Blood Glucose Metabolism
Instructor’s Guide

Time to Complete
Recommended time to complete – 45-60 minutes

Prior Knowledge
• Students should have a basic understanding of the function of glucose in normal metabolism.
• Students should have a basic understanding of endocrine glands, hormones, and hormone transport.

Content Objectives
• Students will be able to identify both normal and abnormal results for the Oral Glucose Tolerance Test.
• Students will be able to explain the relationship between insulin and glucose levels in the blood.
• Using the concept of glycemic index, students will be able to predict relative rates of changes in blood glucose levels relative to diet.

Process Objectives
• Information processing: Students are required to graph tabular data.

Implementation Notes for Instructors
After completing this activity, students should be familiar with the Oral Glucose Tolerance Test, be familiar with how blood glucose levels change over time in relation to the ingestion of sugar, develop a basic understanding of the relationship between insulin and glucose levels, and a basic understanding of diabetes mellitus. Question 8 asks students to brainstorm what they know about diabetes, and it should be expected that some students give inaccurate information. Instructors may want to refer back to this question during the end of class discussion, e.g., “what did you write down for question 8?”

(Note: the activity does not include the mechanism of action for insulin.)

The activity sets the stage for an end-of-class discussion, or instructor-led presentation, on diabetes mellitus. Optional challenge questions are included at the end of this activity that can be used to extend the activity either in class or as homework.
Student Roles
(The following roles are standard for most POGIL lessons)

- **Reader**: reads the text of the activity (directions, questions, etc.) out loud so all members of the group can hear and follow along. Note: the reader should attempt to verbalize what is seen / communicated in graphs and data tables.

- **Recorder**: makes final decisions as to what is written down for final answers. The goal of the recorder is to determine final language of each answer and to provide the official text. A group often has different ideas as to what a final answer should be. The recorder is responsible for determining this final answer, taking into account the group’s ideas.

- **Taskmaster**: in charge of making sure the group completes the activity on time and keeps group members focused. Frequently says, “Are we sure about this?” “Are we ready to move on?” and even “Put away your phone - we need to get back on task.” The taskmaster is often called upon to be the spokesperson for the group at the end of the class and report answers to the class.
Blood Glucose Regulation

Model #1: The Oral Glucose Tolerance Test (OGTT)

The Oral Glucose Tolerance Test is often used to detect diabetes mellitus. The following procedure is used to conduct an OGTT:

- Patient is instructed to eat a normal diet during the days leading up to the test.
- Patient is instructed to fast (no eating or drinking) for 8 to 10 hours prior to the test (usually overnight).
- At the lab, the patient drinks a prepared glucose solution (the volume and concentration of the solution varies according to the patient’s body weight).
- Measurements of the patient’s blood glucose levels are taken every 30 minutes or every hour for 2 hours (no additional food or drink is consumed during the administration of the OGTT). In most clinical settings, readings for blood glucose are taken at time zero and at two hours. In research studies using the OGTT, glucose levels are recorded more frequently and for longer durations of time.

The following data table shows acceptable minimum and maximum values for the OGTT.

<table>
<thead>
<tr>
<th>Time (minutes)</th>
<th>0</th>
<th>30</th>
<th>60</th>
<th>90</th>
<th>120</th>
</tr>
</thead>
<tbody>
<tr>
<td>Maximum Blood Glucose (mg/dL)</td>
<td>100</td>
<td>170</td>
<td>160</td>
<td>130</td>
<td>105</td>
</tr>
<tr>
<td>Minimum Blood Glucose (mg/dL)</td>
<td>80</td>
<td>150</td>
<td>140</td>
<td>110</td>
<td>85</td>
</tr>
</tbody>
</table>

QUESTIONS:

1. What do people consume at the start of the Oral Glucose Tolerance Test? How is the volume and concentration determined?
   - A glucose solution - volume and concentration vary according to body weight

2. What is the time duration of the OGTT?
   - 120 minutes or 2 hours

3. What is the range of normal values of blood glucose at the beginning (time zero) of the test?
   - 80 mg/dL to 100 mg/dL

4. What are the highest acceptable blood glucose levels during the test? At what time in the test do these values occur?
5. What is the range of normal values of blood glucose at the end of the OGTT?

85 to 105 mg/dL at the end of the test – 120 minutes

6. Two individuals (Maria and Laura) both complain to their doctor of frequent thirst and frequent urination. Maria has the additional symptom of blurry vision and a “tingling sensation” in her fingers and toes. The doctor suspects diabetes mellitus, a disease in which blood glucose metabolism does not stay within normal ranges. The doctor orders both to undergo an Oral Glucose Tolerance Test to test this prediction. Below are the results of the OGTT.

