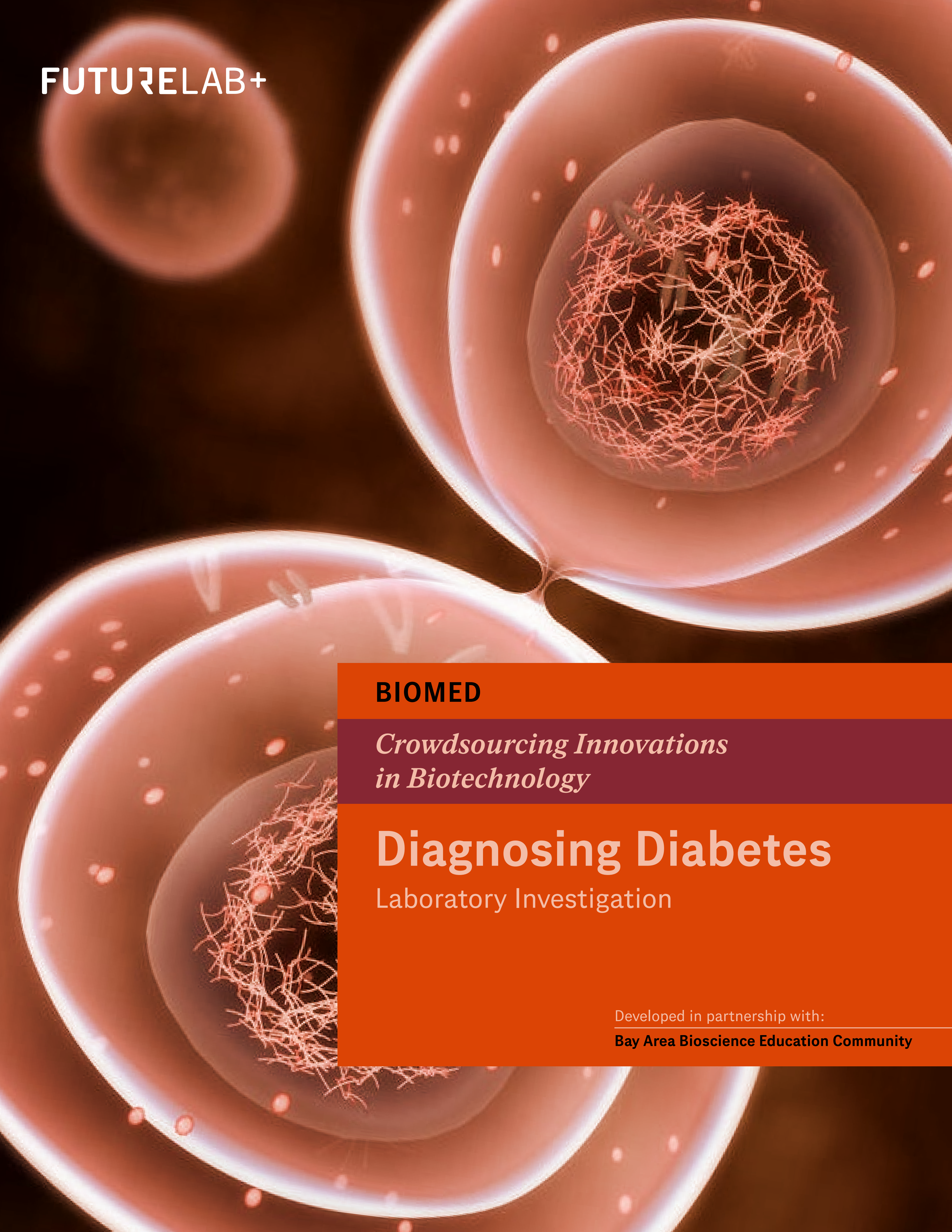


FUTURELAB+

BIOMED

Crowdsourcing Innovations in Biotechnology

Diagnosing Diabetes

Laboratory Investigation

Developed in partnership with:

Bay Area Bioscience Education Community

In this Lesson Plan:

Print the **Teacher Section** →

Print the **Student Section** →

This document is separated into two sections, For Teachers [T] *and* Student Resources [S]*, which can be printed independently.*

Select the appropriate printer icon above to print either section in its entirety.

Follow the tips below in the Range field of your Print panel to print single pages or page ranges:

Single Pages (use a comma): T3, T6

Page Range (use a hyphen): T3–T6

Cover Image
The image shows a cell that has been divided by mitosis.

BIOTECHNOLOGY / BIOTECHNOLOGY AND DISEASE

Lab: Diagnosing Diabetes

ACTIVITY DURATION

Four class sessions
(45 minutes each)

DRIVING QUESTION

How can we use glucometers, biosensors which measure blood glucose concentration, to detect if someone has diabetes?

OVERVIEW

Medical devices devices such as glucometers are essential for people with chronic diseases, like diabetes, to monitor their illness. They can also help doctors diagnose a patient with a disease or detect if a patient is are at risk for developing a disease. Doctors and diabetes patients can track the concentration of glucose in blood plasma as a biomarker of the disease. If a patient's blood glucose level is abnormally high, this may indicate he or she is are diabetic or at risk of developing diabetes.

In this lab, students will first make glucose solutions of known concentrations to evaluate the reliability of the glucometer and consider the impacts of lab technique error. Then, students will receive a patient's "blood" sample to perform a mock Oral Glucose Tolerance Test and use a glucometer to measure its glucose concentration. Finally, using their understanding of diabetes, students will make a claim about the likeliness of their patient having diabetes. They will support their claim with evidence and scientific reasoning.

ESSENTIAL QUESTIONS

How can data about blood glucose concentration be used as evidence in a claim about whether a patient has diabetes?

How can glucometers be used in scientific investigations to measure blood glucose concentration?

How can mathematics and computational thinking be used to make solutions of varying concentration in the laboratory setting?

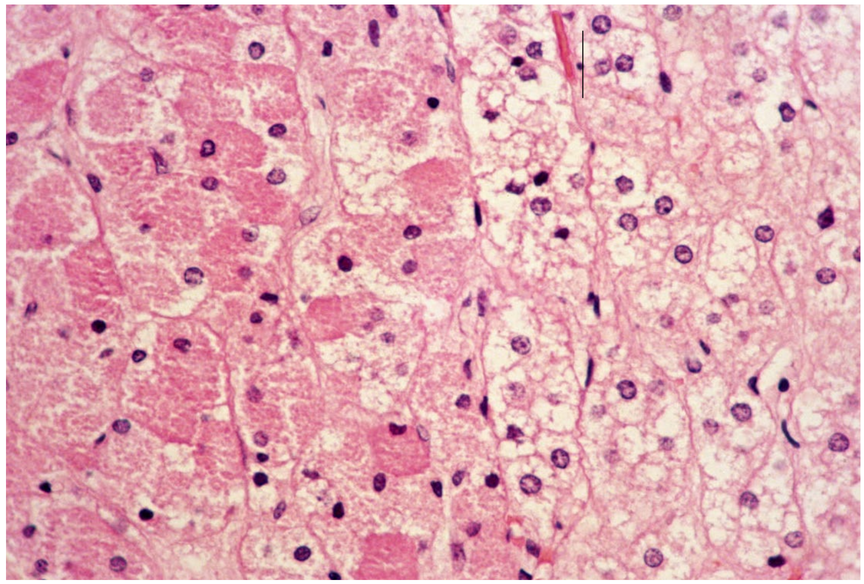
BACKGROUND INFORMATION

Basic understanding of algebra is helpful for the "making solutions" portion of this lab. Familiarity with using dimensional analysis to convert units is particularly helpful but not essential. At this point in the unit, students should have already been introduced to biomarkers and how they can be used to detect and monitor chronic diseases like diabetes.

Have you ever wondered…

How are diseases or illnesses diagnosed?

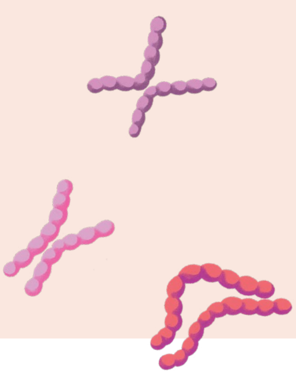
The human body maintains particular levels of molecules such as specific proteins, hormones, and sugars. This state of relatively stable equilibrium is known as homeostasis. When certain diseases occur, these levels can change, either increasing or decreasing. Abnormal levels of these molecules act as biomarkers to detect possible diseases.



MAKE CONNECTIONS!

How does this connect to the larger unit storyline?

Blood glucose concentration is a biomarker that can be used to determine if a person has a chronic condition such as diabetes. Devices like glucometers can be used by diabetics to track their blood glucose concentration.



How does this connect to careers?

Lab technicians use basic lab techniques like measuring mass and volume to make solutions. They follow written protocols as they collect samples and perform tests to analyze body fluids, tissues, and other substances.They maintain clear records of their findings.

Medical device engineers test and develop medical devices such as glucometers.

How does this relate to the product development life cycle?

When developing a new medical device, an important step is to first research and understand existing medical devices, like glucometers. It is essential to understand how to use them to collect the relevant biometric data.

Pedagogical Framing

Instructional materials are designed to meet national education and industry standards to focus on in-demand skills needed across the full product development life cycle—from molecule to medicine—which will also expose students and educators to the breadth of education and career pathways across biotechnology.

Through this collection, educators are equipped with strategies to engage students from diverse racial, ethnic, and cultural groups, providing them with quality, equitable, and liberating educational experiences that validate and affirm student identity.

Units are designed to be problem-based and focus on workforce skill development to empower students with the knowledge and tools to be the change in reducing health disparities in communities.

SOCIAL-EMOTIONAL LEARNING

The lab is centered around three patients with different backgrounds and symptoms, allowing students to develop a broader social awareness of the impacts of diabetes. Students work cooperatively with a partner throughout the lab, helping them build relational skills.

CULTURALLY RESPONSIVE INSTRUCTION

Diabetes provides a culturally relevant context for exploring biomarkers, medical devices, and making solutions of different concentrations. Most students have some personal experience with diabetes (if not themselves then a friend or family member) and can therefore connect the content and lab skills to their lives. Students also learn that Type 2 diabetes disproportionately affects people of color and consider the complex reasons underlying this trend.

COMPUTATIONAL THINKING PRACTICES

Students engage in multiple computational thinking strategies throughout this lab, including decomposing problems, collecting data, finding patterns, and analyzing data. In order to make glucose solutions of known concentrations, students utilize metric unit conversions as well as algebraic principles. Students also collect multiple data points to measure glucose concentration and identify patterns in their data. By analyzing these patterns, students can then determine the likelihood that a patient has diabetes, as well as consider sources of error.

OBJECTIVES

Students will be able to:

Identify blood glucose concentration that are considered normal, prediabetic, and diabetic, using scientific guidelines.

Calculate how to make solutions of different concentrations in mg/dL using computational thinking.

