Analyzing a Stock and Flow Model to Understand the Body's Ability to Process Alcohol

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This project, conducted in a high school Anatomy & Physiology class, expands upon the "Thinking About Drinking" simulation available on the CLE website by having students analyze the simulation's underlying stock and flow model. It was developed as a cumulative assessment to challenge students to draw connections between the respiratory, circulatory, and digestive systems and then to communicate their learning through a scientific poster.

As an introduction to the project, students described how a breathalyzer test works using their prior learning from class on the respiratory, circulatory, and digestive systems (i.e., how does alcohol leave through our breath when it initially enters our stomach through drinking?) After brainstorming in groups, I gave students a list of anatomical vocabulary words to include in their individually written answer, including the words artery, vein, capillary, alveoli, trachea, right atrium, pulmonary valve, etc. Below is an example student response:

> *"The alcohol is absorbed in the stomach and small intestine. It enters the bloodstream through the capillaries. It travels through the veins and enters the heart through the vena cava. It then goes through the right atrium, tricuspid valve, and into the right ventricle. From there, it will travel through the pulmonary valve and out of the heart in the pulmonary arteries. It will go towards the lungs and into capillaries. There, it will diffuse into the alveoli and travel through the bronchioles and bronchi as you exhale. It will go up through the trachea and out of your mouth. The ethanol will have to cross the membranes of your capillaries." - Student work by Divya Adabala*

Next, students explored the Thinking About Drinking simulation on the CLE website. The simulation allows students to view a graph of Blood Alcohol Content (BAC) over time based on how much is consumed (# of drinks per hour and # of hours spent drinking) and personal

characteristics of the person drinking (biological sex, height, and weight). In class, students spent around an hour working through the simulation using the available student handout provided under teaching resources - here is my slightly modified version of the handout.

The underlying stock and flow model used by the simulation (see Figure 1 below) can be explored here on the CLE website. In short, the model tracks the rate at which alcohol is consumed, absorbed, and excreted from the body:

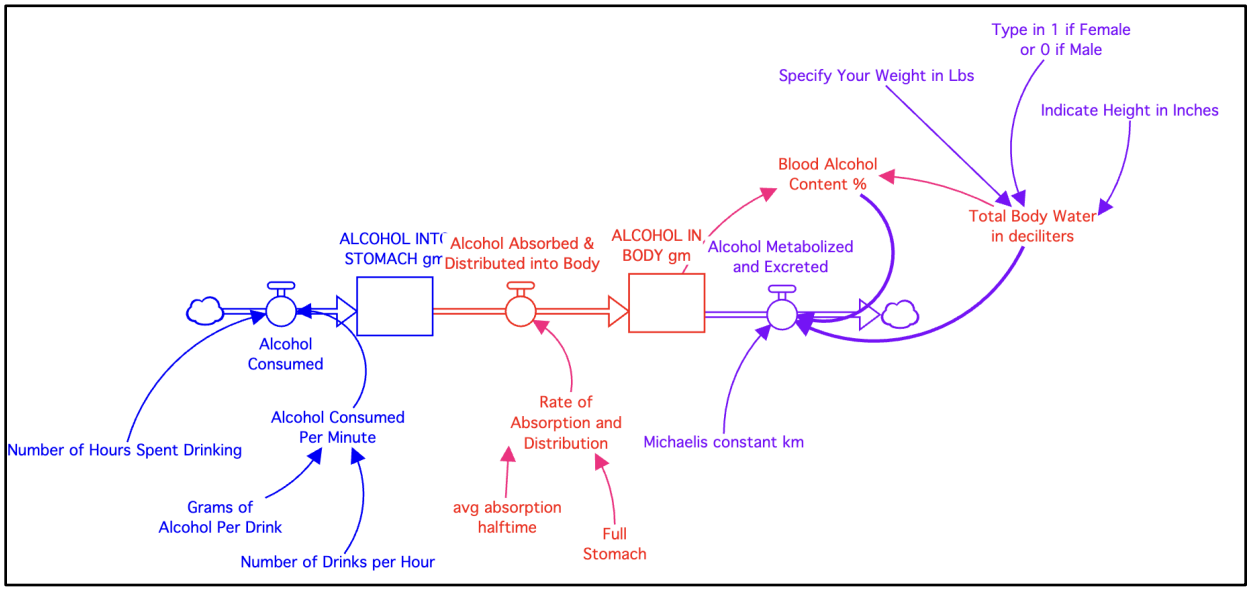

Figure 1. Thinking About Drinking Stella Model from the CLE.

