Lesson Four

Glucose in balance

Overview
Students model blood glucose homeostasis using a game board and pasta pieces to simulate how blood glucose levels are regulated by the hormones insulin and glucagon, and how the liver, fat cells, muscle and brain play a role in blood glucose homeostasis. Using their models, students first explore how blood glucose levels in healthy individuals are affected by eating and fasting. They then model how insulin resistance leads to elevated blood glucose levels, and predict the effects of β cell damage, exercise, and medication on blood glucose levels. Students also discuss the limitations of using a model to show relationships and connections within complex systems.

Enduring understanding: Blood glucose levels need to be maintained within specific ranges, and body systems work together to maintain this range through the process of homeostasis. Type 2 diabetes can develop over time if the mechanisms that maintain blood glucose levels are challenged and eventually fail.

Essential question: How do our body systems work together to maintain balanced glucose levels, and how does type 2 diabetes develop when this balance is upset?

Learning objectives
Students will be able to:
- Model the mechanism for maintaining glucose balance.
- Predict how insulin resistance, exercise, medication and β cell damage may affect type 2 diabetes.

Prerequisite Knowledge
Students should have an understanding of the following terms: cell, tissue, organ, glucose, fat, protein, hormone.

Time: Approximately 90 minutes

This lesson connects to the Next Generation Science Standards in the following ways:

Performance Expectations
HS LS1-3 Conduct an investigation to provide evidence that feedback mechanisms maintain homeostasis.
HS LS1-2 Use a model to illustrate the hierarchical organizations of interacting systems that provide specific functions.

HS LS1.A Disciplinary Core Idea
Structure and Function: Feedback mechanisms maintain a living system's internal conditions within certain limits and mediate behaviors, allowing it to remain alive and functional even as external conditions change within some range.

This lesson highlights the Practices of **Using Models, Interpreting Data** and the Crosscutting Concept of **System Models**.

