



TOPICS 1-3

Integrate Data Science Investigate Medicine

Purpose

Students will investigate how the body processes medication by analyzing mathematical functions that model medicine concentration over time. They will research, analyze, and interpret data findings and use the math they have learned to answer questions posed or questions of particular interest to them. They will use the data to drive decisions and to make predictions.

Students have the opportunity to apply all or a subset of the concepts and skills they have learned in Topics 1-3.

Pacing

Allow 3–4 days for students to complete the investigation and optional extension.

Invite Student Questions and Conjectures

To engage students in the context and have them bring their own unique experiences and ideas to the situation, consider these prompts:

- Q:** Have you ever wondered how doctors determine the right dosage and frequency for your medication?
- Q:** Why might some medications need to be taken with food, while others should be taken on an empty stomach?
- Q:** What do you think happens when a medicine is absorbed too quickly or too slowly in the body?



Interactive version is available at SavvasRealize.com.

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How the Body Processes Medication

Absorption: GI tract, stomach, and intestines

Distribution: From blood to tissues

Metabolism: The liver metabolizes and detoxifies medicine

Excretion: Kidneys and intestines

Medicines interact with the body in complex ways. As painkillers move through the bloodstream, enzymes break them down, and the body gradually removes the medicine over time. For medicines to work effectively, their concentration must be just right—too low, and they won't have an effect; too high, and they could be harmful.

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English Language Development

MLR2 Collect and Display



Activity

Notice and Wonder WHOLE CLASS

Engage students in classroom discourse as they notice and wonder about the absorption of medicine in the body.

MLR2 Collect and Display

Record what students notice and wonder, and revisit the lists during the investigation. While recording, listen for informal words students may use, and revise what you record as students refine their terminology.

Notice	Wonder
• I notice that all the graphs increase to a maximum before decreasing. • I notice that as time goes on, the concentration of medication gets closer to 0. • The shapes of the graphs look similar to a parabola, but they are not symmetric. • The maximum concentration is different for each medication.	• I wonder why the medications have different maximum concentrations? • I wonder if the shape of the graph depends on the dosage of the medicine? • I wonder if all medications have this shape?

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Comparison of Medicine Concentrations in Bloodstream Over Time

Concentration of Medicine (mg/L)

Time (hours)

Medicine A
Medicine B
Medicine C
Medicine D

What do you notice?

What do you wonder?

If you make a claim based on your observations, where can you find the evidence to support it?

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Activity

Promote Mathematical Discourse

Before answering questions, have students work in small groups to review the problem statement and graph. Have them write a list of what they notice and wonder. Add to the class notice and wonder display as students share their observations. **MLR2**

- Q:** When you take medicine, why do you think the dosage instructions often say to take it every few hours? [Sample response: I think the medicine wears off after a while, so you have to take more to keep it working in your body.]
- Q:** Why do you think it's important for medicines to have specific dosage instructions? [Sample response: If you take too much of the medicine, it might be dangerous, and if you take too little, it might not work.]

Launch the Investigation SMALL GROUP

You may choose to complete parts 1–4 as a class or in small groups. Facilitate classroom discussion at pause points between each part.

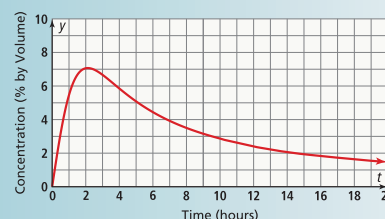
1. Sample response: The medicine is most effective at the maximum at about 2.1 hours or 2 hours and 6 minutes. This is the time the medicine is most effective because the concentration is at the highest, while remaining in the safe range (between 5% and 7.5% concentration in the bloodstream).
2. Sample response: There is a positive rate of change from about 1 to 2 hours, then a negative rate of change, as concentration decreases at a slower rate until 10 hours. From 10 to 20 hours, the rate of change is still negative and tends toward 0.
3. Sample response: As time goes to infinity, the graph $f(t)$ approaches 0. This means that as time goes on, the concentration of medicine in the blood will also diminish, but probably at a faster rate and eventually it will reach 0.
4. Sample response: The concentration is increasing until the maximum at about $t = 2.1$, then the concentration decreases. I think the concentration is probably not effective when it reaches below 1%, which is at about 20 hours.