I provided a series of guiding questions for students as they worked to understand different stocks, inflows, and outflows in the model. Some examples of the questions are below; see the entire document here.

- How is the BAC calculated?
- What variables affect someone's total body water?
- What determines the rate of the "Alcohol Metabolized and Excreted" flow?
- Summarize the model in the table below. Parts of the table have already been filled out to help you get started.

Stock	Inflow	Outflow	Factors that affect the stock
Alcohol into stomach (gm)	Alcohol consumed	???	**Factors that affect the inflow:** - # of hours spent drinking - Grams of alcohol per drink - # of drinks per hour **Factors that affect the outflow:** - ???
???	???	???	**Factors that affect the inflow:** - ??? **Factors that affect the outflow:** - ???

Students generally did well on the questions as the class had learned about stock and flow models in a previous class project and the website does a good job explaining the components of the model. Here is sample of two students' work — a stronger example and an emerging example.

Now that students understood the model, I asked them to use the model to more deeply understand how biological sex affects BAC. I chose this variable to focus on as I felt it is important for students to understand the role of biology in their risk of impairment if they choose to drink. To guide students, I asked them to describe how 3 factors that vary based on biological sex — the amount of alcohol dehydrogenase (ADH) enzyme, water percent of body mass, and amount of estrogen — can affect a person's BAC. Students worked in groups to brainstorm and were challenged to refer to specific stocks, flows, and variables from the model. Here is a handout I created, along with class notes, to guide students in this task. When discussing the first factor as a class, the amount of ADH enzyme, I found that students struggled to identify the specific part of the stock and flow model which is initially impacted by the amount of ADH. Many students initially identified the "alcohol eliminated" flow as being first

impacted, when in reality the amount of ADH affects the "Alcohol in Stomach" stock. This led to a rich class discussion and helped students more deeply understand the content and model.

As the culmination of their learning, students made a tri-fold scientific poster — see the poster requirements and rubric here. Students practiced communicating their learning on the poster by:

1. Including an explanation and visual representation of how alcohol moves from the stomach to being exhaled through the mouth.
2. Showcasing a graph or graphs from the model visualizing how BAC varies between biological males and females.
3. Explaining how biological sex affects BAC by highlighting/referring to specific parts of the stock and flow model.

Below are a few examples of these different sections, along with one students' entire poster:

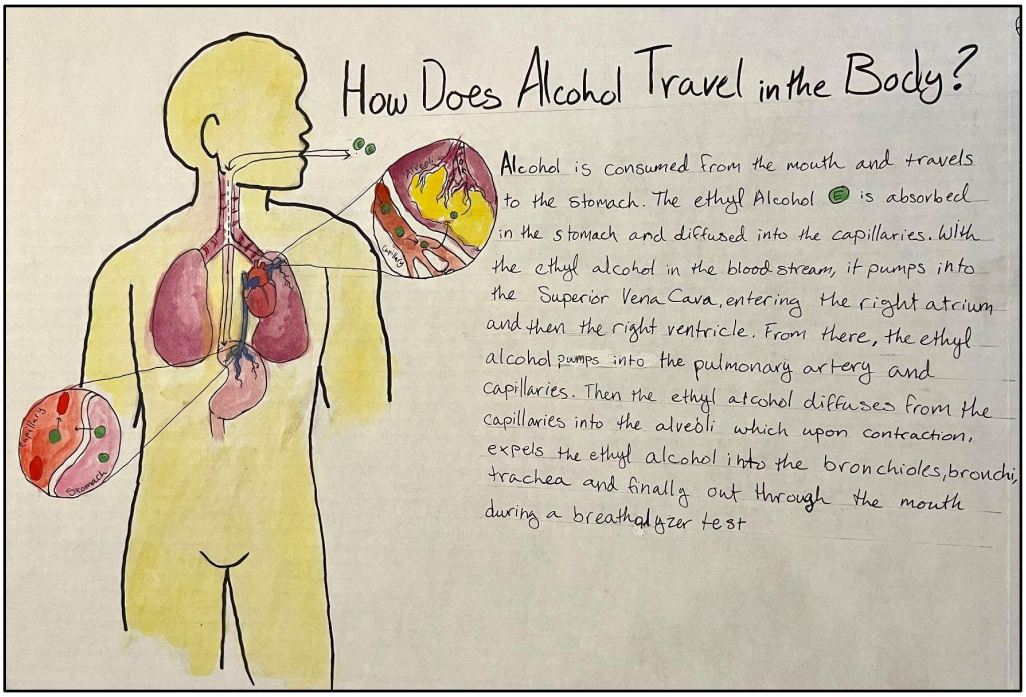

Figure 2. Explanation and visual of alcohol movement from consumption to exhalation. Student work by Ryl Valiente.

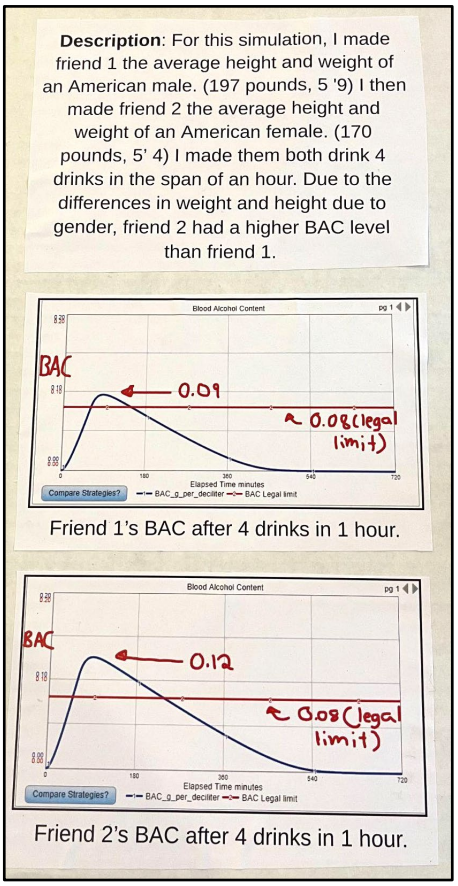

Figure 3. Example of model graphs showing the BAC of a biological male vs. female. Student work by Ella McGuire.

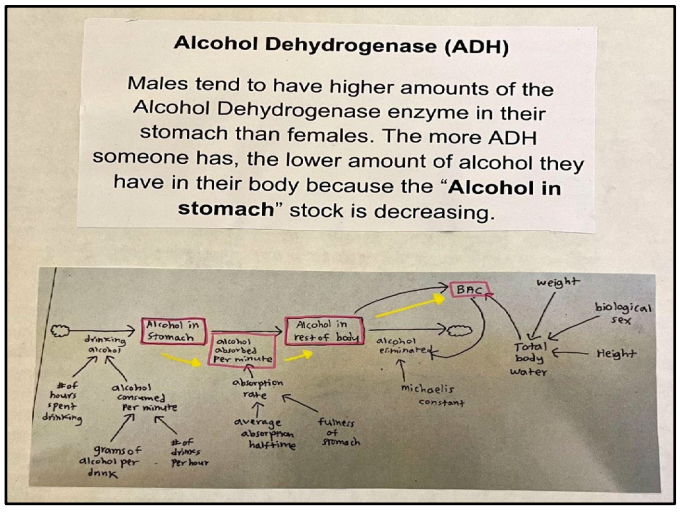

Figure 4. Example explanation and visual of how ADH enzyme affects a person's BAC. Student work by Ella McGuire.