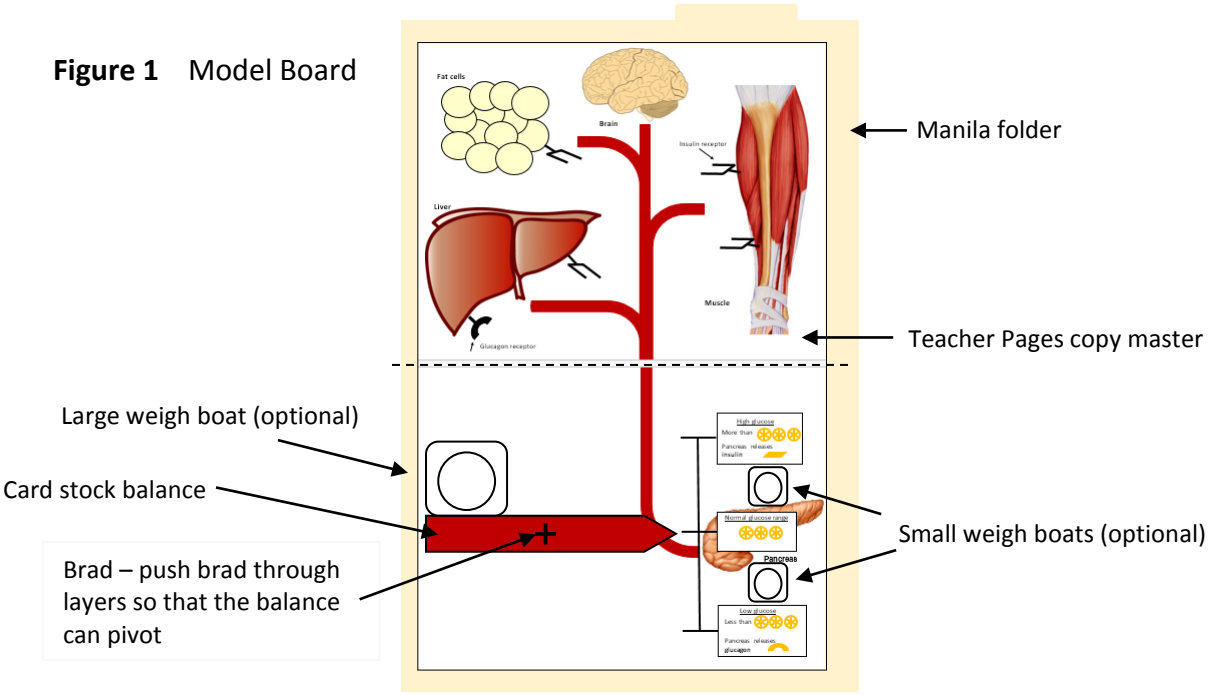
Materials

Materials	Quantity
Computer and projector, or 1 computer per student pair	1 per class or pair
PowerPoint presentation found at http://gsoutreach.gs.washington.edu/ (see GEM Instructional Materials)	1 per class
Model set (see Figure 1) Each set contains: 1 Manila folder 1 2-page photocopy of model board 1 brad 1 balance made from red card stock, approximately 7.5 in x 1 in, and pointed at one end. Teachers may wish to write the word "homeostasis" on the balance to underscore the concept. 20 pieces of wheel-shaped (rotelle) pasta to represent glucose 20 pieces of I-shaped (penne) pasta to represent insulin 10 pieces of curvy-shaped (macaroni) pasta to represent glucagon 1 small sticky note cut into 4 strips, each with a sticky end Optional: 2 small weigh boats, and 1 large weigh boats to hold pasta	1 per group
Student Sheet 4	1 per student
Optional: A helpful, and surprising, visual for this lesson includes: • Container(s) to hold 5 liters of liquid, preferably red, representing the approximate amount of blood adults have in their bodies. • 1 baggie with 4 g of sugar in it, representing the approximate amount of blood glucose a healthy adult would have when waking in the morning (80 mg/dl). • 1 baggie with 16 g of sugar in it, representing very high blood glucose levels of a person with diabetes (320 mg/dl). • 1 baggie with 65 g of sugar in it, representing the amount of sugar in one 20 ounce Coca-Cola.	1 per class

Lesson Preparation

- The PowerPoint presentation for this lesson is integral to the lesson. If possible, the PPT should be loaded onto student computers so that student groups can proceed at their own pace, with stopping points built in for teachers to check for understanding. If student computers are not available, the teacher may direct the lesson with the whole class.
- Photocopy Student Sheet 4 for each student.
- Make enough model boards for each group, as shown in Figure 1. Add the correct number of pasta pieces and sticky notes.
- Make up the baggies containing sugar and containers with liquid, if showing the optional visual model for this lesson.

Figure 1 Model Board



Presenting the Lesson

Tell students that they will be learning about the biological mechanism of type 2 diabetes in this lesson by working with a model. Models can be useful to show relationships and connections within complex systems. However, every model has limitations, especially a model that works to simplify a very complex system. Some limitations of this model are, for example, that it focuses on only a few cell types even though every cell can use glucose for energy. In addition, the role of fats and triglycerides is not well-addressed, nor are the model pieces to scale. Tell students that they will have a chance to address any other limitations of the model at the end of the lesson.

Procedures

Part 1 (Engage): Life in Balance (*5 minutes*)

1. If the concept of ***homeostasis*** is new for students, begin the class with a discussion about balance.

2. Have a student volunteer stand up and stand on one leg. Ask students to make observations about the student. What does it take to stay in balance?

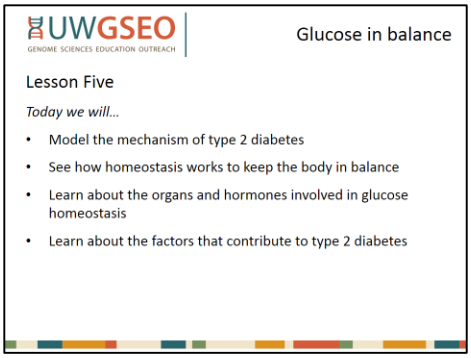
3. Throw the student a tennis ball. Ask students to think about all of the different cells, organs and body systems working to keep the student upright.

4. Tell students that all living things have feedback mechanisms that allow them to cope with changing environmental conditions. ***Homeostasis*** is the ability of an organism to adjust its internal environment to maintain stability, or balance, even as the external environment changes.

Part 2 (Explain): Who's who of diabetes (*20 minutes*)

5. Show students the first slide of the PowerPoint presentation and go over the goals of the lesson.

Slide 1

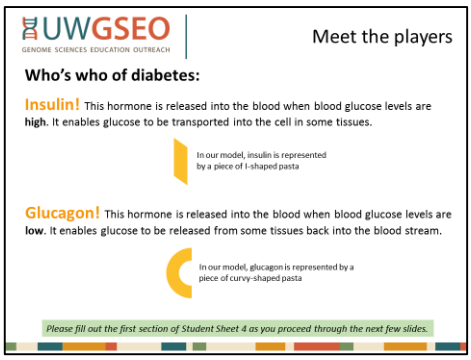


6. Pass out *Student Sheet 4* for students to take notes on during the lesson

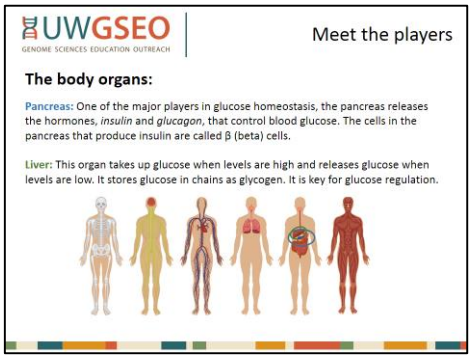
7. Let students proceed through slides 2 through 9.