Measure mass and volume using a lab scale and graduated cylinders.

Develop a claim about the likeliness that a patient has diabetes using evidence collected from the lab and scientific reasoning.

Materials *Documents*
Lab Preparation (for teacher)
Background Reading: Diabetes and Blood Glucose (1 per student)
Background Reading: Making Solutions (1 per student)
Vocabulary Tool (1 per student)
Patient Profile Cards (1 per pair)
Student Guide (1 per student) **Internet Access**
Student Protocol (1 per pair)

Materials *Lab Equipment and Reagents*
Glucose/Dextrose (~35–40g)
Scales/balances (at least 1 per 4 students, ideally 1 per pair)
Weigh paper (1 per pair)
Beakers/containers (1 per pair, size dependent on which solution the pair makes) — *500 mL or 1 L (for the 50 mg/dL solution)* — *250 mL (for the 100 mg/dL and 200 mg/dL solutions)* — *100 mL (for the 400 mg/dL solutions)*
Graduated cylinders (or volumetric flasks) (1 per pair, size dependent on which solution the pair makes) — *500 mL or 1 L (for the 50 mg/dL solution)* — *250 mL (for the 100 mg/dL and 200 mg/dL solutions)* — *100 mL (for the 400 mg/dL solutions)*
Stirring implement (rod, popsicle stick, spoon, etc) (1 per pair)
Weighing implement (scoop, spoon, etc) (1 per pair)
Small containers (glass or plastic beakers, condiment cups, etc) (2 per pair)
Label tape (1 per pair)
Permanent marker (1 per pair)
Glucometers (1 per pair)*
Glucometer strips (6 per pair)*
Calculators (1 per student)

*
Diastix (used to measure glucose concentration in urine similar to a pH strip) may be used as a cheaper alternative to glucometers.

Day 1

Procedure

LEARNING OUTCOMES

Students will be able to:

Communicate knowledge of diabetes using a graphic organizer.

Compare the causes and effects of type 1 and type 2 diabetes and the ways in which they affect homeostasis within the human body using scientific text.

Explain how glucometers can be used to diagnose diabetes using scientific text.

Whole Group (20 minutes)	
1	Warm up: Instruct students to create a KWL chart in their notebook with three columns labeled from left to right with: what they KNOW, WANT to know and want to LEARN about diabetes.
2	Tell students that they will have five minutes to work with their partner to complete the first two columns of their own individual chart.
3	As a class, select two to three students to share their notes from the KWL chart using calling sticks.
4	Note any similarities or differences with what they already know versus what they want to learn about the disease. Tell students that they will be exploring more about diabetes and how it is diagnosed throughout the week and adding to the “LEARN” section of their chart.
5	Show the following video(s) that reveal a personal story about an individual living with type 2 diabetes to help facilitate further discussion with students. Prompt students to add to their KWL chart after watching if new information comes up for them. **a.** *Living with Type 1 diabetes | Erin’s Story*, Diabetes UK **b.** *Living with Type 2 Diabetes*, Peter Sheehan Diabetes Care Foundation

Teacher Note > *Possible discussion questions include: What is one way having diabetes affects someone’s life?, Do you know anyone living with diabetes?, How does it affect their life?, What are some of the symptom’s people notice when they are diagnosed with diabetes?.*

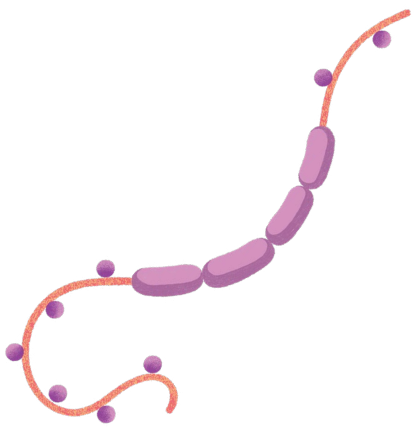
6	Inform students that they will be working on a lab this week that involves using a glucometer, a type of biosensor, to determine if patents have diabetes.. In order to validate or check the accuracy of the glucometer, they will also be learning how to make solutions. Share the learning outcomes for today.
7	Hand out the *Background Reading: Diabetes and Blood Glucose* and read the first paragraph together as a class, taking time to make annotations that increase reading comprehension.

Continues next page >

Day 1

Continued

Procedure



Small Group (20 minutes)	
1	Instruct students to finish reading and answering the questions on *Background Reading: Diabetes and Blood Glucose*.
2	After completing the questions, students can check their answers with the key. If students do not finish in the allotted time, assign for completion as homework.
3	Hand out the *Vocabulary Tool* to early finishers and have students write their own sentences for the first eight words for homework. You may also wish to assign flashcards for additional practice.

Individual (5 minutes)	
1	Reflection/Exit Ticket: Ask students to add at least two new things they learned about diabetes to their KWL chart.

Day 2

LEARNING OUTCOMES

Students will be able to:

Explain what it means for a solution to have a certain concentration using scientific text.

Convert between units of grams and milligrams and between deciliters and milliliters using computational thinking.

Prepare a solution of a given concentration in mg/dL using computational thinking.

Procedure

Whole Group (10 minutes)	
1	Warm-up: Show students pictures of a powder-based drink with a high concentration and with a low concentration. You can also make the concentrations in a demonstration. Ask students to describe differences and similarities between the two concentrations, using words or drawings
2	Draw students attention to "concentration" as the property that is different between the two drinks. Remind them that for their lab, they will be using a biosensor called a glucometer to measure the concentration of glucose (a sugar) in a patient's blood. Share the learning outcomes for today.
3	Hand out *Background Reading: Making Solutions* and ask students to take out their calculators. Read the first paragraph together as a class, taking time to make annotations that increase reading comprehension.

Small Group (30 minutes)	
1	Break students into pairs and ask them to finish reading and answer the questions on *Background Reading: Making Solutions*.
2	When students finish, ensure that they check their answers with the key.
3	Extension activities for early finishers: **a.** With your partner, create your own "making solutions" problems and a key. Find another pair to switch with and answer each other's questions. **b.** Devise another method of converting between metric units. **c.** If you have available materials (water, salt or sugar, balance, beakers), practice making some of the solutions you calculated.

Teacher Note > *There will likely be a lot of variation in students' comfort level with metric unit conversions and the math involved in making solutions. Students who have taken chemistry and algebra will likely pick up the material very quickly and move through the assignment at a much faster pace than those who have not. Suggest pairing students with similar experience so they can work together and you can provide more targeted help to struggling students. You may also want to walk though at least one example of a unit conversion and make a solution example as a whole class.*

Continues next page >

Day 2
Continued

Procedure

Individual (5 minutes)	
1	Instruct students to write their own sentences for the last three words on their *Vocabulary Tool* for homework.
2	Reflection/Exit Ticket: Ask students to describe the key steps to making a solution of a certain concentration ("First, Next, etc…").

Day 3

LEARNING OUTCOMES

Students will be able to:

Predict whether a patient has diabetes using information in a patient profile.

Prepare a glucose solution of a given concentration in mg/dL using appropriate laboratory equipment.

Collect multiple data points from known glucose solutions and the patient sample using a glucometer.

Procedure

Whole Group (10 minutes)

1 Prior to students arriving:

a. Set up lab stations and prepare the patient blood samples using *Lab Preparation* reference sheet.

b. Make a class set of the *Student Protocol* and *Patient Profile Cards*. Both of these documents can be kept in sheet protectors for reuse. The patient cards should be cut out so that each pair of students will have one patient profile.

c. Write the glucometer test strip code, found on the container of strips that you are using for your class, on the board or display somewherevisible to the class—students will need to verify that their strips match the code.

Teacher Note > *Test strips are coded because the enzymes used in them to gauge blood glucose can vary from batch to batch. The coding system is a way to calibrate the meter to the particular strength of enzyme in a given batch.*

2 Ask students to answer the warm-up question individually: Why might an individual with diabetes have sugar in their urine?

3 Have students pair-share their answers and discuss as a whole class. Check for understanding that individuals with diabetes do not produce insulin, or have become resistant to it. Therefore their cells cannot take in sugar, leading to high blood sugar. This excess sugar is excreted in the urine.

Teacher Note > *'Diabetes mellitus' is derived from the Greek word 'diabetes' meaning 'siphon—to pass through' and the Latin word 'mellitus' meaning 'honeyed or sweet'. This is because diabetes causes excess sugar to accumulate in the blood, which is filtered out by the kidneys and excreted as urine.*

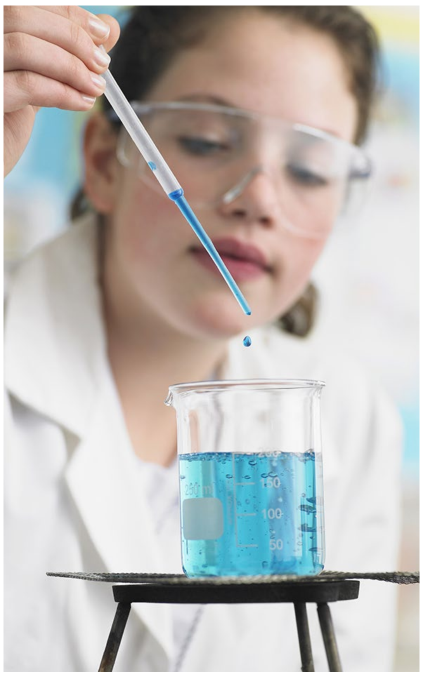
4 Pass out the *Student Guide*. Introduce the lab to students and inform them that they will be working in pairs to make glucose solutions. They will use glucometers to test their solutions and patient sample to determine if the blood glucose levels are normal, prediabetic, or diabetic.

5 Demonstrate how to use the glucometer by performing Step #7 from the Student Protocol. Point out key steps such as verifying the strip code, inserting the arrow side of the strip, dipping the strip to a depth of about 1 mm into the solution, and holding it therefor 5 seconds until the glucometer beeps and displays a reading.

Continues next page >

Day 3
Continued

Procedure



Small Group (30 minutes)	
1	Break students into pairs and pass out one *Patient Profile Card* to each pair. Instruct students to borrow their patient blood sample from the front when they have finished testing both known solutions and are ready to perform Step #7 in *Student Protocol* on the Patient Blood Sample
2	Have student pairs read their patient profile card, which includes the patient's chief complaint, past medical history, and fasting glucose. Instruct students to use their patient profile to predict whether their patient has diabetes. Students should explain their rationale on question #1 in the *Student Guide, Part 1: Pre-Lab*.
3	Students should then complete questions #2-4 in the *Student Guide, Part 1: Pre-Lab* and check their answers, particularly the values on question #2, before moving onto the *Student Protocol.*
4	Direct students to select one out of the four solutions (50 mg/dL, 100 mg/dL, 200 mg/dL or 400 mg/dL) and and record their selection in their data table for the *Student Guide, Part 2: Lab*. Each partner will make the solution twice, then test the solution twice, then record their results in the table. This should yield four data points (i.e. both versions of the solution are tested two times).