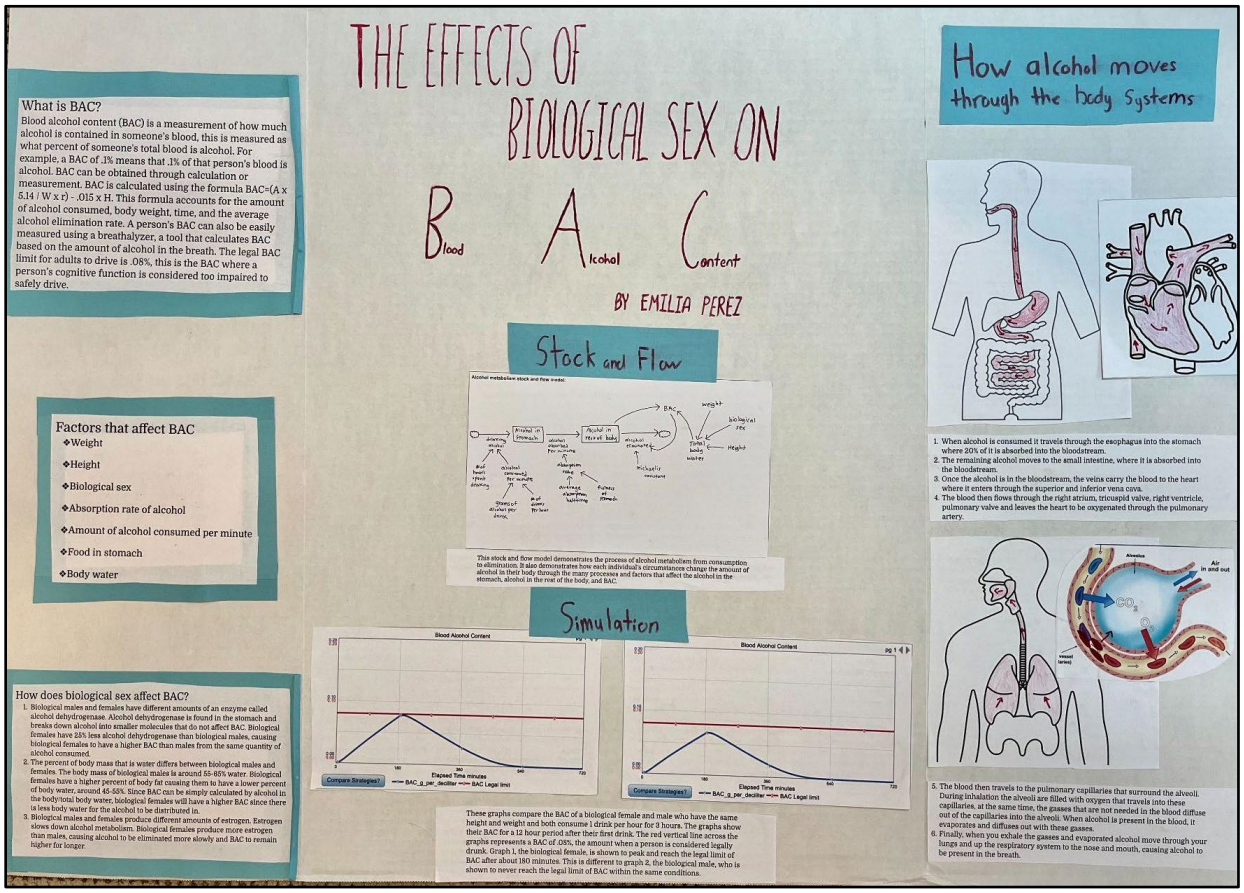

Figure 5. Example of entire poster. Student work by Emilia Perez.