Slide 2

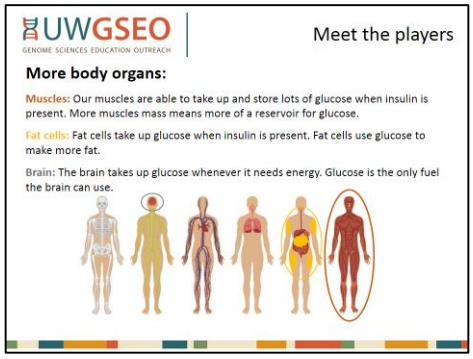
Slide 3



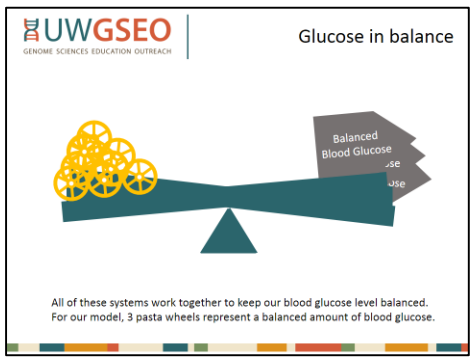
Slide 4



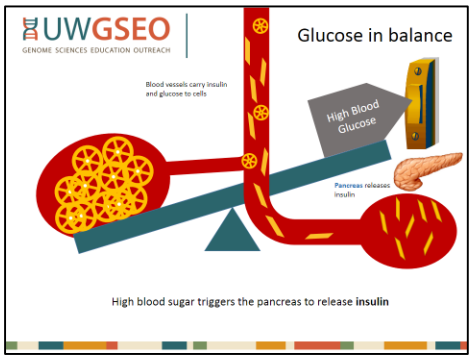
Slide 5

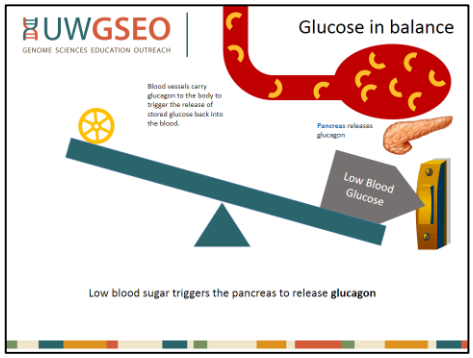


Slide 6

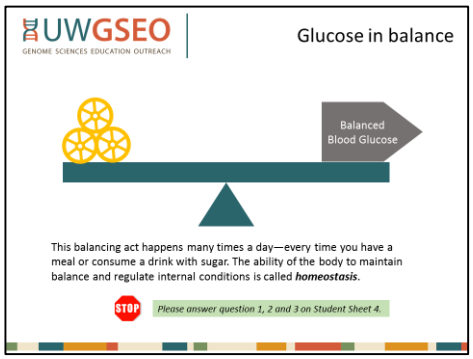


Slide 7





Slide 8



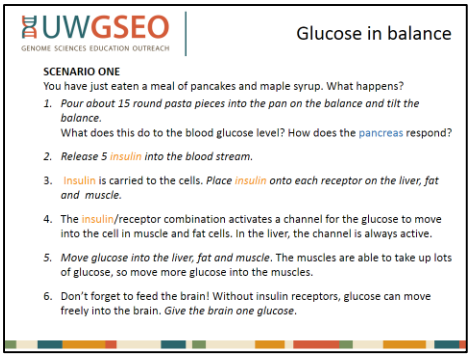
Slide 9

Part 3 (Explore): Glucose in and out of balance (*30 minutes*)

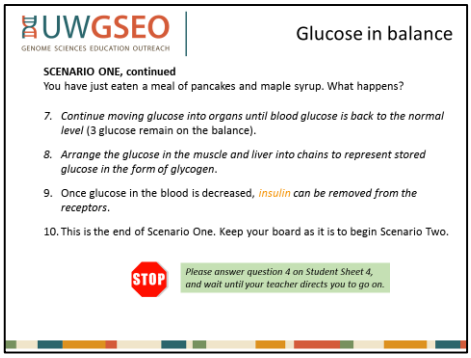
8. Hand out the model boards to each student group of 2-3 students. Make sure that students have a supply of the three types of pasta (rotelle, penne and macaroni).

9. Check for student understanding of the previous slides and let students explore the balance mechanism of their game boards.

10. Have students progress through Scenario One using Slides 10 and 11.

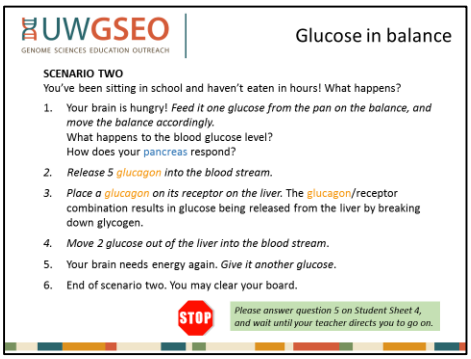


Slide 10



Slide 11

11. Check for understanding of Scenario One and proceed to Scenario Two on Slide 12.



Slide 12

12. Show students the *first step* of Slide 13 (black line only), which illustrates the normal fluctuations in glucose. Use the following prompts to have students make predictions (in pencil) on *Student Sheet 4* about how insulin and glucagon might respond after a healthy individual eats a meal.

    - For the blood glucose line, in **black**:
      What are normal levels of fasting blood glucose? *Between 80 – 90 mg/dL.*
      About how long are glucose levels elevated after a meal? *About two hours.*

      The next line will show insulin. What do you predict the line will look like?
      It should go up when blood glucose goes up, and go down when blood glucose goes down.