Teacher Note > *In order to ensure that there will be multiple data points for each solution, you may wish to assign lab pairs to particular solutions.*

5 Each partner will then test their Patient Blood Sample twice to determine the patient's blood glucose level two hours after drinking a sugary drink. Students should record their results in their data table.

- **a.** Patient A should have a blood glucose level between 140–199 with a diagnosis of pre-diabetes.
- **b.** Patient B should have blood glucose level greater than 200 mg/dL with diabetes.
- **c.** Patient C should have blood glucose level less than 139 mg/dL with no diabetes.

Continues next page >

Day 3

Continued

Procedure

Small Group continued (30 minutes)

6 When students have finished their testing, they will follow the clean-up procedures listed below.

a. Dump any remaining liquid from the beakers into the sink.

b. Dispose of used glucose strips in the trash.

c. Rinse the beakers and cups thoroughly with water. You do not need to use soap.

d. Return all supplies back to the lab tray.

7 Prompt students to record all six readings on a Class Data Table for further analysis (each pair should have four readings for one known glucose solution and two readings for a patient). This can be done on a shared Google document or on the board. An example is provided below:

	Known Solutions				2-Hour Blood Samples		
Reading	50 mg/dL	100 mg/dL	200 mg/dL	400 mg/dL	Patient A	Patient B	Patient C
1	55 mg/dL					210 mg/dL	
2	40 mg/dL					225 mg/dL	
3	42 mg/dL						
4	60 mg/dL						

Individual (5 minutes)

1 Reflection/Exit Ticket: Ask students to add one new thing they learned about diabetes to their KWL chart from Day 1 (if time permits).

Day 4

Procedure

LEARNING OUTCOMES

Students will be able to:

Calculate average glucose concentrations and percent error for known glucose solutions using data collected from the lab.

Identify patterns and potential sources of error in the laboratory protocol using data collected from the lab.

Develop a claim about the likeliness that a patient has diabetes using evidence collected from the lab and scientific reasoning.

Whole Group (10 minutes)

1 Warm-up: Ask students to consider how medical devices, like the glucometer they used during the last class, can be useful for different groups of people such as doctors, patients, and research scientists.

2 Show an example of how to calculate the average of two glucose readings and the percent error for a known solution. Ask students to calculate the averages and percent errors for their data on question #1 in the *Student Guide, Part 3: Data Analysis*.

$$\text{Average} = \frac{\text{Reading 1}\left(\frac{\text{mg}}{\text{dL}}\right) + \text{Reading 2}\left(\frac{\text{mg}}{\text{dL}}\right)}{\text{Total \# Readings}}$$

$$\text{\% Error} = \left| \frac{\text{Average Reading}\left(\frac{\text{mg}}{\text{dL}}\right) - \text{Expected Concentration}\left(\frac{\text{mg}}{\text{dL}}\right)}{\text{Expected Concentration}\left(\frac{\text{mg}}{\text{dL}}\right)} \right| \text{ x } 100\%$$

Example	Glucose Concentration (mg/dL)
	Known Solution: 100 mg/dL
Reading 1	98 mg/dL
Reading 2	106 mg/dL
Average	(98 mg/dL + 106 mg/dL) / 2 = **102 mg/dL**
% Error	|(102 mg/dL – 100 mg/dL) / 100 mg/dL| x 100% = **2%**

Continues next page >

Day 4

Continued

Procedure

Small Group (20 minutes)	
1	Ask students to work with their lab partner to complete questions #2–10 in the *Student Guide, Part 3: Data Analysis*.
2	Ask each pair to complete the CER organizer on a piece of paper or whiteboard to answer the following question: *How likely is it that your patient has diabetes?* The purpose of this is to help students think through the lab together. They should not write in complete sentences at this time to avoid plagiarizing each others' words.
3	If time permits, have students have students informally present their CER organizers to another lab pair and get feedback from each other using the rubric as a guide.

Individual (15 minutes)	
1	Ask students to write a complete CER paragraph in their own words.

National Standards

Next Generation Science Standards

LS1.A: 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. Feedback mechanisms can encourage (through positive feedback) or discourage (negative feedback) what is going on inside the living system.

Engaging in Argument from Evidence
Make and defend a claim using evidence from an investigation and scientific reasoning.

Scale, Proportion, and Quantity
Using the concept of orders of magnitude.

Career and Technical Education (CTE)

A4.7
Conduct indicator tests for the common macromolecules of the cell.

A6.2
Prepare solutions based on both percent and weight composition to demonstrate proficiency in use of mechanical and digital microbalances.

A8.1
Follow written protocols and oral directions to perform a variety of laboratory and technical tasks.

A8.6
Properly and safely use and monitor a variety of scientific equipment, including pH meters, microscopes, spectrophotometers, pipettes, micropipettes, and balances.

A8.7
Determine which equipment is appropriate to use for a given task and the units of measurement used.

Math

MP.1 Make sense of problems and persevere in solving them.
Calculate how to make a solution given its concentration and volume.

MP.2 Reason abstractly and quantitatively.
Convert between metric units.

Lab

Preparation

KEY

When the preparation task should take place in relationship to the lab

The amount of time necessary to complete the preparation task

Quick Tips

1	Before continuing, check the *Materials List* to make sure you have all the necessary equipment and reagents for the lab.
2	We recommend having students complete this lab in **pairs**, but if you do not have enough equipment (like balances or glucometers) you can set up stations around the classroom and multiple pairs can share.
3	*Virtual Learning Options* for this lab, including digital-only resources, are provided.

Preparation

1 Within two hours of the lab's start time — 30 min

☐ Make the patient blood samples (2-hour blood glucose samples for the Oral Glucose Tolerance Test) using the table below.

Note > *Solutions are not shelf stable. Make them within two hours of the lab's start for the most accurate readings.*

Note > *Adjust the numbers according to what your scale can accurately weigh out. Each class section will only need 10 mL of each patient sample. You can add red food coloring to simulate blood.*

	Patient A	Patient B	Patient C
	160 mg/dL	240 mg/dL	100 mg/dL
Water	500 mL	500 mL	500 mL
Glucose/ Dextrose	0.80 g	1.20 g	0.50 g

☐ Aliquot each patient blood sample into at least three small containers (to be shared by multiple pairs in a class and between classes).

Continues next page >

Lab

Continued

Preparation

2	Anytime before the lab	30 min
☐	Aliquot glucose into containers (cups, tubes, or beakers) with at least 2g per pair.	
☐	Divide glucometer test strips into bundles of six for each pair. **Note >** *Each strip can only be used once* ***so be sure*** *to emphasize the importance of using them properly.* *It may be helpful to have these warnings printed out and placed with the test strips:* *— Keep dry* *— Do not touch until ready to use* *— Insert tightly into the glucometer arrow facing in* *— Only dip the tip into the solution—not the entire strip*	
3	Anytime before the lab	30 min
☐	Set up lab stations (one per pair). **Note >** *Beaker and graduated cylinder size are dependent on the solution the student pair is making:* *— 500 mL or 1 L (for the 50 mg/dL solution)* *— 250 mL (for the 100 mg/dL and 200 mg/dL solutions)* *— 100 mL (for the 400 mg/dL solutions)*	

Continues next page >

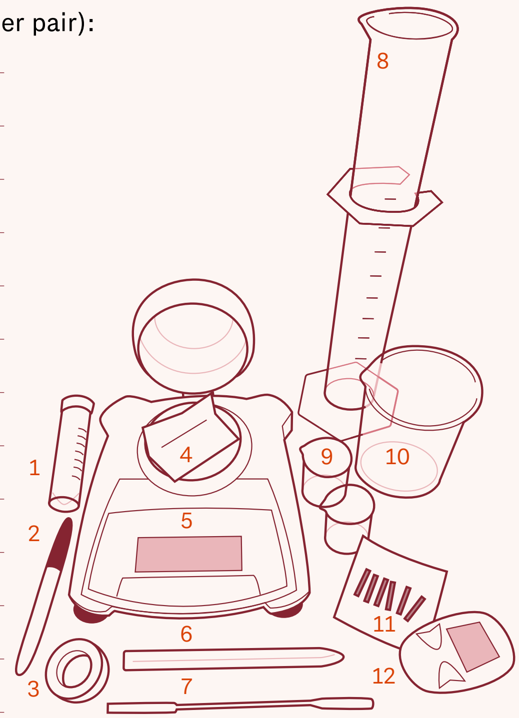
Lab

Continued

Preparation

☐ Gather materials (one set of supplies per pair):

1	Glucose (~2 g)
2	Permanent marker
3	Labeling tape
4	Weigh paper
5	Balance
6	Scoop
7	Stirrer
8	Graduated cylinder (100–500 mL)
9	2 Small cups (plastic or glass)
10	Beaker (100–500 mL)
11	6 Glucometer test strips
12	1 Glucometer



4 After the lab — 15 min

☐ Properly dispose of lab supplies:

- Glucose solutions can go down the drain.
- Spilled glucose powder and used glucose test strips can go in the trash.
- Excess glucose powder can be stored for later use.

Continues next page >

Lab
Continued

Virtual Learning Options

1 Anytime 30 min

☐ *Digital:* Ask students to explore this *Concentration Simulation* and answer the following questions:

— Click around the simulation to see what it does. Record five observations and five questions you have.
— What happens to the color of the solution when you add more "drink mix"? Why do you think this is?
— What happens to the concentration of the solution (in mol/L) when you drain some of the liquid? Why? What happens when you add more liquid? Why?
— Keep adding solid until the solution says, "Saturated!" What do you think "saturated" means? (Use the following words in your definition: solution, mass, volume, concentration)

Note > *The Concentration Simulation measures concentration in moles per liter. If students are unfamiliar with moles, suggest reviewing how to convert between moles and grams of a substance. However, an understanding of the mol/L unit is not essential for meaningfully engaging with the simulation and identifying patterns in concentration.*

2 Anytime 30 min

☐ *Digital:* Give students this completed data table and have them complete the rest of the *Student Guide*:

	Glucose Concentration (mg/dL)		
	Known Solutions: 200 mg/dL		Patient B
	Solution 1	Solution 2	2-Hour blood glucose
Reading 1	187	210	238
Reading 2	189	209	238

3 Anytime 30 min

☐ *At home:* Students can make solutions at home. They will need glucometers and test strips or Diastix and glucose or dextrose. You can give them the 2-hour blood glucose numbers or have the solutions delivered.

Conversions:
1mL = 0.2 teaspoons, 0.07 tablespoons, 0.004 cups
1 g = 0.24 teaspoons

Diabetes and Blood Glucose Questions

ANSWER KEY — **Do not share with students**

Directions
Answer the questions below after closely reading the background material.