I devoted two weeks' of class time to this project - one week for learning about the model, and one week to complete the final poster. Our class met 3 times a week for 4 hours total per week.

Overall, this project enabled students to explore a real-world application for Anatomy class content and communicate their understanding through visuals, graphs, and a stock and flow model. In order to effectively communicate their learning on the poster, students had to first have a deep understanding of the biology content. Students also had the opportunity to share their posters at our school's "Exhibition Night" to an audience of faculty, peers, and parents. Beyond an Anatomy and Physiology class, this project, or components of this project, could be applied as part of a high school health curriculum to help students better understand the role of

biology on their risk of impairment from alcohol, risk of long-term disease, and to know how to minimize the negative consequences of drinking alcohol.

Simulation: Thinking about Drinking
What are the effects of drinking alcohol?

http://www.clexchange.org/curriculum/simulations/alcohol_simulation.asp

1. Open the simulation, then read the **Introduction** and **What is BAC?** sections. List and briefly describe at least five factors that influence Blood Alcohol Concentration % over time **and why**.

2. In **Simulation Set-up**, describe the personal characteristics of a person (Individual #1) who will be drinking. (The simulation defaults to a 5'7" male weighing 150 pounds but you can change this.)

Male (0) or Female (1): _____
Weight in pounds: _____
Height in inches: _____

3. Next, go **To Simulation** page. Run using the default condition (1 drink per hour, 1 hour spent drinking, empty stomach, start drinking at 3 p.m.). You will need to click Run *12 times* for the graph to reach 720 minutes (12 hours). Click **Time on Clock** to record information for the last column.

Repeat runs for the same individual under different conditions (you choose these) and record.

Individual #1: "Impact of BAC on Behavior" "BAC and Time of Day"

# Drinks per Hour	# Hours Spent Drinking	Stomach Empty / Full	Peak BAC %	Describe Behavior Impairment	Time (hours) BAC > 0.08%
1	1	Empty			

4. Describe a surprise or unexpected result you noted from the above exercise. Use specific data to back up your statements.

5. What difference do personal characteristics make? Using eithers the personal characteristics specified for “Friend 2” and “Friend 3” (on **Simulation Set-Up** page) OR two other individuals of your own choosing, run the same scenarios you ran before and record the results below.

Individual # 2 M/F____ Weight (pounds)____ Height (inches) _____

# Drinks per Hour	# Hours Spent Drinking	Stomach Empty / Full	Peak BAC %	Describe Behavior Impairment	Time (hours) BAC > 0.08%
1	1	Empty			

Individual #3 M/F____ Weight (lbs)____ Height (inches) _____

# Drinks per Hour	# Hours Spent Drinking	Stomach Empty / Full	Peak BAC %	Describe Behavior Impairment	Time (hours) BAC > 0.08%
1	1	Empty			

6. Use the information for your three individuals to describe how personal characteristics can influence the effects of drinking alcohol under different conditions. Use specific data to back up your statements.

7. What aspect of this simulation would you describe to a friend as most important to understand when potentially making future choices about drinking?

Blood Alcohol Project - Examining the Stock and Flow Model

Today, you will explore in detail the stock and flow model behind the simulation you worked with yesterday. Go to this website, and then click on "3. How the System Works". The website will talk you through the components of the model as you hit the spacebar. As you work through it, answer the questions below. You can work on your own or with a partner (if you work with a partner, your answers should be in your own words, though).

1. What units is the "Alcohol in the Body" stock measured in?
2. How is the BAC calculated?
3. What variables affect someone's total body water?
4. How many grams of alcohol are in a "standard drink"?
5. What affects the "Alcohol consumed" flow?
6. How does alcohol move from the stomach to the body stock?
7. What affects the "Alcohol Absorbed and Distributed into Body" flow?
8. What determines the rate of the "Alcohol Metabolized and Excreted" flow?
9. Summarize the model in the table below. Parts of the table has already been filled out to help you get started.