Interactive version is available at SavvasRealize.com.

MEDICINES MUST REACH THE RIGHT CONCENTRATION IN THE BODY TO BE EFFECTIVE.

A certain medicine is effective if its concentration is at least 5% but not above 7.5%, which can cause side effects. The concentration of the medicine can be modeled with the rational function $f(t) = \frac{30t}{t^2 + 4.5}$, when $t \geq 0$.



- 1 When is the medicine most effective?
- 2 Does the change in concentration happen at a constant rate? How do you know?
- 3 Describe the end behavior of the function. Explain what this means in context.
- 4 When is the concentration of medicine increasing? When is it decreasing? When might another dose need to be administered?

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Activity

DRIVE YOUR INVESTIGATION

Anticipate

As you plan, anticipate ways that students will ...

- interpret graphs and equations
- use tools to plot the search areas
- connect mathematical models to real-life scenario
- use tools to build a model

Also anticipate errors that may occur like:

- misunderstanding the context
- misinterpreting the variables
- drawing conclusions without mathematical evidence to back it up

Monitor

Questions for Students Before Starting the Investigation

- Q:** Why do you think it's important for doctors and healthcare workers to understand how medicine levels change in the bloodstream? [To keep patients safe and prevent harmful reaction to medication.]
- Q:** What shapes or patterns do you expect to see in a graph of medicine concentration over time? [I expect there to be an increase to a maximum, then a decrease towards 0.]

Questions for You As You Observe

As you monitor students working, ask yourself the following questions:

- **Which students need support with researching the information they need?** Refer students to the guided activity as a reference, or data from official websites.
- **Which students need help creating models that represent the data?** Encourage students to use technology tools such as Desmos Graphing Calculator, graphing calculators, grid paper or a coordinate grid.

Questions for Students During the Investigation

- Q:** What does the graph of the data suggest about how long the medicine stays effective? Encourage students to think about the variables and what they mean in context.
- Q:** How can you determine if a rational function is a good fit for the data? What might the shape of the graph or key features like asymptotes tell you? Guide students to think critically about the appropriateness of their model and its mathematical characteristics.



Interactive version is available at SavvasRealize.com.

DRIVE YOUR INVESTIGATION

Investigate the concentration of a different medicine in blood over time. To drive your investigation, search for this data on official websites.

- 1. Make Sense of the World** How does the concentration of the medicine change over time? What kind of function could model this change?
- 2. Predict** How does food affect the medicine's concentration in blood over time? What other factors might influence the dosage a patient receives?
- 3. Make An Impact** How can using data and mathematical models help doctors create more personalized treatments for their patients?

REFLECT ON MATH PRACTICES AND PROCESSES

Choose two of the following questions to reflect on how you engaged the math practices and processes during the investigation.

- 1. Model with Mathematics** How did you use mathematical models to represent the data?
- 2. Reason** How did you interpret the results of the model in terms of the context?
- 3. Look for Relationships** What relationships did you notice in the behavior of the concentration over time? How did you use these relationships to make predictions?
- 4. Construct Arguments** What evidence could you use to show that your model is accurate?

EXTENSION

Investigate how artificial intelligence (AI) helps doctors to advance treatment.

- Investigate how artificial intelligence can improve the accuracy and safety of medication dosages for patients.
- Based on your investigation, design a simple prototype or create a concept for an AI-based tool or app. This tool should help doctors, pharmacists, or patients ensure accurate and safe medication dosages.
- Explain how your product could make an impact on healthcare and improve patient outcomes.

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Questions to Assess Student Understanding (Assessing Questions)

- Q:** How are your conclusions supported by the data?
- Q:** What adjustments would you make to your model if the data showed the medicine staying in the bloodstream longer or shorter than expected?