1. Describe what diabetes is in your own words and how it affects the body.

Diabetes means your blood glucose, or blood sugar, levels are too high. It is a long-term, persistent illness where the hormone insulin is not being produced or not being used properly, so the individual's body cells cannot take in glucose. Therefore, glucose stays in the blood.

2. Fill in the chart below comparing and contrasting type 1 and type 2 diabetes

Diabetes Type	**1**	**2**
Formerly known as?	Juvenile-onset diabetes	Adult-onset diabetes
Characteristics of people typically diagnosed	Children and young adults	Adults who are overweight and inactive and some children
Percentage of overall diabetes cases	5–10%	>90%
What causes the high blood glucose levels?	The immune system attacks and destroys the beta cells in the pancreas. Thus, the pancreas can no longer produce insulin.	These individuals do not make or use insulin well. Obesity and an inactive lifestyle are two of the most common causes, along with other risk factors.
How is it treated?	Take insulin daily.	Lifestyle changes including physical activity and healthy food choices. Some people might also take insulin or medications that lower blood sugar.

3. What is a glucometer used for and why do you think it is considered a 'biosensor'?

A glucometer is a device used to measure a person's blood sugar. It is considered a biosensor because it is measuring an analyte or biological molecule.

4. Describe the parts of a glucometer in very simple terms or draw an image to represent the function of each component

Analyte: what you're measuring
Bioreceptor: the substance that interacts with the thing you're measuring
Transducer: converts bioreceptor to signal
Display: processes signal for display/reading

5. Why do you think an OGTT includes a fasting blood sample and a sample two hours after drinking a sugary solution?

A fasting blood sample is taken to establish a baseline and the two hour sample is taken to determine how well the body can process a large amount of sugar (move it out of blood and into cells).

Making Solutions Questions

ANSWER KEY — **Do not share with students**

Directions
Answer the questions below after closely reading the background material.

1. What is an example of an everyday product that can have different concentrations (think about drinks, cleaning products, etc.)? Explain the difference between this product in high and low concentrations.

Example: The longer you steep a tea bag in hot water, the more concentrated the tea will be. It will be stronger tasting and more caffeinated in higher concentration.

2. What unit is blood glucose concentration measured in? How many milligrams are in a gram and how many deciliters are in a liter?

mg/dL; 1000 mg in 1 g; 100 mL in 1 dL

3. Convert the following:

a. 30 g into mg

30,000 mg

b. 600 mg into g

0.6 g

c. 5 mg into g

0.005 g

d. 100 mL into dL

1 dL

e. 30 mL into dL

0.3 dL

f. 5 dL into mL

500 mL

4. How much glucose (in g) and how much water (in mL) do you need to make the following solutions?

a. 700 mL of 30 mg/dL glucose solution

0.21 g glucose + 699.79 mL water

b. 10 mL of 800 mg/dL glucose solution

0.8 g glucose + 99.2 mL water

c. 450 mL of 200 mg/dL glucose solution

0.9 g glucose + 449.1 mL water

d. 65 mL of 300 mg/dL glucose solution

0.39 g glucose + 64.61 mL water

5. Look back at your calculations in #4 and record three patterns/observations you notice:

Examples:

The amount of water you need is very close to the total amount of solution.

All of the masses of glucose are less than 1 g (very small).

The highest concentration does not require the highest mass because it has a small volume.

Student Guide, Part 1: Pre-Lab

ANSWER KEY — **Do not share with students**

Directions

In this lab, you will play the part of a clinical laboratory technician tasked with measuring the concentration of glucose in a patient's blood. The blood samples have been taken two hours after drinking a solution as part of an Oral Glucose Tolerance Test (OGTT). Each patient's fasting blood glucose, as well as their current medical complaint and medical history, are provided on their profile card. Before analyzing the patient sample, you will first make glucose solutions of known concentrations to evaluate the reliability of the medical device you are using (a glucometer) to perform the measurements. Record your measurements in the data table in Part 2.

Driving Question

How likely is it that your patient has diabetes?

1. Predictions: How likely is it that your patient has diabetes (very likely, somewhat likely, unlikely)? Explain your reasoning.

Answers will vary but, should include evidence from the patient profile to support predictions.

2. Calculate g of glucose and mL of water to make each glucose solution:

a. 500 mL of 50 mg/dL glucose solution

0.25 g glucose and 499.75 mL water

b. 250 mL of 100 mg/dL glucose solution

0.25 g glucose and 249.75 mL water

c. 200 mL of 200 mg/dL glucose solution

0.4 g glucose and 199.6 mL water

d. 100 mL of 400 mg/dL glucose solution

0.4 g glucose and 99.6 mL water

3. Consider the similarities and differences between the calculations you made for the solutions in question #2. Why might two different concentrations require the same mass of glucose?

The concentration changes with the amount of water. For example, diluting the same mass of glucose in double the amount of water would halve the concentration. Diluting the same mass of glucose in half the amount of water would double the concentration.

4. Why is it necessary to "validate" or check the accuracy of the glucometer with solutions of known concentration?

Validation ensures that the glucometer is working properly and accurately by detecting the same (or close to the same) value multiple times.

Student Guide, Part 2: Lab

ANSWER KEY — **Do not share with students**

Directions

Follow the Student Protocol to complete the lab with your partner. Record the six glucose concentration readings from the glucometer in the table below:

Example	**Glucose Concentration (mg/dL)**		
	Known Solutions: 100 mg/dL		Patient: A
	Solution 1	Solution 2	2-Hour blood glucose
Reading 1	98 mg/dL	103 mg/dL	166 mg/dL
Reading 2	106 mg/dL	95 mg/dL	152 mg/dL
Average	(98 mg/dL + 106 mg/dL) / 2 = 102 mg/dL	(103 mg/dL + 95 mg/dL) / 2 = 99 mg/dL	(166 mg/dL + 152 mg/dL) / 2 = 159 mg/dL
% Error	(102 mg/dL – 100 mg/dL) / 100 mg/d * 100% = 2%	(99 mg/dL – 100 mg/dL) / 100 mg/dL * 100% = 1%	

Student Guide, Part 3: Data Analysis

ANSWER KEY — **Do not share with students**

Directions
Use the glucose readings collected from the lab to answer the questions below.

1. Calculate the following using the formulas in the *Student Guide, Part 2: Lab*, and record your answers in the table on that page:

   a. average concentration of the two readings for each known solution

   b. average concentration of the patient's 2-hour blood sample

   c. percent error for each known solution

Please see the *Answer Key for Student Guide, Part 2: Lab* on the previous page.

2. Why might it be important to collect multiple data points (in this case two readings) for each sample?

Having a larger data set increases the reliability of the data. If you only take one reading, there is a chance that it is an outlier and doesn't accurately reflect the true glucose concentration. In a real OGTT, the doctor will not diagnose a patient until the test has been repeated and the results have been duplicated.

3. Is there a larger difference between the two readings of the same solution or between the average readings of the two solutions? Does this mean the larger source of error is the glucometer or lab technique?

It is likely that there is a larger difference between the average readings of the two solutions. Because the concentrations are relatively low, there is a high chance of lab technique error affecting the results. Also, because students are making two solutions from scratch, there are many places that error can be introduced each time (for example, weighing the glucose, transferring it to the beaker, adding water, etc.).

4. Look at the class data for all of the glucose readings for the known solutions and patient samples. Identify three patterns or observations in the data, using the following questions to guide you:

— What surprises or stands out to you?

— Where do you see the least/most amount of variation between readings? Between % error?

— How does the class data compare to your own data?

There is likely more variation and a higher percent error in the lower concentrations. The class % error is likely lower than the pair's % error because there are more data points. There is likely less variation between readings of the patient samples because each patient sample is only one solution, whereas each known solution was made multiple times.

5. Describe 2 potential sources of error in this lab and how they may affect the results: (any two are acceptable)

	Sources of Error	Affect to the results
a.	Using graduated cylinders and beakers larger than needed	Larger graduated cylinders and beakers measure volume less accurately than smaller ones.
b.	Variation in length of time solutions sit before being tested	May result in water evaporation, leading to concentration readings being artificially high
c.	Too much water added to graduated cylinder during last step of making the solution	Cause concentration to be lower than intended
d.	Equipment error—balance miscalibrated	The weight of the glucose may be artificially low or high, causing the concentration to be lower or higher than intended.

Continues on next page >

Student Guide, Part 3: Data Analysis

ANSWER KEY **Do not share with students**

Continued

6. On a scale of 1–5, how reliable do you think your results for the patient's 2-hour blood sample are? (1 = Not reliable at all, 5 = completely reliable) Give evidence or rationale for your rating.

Encourage students to think about variability between the readings and compare their data to the class data. (If the two readings for the solutions are always very close to each other, the reading for the patient sample is likely accurate. If the readings vary, the glucometer may not be a reliable tool. The class data are more accurate than their data because there are more data points.)

7. If you were to do a follow-up experiment, what would you do to increase the reliability of your results? How does this modification increase reliability?

Examples:

— Repeat the OGTT—take more blood samples

— Take more readings for each solution

— Use multiple different glucometers

8. Using the information in *Background Reading: Diabetes and Blood Glucose* and the results from the lab, how likely is it that your patient has diabetes (very likely, somewhat likely, unlikely)? This will be your claim for Part 4.

Fasting (mg/dL)	2-Hour Plasma Glucose (mg/dL)	Diagnosis
80–100	139 and below	Not diabetic
101–125	140–199	Prediabetes (impaired glucose tolerance)
126 and above	200 and above	Diabetes

Very likely—patient had fasting glucose well above 126 mg/dL and multiple readings for 2-hour glucose well above 200 mg/dL. Other symptoms are consistent with diabetes.

Somewhat likely—patient had fasting glucose around 126 mg/dL and readings for 2-hour glucose around 200 mg/dL. Other symptoms may or may not be consistent with diabetes.

Unlikely—patient had fasting glucose below 100 mg/dL and readings for 2-hour glucose well below 140 mg/dL. Other symptoms are not consistent with diabetes.

Students can also consider the reliability of the glucometer based on their results.

9. If it *is* likely, which type of diabetes is more likely for this patient (Type 1, Type 2, cannot determine)?

Type 1 is genetic (you are born with it) and therefore usually diagnosed in children or young adults. Type 2 develops later so is generally diagnosed in adults, but can also develop in children. The symptoms and blood glucose levels are similar so from these data alone it may be difficult to determine.

10. Was your prediction accurate? Cite data to support your evaluation of your prediction.

Students should compare their results to their prediction in *Student Guide, Part 1: Pre-lab #1*.

FUTURELAB+

Background Reading: Diabetes and Blood Glucose

What Is Diabetes?

Diabetes is a disease in which blood glucose (sugar) levels are abnormally high. It is a *chronic* (long-term) disease that can be treated. However, if left untreated over time, it can eventually lead to significant damage to the nerves, blood vessels, kidneys, heart, and more.