<table>
<thead>
<tr>
<th>Time (minutes)</th>
<th>0</th>
<th>30</th>
<th>60</th>
<th>90</th>
<th>120</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Maria:</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Blood Glucose (mg/dL)</td>
<td>90</td>
<td>140</td>
<td>150</td>
<td>135</td>
<td>110</td>
</tr>
<tr>
<td><strong>Laura:</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Blood Glucose (mg/dL)</td>
<td>110</td>
<td>170</td>
<td>220</td>
<td>270</td>
<td>300</td>
</tr>
</tbody>
</table>

a) Which individual is more suspect of having diabetes mellitus?

*Laura is more likely to have diabetes.*

b) Justify your answer comparing each person’s OGTT data to data found in Model 1.

*Her blood glucose values are out of range of the normal values.*
**Model #2: Blood Glucose and Blood Insulin Levels**

Insulin is a protein hormone that is secreted into the blood by the pancreas. Clinicians rarely measure insulin levels, but the procedure is regularly done in research labs studying diabetes.

The following data show blood insulin levels that correspond to the blood glucose levels in the OGTT used in Model 1.

**Measurements recorded during OGTT**

<table>
<thead>
<tr>
<th>Time (minutes)</th>
<th>0</th>
<th>30</th>
<th>60</th>
<th>90</th>
<th>120</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Maria</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Blood Glucose (mg/dL)</td>
<td>90</td>
<td>140</td>
<td>150</td>
<td>135</td>
<td>110</td>
</tr>
<tr>
<td>Blood Insulin (pmol / L)</td>
<td>45</td>
<td>140</td>
<td>200</td>
<td>220</td>
<td>150</td>
</tr>
<tr>
<td><strong>Laura</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Blood Glucose (mg/dL)</td>
<td>110</td>
<td>170</td>
<td>220</td>
<td>270</td>
<td>300</td>
</tr>
<tr>
<td>Blood Insulin (pmol / L)</td>
<td>25</td>
<td>60</td>
<td>80</td>
<td>85</td>
<td>90</td>
</tr>
</tbody>
</table>

**QUESTIONS:**

7. What units are used to measure blood glucose? What units are used to measure blood insulin?

   - Blood glucose is measured in mg / dL (milligrams per deciliter)
   - Blood Insulin is measured in pmol / L (picomole per liter)

8. On your own, draw two graphs-- one showing Maria’s glucose and insulin levels vs. time, and the second showing Laura’s glucose and insulin levels vs. time. After all individuals have completed drawing graphs, compare them with your group members. *(Use a separate piece of paper if you choose)*
Note to instructors: If time is short, you can provide suggestions or even extra page that shows a blank graph but with labeled axes. It's best, however, is students have to work together to generate their own graphs on an empty page so as to figure out what type of graph to use, and in this case, how to put both blood glucose and blood insulin on the same graph.

Graphs will vary in many ways. Many students will have difficulty with the units required on the y-axis: glucose (mg/dL) and insulin (pmol / L) use different units and can be accommodated by labeling the y-axis on the right and left sides of the graph.

9. Which individual above (Maria or Laura) had the greater pancreatic response to the OGTT? How do you know?

Maria had a greater pancreatic response. The data in Model 2 show Maria’s levels of insulin to be higher than Laura’s.

10. On your own, write a grammatically correct sentence describing the relationship between blood glucose and blood insulin levels. After each individual is finished, compare sentences and, as a group, decide on the most accurate sentence.

Example response (student answers will vary): As blood glucose rises, the body responds by releasing insulin. Insulin enters the blood and causes blood glucose levels to fall. Insulin causes a reduction in blood glucose levels.

Note – student response should not make reference to “how” insulin functions. That level of detail is not present in the model.

11. Diabetics are often required to monitor their blood glucose levels to determine if/when they require a shot of insulin. Under what conditions should diabetic individuals give themselves a shot of insulin?
Example response (student answers will vary): A shot of insulin may be needed if blood glucose levels are too high (hyperglycemia), or if a diabetic is about to consume foods that have a high glycemic index, e.g., have a high amount of simple sugars.

Model 3: Glycemic index and changes in blood glucose

Three college students (Carter, Linden, and Miriam) have their blood glucose levels measured for six hours. All three recorded what they ate for breakfast at 7:30 am, but did not record any other intake of food.

*Carter’s Breakfast:* Orange juice, high fiber regular oatmeal, and a banana.

*Linden’s breakfast:* Sugar soda pop, Chocolate Frosted Sugar bombs, and two cups of coffee (with sugar).