Stock	**Inflow**	**Outflow**	**Factors that affect the stock**
Alcohol into stomach gm	Alcohol consumed	???	**Factors that affect the inflow:** - # of hours spent drinking - Grams of alcohol per drink - # of drinks per hour **Factors that affect the outflow:** - ???
???	???	???	**Factors that affect the inflow:** - ??? **Factors that affect the outflow:** - ???

Alcohol Project - Examining the Stock and Flow Model

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1. What units is the "Alcohol in the Body" stock measured in?
   Grams

2. How is the BAC calculated?
   Total grams of alcohol divided by total body water

3. What variables affect someone's total body water?
   Height, Weight, Sex

4. How many grams of alcohol are in a "standard drink"?
   14 grams

5. What affects the "Alcohol consumed" flow?
   The number of drinks consumed, the percent of alcohol in those drinks and the frequency they consume these drinks

6. How does alcohol move from the stomach to the body stock?
   Roughly 20% is absorbed through the stomach and 80% is absorbed through the small intestine

7. What affects the "Alcohol Absorbed and Distributed into Body" flow?
   Whether the stomach is full or empty affects the alcohol absorbed and distributes into the body flow

8. What determines the rate of the "Alcohol Metabolized and Excreted" flow?
   There is a constant rate called Michaelis Constant and amount of body water

9. Summarize the model in the table below. Parts of the table has already been filled out to help you get started.

Stock	**Inflow**	**Outflow**	**Factors that affect the stock**
Alcohol into stomach gm	Alcohol consumed	Alcohol absorbed and distributed into body	**Factors that affect the inflow:** - # of hours spent drinking - Grams of alcohol per drink - # of drinks per hour **Factors that affect the outflow:** - Average absorption halftime - Full stomach - Rate of absorption and distribution
Alcohol in body in grams	Alcohol absorbed and distributed into body	Alcohol metabolized and excreted	**Factors that affect the inflow:** - Average absorption halftime - Full stomach - Rate of absorption and distribution **Factors that affect the outflow:** - Michelles constant km - Blood alcohol content % - Total body water in deciliters

Alcohol Project - Examining the Stock and Flow Model

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1. What units is the "Alcohol in the Body" stock measured in?

   BAC: Body alcohol content

2. How is the BAC calculated?

   Grams of alcohol in the body

3. What variables affect someone's total body water?

   Sex, Weight, Height

4. How many grams of alcohol are in a "standard drink"?

   14

5. What affects the "Alcohol consumed" flow?

   Hours spent drinking, alcohol consumed per minute, grams of alcohol per drink, number of drinks per hour