After you eat, the food you ingested is broken into a simple sugar called glucose. In people without diabetes, this glucose is moved out of the bloodstream and into their cells, where it can be converted to usable cellular energy. The molecule responsible for this process is a hormone made in the pancreas called insulin. People with diabetes, however, either do not make insulin or their cells are no longer able to respond to the insulin they do produce. As a result, they are unable to move glucose out of their bloodstream and into their cells, leading to high blood sugar levels. This also means that their cells are essentially starved of glucose and not able to get the energy they need to function properly.

Type 1 Diabetes

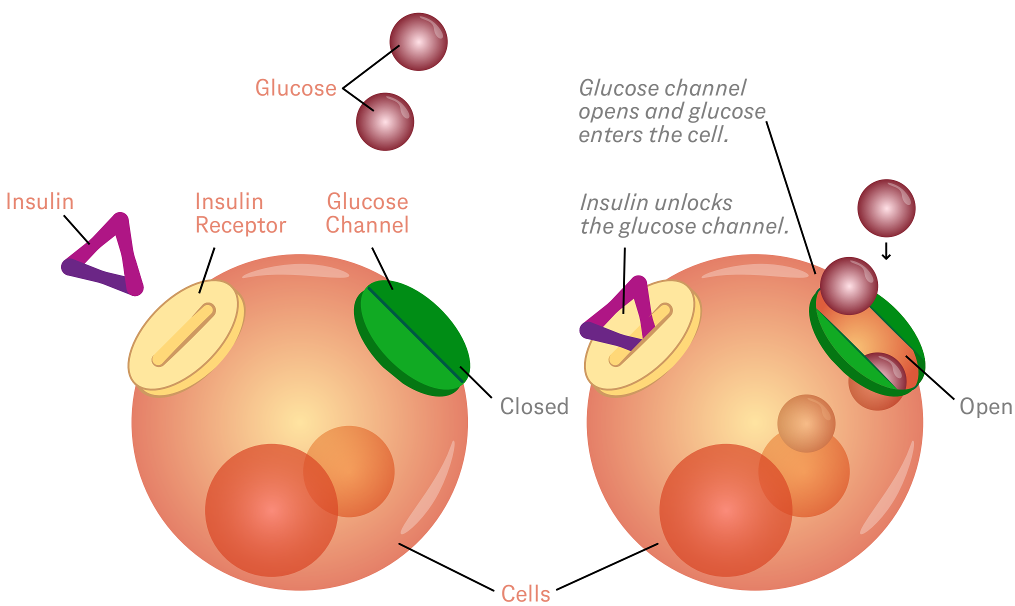
Type 1 diabetes, also known as juvenile-onset diabetes mellitus, is an autoimmune disease that affects the pancreas. Specifically, the immune system destroys beta cells in the pancreas, which are the cells responsible for producing insulin. Since their bodies no longer naturally produce insulin, people with type 1 diabetes must inject themselves daily with insulin. The insulin used to treat diabetics is manufactured using bacteria that have been genetically modified with the human insulin gene.

Type 1 diabetes usually occurs in children and young adults, though it is possible to develop it at any age. It is the more rare form of diabetes, accounting for about 5–10% of cases (UAB, 2021). Symptoms of type 1 diabetes include increased thirst and hunger, frequent urination, unexplained weight loss, blurred vision, and fatigue (feeling tired). If left untreated, it can lead to a serious condition known as diabetic ketoacidosis.

The cause of type 1 diabetes is still unknown, but research is ongoing and points to a complex interaction between an individual's genes and environment.

Continues next page >

How Insulin Works



FUTURELAB+

Background Reading: Diabetes and Blood Glucose

Continued

Type 2 Diabetes

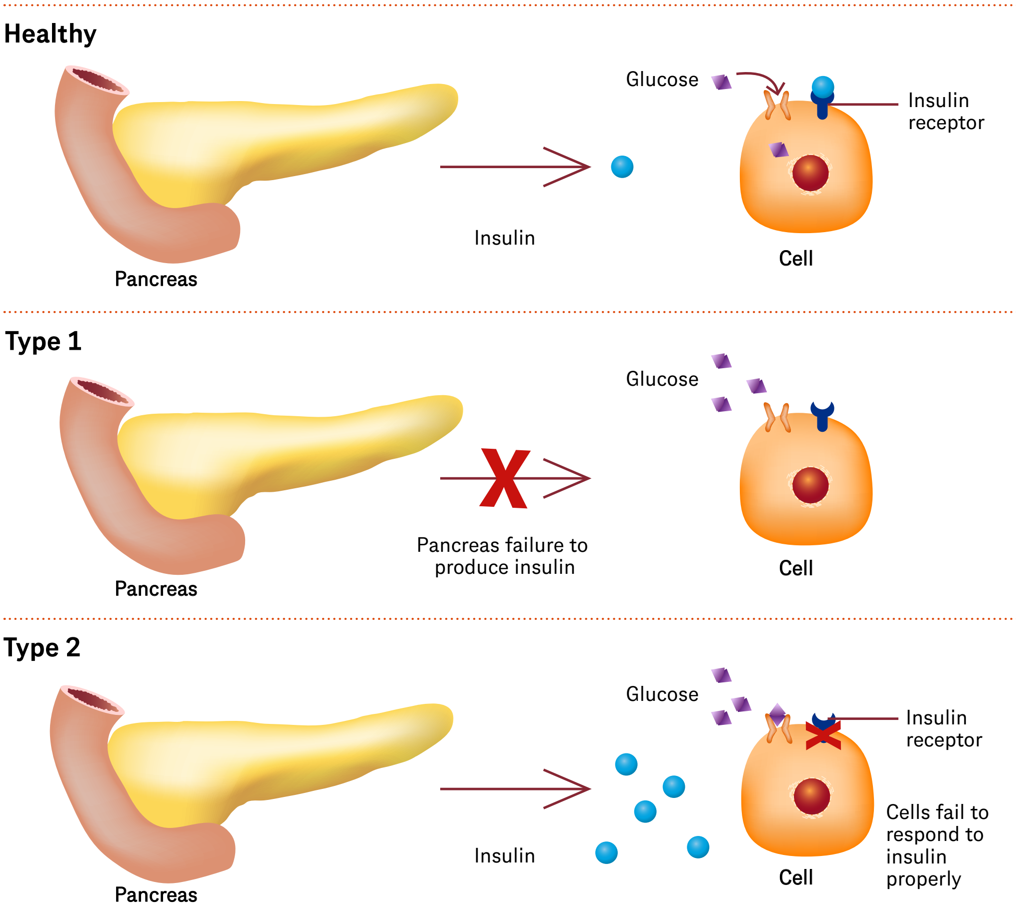
Type 2 diabetes, also known as adult-onset diabetes mellitus, is the most common form of diabetes, accounting for about 90–95% of cases (UAB, 2021). People with type 2 diabetes can usually still make insulin, but their cells have become resistant to it.

Type 2 diabetes can occur at any age, though is typically diagnosed in adulthood. There is no single cause, but there are many risk factors including being overweight, having an inactive lifestyle, and having a family history of the disease. It also disproportionately affects people of color. Though it is often presented solely as an individual diet issue, the reality of type 2 diabetes is much more complicated. For example, income disparities and zip codes affect access to healthy foods and proper healthcare. There are also cultural factors such as perceptions around the effectiveness of treatment or cause of diseases that may act as barriers to preventing diabetes and controlling the disease appropriately.

Symptoms of type 2 diabetes can be similar to those of type 1 diabetes, including feeling tired and needing to urinate often. To manage their blood sugar levels, people with type 2 diabetes can maintain a healthy weight, diet, and level of physical activity as well as take blood glucose-lowering medications like metformin.

Continues next page >

Diabetes Mellitus



FUTURELAB+

Background Reading: Diabetes and Blood Glucose

Continued

Diagnosing Diabetes

One way for doctors to diagnose a patient with type 1 or type 2 diabetes is to perform an *oral glucose tolerance test (OGTT)*. This test indicates how well the patient's body manages blood sugar levels after eating. In an OGTT, the individual's blood sugar level is measured after fasting (not eating) and again two hours after drinking a sugary solution. The table below shows the ranges of blood glucose levels that are used to determine if the individual has diabetes. If their two-hour blood glucose is over 200 mg/dL, the doctor will administer the OGTT again on another day to confirm. If both tests show a two-hour blood glucose level of at least 200 mg/dL, the patient is diagnosed with diabetes (ADA, 2021).

Blood sample ready to to be placed on a testing strip and analyzed by the glucometer

Fasting (mg/dL)	2-Hour Plasma Glucose (mg/dL)	Diagnosis
80–100	139 and below	Not diabetic
101–125	140–199	Prediabetes (impaired glucose tolerance)
126 and above	200 and above	Diabetes*

*
Confirmed by repeating the test on a different day or using an additional test

To monitor their disease, people with type 1 or type 2 diabetes must regularly measure their blood glucose levels. One tool they can use for this is a glucometer—a small, portable biosensor. A glucometer analyzes a tiny droplet of blood that has been applied to a special disposable test strip and displays the blood glucose concentration on its screen. In general, biosensors contain five major components (Bhalla et at., 2016). See next page for a description of each component of the glucometer.

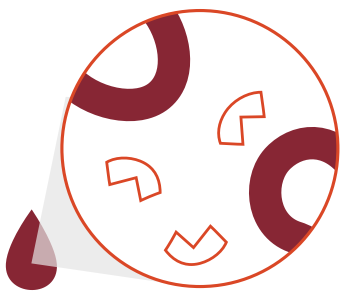
Continues next page >

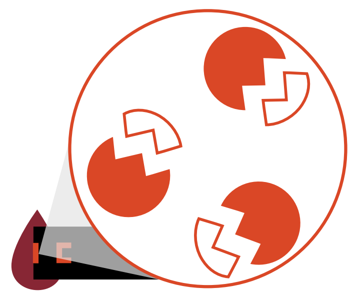
FUTURELAB+

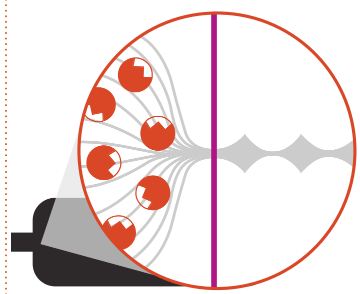
Background Reading: Diabetes and Blood Glucose

Continued

Biosensor Components







Analyte	Bioreceptor	Transducer	Electronics and display
The molecule in the blood that is being detected by the biosensor. For a glucometer, the analyte is glucose.	A molecule that can bind to the analyte. For a glucometer, the bioreceptor is an enzyme on the disposable test strip that recognizes glucose.	Converts the analyte-bioreceptor interaction into a measurable signal. For a glucometer, the transducer produces an electrical signal.	Processes the signal from the transducer and shows the result to the user. For a glucometer, the blood glucose concentration is shown numerically on a black and white screen.