Questions for Students Who Need Help (Assessing Questions)

- Q:** What do you notice about how the concentration changes at the beginning compared to later? Is it increasing, decreasing, or staying the same?
- Q:** Can you describe what is happening to the medicine in the body when the concentration starts to decrease?
- Q:** If you could draw a sketch of the data, what would it look like? Do any specific points or patterns stand out?

Questions to Help Students Think More Deeply (Assessing Questions)

- Q:** If someone asked you to predict when the medicine stops being effective based on the data, how would you explain your reasoning?



Select and Sequence Solutions

The following is a possible sequence for the presentation of sample student work with suggested questions. This sequence of solutions does not have a particular coherence and can be reordered in any way. You should select and sequence responses from your own students, using the sample responses provided only as needed.

It is recommended that this part of the lesson take place after the Investigation.

1. **A student analyzes medicine concentration data from an official website.** (Student Work A)
 - Q: Which tools did you use to analyze the data?
 - Q: How does the data support your conclusion?
2. **A student develops a model to analyze the medicine concentration data from an official website.** (Student Work B)
 - Q: Why did you choose rational functions to model the concentration over time?
 - Q: How does food affect the concentration of medicine and its effectiveness?
 - Q: How could your findings inform decisions about when and how to take the medicine for maximum effectiveness?
3. **A student uses a piecewise function to model medicine concentration in the blood over time.** (Student Work C)
 - Q: Which functions did you use to model the concentration over time? Why?
 - Q: How does the rate of change compare over different intervals of time?
 - Q: How did you determine the domain for each part of your model?
4. **A student analyzes the concentration of anesthesia over time.** (Student Work D)
 - Q: What key features of the graph can you identify?
 - Q: How does the data support your conclusion?

Connect to the Goals of the Investigation

After allowing students to finish the questions for the lesson, return to an all-class discussion to solidify the connection to the goals of the lesson.

- Q: What types of functions could model the concentration of medicine over time?
- Q: How would you describe the concentration before, at, and after the maximum value? What does this tell you about the absorption and elimination of the medicine?
- Q: How do the rate of change and shape of the graph help you understand the dynamics of medicine in the body?
- Q: What are some distinct differences between your model and how you expect the medicine to actually behave in the body?
- Q: How is student A's strategy different from student B's? How is it similar?
- Q: Could student C use their model to make a prediction about the concentration at $t = 12$ hours and at $t = 19$ hours? How confident would you be in that prediction?
- Q: Predict how Student D's model could change if the dosage is increased or decreased. What evidence is there to support your prediction?

REFLECT ON MATH PRACTICES AND PROCESSES

Ask students to choose two of the math practices and processes questions that reflect the ways that they engaged with math practices during the investigation.

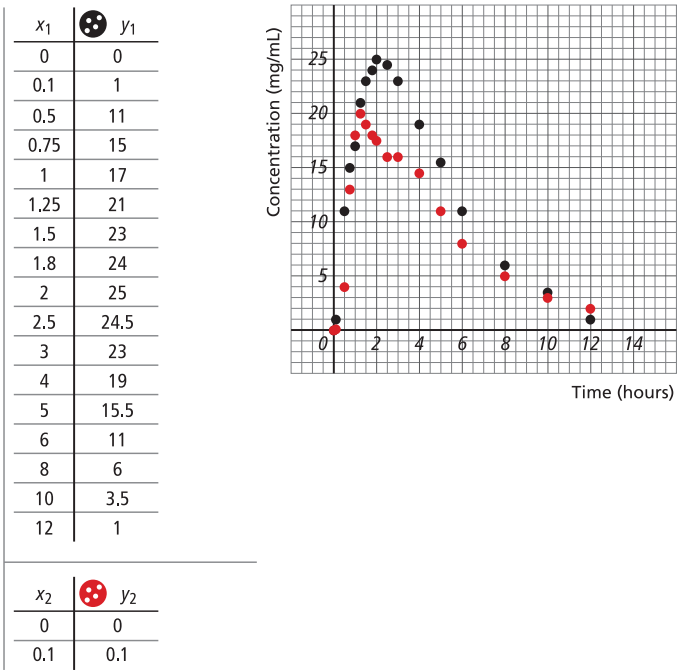
You may also assign questions to facilitate discussion about how students demonstrated proficiency with the math practices and processes.