6. How does alcohol move from the stomach to the body stock?

   It goes to alcohol in body

7. What affects the "Alcohol Absorbed and Distributed into Body" flow?

   Rate of absorption and distribution, average absorption halftime, full stomach

8. What determines the rate of the "Alcohol Metabolized and Excreted" flow?

   Michaelis constant km

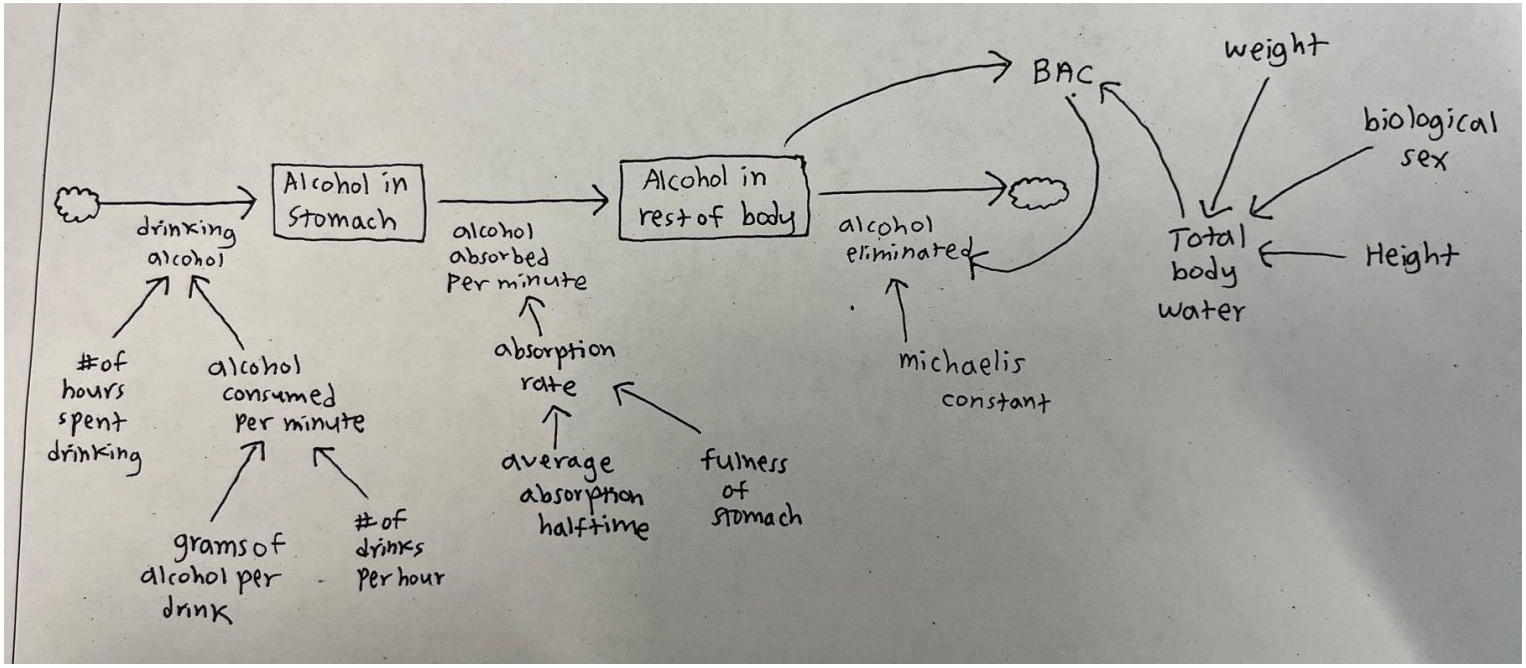
9. Summarize the model in the table below. Parts of the table have already been filled out to help you get started.

Stock	**Inflow**	**Outflow**	**Factors that affect the stock**
Alcohol into stomach gm	Alcohol consumed	Alcohol absorbed and distributed into body	**Factors that affect the inflow:** - # of hours spent drinking - Grams of alcohol per drink - # of drinks per hour **Factors that affect the outflow:** - Rate of absorption and distribution - Average absorption halftime - Full stomach
Alcohol in body gm	Alcohol absorbed and distributed into body	Alcohol metabolized and excreted	**Factors that affect the inflow:** - Rate of absorption and distribution - Average absorption halftime - Full stomach **Factors that affect the outflow:** - Michaelis constant km

Name: _____Class Notes in Red_____

How does biological sex affect alcohol metabolism?

Alcohol metabolism stock and flow model:



Blood Alcohol Content (BAC) = Alcohol in rest of body

Total body water

What factors impact BAC?

- Weight
- Height
- Biological sex ** the focus of our project **
- Absorption rate of alcohol
- Amount of alcohol consumed per minute
- Body water percentage

Differences between biological males and females:

Factor	**Biological males**	**Biological females**	**How does this factor affect a person's BAC?** *Refer to specific stocks, flows, and/or variables from your model.*
Alcohol Dehydrogenase (ADH) *This enzyme helps break down alcohol (into smaller molecules that are not detected in a brethalizer test)*	Males have higher amounts of the ADH enzyme in their stomach.	Females have lower amounts (around 25% less) of the ADH enzyme in their stomach.	First impacts the "**Alcohol in stomach**" stock, which then impacts "Alcohol absorbed per minute" flow, which then impacts the "Alcohol in rest of body" stock, which then impacts the "BAC". The more ADH someone has, the lower amount of alcohol that they have in their body because the "**Alchol in stomach**" stock is decreasing.
Water % of body mass	Males have a higher % of their body mass made up of water (around 55-65%)	Females have a lower % of their body mass made up of water (around 45 - 55%). This is because females have a higher % of their body mass made up of fat.	