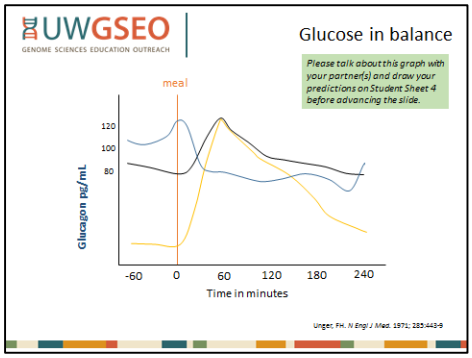
    - For the insulin level line, in **gold**:
      Does the line show what you predicted it would? Why or why not?

      The next line will show glucagon. What do you predict the line will look like?
      It should go up when blood glucose in low, and go down when blood glucose is high (i.e. inverse relationship).

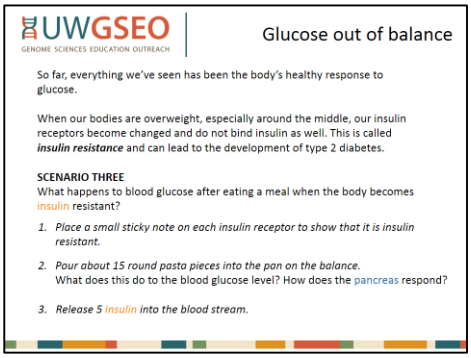
    - For the glucagon level line, in **blue:**
      Does the line show what you predicted it would? Why or why not?

    If student predictions are not very accurate, have them re-draw the three lines on *Student Sheet 4* to show the correct relationships. Point out for students that the even though glucose, insulin and glucagon are shown on the same graph at the same scale, they are all measured in different units.

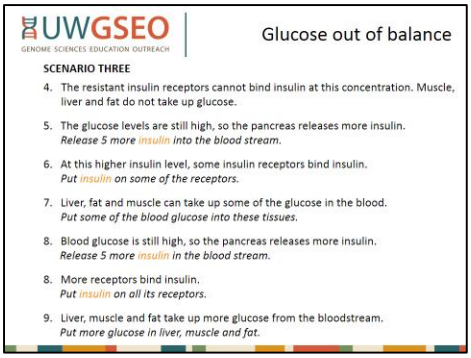
Slide 13



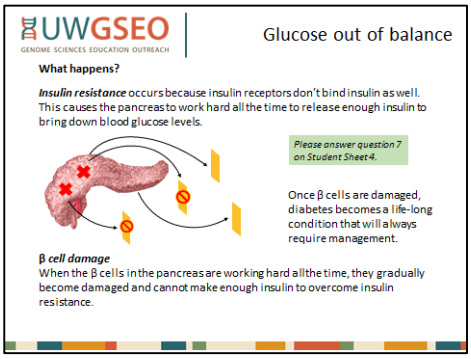
13. Go through Slides 14 through 18, either as a class or in small groups, discussing Scenario Three, insulin resistance and β cell damage, and the ways in which prediabetes and diabetes are defined and diagnosed.



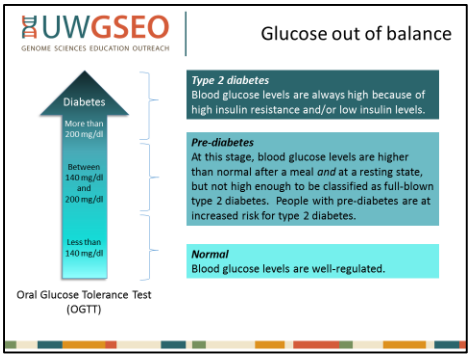
Slide 14



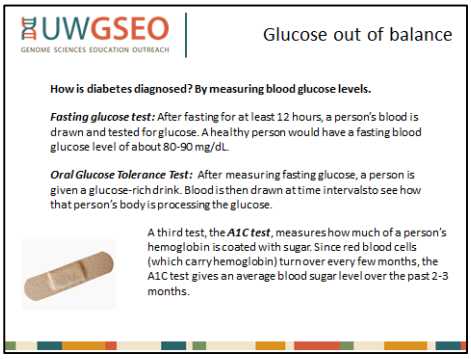
Slide 15



Slide 16

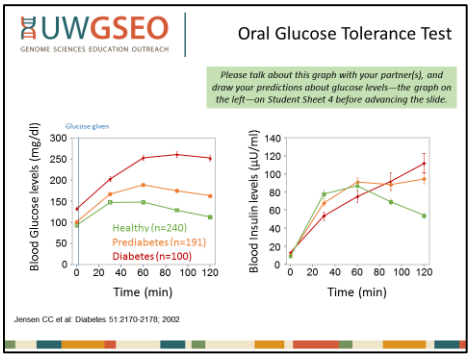


Slide 17



Slide 18

14. For Slide 19, again make sure students pause between each step of the animation to predict blood glucose levels for individuals who are healthy, have prediabetes, and have diabetes. Students can make predictions using *Student Sheet 4*. If their predictions are incorrect, make sure that they correct their graphs in order to have accurate information.

