heated the potato extract? Why?

the catechol oxidase enzymes denatured due to the heat, the reaction will not work because the enzyme cannot function when denatured

22. What happened when you chilled the potato extract? Why?

the catechol oxidase enzymes would move slower because they were cold, reaction will not go as fast

Explaining the Driving Question

23. Look back at the picture of the Siamese cat in the Prediction section. What parts of the cat's body would be the warmest? What parts would be the coolest?

warmest - body, coolest - ears, face, tail, paws

24. Do you notice a pattern between the cat's coat color and the temperature of the body areas?

yes, lighter color where warm, darker color where cooler

25. Siamese cats have tyrosinase enzymes to make dopaquinone, and then melanin. However, their enzymes have a mutation that causes them to denature more easily in lower temperatures than the non-mutated enzymes normally would. What does this mean for the enzyme?

a little bit of heat will denature the enzyme as opposed to the normal high amount of heat it takes

26. If Siamese cats have tyrosinase and the ears of the cat are cooler, why are they dark colored?

in the areas that are cooler (like the tail and ears), the enzyme does not denature so it makes dopaquinone to make melanin so they are darker because melanin (a pigment) is present

27. Why are Siamese cats light colored on their warmer body?

the tyrosinase is heat sensitive so in the areas that are warm (like the body), the enzyme denatures and does not make dopaquinone to make melanin so the body is light in color

28. What would happen if you left a Siamese cat outside all winter? Why?

the cat would be colder, so it would be darker all over (enzyme would not denature as much so it would make more dopaquinone/melanin)

29. What would happen if you put boots on the feet of a Siamese cat? Why?

the feet would get warm, so the enzyme would denature in the feet so the feet would be lighter in color because less/no dopaquinone/melanin would be made

30. Can proteins lead to visible traits? _____ Why or why not?

various responses, hopefully a lot of "yes"

31. Create your final model of how Siamese cats get their coat coloration and pattern. Be sure to include anything helpful you have learned in this unit.

model should show how tyrosinase makes dopaquinone/melanin from tyrosine in the cool parts (ears, tail, face, feet) of the cat leading to the dark color

model should show how the enzyme tyrosinase denatures in the warmer parts (body) of the cat to not be able to catalyze the reaction to make dopaquinone/ melanin, leading to the light color