Estrogen *This hormone slows down alcohol metabolism*	Males typically produce **lower** amounts of estrogen	Females typically produce higher amounts of estrogen	

Sources:

Duke University. The Alcohol Pharmacology Education Partnership: Gender differences in alcohol metabolism.

Blood Alcohol Project Poster

Project Goals:

- Make connections between structures and processes in the digestive, circulatory, and respiratory systems
- Use a stock and flow model to more deeply understand factors that affect BAC
- Effectively communicate learning through a poster

Logistics:

- After today's class, you will have all of the background content/knowledge to complete the project
- You can work on your own or with a partner on the poster. I suggest you work with a partner!
- Tri-fold posters will be provided Monday after break

Poster Requirements:

- Informative title (not "Alcohol Project"). Think about the main idea you want to communicate through your poster.
- Student name(s)
- Explanation and visual of how alcohol moves from drinking in the mouth to exhaling through the lungs for a breathalizer test. Use specific vocabulary from class such as artery, vein, capillary, right atrium, pulmonary valve, alveoli, trachea, etc. You may want to have an overall visual and several zoomed in pictures of specific areas to show more detail.
- An explanation of what BAC is, how it is calculated, how it is measured, and what the legal limit for driving is.
- Alcohol absorption stock and flow model (you can use the one provided in class) along with a few sentences describing the model.
- A list of factors that affect BAC
- An example screenshot of the simulation comparing BAC of biological males vs. females (your choice what the other constant variables should be). Your graph should have a title, axis labels, and a brief description.
- An explanation of how/why biological sex affects a person's BAC. For this part, it would be good to highlight/circle and refer to specific parts of your stock and flow model to aid in your explanation.

Timeline:

You will have a total of 1 weeks' class time (4 hours) to work on this project during school. If you are absent for any of the work days, you should plan on catching up at home to stay on track.

Date	Class time	Recommended goal(s)
Wednesday, February 15th	½ class	Write alcohol movement explanation and create visual
Thursday, February 16th	½ class	Write caption for stock and flow model; Capture screenshots of model runs and write caption.
Monday, February 27th	Whole class	**** Mini 10 min lesson on poster layout **** Write biological sex explanation; Finalize and proofread writing and visuals
Wednesday, March 1st	Whole class	Print everything; assemble poster
Monday, March 6th	**Project due by 2:45 pm (can pass in during class, or on my desk in room 245)**	

Project Rubric

Incomplete / Missing (D / F)	Approaching (C)	Meeting (B)	Exceeding (A)
Several or all parts of section are missing.	A few small parts of requirements are missing, or section is not very detailed or missing some important vocabulary/concepts.	All components in project description are included. Class vocabulary is incorporated.	Section is especially thorough, incorporating and explaining vocabulary and concepts discussed class

Enduring Understanding Strand (10 points)

Section	Points Possible (C/B/A)	Points Earned	Comments
Title and name(s)	1.5 - 1.75 - 2		
Explanation and visual of how alcohol moves from consumption to exhalation	3.5 - 4.25 - 5		
BAC explanation	2.25 - 2.5 - 3		

Modeling Strand (15 points)

Section	Points Possible (C/B/A)	Points Earned	Comments
Stock and flow model explanation	2.25 - 2.5 - 3		
Factors that affect BAC	1.5 - 1.75 - 2		
Graph comparing BAC of biological males vs. females (including a title, axis labels, and a brief description)	3 - 3.5 - 4		
Overall explanation of how biological sex affects BAC, including references to stock and flow model.	4.5 - 5 - 6		