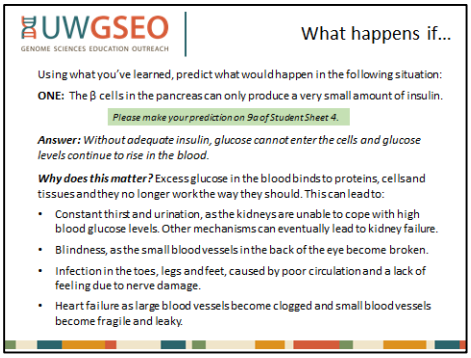


Slide 19

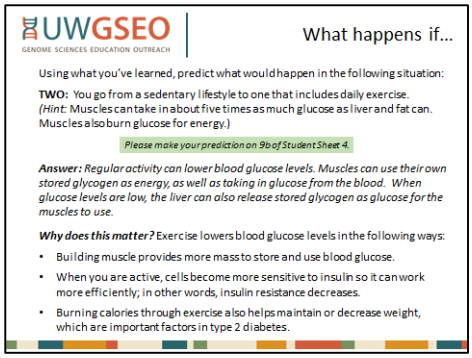
Note: This is a good place to show students the visual representation of normal and high levels of blood sugar using the baggies and 5 L of liquid (see the ***Materials*** section). 80 mg/dl translates to 4 grams of sugar in 5 liters of liquid (the approximate amount of blood in an adult). Students can also compare this to the amount of sugar in a 20-oz Coca-Cola.

Part 4 (Elaborate/Evaluate): What happens if…? (*25 minutes*)

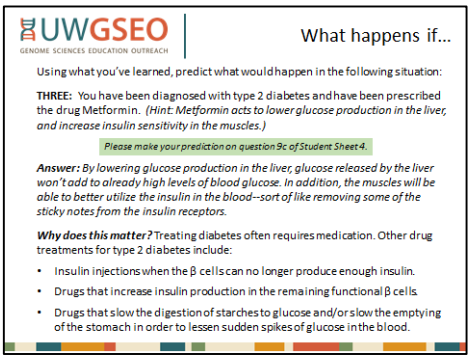
15. Slides 20 through 23 can be used in a number of ways (see note below). They challenge students to use what they have learned to predict how the body would react in three different situations— if β cells are damaged, if a person exercises, or if a person is put on diabetes medication. Additional information about symptoms of type 2 diabetes for each circumstance is provided for each situation.



Slide 20



Slide 21



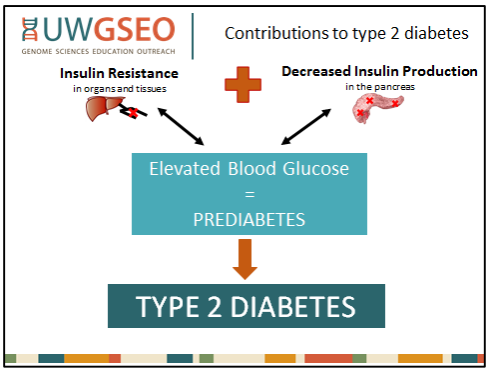
Slide 22

Note: Teachers could use these scenarios in a number of ways, such as going through each slide as a class, assigning scenarios to different groups and having them report back to the class, or assigning scenario(s) for homework with follow up the next class period.

Closure The Big Picture (*5 minutes*)

16. Close the class by showing Slide 23. Some important points to make are:
    - *Insulin resistance* and *decreased insulin production* are interconnected processes that lead to type 2 diabetes.
    - Both processes can be affected by environmental and genetic influences. For example, a person may be genetically predisposed to have β cell damage.
    - Lifestyle changes that lead to increased exercise and/or weight control can have a major impact in reversing prediabetes (point out reversible arrows).
    - Once type 2 diabetes is diagnosed, it can be controlled and managed, but not "cured" as yet (point out the one-way arrow).
    - Especially if caught early, prediabetes and type 2 diabetes are preventable and/or treatable.

Slide 23



17. Give students a chance identify any limitations to the model they used today.

Call to Action Product

17. Ask students how this lesson contributes to their understanding of the Driving Question**: How can the growth of type 2 diabetes in the Yakima Valley be slowed?**

18. Look through the questions currently on the Question Wall to identify questions that have been answered by today's lesson and can help students in their Call to Action product.

19. Ask students if they have any new questions to add to the Question Wall.

20. Let students know that no matter the specific topic or focus of their Call to Action product, each student will need to have a solid understanding of the roles of glucose, insulin, glucagon in blood glucose homeostasis.

Glossary

Glucose: A simple, single-ring sugar that serves as the main source of energy for most living things.