EXTENSION

- Q: In what ways can AI reduce human error when calculating or administering dosages?
- Q: Based on what you already know about the topic, can you think of any experts, organizations, or institutions that might have relevant research or data?

ANALYZE STUDENT WORK Project these individually or together from SavvasRealize.com.

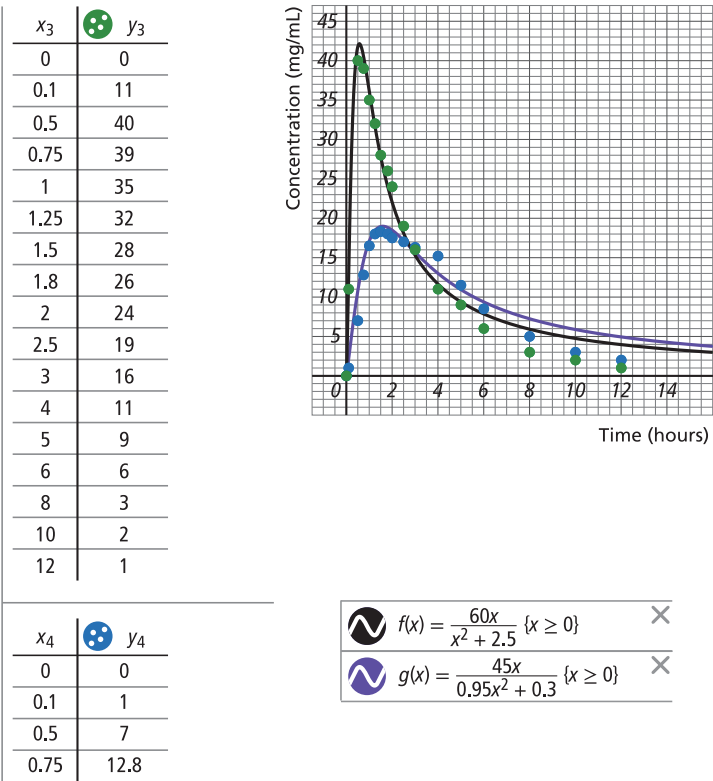
Student Work A



I analyzed time vs. Ibuprofen + caffeine (no food), which shows a parabolic curve that becomes asymptotic around 10 hours. The data for time vs. Ibuprofen + caffeine (with food) has a lower maximum (20 vs. 25) and is less parabolic. This shows that Ibuprofen with caffeine works faster than with food. Factors like age, weight, health, and interactions with other medications can affect how a patient responds. Data and models help doctors analyze patterns and understand how individuals might react to treatments.

To review content, refer students to Topic 1, Lesson 1.

Student Work B



I analyzed Ibuprofen-lysinate + caffeine (with and without food) and observed that Ibuprofen without food is most effective. I used rational functions to model the concentration of each medicine over time:

With food: $f(x) = \frac{60x}{x^2 + 2.5}, x \geq 0$

Without food: $f(x) = \frac{45x}{0.95x^2 + 0.3}, x \geq 0$

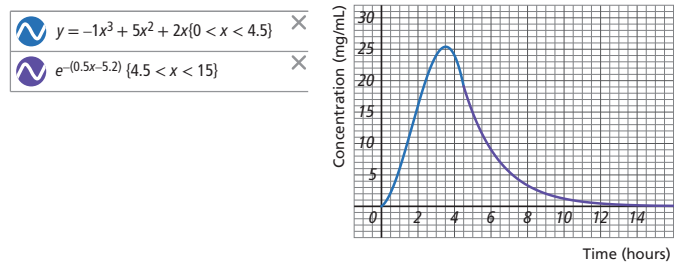
The ratio of a first-degree over a second-degree polynomial best matched the curve. Both models have a horizontal asymptote at $y = 0$. By adjusting the coefficients, I obtained a higher maximum for Ibuprofen without food, reaching 42 mg/mL at $t = 0.6$ hours. Both models have a domain of $x > 0$.

To review content, refer students to Topic 1, Lessons 1 and 2.



