Kinetics and Metabolism

1. ChemMatters February 1985 Alcohol
   a. This ChemMatters article looks at how the human body reacts to ingesting another organism’s waste product.
   b. The article starts on page 9 of this document.

2. ChemMatters Alcohol Questions
   a. The reading questions for the article can be found in this document.
   b. Page 10
by Robert H. Goldsmith

Alcohol can be confusing. Although it is a concentrated source of calories and can be technically classified as a food, it can also have a negative effect on nutrition. The alcoholic, according to popular image, is malnourished and in bad health, but researchers have discovered thousands of “healthy,” well-nourished alcoholics. Alcohol is widely sold as a beverage, yet doctors call it a drug and say it has greater effects on the body than many prescription medicines. Just what is the truth about this contradictory chemical?

Alcohol is a relatively simple compound with the formula C₂H₅OH. Its chemical name is ethyl alcohol or ethanol (Figure 1). The ethyl alcohol molecule is small and contains an OH group, making it somewhat similar to a water molecule. In fact, the alcohol

![Figure 1. Ethyl alcohol (left) has some similarity to water (right)](image)

molecule binds loosely to water. Its small size and ability to move through an aqueous environment allow alcohol to pass rapidly from the gastrointestinal system into the blood. This means that a drinker feels the effects of alcohol quickly. Once absorbed, alcohol immediately begins to be metabolized, or processed by the body.

**Alcohol metabolism**

The body processes alcohol in three steps. First, within the liver, alcohol is converted to acetaldehyde. This chemical change is aided by the enzyme alcohol dehydrogenase (Figure 2). Enzymes are biological catalysts, which speed up chemical reactions. Alcohol dehydrogenase, which is present in the liver, accelerates what would otherwise be a very slow reaction. It metabolizes alcohol in the blood as it flows through the liver, and thus eventually removes alcohol from the entire body.

![Figure 2. Ethyl alcohol converted to acetaldehyde](image)

In the second step the acetaldehyde is changed to acetic acid. This reaction is catalyzed by the enzyme aldehyde dehydrogenase (Figure 3).

![Figure 3. Acetaldehyde converted to acetic acid](image)

In the last step, acetic acid is incorporated into the body’s central energy-producing process. It enters the Krebs cycle, in which the acetic acid is broken down into carbon dioxide, water, and energy (Figure 4).

![Figure 4. Krebs cycle](image)

Some research suggests that acetaldehyde is responsible for many of the effects of drinking, including hangovers. Acetaldehyde can cause headache, gastric upset, vertigo, and other unpleasant reactions. In the treatment of alcoholics, this effect can be turned to advantage by administering disulfiram. This drug inhibits aldehyde dehydrogenase. It slows the rate at which the enzyme breaks down acetaldehyde and therefore causes acetaldehyde levels in the body to increase. In an alcoholism treatment...
program, the patient must take the drug—which is known by the trade name Antabuse—voluntarily and regularly. It has no effect in the absence of alcohol. However, when the patient consumes alcohol, it causes heart palpitations, flushed skin, and nausea—symptoms that discourage future drinking.

**Drinking and dieting**

Because the metabolism of alcohol produces a substantial amount of energy, it can wreck a diet. One gram of alcohol generates seven calories of energy. For comparison, the carbohydrates and proteins in food both produce four calories per gram; fat yields nine calories per gram. Suppose a middle-aged man is trying to lose weight. He eats light meals and has a lettuce salad with dinner. Each evening he drinks a beer with dinner, but ignores the calories from the alcohol. If he drinks 20 oz of beer, he will consume an additional 300 calories—enough to supply 12-20% of his energy needs for the day. The effect can be dramatized by comparing alcohol with lettuce. How many lettuce salads would he have to eat to acquire the same 300 calories? If we assume that one salad contains half of a head of lettuce (15 calories), we can easily estimate that he would have to eat 20 lettuce salads. It is easy for a drinker to gain weight by overlooking the energy content of alcohol. The solution to the dieter’s problem may not be as simple as eating less.