*Miriam’s breakfast:* Bacon, eggs, and two cups of black coffee.

<table>
<thead>
<tr>
<th>Time of Day</th>
<th>7 AM</th>
<th>8 AM</th>
<th>9 AM</th>
<th>10 AM</th>
<th>11 AM</th>
<th>Noon</th>
<th>1 PM</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Carter</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Blood Glucose (mg/dL)</td>
<td>70</td>
<td>140</td>
<td>140</td>
<td>80</td>
<td>80</td>
<td>80</td>
<td>115</td>
</tr>
<tr>
<td><strong>Linden</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Blood Glucose (mg/dL)</td>
<td>70</td>
<td>170</td>
<td>55</td>
<td>170</td>
<td>55</td>
<td>160</td>
<td>55</td>
</tr>
<tr>
<td><strong>Miriam</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Blood Glucose (mg/dL)</td>
<td>70</td>
<td>80</td>
<td>80</td>
<td>80</td>
<td>70</td>
<td>70</td>
<td>90</td>
</tr>
</tbody>
</table>

QUESTIONS:

12. Construct one graph that documents how each student’s blood glucose levels changed over the time period shown. *(You may choose to use a separate piece of paper)*
Carter’s line should show a gradual rise and fall, with a slight rise at the end. Linden’s line should show rapid rises and falls – three peaks. Miriam’s line does not rise past 100 .. pretty flat.

13. How many times do you think each person ate during the 6-hour span? How do you know?
   - Carter – probably twice.
   - Linden – probably three times.
   - Miriam – probably twice.
   Important: look for increases in blood sugar levels. If a food with no sugar is consumed, the blood sugar levels might not rise.

14. What types of foods are associated with the most rapid changes in blood glucose levels?
   - **Foods that contain large quantities of simple sugars, such as fructose.**
     e.g.: foods that cause fast rise in blood glucose:
     - Soda pop
     - Frosted sugar bombs
     - Coffee with sugar
   
   - **Foods that cause moderate rise in blood glucose:**
     - Orange juice
     - High fiber oatmeal
     - Banana

   - **Foods that cause slow rise in blood glucose levels:**
     - Coffee (no sugar)
     - Bacon
     - eggs

15: Glycemic Index (GI) is a numeric scale (ranging from 1 to 100) that serves as an indicator of how rapidly a food causes an increase in blood glucose levels.
Carbohydrates that cause a rapid increase in blood glucose have high numbers, whereas carbohydrates that cause a gradual increase in blood glucose have lower numbers.

a) Using the term “glycemic index,” describe Carter, Linden, and Miriam’s breakfasts.
   **Carter:** Consumed foods that had a “medium” glycemic index number compared to the other two.
   **Linden:** Consumed foods that had a “high” glycemic index number compared to the other two.
   **Miriam:** Consumed foods with the lowest glycemic index number compared to the other two.

b) Which breakfast had the highest glycemic index?  
   Linden’s breakfast

c) Which breakfast had the lowest glycemic index?  
   Miriam breakfast

16. Using the term “glycemic index,” write one or two sentences that describe the components of a healthy breakfast; one that would not cause a rapid change in blood glucose.

   A healthy breakfast should involve foods with a moderate glycemic index, which would lead to a gradual increase in blood glucose levels.

**CHALLENGE QUESTIONS:**

17. It is sometimes very dangerous to give someone a shot of insulin. Under what conditions should insulin *never* be administered?

   *Example response (student answers will vary): A shot of insulin could cause unconsciousness or even death if given to someone who is already hypoglycemic.*

18. Explain how a disease of the pancreas might cause problems with glucose metabolism:

   *Example response (student answers will vary): The inability of the pancreas to release insulin would lead to problems with glucose regulation. More specifically, blood sugar levels would rise after eating, and would be very slow to return (or would not return at all) to regular levels.*
The next question will address the condition of a hyperactive pancreas, resulting in lower than desired blood glucose levels.

19. Using your knowledge of medical terminology, define the term hyperinsulinemic hypoglycemia. What might cause this condition?

   Example response (student answers will vary): Too much insulin leading to low levels of blood glucose. One disease that could cause this condition is cancer of the pancreas.

20. Many people have preconceptions about diabetes mellitus. Not all of them are correct. As a group, brainstorm what you think you know about diabetes mellitus. For example, what do you think causes diabetes mellitus? What are the long-term effects of diabetes? Can diabetes kill you? If so, what is the COD (Cause of Death)?

   Answers will vary greatly – most like to be associated with overeating and inactivity – genetics, etc… It is unlikely students will know much of the difference between Type 1 or Type 2 – and that distinction is NOT made in this activity.