Gizmos

Name: ______________________________________ Date: ________________________

Student Exploration: Dye Elimination

[Note: This Gizmo explores the mathematics behind the concepts introduced in the Drug Dosage *Gizmo. We recommend beginning with that Gizmo before trying this one.]*

Vocabulary: dosage, equilibrium, excretion, target organ

Prior Knowledge Question (Do this BEFORE using the Gizmo.)
In the *Drug Dosage* Gizmo, you learned how to create a **dosage** schedule that leaves the proper concentration of drug in your bloodstream.

1. Suppose your bloodstream contains a certain concentration of a drug. How is the drug eliminated (removed) from your body? ____

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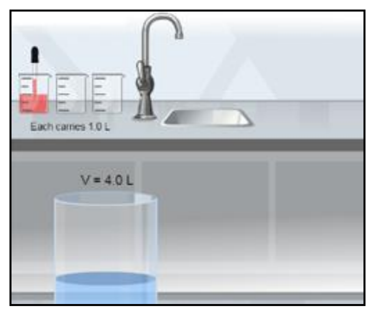
2. How will the rate of drug elimination change as the bloodstream drug concentration is reduced? ____

Gizmo Warm-up
The *Dye Elimination* Gizmo models how a drug is eliminated from the bloodstream. Dye representing the drug is added to a large container of water that represents the bloodstream. Water containing the dye is then removed from the container (representing **excretion**), while fresh water is added.



To begin, check that the **Container volume** is 4.0 L and the **Water intake, liquid output** is 1.0 L. Click **Begin**.

1. On the SIMULATION pane, click **Add dye** to add 8.0 mL of dye. How does this affect the water? ____

2. Click **Run cycle**. How does the process shown in the Gizmo relate to what happens in your body? ____

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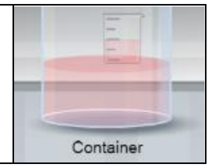
Activity A: **Single dose**	<u>Get the Gizmo ready</u>: • Click **Reset**. • Check that the **Container volume** is 4.0 L. • Set the **Water intake, liquid output** to 2.0 L.	

Introduction: When you take a pill, the drug it contains is absorbed into your bloodstream. Over time, the drug is eliminated in your urine as you drink water to replace the liquid you lose. This process can be modeled.

Question: How quickly is a single dose of a drug eliminated from the bloodstream?

1. <u>Predict</u>: Click **Begin**. Set the **Amount of dye** to 16.0 mL and click **Add dye**. There is now 16.0 mL of dye in the container. When you click **Run cycle**, two liters of dyed water will be removed from the container and two liters of fresh water will be added.

   A. How much dye do you think will remain in the container after one cycle? __________

   B. How much dye do you think will remain after two cycles? __________

2. <u>Test</u>: Select the BAR CHART tab and turn on **Show numerical value(s)**. Click **Run cycle**.

   How much dye is left after one cycle? __________

   Click **Run cycle** again. How much dye is left after two cycles? __________

3. <u>Gather data</u>: Let d_0 represent the original amount of dye in the container and d_1, d_2, etc. represent the dye left after each cycle. Click **Run cycle** several more times, recording the amount of dye left after each trial in the table below.

Cycle	d_0	d_1	d_2	d_3	d_4	d_5
Dye in container	16.0 mL					

4. <u>Observe</u>: What pattern do you notice in your data? ______________________________

   ____

5. <u>Analyze</u>: How does this pattern relate to the amount of water removed compared to the volume of the container? ____

   ____

   ____

(Activity A continued on next page)

Activity A (continued from previous page)

6. Predict: Click **Reset**. On the DESCRIPTION pane, set the **Water intake, liquid output** to 1.0 L. What pattern do you expect in the amount of dye remaining now?

____

7. Gather data: Select the BAR CHART tab. Click **Begin** and **Add dye**. Click **Run cycle** five times and fill in the second row of the table. Next, calculate the ratio of each amount to the previous amount (d_1/d_0, d_2/d_1 … d_n/d_{n-1}).

Cycle	d_0	d_1	d_2	d_3	d_4	d_5
Dye in container	16.0 mL					
Ratio d_n/d_{n-1}	-----					

8. Analyze: How does d_n/d_{n-1} relate to the ratio between the water removed in each cycle and the volume of the container? ____

9. Apply: What ratio of d_n/d_{n-1} would you expect if you set the **Container volume** to 5.0 L and the **Water intake, liquid output** to 2.0 L? ______________________________________

   Check your answer using the Gizmo.

10. Manipulate: Suppose the volume of the container was V and the volume removed in each cycle was V_R. The original amount of dye in the container is d_0 and the dye remaining after n cycles is d_n. (Show your work on a separate piece of paper and turn it in with this sheet.)

    A. Write an equation for d_1 based on d_0, V, and V_R: $d_1 =$

    B. Write an equation for d_2 based on d_1, V, and V_R: $d_2 =$

    C. Substitute your expression for d_1 into the second equation to write an equation for d_2 based on d_0, V, and V_R: $d_2 =$

    D. Write an equation for d_n based on d_0, V, and V_R: $d_n =$

    Check your last equation with your classmates and teacher, and use the Gizmo to validate its results.

Activity B: **Multiple Doses**	Get the Gizmo ready: • Click **Reset**. • Set the **Container volume** to 4.0 L. • Set the **Water intake, liquid output** to 2.0 L.	

Introduction: In many cases, you may take a pill every day while you are sick. In this case, the goal is to maintain an optimal concentration of the drug in your bloodstream. You can use the Gizmo to model this situation.