Sources:

Helping the Student with Diabetes Succeed: A Guide for School Personnel

Type 2 Diabetes—Symptoms and Causes

Racial and Ethnic Minority Communities Hit Hard by Type 2 Diabetes: Here's What We Can Do

Food Deserts: Causes, Consequences and Solutions: Learning for Justice

Types of Diabetes

Introduction to Biosensors

Diagnosis

Glucose Sensors: What They Are and How They Work

FUTURELAB+

Diabetes and Blood Glucose Questions

Directions
Answer the questions below after closely reading the background material.

1. Describe what diabetes is in your own words and how it affects the body.

2. Fill in the chart below comparing and contrasting type 1 and type 2 diabetes.

Diabetes Type	1	2
Formerly known as?		
Characteristics of people typically diagnosed		
Percentage of overall diabetes cases		
What causes the high blood glucose levels?		
How is it treated?		

Continues next page >

FUTURELAB+

Diabetes and Blood Glucose Questions

Continued

3. What is a glucometer used for and why do you think it is considered a “biosensor”?

4. Describe the parts of a glucometer in very simple terms or draw an image to represent the function of each component.

5. Why do you think an OGTT includes a fasting blood sample and a sample two hours after drinking a sugary solution?

FUTURELAB+

Background Reading: Making Solutions

What is concentration?

A *solution* is a mixture of two or more substances, often a solid that has been dissolved in a liquid. The *concentration* of a solution describes the amount of a solid that has been dissolved in a certain amount of liquid. Have you ever made a powdered drink? What does it look and taste like when you add a lot of powder? The more powder you add to the water, the more *concentrated* it is.

$$\text{Concentration} = \frac{\text{mass}}{\text{volume}}$$

Concentration is calculated by dividing the amount of the solid (measured in mass) by the amount of liquid it is dissolved in (measured in volume). If a solution has a "high" concentration, it has a lot of the solid dissolved in liquid (like the flask on the right in the image below). If there is less solid dissolved in the same amount of liquid, it has a "low" concentration (like the flask on the left).

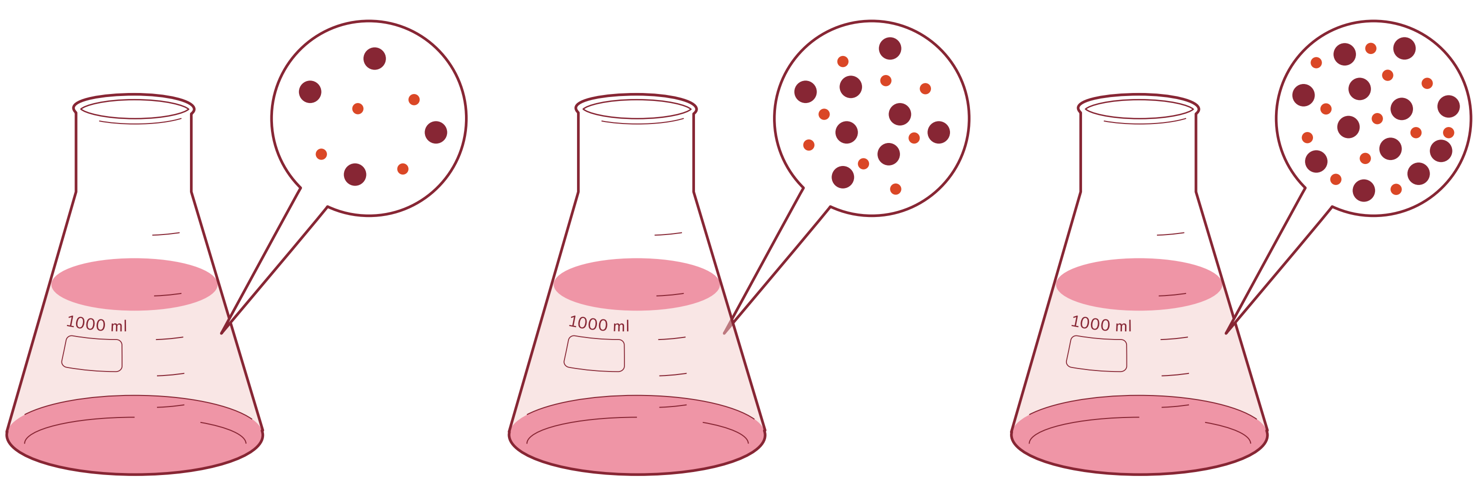
Metric Units

When we measure someone's blood glucose, we measure the concentration of glucose (a solid) in their blood (a liquid). The unit used for measuring blood glucose is mg/dL (milligrams of glucose per deciliter of blood). Milligrams is a metric unit of mass (in this case, the solid glucose) and deciliters is a metric unit of volume (in this case, the liquid blood). Grams is the base unit of mass and liters is the base unit of volume. "Milli" and "deci" are examples of prefixes that describe the relationship between the metric units.

Continues next page >

Different Concentrations of a Solution

● = Na+ ● = OH−

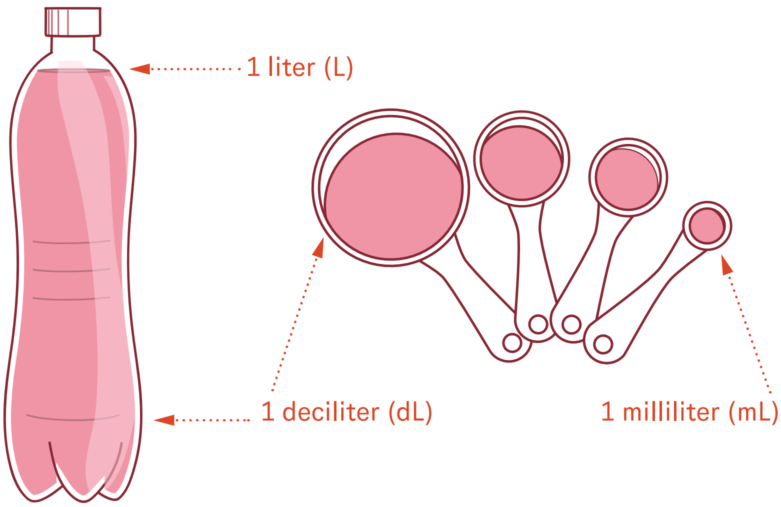


0.5 mg/dL	**1.0 mg/dL**	**1.5 mg/dL**

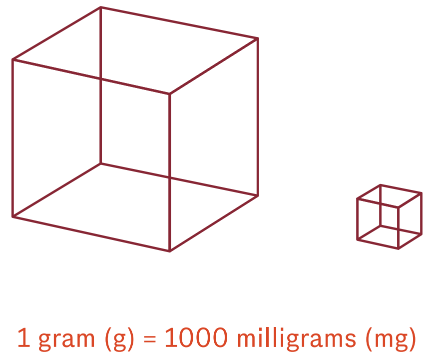
FUTURELAB+

Background Reading: Making Solutions

Continued



Volume



Mass

Look at the images above to see how deciliters compare to liters and how milligrams compare to grams:

You can see from the pictures above that a deciliter is 10 times smaller than a liter. Another way to think about it is a deciliter is 1/10th of a liter. A milligram is 1000 times smaller than a gram. Another way to think about it is 1 milligram is 1/1000th of a gram.

Continues next page >

FUTURELAB+

Background Reading: Making Solutions

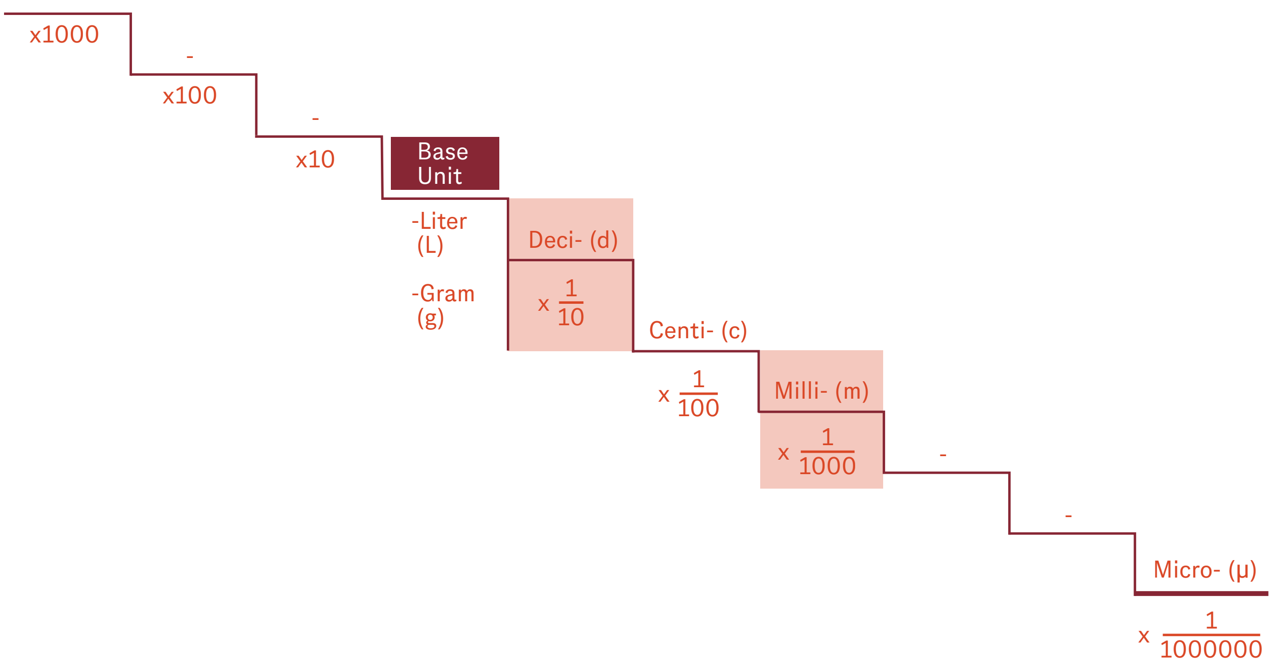
Continued

See the chart and staircase below for a summary of the metric units. The dashed line (---) indicates the base unit in the metric system.

Metric Units

Prefix	Multiplier	Symbol	Example
Kilo-	1,000	k	Kilogram
Hecto-	100	h	Hectogram
Deca-	10	Da	Decagram
----	1	---	Gram
Deci-	0.1	d	Decigram
Centi-	0.01	c	Centigram
Mili-	0.001	m	Milligram
Micro-	0.0001	μ	Microgram

Each step on the stairs is **10x** larger than the step below it.



Continues next page >

FUTURELAB+

Background Reading: Making Solutions

Continued

Converting between metric units

In this lab, you will be making solutions using the units of blood glucose concentration (mg/dL), but your lab tools use different units. The scale measures mass in *grams (g)* and beakers and graduated cylinders measure volume in *milliliters (mL)*. Therefore, you need to be able to convert between grams and milligrams and milliliters and deciliters.