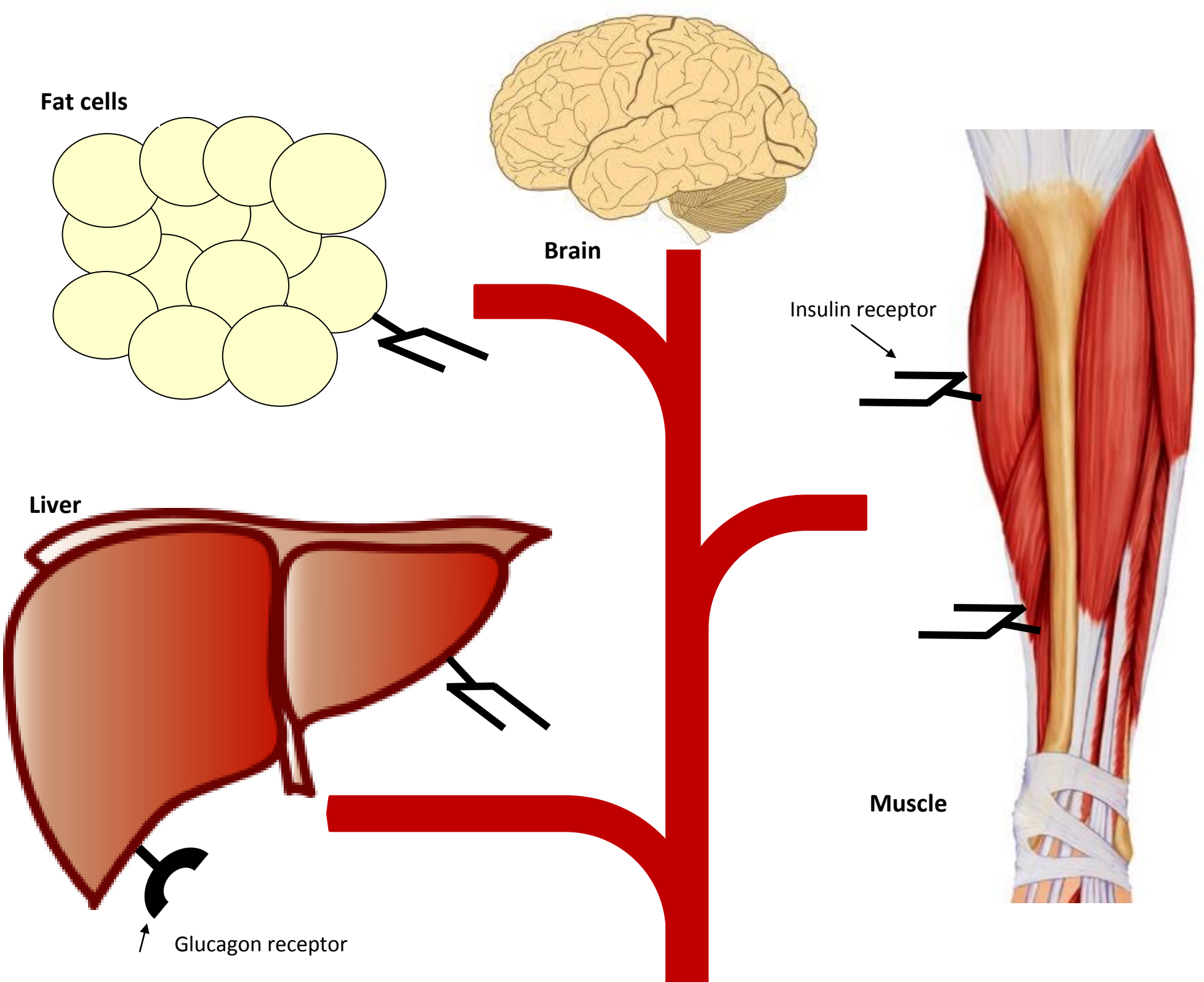
Insulin: A hormone made by the beta cells of the pancreas to regulate the amount of glucose in the blood.

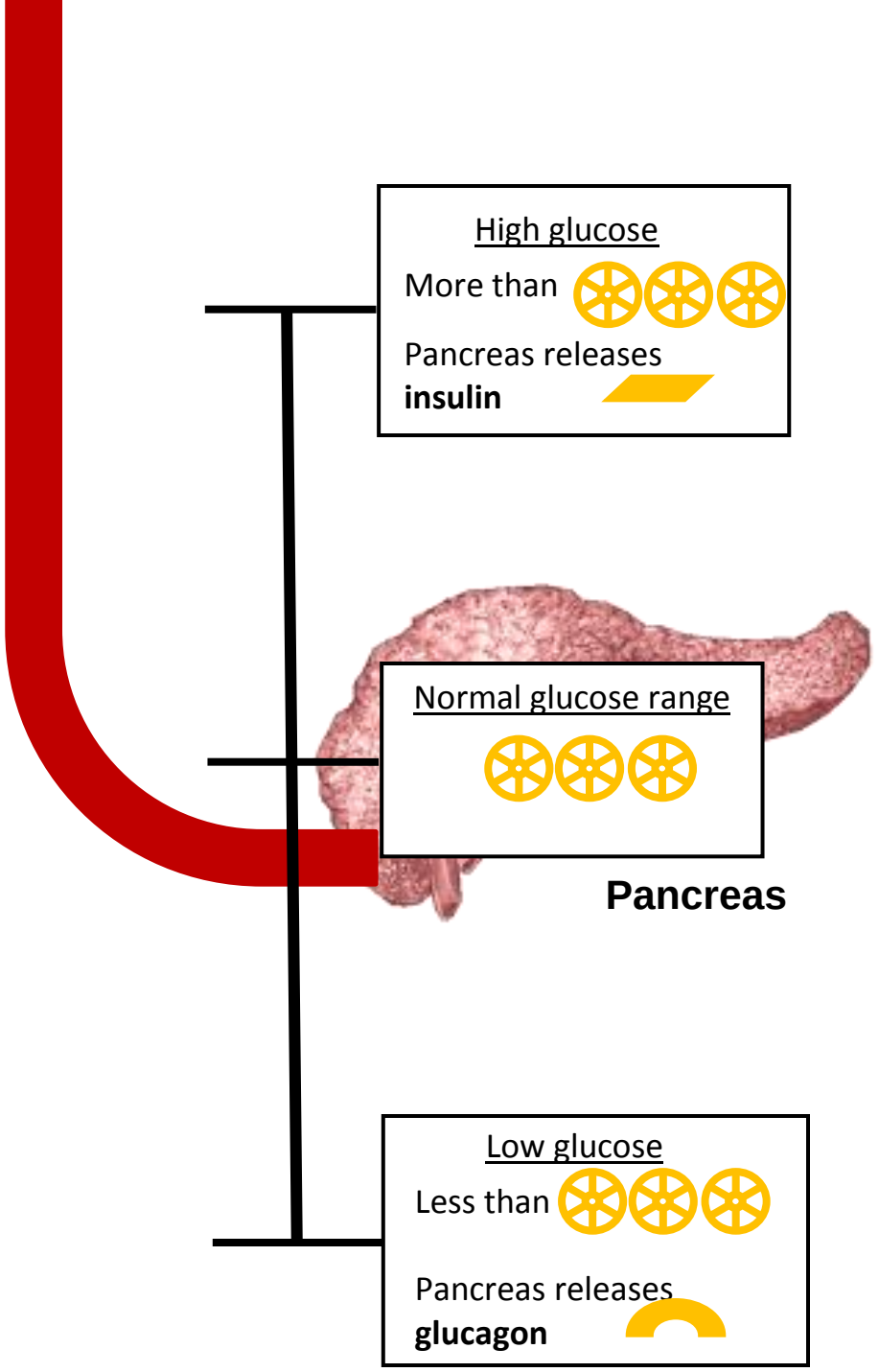
Glycogen: A storage form of glucose produced mainly in the liver and muscle cells.