If a drinker regularly substitutes alcohol calories for food calories, a nutrition problem may result. Alcohol contains energy but does not contain nutrients. The replacement of good calories (calories from nutritious foods) by empty calories (calories without significant vitamins or minerals) can be hazardous. The lack of key nutrients can lead to damage to the gastrointestinal tract and the liver, the major site of metabolism in the body.

**Alcohol and behavior**

The rate of alcohol metabolism, unlike the rate of consumption, is fixed. A 154-lb person can metabolize approximately 12 mL of alcohol per hour. What happens if alcohol intake is greater than this? Because it is being ingested faster than it is being metabolized, the level of alcohol in the blood and in other tissues increases. Small amounts of alcohol leave the body by being excreted with the urine or exhaled through the lungs. Most of the alcohol remains in the body, waiting to be metabolized, meanwhile affecting the drinker’s senses, thinking, emotions, and behavior.

The behavioral effects of alcohol are contradictory. Its real effects are different from the feelings it imparts. Alcohol depresses certain inhibitory centers in the cerebrum, leading the drinker to feel free of social constraints and self-restrictions. The drinker may feel more competent and skillful than usual when, in fact, he or she is less competent. The alcohol also depresses the ability to perform physical tasks, especially those that require conditioned reflexes. Tasks for which people have tested poorly under the influence of alcohol include target shooting, typing, mountain climbing, and driving.

**Driving**

Driving is a complex skill that requires many tasks to be performed rapidly with sound judgment. Alcohol impairs the driver’s judgment and coordination and yet, due to its cerebral effects, may increase the driver’s self-confidence, leading the driver to believe that he or she can do no wrong behind the wheel.

In most states a driver is considered legally drunk if his or her alcohol concentration is 0.1 g per 100 mL of blood or higher. For simplicity, this is
usually expressed as 0.10%. (Exceptions: In Georgia, the limit is 0.12; in Oregon and Utah it is 0.08.) Many drivers have assumed that a blood alcohol level below the legal limit was safe. More recent research has shown that this is false. In the past, data came from “worst case” samples. Blood samples were taken from people who died in an accident or whose driving was so obviously dangerous that it attracted the attention of a police officer. Alcohol in the blood of someone involved in a routine accident usually went undetected. This deficiency was corrected by an unusual study conducted in Grand Rapids, Mich.

The researchers accompanied police to the scene of an accident, where they interviewed the driver and took blood alcohol samples. Then, on a later day, researchers stopped drivers at the same location, at the same time, on the same day of the week. Interviews and blood samples were collected from these drivers, who had not been involved in an accident. Data were collected from 6000 drivers who had accidents and 7000 drivers who did not. The study was unique in design and size. The results are summarized in the graph in Figure 5. The curve shows that the probability of causing an accident is doubled at a blood level of 0.06%; it is increased six times at 0.10% and more than 25 times at 0.15%. In most states, drivers are not in violation of the law until blood alcohol reaches 0.10% which, according to this study, is a very dangerous level.

**Nutrition research**

Our image of the alcoholic—gained largely from movies and novels—is out of date. We picture the alcoholic as a malnourished person in poor health. Early scientific studies of alcoholics are largely responsible for this image. They often studied alcoholics who were indigent or hospitalized with liver disease or other ailments, and it is not surprising that these people were generally malnourished.

More recent research, focusing on typical, not just indigent, alcoholics, has challenged this view. The author of this article participated in a study that compared alcoholics of middle socioeconomic status with those of lower socioeconomic status. An alcoholic can be anyone who is addicted to excessive use of alcohol. We studied patients who had been admitted to an alcohol treatment center, had been drinking heavily for the preceding 60 days, and had no major illnesses that might influence their nutrition. Fifty were classified as medium socioeconomic status alcoholics because they held jobs, had addresses, and earned more than $400 per month. The other 50, lacking these characteristics, were classified as low-status alcoholics.