1 g = 1000 mg	1 dL = 100 mL

When you convert a number to a new unit, multiply it by a conversion factor that contains the original unit and the new unit. The goal is to cancel out the original unit so that you end up with the new unit. To do this, make sure the original unit is in the denominator and the new unit is in the numerator of your conversion factor.

Read through the examples below to see how to convert between mg↔g and dL↔mL:

Convert 50 mg into g:

$$50\ \cancel{\text{mg}} \times \frac{1\ \text{g}}{1000\ \cancel{\text{mg}}} = 0.05\ \text{g}$$

Original unit = mg

Conversion factor with new unit in numerator and original unit in denominator

Convert 0.05 g into mg:

$$0.05\ \cancel{\text{g}} \times \frac{1000\ \text{mg}}{1\ \cancel{\text{g}}} = 50\ \text{mg}$$

Convert 2 dL into mL:

$$2\ \cancel{\text{dL}} \times \frac{100\ \text{mL}}{1\ \cancel{\text{dL}}} = 200\ \text{mL}$$

Convert 200 mL into dL:

$$200\ \cancel{\text{mL}} \times \frac{1\ \text{dL}}{100\ \cancel{\text{mL}}} = 2\ \text{dL}$$

Continues next page >

FUTURELAB+

Background Reading: Making Solutions

Continued

Making Solutions

In this lab, you will need to make glucose solutions with different concentrations in mg/dL. This will help you test your glucometer to validate that it will accurately read the glucose concentration in a "blood" sample.

When making a glucose solution of a certain concentration, you need to know two things:

1. How much glucose you need to weigh out in grams (g).

2. How much water needed to dissolve the glucose in millimeters (mL).

Example: **Make 500 mL of a 20 mg/dL glucose solution.**

1. How much glucose you need to weigh out in grams (g).

1a. Convert milliliters (mL) to deciliters (dL) so that the volume of your solution has the same unit as the concentration of the solution.

$$500 \text{ mL} \times \frac{1\text{dL}}{100 \text{ mL}} = 5 \text{ dL of water}$$

1b. Multiply the volume by the concentration. This will cancel out the volume units and leave you with the mass of glucose needed in milligrams (mg).

$$5 \cancel{\text{dL}} \times \frac{20 \text{ mg}}{\cancel{\text{dL}}} = 100 \text{ mg of glucose}$$

1c. Convert milligrams (mg) to grams (g) so you can weigh the mass of glucose out on the scale.

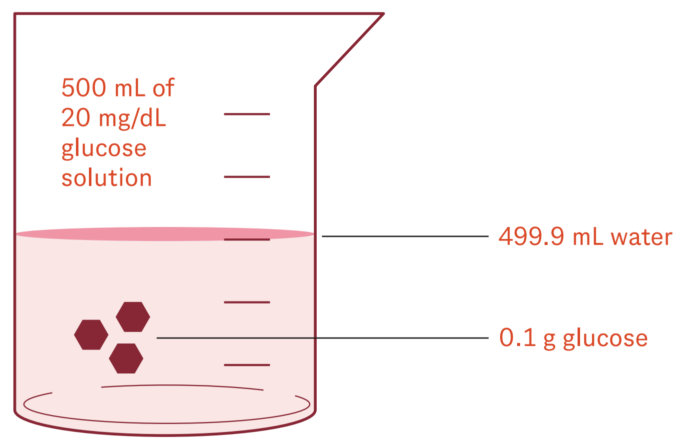
$$100 \cancel{\text{mg}} \times \frac{1 \text{ g}}{1000 \cancel{\text{mg}}} = \textbf{0.1 g of glucose}$$

2. How much water you need to dissolve the glucose in millimeters (mL).

2a. Subtract the grams of glucose from the total volume you need (since we are assuming the density of water is 1 g/mL).

$$500 \text{ mL} - 0.1 \text{ g} = \textbf{499.9 mL of water}$$

3. Therefore, to make 500 mL of a 20 mg/dL solution, add 0.1 g of glucose to 499.9 mL of water:



When making the solution, you would not actually measure out 499.9 mL of water (graduated cylinders are not accurate enough). Instead, you would dissolve the glucose in about 400 mL of water in a beaker, add the solution to a graduated cylinder (or a volumetric flask), and fill up to the final volume of 500 mL with water.

Sources:

Concentrations of Solutions

Dimensional Analysis

FUTURELAB+

Making Solutions Questions

Directions
Answer the questions below after closely reading the background material.

1. What is an example of an everyday product that can have different concentrations (think about drinks, cleaning products, etc.)? Explain the difference between this product in high and low concentrations.

2. What unit is blood glucose concentration measured in? How many milligrams are in a gram and how many deciliters are in a liter?

3. Convert the following:

a. 30 g into mg

b. 600 mg into g

c. 5 mg into g

d. 100 mL into dL

e. 30 mL into dL

f. 5 dL into mL

4. How much glucose (in g) and how much water (in mL) do you need to make the following solutions?

a. 700 mL of 30 mg/dL glucose solution

b. 10 mL of 800 mg/dL glucose solution

c. 450 mL of 200 mg/dL glucose solution

d. 65 mL of 300 mg/dL glucose solution

Continues next page >

FUTURELAB+

Making Solutions Questions

Continued

5. Look back at your calculations in Step 4 and record three patterns or observations in the data.

5a.

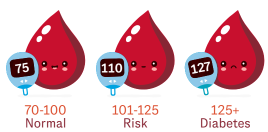
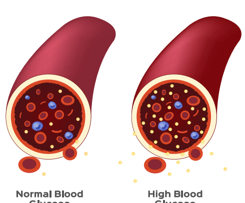
5c.

5b.

FUTURELAB+

Vocabulary Tool

Directions
For each vocabulary word, write a new sentence that helps you practice using it.

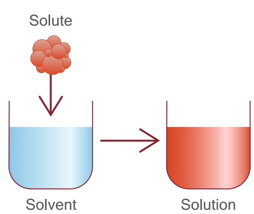
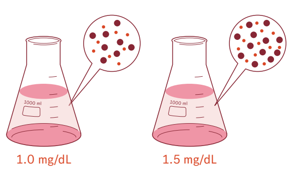
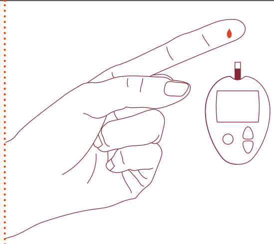
Word	Image	Definition	Example Sentence	My Sentence
Diabetes		A disease in which blood glucose (sugar) levels are abnormally high	People with *diabetes* are either not able to make or respond to the hormone insulin.	
Type 1 Diabetes		An autoimmune disease in which the body destroys its insulin-producing beta cells in the pancreas	Most people diagnosed with *type 1 diabetes* are children or young adults.	
Type 2 Diabetes		A disease in which the body is unable to respond to insulin	*Type 2 diabetes* can be managed with a healthy lifestyle as well as blood sugar-lowering medication.	
Blood Glucose		The concentration of glucose or sugar in the blood	Managing *blood glucose* and understanding what makes levels rise is critical to living with diabetes.	
Biomarker		A biological process or molecule that can be measured to detect or monitor disease	Blood sugar may be used as a diagnostic *biomarker* to identify patients with diabetes.	

Continues next page >

FUTURELAB+

Vocabulary Tool

Continued

Word	Image	Definition	Example Sentence	My Sentence
Insulin		A hormone produced by the pancreas that allows cells to bring in glucose and convert it to usable energy	People with Type 1 diabetes need to inject themselves with *insulin* because their pancreases cannot make it.	
Glucometer		A type of biosensor that can be used to measure blood glucose concentration	Doctors and diabetes patients can use *glucometers* to detect the level of glucose in a blood sample.	
Oral Glucose Tolerance Test (OGTT)		A test that indicates how well an individual's body manages blood sugar levels after eating	In order to diagnose someone as diabetic, a doctor may perform an *oral glucose tolerance test* to see if their blood glucose levels are abnormal.	
Solution		A mixture of two or more substances, often a solid that has been dissolved in a liquid	A glucose *solution* is made by dissolving powdered glucose in water.	
Concentration		The amount of a solid that has been dissolved in a certain amount of liquid (mass/volume)	The *concentration* of a solution gets higher when you dissolve more of the solid in the volume of liquid.	
Milligrams per deciliter (mg/dL)		The metric unit of concentration for blood glucose levels	Blood glucose that is higher than 200*mg/dL* indicates that a patient likely has diabetes.	

FUTURELAB+

Patient Profile Cards

Directions

Copy, cut out, and distribute the patient profile cards so that each pair of students will have one patient profile.

Patient A

Chief Complaint: Patient is 52 years old and has been experiencing pain in both knees. Pain began Thursday afternoon and has increased steadily. She describes it as “a dull ache” at a 7/10 on the pain scale and says it’s affecting her sleep. Over-the-counter pain relievers did not improve symptoms.

Past Medical History:

Hypercholesterolemia, diagnosed at age 50

Family history of type 2 diabetes and high blood pressure

Fasting Blood Glucose: 100 mg/dL

Patient B

Chief Complaint: Patient is 15 years old, in relatively good health until the last month when he began experiencing weakness and fatigue. Patient could “run an 8-minute mile one month ago, no problem”, but over the past month, symptoms progressed to the point that he cannot walk 50 feet without stopping to catch his breath. Today the patient reported, “I got lightheaded, my vision was blurry and I felt too weak to walk.

Past Medical History:

Appendix removed at age 7

No family history of lung disease or asthma

Fasting Blood Glucose: 150 mg/dL

Patient C

Chief Complaint: Patient is 33 years old and has been experiencing severe abdominal pain, followed by vomiting and diarrhea. She also reports a general feeling of increased thirst that gets stronger after vomiting or diarrhea. The abdominal pain started on Monday morning and was about a 6 on the pain scale for a few hours. The pain temporarily got less intense and increased again last night. There were no signs of blood in her stool.