Glucagon: A hormone made by the pancreas in response to a fall in blood glucose levels.

Beta cell (β cell): A type of cell in the pancreas that makes and secretes insulin.

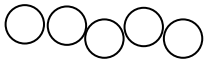
Homeostasis: The ability to maintain a living system's internal conditions within certain limits even as external conditions change within some range, often involving feedback mechanisms.


Fat cells
Brain
Insulin receptor
Liver
Muscle
Glucagon receptor


High glucose
More than
Pancreas releases
insulin
Normal glucose range
Pancreas
Low glucose
Less than
Pancreas releases
glucagon

POSSIBLE ANSWERS to Student Sheet 4

Meet the Players:

Player	Game piece	Function
Glucose		*Blood sugar, used as energy*
Glycogen		*Stored glucose, made of many units of glucose*
Insulin		*Hormone allows glucose storage*
Glucagon		*Hormone allows glucose to be released*

Organ	Role
Pancreas	*Makes and releases insulin and glucagon. Has β cells, which make insulin.*
Liver	*Regulates glucose levels in blood by both taking up and releasing glucose*
Muscles	*Can take up lots of glucose from the blood, use glucose, and store glucose*
Fat cells	*Can take glucose into the fat cell when glucose in present*
Brain	*Uses glucose for fuel; does not need insulin*

Glucose in Balance

1. When our blood glucose is high, the ___***pancreas***___ releases ____***insulin***_____.

2. When our blood glucose is low, the ___***pancreas***____ releases ____***glucagon*** ____.

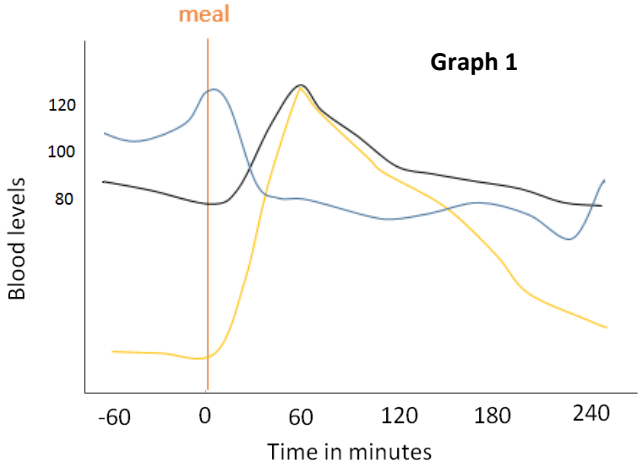
3. Define homeostasis:
The ability of the body to maintain balance and regulate internal conditions.

4. Summarize what happens in the body in scenario **one** (after a meal).
Digestion releases glucose into the blood stream. Glucose levels become high, so the pancreas releases insulin. Insulin in receptors allows muscle, liver and fat to take up and store glucose.

5. Summarize what happens in scenario **two** (after not eating).
Low blood glucose levels trigger the release of glucagon from the pancreas. The liver receives the glucagon message and releases stored glucose into the blood.