Question: How can an optimal concentration of drug in the bloodstream be established?

1. Observe: Click **Begin**. Set the **Amount of dye** to 10.0 mL and click **Add dye/Run cycle**.

   What happens? ____

   ____

2. Explain: Select the BAR CHART tab. How much dye remains after one cycle? ___________

   Why is this amount left? ____

   ____

3. Explore: Click **Add dye/Run cycle** again. How much dye remains now? ___________

   Why is this amount left? ____

   ____

4. Observe: Click **Add dye/Run cycle** about 20 times. Select the GRAPH tab and use the zoom controls to see all the data. Notice there are two sets of dots. The light-purple dots represent the amount of dye after dye is added in each cycle. The dark-purple dots represent the dye that remains at the end of each cycle.

   What do you notice? ____

   ____

5. Analyze: **Equilibrium** is established when the dye removed in each cycle is equal to the dye added in each cycle.

   What is the equilibrium amount of dye in this situation? ____________________________

   (Use the value at the end of the cycle.)

(Activity B continued on next page)

Activity B (continued from previous page)

6. Identify: You can use algebra to predict the equilibrium amount of dye. Let *d* represent the amount of dye in the container, d_{in} the amount of dye added in each cycle, and d_{out} the dye removed in each cycle.

   At equilibrium, what is the relationship between d_{in} and d_{out}? _________________________

7. Manipulate: The amount of dye removed from the container is equal to the amount of dye already in the container (*d*) plus the newly added dye (d_{in}) multiplied by the fraction of water removed from the container (V_R/V):

$$d_{out} = (d + d_{in}) \cdot \frac{V_R}{V}$$

   At equilibrium, d_{in} is equal to d_{out}, so you can substitute d_{in} for d_{out} in the last expression:

$$d_{in} = (d + d_{in}) \cdot \frac{V_R}{V}$$

   Solve this expression for *d* to find the equilibrium value of *d*. *d* =

   Show your work:

8. Check: Check your equation using the values shown in the Gizmo: V = 4.0 L, V_R = 2.0 L,

   and d_{in} = 10.0 mL. Did you get the correct value for the equilibrium value of *d*? ___________

9. Predict: Based on your equation for *d*, what is the equilibrium amount of dye in the container if the volume of the container (*V*) is 7.0 L, the water intake/liquid output (V_R) is 2.0 L, and the amount of dye added in each cycle (d_{in}) is 11.0 mL? Test your prediction using the Gizmo.

   Show your work: *d* = ________

10. Challenge: A patient has 4.5 liters of blood. Every day, the patient drinks about 1.5 liters of water. A doctor wants the patient to have an equilibrium level of 500 mg of a drug in her bloodstream.

    How many milligrams of the drug should the patient take each day? ___________________

    Show your work on an additional sheet of paper.

Activity C: **Multiple Doses**	Get the Gizmo ready: • Click **Reset**. • Set the **Container volume** to 4.0 L and the **Water intake, liquid output** to 1.0 L. • Turn on **Add bowl**, set the **Bowl volume** to 2.0 L, and set the **Exchange, inflow/outflow** to 1.0 L.	

Introduction: Sometimes a drug is designed to affect a particular **target organ**. In this case, the concentration of the drug in the organ is much more important than the concentration of the drug in the blood. The target organ is modeled by placing a bowl next to the original container.

Question: How is the equilibrium level of a drug in a target organ determined?

1. Observe: Click **Begin**. Check the **Amount of dye** is 10.0 mL. Click **Add dye/Run cycle**.

   What happens? ____

   ____

2. Calculate: Use the equation you derived in activity B to determine the equilibrium level of dye in the larger container. Ignore the bowl for now. Show your work.

   d = _________

3. Observe: Select the BAR CHART. Click **Add dye/Run cycle** until the amount of dye in the larger container is at equilibrium.

   A. Did the addition of a bowl affect the equilibrium amount of dye in the container? ____

   B. What is the equilibrium amount of dye in the bowl? ___________________________

4. Calculate: Based on the volume of the container, the amount of dye in the container, and the amount of liquid that is transferred from the container to the bowl in each cycle, how much dye is transferred to the bowl in each cycle?

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   Hint: If the volume of the container is 10.0 L and the container has 100 mL of dye, then removing 1.0 L of water from the container will remove one-tenth of the dye, or 10 mL.

   Explain your answer: ____

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(Activity C continued on next page)

Activity C (continued from previous page)

5. Challenge: Calculate the equilibrium amount of dye in the bowl. (Hint: At equilibrium, the dye removed from the bowl is equal to the amount of dye added to the bowl. You can calculate the dye removed from the bowl using the same method as in question 4.)

   Equilibrium amount of dye in the bowl: _______________

   Explain your answer: ____

   ____

   ____

   ____

6. Apply: The **concentration** of dye is found by dividing the volume of dye by the total volume of liquid. In this case, the units of concentration are mL per L, or mL/L.

   A. What is the equilibrium concentration of dye in the container? __________________

   B. What is the equilibrium concentration of dye in the bowl? ______________________

   C. What does this imply about medications and target organs? ___________________

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7. Critique: The *Dye Elimination* Gizmo uses a model of adding dye to a container of water to help you study and understand how drugs are absorbed in the body.

   A. What are the advantages of using this model to study drug dosages? ____________

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   B. What are the disadvantages of using this model to study drug dosages? (Hint: What factors are not included in this model? ____________________________________

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