How is Alcohol Metabolized?

In order to answer this question, first you must know what makes alcohol different from other foods and beverages. The answer? It’s the chemical makeup of alcohol! All types of alcohol contain ethanol, or C₂H₅OH. The picture to the left shows what the actual compound looks like. The ethanol molecule is a molecule that belongs to a class of compounds called alcohols (which is why we call drinks with this type of molecule alcohol). All alcohols have a hydroxide molecule (-OH) attached to one of the carbon atoms in the molecule, and it is this chemical makeup that makes the breakdown of alcohol so much different from the breakdown of all other foods and beverages, since most foods are made up of solely carbohydrates, lipids, and proteins which do not have a hydroxide molecule. In this activity you will explore how alcohol is metabolized by the body, and you will even be able to create your own experiment to further research this topic!

1. The breakdown of alcohol requires an enzyme called alcohol dehydrogenase (ADH) to be present in order for the breakdown to occur. In your own words, define “enzyme” and use this definition to explain the necessity of ADH.
   
   An enzyme is a substance produced by a living organism that acts as a catalyst to bring about a specific biochemical reaction. In this case, ADH is needed because it specifically binds to the ethanol, placing it in the configuration most desirable for changing it into acetaldehyde.

2. In the reaction catalyzed by ADH, ethanol is converted to acetaldehyde.
   
   Ethanol → Acetaldehyde

   a. What does it mean for a reaction to be “catalyzed” by an enzyme? Explain in your own words. A reaction is catalyzed by an enzyme when the enzyme actually reduces the amount of energy required to change one substance to another. This is usually done by the enzyme forcing the reactant into a configuration that is desirable for changing it into the product. Once the reactant is in this configuration, the product can easily be formed and the reaction occurs more quickly than it originally would have.
b. The main factor that affects the metabolism of alcohol is the amount of ADH enzymes that each person has in their body, and as you may know, the consumption of alcohol leads to many negative effects on the body. If a person continued to drink alcohol at high rates, what would the body have to do in order to maintain homeostasis? Explain your answer using your own definition of homeostasis. **Homeostasis** is the tendency toward a relatively stable equilibrium. The body must maintain homeostasis so that all of the chemicals and processes are in balance with one another. If a person continued to drink at high rates, then there would always be a much higher amount of ethanol in the person’s system than there normally would be. Therefore, the body would create more ADH enzymes to counteract the continued addition of ethanol to the body.

c. A positive feedback loop is a relationship where the increase in a response causes and increase in the stimulus and the increase in the stimulus causes an increase in the response. An example is shown below.

![Diagram](image)

Use a positive feedback loop to further explain how the body may maintain homeostasis when high amounts of alcohol are consumed. A person continues to drink more alcohol, so the body creates more ADH enzymes thus causing that person to need more alcohol to feel the effects, the person drinks more alcohol, so the body creates more ADH enzymes. This is also partly how tolerance is built.
3. After the ADH converts ethanol to acetaldehyde, another enzyme called acetaldehyde dehydrogenase (ALDH) further breaks down the acetaldehyde into acetate.

\[
\text{Acetaldehyde} \rightarrow \text{Acetate}
\]

But acetaldehyde is actually a poisonous molecule that is responsible for many of the negative effects of alcohol. How would the number of ALDH enzymes affect how a person reacts to alcohol consumption? If a person had many ALDH enzymes, he/she would most likely not have many of the negative sides of alcohol intake such as headache, dizziness, nausea, etc. But if a person had very few of these enzymes, then he/she would not be able to breakdown acetaldehyde, thus causing it to build up in his/her system. This would cause many of these negative systems such as headache, dizziness, nausea, flushed skin, etc.

4. Some ethnic groups have very few ALDH enzymes, which causes them to have adverse effects of alcohol consumption, such as flushed skin soon after drinking. What biological phenomena could explain why certain ethnic groups have so few of these enzymes? (Think about things like genetics and evolution) Maybe these ethnic groups did not have access to alcohol, thus lessening the need for ALDH enzymes over time. Or maybe in order to break down certain foods they needed more of another enzyme, so the body increased that production rather than the production of ALDH and over time this need has been genetically passed down. There will be a variety of answers for this question.

5. The next step in the breakdown of alcohol is for the body to break down acetic acid into carbon dioxide (CO\textsubscript{2}) and water (H\textsubscript{2}O) via the Krebs cycle. The overall energy that is gained from the total breakdown of ethanol to CO\textsubscript{2} and H\textsubscript{2}O is 1497.7 kJ/mol.

\[
\text{C}_2\text{H}_5\text{OH} \rightarrow \text{CO}_2 + \text{H}_2\text{O}
\]

If the creation of ATP requires 30.5 kJ/mol, how many moles of ATP molecules can be created per mole of ethanol breakdown?

\[
\frac{1497.7 \text{kJ/mol}}{30.5 \text{kJ/mol}} = 49 \text{ATP}
\]

# ATP moles: 49
a. Whenever an ATP molecule is broken down into ADP, it releases 7 Calories/mol. Based on the number of moles ATP molecules you calculated in the previous question, how many Calories do you gain from the breakdown of 1 mole of ethanol?

\[ 49 \text{ moles ATP} \times 7 \text{ Calories/mole ATP} = 343 \text{ Calories} \]

b. A 1.5 oz. shot of 80 proof (40%) alcohol contains 0.6 oz. of ethanol, or 17.01 g of ethanol. The molecular weight of ethanol is 46.07 g/mol, so each shot contains 0.37 moles of ethanol. How many Calories do you gain from the breakdown of one 1.5 oz. shot of 80 proof alcohol?

\[ 343 \text{ Calories/mole ethanol} \times 0.37 \text{ moles ethanol} = 127 \text{ Calories} \]

6. One pound of fat is equivalent to 3500 Calories. How many shots of 40% alcohol would a person have to drink in order to gain one pound?

\[ 3500 \text{ Calories} / 127 \text{ Calories per shot} = 27.5 \text{ shots} \]

7. Many people who drink a lot of alcohol gain weight. Based on all of the data you just calculated, explain why this happens. Every drink contains 127 calories, and it takes 27.5 drinks for a person to gain one pound. But when people drink, they tend to drink more than one night per week. If a person average 4 drinks per night for 3 nights every week, then he/she would approximately gain a pound every two weeks. That is 26 pounds per year! Many people also have the occasional beer with dinner, etc. adding to the amount of Calories they gain from drinking.
8. Create your own experiment! Now that you know how alcohol is metabolized, create a hypothesis comparing the metabolism of ethanol to glucose, and create your own procedure for testing this hypothesis. Good luck!

Answers will vary for their hypothesis and procedure. This is an added step, if you do not want your students to complete this part, then you can simple edit out this question.