ANALYZE STUDENT WORK Project these individually or together from SavvasRealize.com.

Student Work C



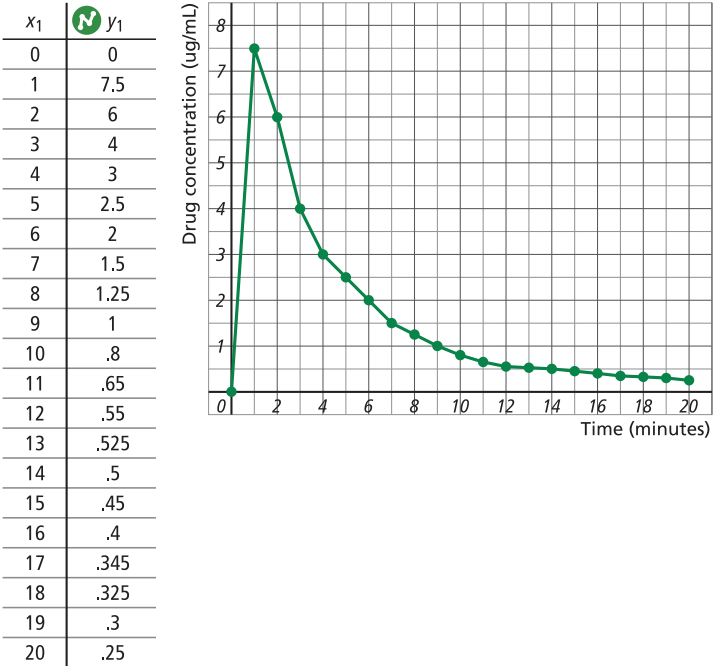
I used a piecewise function to model the concentration (mg/mL) of a medicine over time (hours). In general, the concentration of medicine in the blood over time increases to a maximum, then decreases asymptotically toward 0. I used a polynomial function model the concentration from $0 \leq x < 4.5$ hours, as the rate of change before the maximum is steeper than after. For $x \geq 4.5$ hours, I used an exponential decay model to reflect the concentration approaching 0 over time.

$$y = \begin{cases} -x^3 + 5x^2 + 2x, & 0 \leq x < 4.5 \\ e^{-0.5x - 5.2}, & x \geq 4.5 \end{cases}$$

At $t = 0$, the concentration starts at 0 and rises to just over 25.4 mg/mL at $t = 3.5$ hours. The average rate of change over the interval from 0 to 3.5 hours is 7.5 mg/mL per hour. After reaching the maximum, the rate of change decreases, and the graph levels off around $t = 14$ hours. Although the model never reaches 0, the concentration of medicine in the body will effectively reach 0 over time.

To review content, refer students to Topic 1, Lesson 3 and Topic 2, Lesson 1.

Student Work D



I researched general anesthesia. This type of drug renders people unconscious in seconds. The concentration often peaks in less than one minute. In my model, I used (1,7.5) as the maximum concentration. The graph from 0 to 1 minute is linear, since the concentration increases at a constant rate. When a general anesthesia drug infusion is stopped, within 10-15 minutes, the drug's concentration in the bloodstream will decrease at an exponential rate. In the model, we can see this decrease so that after about 10 minutes, the concentration reduces by about 20%. I think that food consumption may not be a factor for strong drugs like general anesthesia, but I would need to consider more data.

To review content, refer students to Topic 1, Lesson 3 and Topic 3, Lesson 2.

You can use the space below to reflect on the Integrate Data Science. The questions can be used as a guide, or you can write freely as you reflect on the investigation.

Integrate Data Science Teacher Reflection

Instructional Strategies	Resources and Tools
- Which instructional strategies were most effective? - Which instructional strategies were less effective?	- Which resources and/or tools best supported learning and/or data analysis? - Are there additional resources and/or tools that could be utilized next time?

Key Moments	Review
- What were some memorable insights or unique approaches to the investigation? - Were there any surprising outcomes or shifts in students' thinking?	What skills or concepts need to be reviewed?

Investigate Medicine: Key Takeaways