Why does Blood Flow Change?

Investigating the Math of Blood Flow Dynamics

**Modeling Variation Ticket-to-Enter**

**Complete the following information about Variation:**  (Openstax Elementary Algebra section 8.9) [https://cnx.org/contents/CImQfPDv@8.49:\_L9Vlwth@22/8-9-Use-Direct-and-Inverse-Variation](https://cnx.org/contents/CImQfPDv%408.49%3A_L9Vlwth%4022/8-9-Use-Direct-and-Inverse-Variation)

Direct Variation:

         If y varies directly as x, then an increase in y will produce an increase in x.

         Modeled by the equation:  \_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_ (use the equation in the form y = . . .)

         k is called \_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_

         Looking at the model equation, direct variation uses what operation?  \_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_

Key phrases: “varies directly with” or “is proportional to”

Inverse or Indirect Variation:

         When y varies inversely with x, an increase in x produces a decrease in y.

         Modeled by the equation:  \_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_ (use the equation in the form y = . . .)

         k is still the \_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_

         Looking at the model equation, inverse variation uses what operation?  \_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_

Key phrases: “varies inversely with” or “inversely proportional to”

Joint or Combined Variation:  (Openstax College Algebra section 5.8) <https://openstax.org/books/college-algebra/pages/5-8-modeling-using-variation>

Many situations are more complicated than direct or inverse variation.  They depend on multiple variables.  Some items vary directly, and others vary inversely or multiple items may all vary directly with in the same situation.

Write two sample equations for joint variation:

         All direct variation:

               A combination of direct and inverse variation:

Watch the Variation [video](https://www.youtube.com/watch?v=Nz5xl0GR1y4).

 (<https://www.youtube.com/watch?v=Nz5xl0GR1y4>)

1)  In Direct Variation:  When one item increases, the other item \_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_.  When one item decreases, the other item\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_.

* Give a real-life example of items that vary directly.
* Describe the graph of items that vary directly.
* Describe the equation of items that vary directly.

2)  In Inverse Variation:  When one item increases, the other item\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_.

* Give a real-life example of items that vary inversely.
* Describe the graph of items that vary inversely.
* Describe the equation of items that vary inversely.

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**Modeling Variation In-Class Activity**

During this activity, we will discuss critical variables that contribute to blood flow. The French scientist Jean Louis Marie Poiseuille developed the formula that relates the factors that impact blood flow:

Blood flow = $\frac{πPr^{4}}{8vL}$

π/8 represents a constant of approximately 0.393

P represents blood pressure

r represents the blood vessel radius

v represents the blood viscosity

L represents the blood vessel length

This equation indicates that **four variables affect blood flow: viscosity, vessel length, pressure, and radius** since π/8 is a constant. You can see that the equation includes a combination of direct and inverse variation.

We will be using the following app for this activity:  <https://bmorgante.shinyapps.io/BloodFlow/>

**Instructions on how to use the app:** The four variables for flow rate are seen on the left. As you slide the circles for each variable, the flow rate is calculated at the top of the page. Below the flow rate, you will see the graph for pressure. Click on the tabs for the other variables to see their graphs. Be sure to notice how the y-axis will change as you slide the circles for each variable.

Complete the table below using the link (<https://bmorgante.shinyapps.io/BloodFlow/>) to determine what happens to blood flow when changing each variable independently.

Set the radius to 3 mm, set the viscosity to 3.5, and set the length to 50 mm.  Keep these three variables constant.

|  |  |
| --- | --- |
| Blood Pressure  (mmHg) | Flow Rate  (mL/min) |
| 20 |  |
| 60 |  |
| 100 |  |
| 140 |  |
| 180 |  |

1. Explore Blood Pressure – change the blood pressure to the settings below and record the change in flow rate.
	1. Sketch a graph using the data in the table.
	2. While exercising, a person’s blood pressure will rise.  What is the impact on blood flow?  Explain how you know.
	3. Which of the four variables will be constant in this problem?
	4. What is varying?  \_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_What type of variation exists between the two variables?
2. Define variables and write an equation to model the relationship.
3. Use a pair of numbers to find the constant of variation in the relationship.
4. Use your equation to predict the flow rate when the blood pressure is 220 mL/min.

2. Set the pressure to 100 mm Hg, set the viscosity to 3.5, and set the length to 50 mm.  Keep these three variables constant.

Explore Blood Vessel Radius – change the radius to the settings below and record the change in flow rate.

|  |  |
| --- | --- |
| Vessel Radius (mm) | Flow Rate  (mL/min) |
|  1 |  |
| 2 |  |
| 3 |   |
| 4 |  |
| 5 |  |

1. Sketch a graph using the data in the table.
2. As a person ages, he/she will often experience arteriosclerosis, which is a thickening and hardening of the walls of the arteries.  Arteriosclerosis decreases the radius of the vessels.  How will arteriosclerosis impact blood flow?
3. Which of the four variables will be constant in this problem?
4. What is varying?  What type of variation exists between the two variables?
5. Compare your graph to the graph of question 1.  Both of these have the same type of variation relationship, however, the graphs appear different.  Explain what is different.
6. The French scientist Jean Louis Marie Poiseuille, who was mentioned in the introduction found that flow varies \_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_ with the 4th power of vessel radius.  Define variables and write an equation to model the relationship.  The 4th power is what creates the difference in the graphs.
7. Use a pair of numbers to find the constant of variation in the relationship.
8. Use your equation to predict the flow rate when the vessel radius is 7 mm.

3.  Set the pressure to 100 mm Hg, set the radius to 3 mm, and set the length to 50 mm.  Keep these three variables constant.

Explore Blood Viscosity – change the viscosity to the settings below and record the change in flow rate.

|  |  |
| --- | --- |
| Viscosity | Flow Rate  (mL/min) |
| 1 |  |
| .3 |  |
| 5 |  |
| 7 |  |
| 9 |  |

1. Sketch a graph using the data in the table.
2. Blood doping is the practice of injecting oxygenated blood into a person to enhance athletic performance.  The addition of these red blood cells increases the viscosity of the athlete’s blood.  What is the impact on flow?

1. Which of the four variables will be constant in this problem?
2. What is varying?  What type of variation exists between the two variables?
3. Define variables and write an equation to model the relationship.
4. Use a pair of numbers to find the constant of variation in the relationship.
5. Use your equation to predict the flow rate when the viscosity is 8.

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**Modeling Variation Assessment**

1. Blood Vessel Length – Observe the table of data values for Vessel Length and Flow Rate.

|  |  |  |
| --- | --- | --- |
| Vessel Length (mm) | Flow Rate  (mL/min) |  |
| 10 | 90.8818 |
| 20 | 45.4409 |
| 30 | 30.2939 |
| 40 | 22.7204 |
| 50 | 18.1764 |

1. Sketch a graph of the data in the table.

1. The length of blood vessels changes over the lifespan.  Infants have shorter blood vessels than adults.  How does an increase in length impact blood flow?
2. What type of variation exists between the two variables?  Explain how you know.
3. Define variables and write an equation to model the relationship.
4. Use a pair of numbers to find the constant of variation in the relationship.

1. Use your equation to predict the flow rate when the vessel length is 60 mm.