Past Medical History:

Crohn’s disease, diagnosed at age 28

Allergic to penicillin

Fasting Blood Glucose: 90 mg/dL

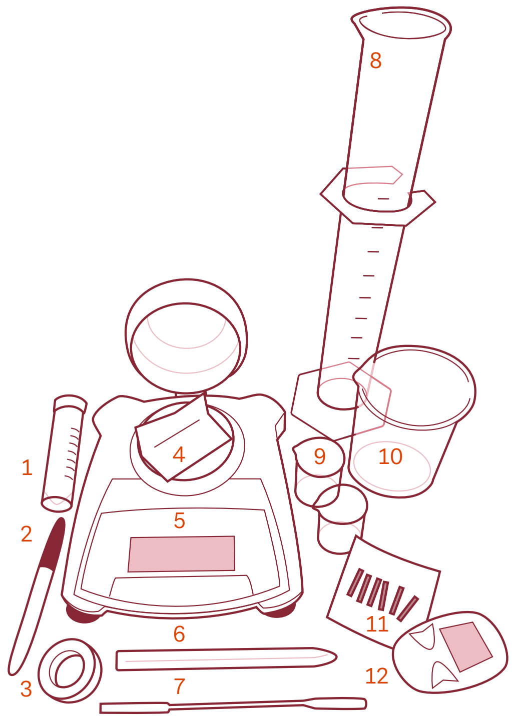
FUTURELAB+

Student Protocol

1 Clean the lab surface and gather all the materials needed to complete the lab.

☐

1	Glucose (~2 g)
2	Permanent marker
3	Labeling tape
4	Weigh paper
5	Balance
6	Scoop
7	Stirrer
8	Graduated cylinder (100–500 mL)
9	2 Small cups (plastic or glass)
10	Beaker (100–500 mL)
11	6 Glucometer test strips
12	1 Glucometer



☐ Patient blood sample

Note > *You will get this from your teacher at the appropriate time.*

2 Choose one of the four glucose solutions.

☐ Choose from: 50 mg/dL, 100 mg/dL, 200 mg/dL, or 400 mg/dL
Then, make and label both of the two small cups with this concentration and #1 or #2.

Note > *For example, 50 mg/dL #1 and 50 mg/dL #2*

3 Determine how much water and glucose you will need.

☐ Refer to your calculations in the pre-lab questions to determine how much water and glucose you will need. You and your partner will each take turns making the solution one at a time.

Continues on next page >

FUTURELAB+

Student Protocol

Continued

4 Prepare the Scale for Weighing.

- [ ] Make sure the scale is clean and free from debris.
- [ ] Turn the scale on.
- [ ] Fold a piece of weigh paper in half, open it back up, and place it on the scale.
- [ ] Press the button that says *tare*.

  Note > *At this point, your scale should read 0.00 g or 0.000 g*

5 Make the Glucose Solution. **Note >** *Best Practices for Making Solutions*

- [ ] Weigh out the calculated amount of glucose.
- [ ] Add the glucose to the appropriately labeled beaker.
- [ ] Measure out ~75% of the volume of water you need with a graduated cylinder.

  Note > *For example, if you are making 100 mL of solution, you would measure approximately 75 mL of water.*
- [ ] Add the water to the beaker with the glucose.
- [ ] Stir to completely dissolve the glucose in the water.
- [ ] Pour the entire solution into the graduated cylinder.
- [ ] *Slowly* add more water to the graduated cylinder until it reaches the final volume you are making.

  Note > *The volume has been reached when the bottom of the meniscus is at the appropriate line. In the image, the bottom of the meniscus is at the 10 mL line.*

  — *Add water from a beaker instead of directly from the faucet, so you have more control.*

  — *If any solution spills out or if you add too much water, this introduces a significant error in the concentration and you should remake the solution.*

  — *Following the example above, you would add water until the volume reaches 100 mL.*
- [ ] Fill one of your labeled cups halfway with the solution.

10 mL line
on the graduated cylinder

Continues on next page >

FUTURELAB+

Student Protocol

Continued

☐	Pour the remaining solution down the drain.
☐	Repeat Step 5 to make the second glucose solution. **Note >** *Rinse and use the same beaker and graduated cylinder your partner used.*
6	**Prepare to use the Glucometer.**
☐	Make sure your glucometer has a battery by pressing the “M” button on the left. It should turn on and may display a glucose reading from the last time it was used.
☐	Each test strip can only be used once. Please make sure to: 1 Keep it dry 2 Do not touch it until ready to use 3 Insert it tightly into the glucometer with the arrow facing in 4 Only dip the tip into the solution—not the entire strip
7	**Use the Glucometer.**
	Note > *Keep in mind you will be testing each solution twice.*
☐	Insert a strip into the glucometer—the end with the arrow goes in.
☐	The glucometer will beep and should display a code. Make sure the code displayed matches the code you were given.
☐	Wait until the screen has an image of a droplet before you continue.
☐	Dip just the end of the strip (still attached to the glucometer) into the first glucose solution you are testing (about 1 mm in depth) and *don’t move*, just hold it there.
☐	The monitor will start beeping and will count down from 5; continue to hold it.

Continues on next page >

FUTURELAB+

Student Protocol

Continued

☐	Record the displayed reading for the first glucose solution and throw out the strip. **Note >** *Each can only be used once*
	Repeat the same process with the same solution to get a second reading for this glucose solution.
☐	Repeat Step 7 for the second glucose solution and your patient blood sample. **Note >** *Get the patient blood sample from your teacher.*
8	Clean up your lab stations.
☐	Pour any remaining liquid from the beakers into the sink.
☐	Put any used glucometer test strips in the trash.
☐	Rinse the beaker and cups thoroughly with water. You do not need to use soap.
☐	Prepare the lab station for the next class per your teacher's instructions.

FUTURELAB+

Student Guide, Part 1: Pre-Lab

Directions

In this lab, you will play the part of a clinical laboratory technician tasked with measuring the concentration of glucose in a patient's blood. The blood samples have been taken two hours after drinking a solution as part of an Oral Glucose Tolerance Test (OGTT). Each patient's fasting blood glucose, as well as their current medical complaint and medical history, are provided on their profile card. Before analyzing the patient sample, you will first make glucose solutions of known concentrations to evaluate the reliability of the medical device you are using (a glucometer) to perform the measurements. Record your measurements in the data table in Part 2.

Driving Question

How likely is it that your patient has diabetes?

1. Predictions: How likely is it that your patient has diabetes (very likely, somewhat likely, unlikely)? Explain your reasoning.

2. Calculate g of glucose and mL of water to make each glucose solution:

a. 500 mL of 50 mg/dL glucose solution

b. 250 mL of 100 mg/dL glucose solution

c. 200 mL of 200 mg/dL glucose solution

d. 100 mL of 400 mg/dL glucose solution

3. Consider the similarities and differences between the calculations you made for the solutions in question #2. Why might two different concentrations require the same mass of glucose?

4. Why is it necessary to "validate" or check the accuracy of the glucometer with solutions of known concentration?

FUTURELAB+

Student Guide, Part 2: Lab

Directions

Follow the Student Protocol to complete the lab with your partner. Record the six glucose concentration readings from the glucometer in the table below:

	Glucose Concentration (mg/dL)		
	Known Solutions: ______ mg/dL		Patient: ______
	Solution 1	Solution 2	2-Hour blood glucose
Reading 1			
Reading 2			
Average			
% Error			

$$\text{Average} = \frac{\text{Reading 1}\left(\frac{\text{mg}}{\text{dL}}\right) + \text{Reading 2}\left(\frac{\text{mg}}{\text{dL}}\right)}{\text{Total \# Readings}}$$

$$\%\ \text{Error} = \left|\frac{\text{Average Reading}\left(\frac{\text{mg}}{\text{dL}}\right) - \text{Expected Concentration}\left(\frac{\text{mg}}{\text{dL}}\right)}{\text{Expected Concentration}\left(\frac{\text{mg}}{\text{dL}}\right)}\right| \text{x } 100\%$$

FUTURELAB+

Student Guide, Part 3: Data Analysis

Directions

Use the glucose readings collected from the lab to answer the questions below.

1. Calculate the following using the formulas in the *Student Guide, Part 2: Lab*, and record your answers in the table on that page:

    a. average concentration of the two readings for each known solution

    b. average concentration of the patient's 2-hour blood sample

    c. percent error for each known solution

2. Why might it be important to collect multiple data points (in this case, two readings) for each sample?

3. Is there a larger difference between the two readings of the same solution or between the average readings of the two solutions? Does this mean the larger source of error is the glucometer or lab technique?

4. Look at the class data for all of the glucose readings for the known solutions and patient samples. Identify three patterns or observations in the data, using the following questions to guide you:

— What surprises or stands out to you?

— Where do you see the least and most amount of variation between readings? Between % error?

— How does the class data compare to your own data?

Continues on next page >

FUTURELAB+

Student Guide, Part 3: Data Analysis

Continued

5. Describe two potential sources of error in this lab and how they may affect the results:

	Sources of error	Affect on results
a.		
b.		

6. On a scale of 1–5, how reliable do you think your results for the patient's 2-hour blood sample are? (1 = not reliable at all, 5 = completely reliable) Give evidence or rationales for your rating.

7. If you were to do a follow-up experiment, what would you do to increase the reliability of your results? How would this modification increase reliability?

8. Using the information in *Background Reading: Diabetes and Blood Glucose* and the results from the lab, how likely is it that your patient has diabetes (very likely, somewhat likely, unlikely)? This will be your claim for Part 4.

9. If it *is* likely, which type of diabetes is more likely for this patient (Type 1, Type 2, cannot determine)?

10. Was your prediction accurate? Cite data to support your evaluation of your prediction.

FUTURELAB+

Student Guide, Part 4: Arguing from Evidence

Directions

Use the organizer below to write a complete Claim, Evidence, Reasoning paragraph that answers the Driving Question: How likely is it that your patient has diabetes?

CER Organizer

Optional Sentence Frames/Guiding Questions	
Claim	Statement that answers the driving question
Evidence: data collected from the patient profile and the lab	What were the fasting and 2-hour blood glucose concentrations of the patient (include units)?
	Is there other relevant information from the patient's profile?
	Based on the known solutions used to validate the glucometer, how reliable are your results?
Reasoning: what scientific principles explain the data?	________ indicates that ________ because ________ .
	________________ explains why ________________ .
	______________ occurs as a result of ______________ .

Key Vocabulary
Blood glucose concentration
Glucometer
Diabetes (Type 1 and Type 2)
Insulin
Oral glucose tolerance test (OGTT)
Biomarker

CER Paragraph:

FUTURELAB+

CER Rubric

Score	4	3	2	1
Claim	In the first sentence, a claim is made which clearly and specifically answers the guiding question.	In the first sentence, a claim is made which clearly answers the guiding question.	A claim is made which answers the guiding question. This claim is unclear OR not in the first sentence.	A claim is made but does not answer the guiding question.
Evidence	At least three pieces of evidence are provided that strongly support the claim. The evidence is very clear (including data analysis and comparison), logical, and relevant to the claim.	At least three pieces of evidence are provided that support the claim. The evidence is mostly clear, logical, and relevant to the claim.	Some evidence (at least two pieces) is provided that supports the claim.	Very little evidence (one piece) is provided that supports the claim. Evidence is irrelevant, unclear, or illogical.
Reasoning	The reasoning uses the evidence to communicate the claim in a convincing way with significant use of scientific principles. Language is clear, explicit, and thorough.	The reasoning clearly and accurately relates the evidence to the claim with some use of scientific principles or real world connections.	The reasoning begins to relate the evidence to the claim. There is some relevant reasoning, but not enough.	The reasoning attempts to relate the evidence and the claim.
Final Score				