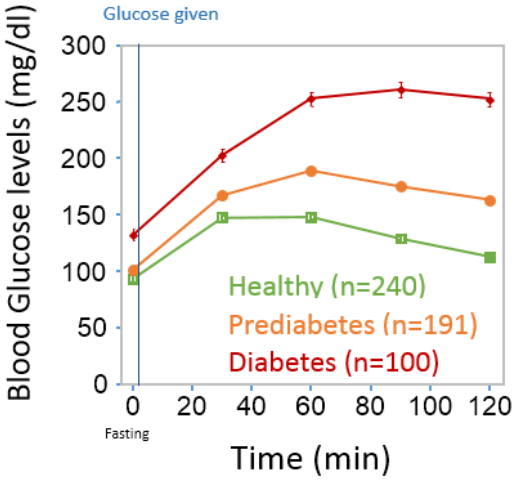
Teacher Pages

6. On the **Graph 1** to the right, blood glucose levels are shown.
   a) Draw in the line you think will best represent ***insulin*** levels
   b) Draw in the line you think will best represent ***glucagon*** levels for a healthy person.



Glucose out of balance

7. Why does one develop type 2 diabetes?
   Insulin resistance (body requires higher levels of insulin to trigger receptors to take up glucose) and beta cell damage (the pancreas cannot produce adequate levels of insulin).



Graph 2

8. 8. On the **Graph 2** to the left, draw the line that best represents ***blood glucose*** levels after eating for:
   a) a person who is healthy
   b) a person who is prediabetic
   c) a person who is diabetic.

9. What happens if…
   a) **ONE:** The β cells in the pancreas can only produce a very small amount of insulin.
   Blood glucose stays high, which leads to complications like blindness, heart disease, amputations, and constant thirst and urination.

   b) **TWO:** You go from a sedentary lifestyle to one that includes daily exercise.
   Exercise decreases blood glucose levels because muscles use blood glucose to work, plus muscles can store lots of glucose so building muscle builds places for glucose storage. Exercise also helps burn calories which can control weight.

   c) **THREE:** You have been diagnosed with type 2 diabetes and have been prescribed the drug Metformin
   Metformin controls blood sugar by not allowing as much stored glucose to be released by the liver. It also allows muscles to take up more glucose.

Name: _____ Date: _____ Period: _____

Meet the Players:

Player	Game piece	Function
Glucose		
Glycogen		
Insulin		
Glucagon		
Organ	**Role**	
Pancreas		
Liver		
Muscles		
Fat cells		
Brain		

Glucose in Balance

1. When our blood glucose is high, the _____ releases _____.

2. When our blood glucose is low, the _____ releases _____.

3. Define homeostasis:

4. Summarize what happens in the body in scenario **one** (after a meal).

5. Summarize what happens in scenario **two** (after not eating).

Lesson Four: *Glucose in balance*

6. On the **Graph 1** to the right, blood glucose levels are shown.
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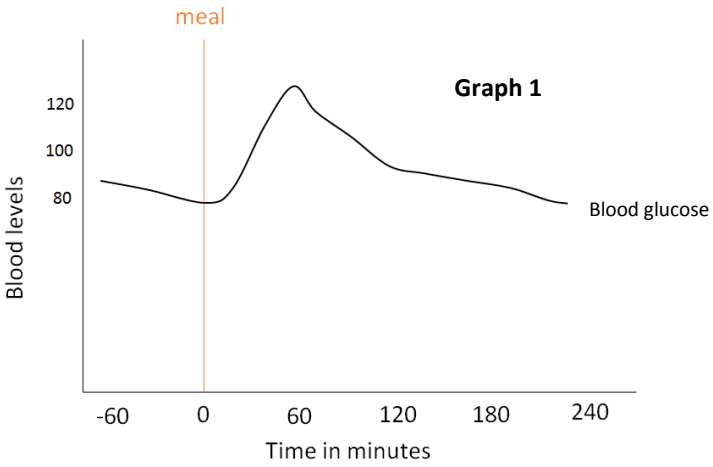
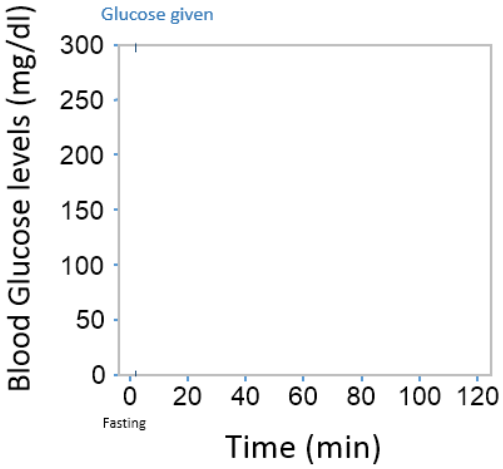
   b) Draw in the line you think will best represent ***glucagon*** levels for a healthy person.



Glucose out of balance

7. Why does one develop type 2 diabetes?



Graph 2

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   a) a person who is healthy

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   c) a person who is diabetic.

9. What happens if…
   a) **ONE:** The β cells in the pancreas can only produce a very small amount of insulin.

   b) **TWO:** You go from a sedentary lifestyle to one that includes daily exercise.

   c) **THREE:** You have been diagnosed with type 2 diabetes and have been prescribed the drug Metformin

Continue on another sheet of paper, if needed