We determined nutritional condition by assessing the weight to height index, the skinfold around the triceps muscle, the midarm muscle circumference, red blood cell count, and hair extraction force (the measurement of the force required to pull a hair from the head). The last measurement was an unusual aspect of our study. This measurement gives an indication of protein quality in the hair and in the diet.

For a nutrition study, a single strand of hair is clipped to a trichotillometer. The device measures the force required to extract the hair—a measure of protein quality.

*Figure 6. Average force required to pull hair from the heads of 50 low-income alcoholics and 50 medium-income alcoholics. Hair extraction force is an indication of protein quality in the hair and in the diet.*
extracted. Figure 6 shows the results of our tests. Previously this test had been used successfully in characterizing protein-calorie malnutrition and for distinguishing alcoholics from nonalcoholics. Our study marks the first time the hair tensile strength test has been used in a comparative alcoholism study.

The individuals we studied did not fit the "starving alcoholic" image. We found a significant difference between low- and medium-status alcoholics. The medium status group was fairly well nourished, with only 8% moderately malnourished and 8% severely malnourished. The low-status group had 24% moderately malnourished and 8% severely malnourished. The majority of both groups showed satisfactory nutrition.

In recent decades, our national nutritional condition has improved. Alcoholics have mirrored this change and are better fed and nourished. This has several implications. Some people who believe that they are not alcoholics because they do not fit the derelict image are kidding themselves. Even poor alcoholics are better able to find food from friends, food services, or public agencies. This does not mean we should not be concerned about the health of alcoholics, but we should be cautious about working from obsolete generalizations. A modern image must make room for the well-to-do, well-nourished alcoholic.

References

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CAUTION: Alcohol affects thinking, judgment, and skills—even when present at very low blood levels. See other side of card.
In most states, the legal alcohol limit for driving is 0.10% (0.10 g of alcohol per 100 mL of blood). Many people believe that they are safe drivers at levels below this limit. The latest data indicates that this is false. A study of 13,000 drivers in Grand Rapids, Mich. showed that the probability of causing an accident doubled when the driver's blood alcohol was just 0.06%. The National Highway Traffic Safety Administration considers that alcohol is involved in an accident when it is present in any detectable amount. Blood alcohol is difficult to estimate because it depends on the amount of alcohol consumed, body weight, and time.

On the other side, turn the wheel to set number of drinks next to body weight.
(A drink is a bottle of beer, glass of wine, or shot of whiskey; they contain about the same amount of alcohol.) The figure in the top window indicates blood alcohol if the drinks are consumed rapidly (with 15 min). The figures in the bottom window show changes in blood alcohol level as time passes. The table below lists some typical effects.

NOTE: this computer gives approximate values only. Individuals differ in their psychological reactions to alcohol and the rate at which their bodies get rid of alcohol.

<table>
<thead>
<tr>
<th>Alcohol-related accidents</th>
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<tr>
<td>• account for 50-55% of all highway deaths;</td>
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<td>• kill about 25,000 people in the U.S. annually— that's one person every 20 min.;</td>
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<td>• are the number 1 causes of death for teenagers.</td>
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IF YOU KNOW SOMEONE WHO DRINKS AND DRIVES, HAVE HIM OR HER READ THIS!

To Assemble . . .
• Punch out parts A, B, & C.
• Punch and discard: centers of B & C, windows of A. Place A over B so numbers show through windows; punch center of A, pushing triangles through center of B.
• On back, place C around triangles; fold out triangle and flatten; fasten triangles to C with small strips of tape.
1. Give the chemical formula and draw the structure of ethanol.
2. What enables alcohol to pass rapidly through the gastrointestinal system into the blood?
3. **Thoroughly** explain the process (3 steps) of alcohol metabolism.
4. What chemical compound is responsible for ‘hangovers’ and what are its physiological effects?
5. What is **disulfiram** and how does it work physiologically? *(Be thorough)*
6. One gram of alcohol generates ______ calories of energy.
   One gram of carbohydrates/protein produces _______ calories of energy.
   One gram of fat produces _____ calories of energy.
7. Why do nutrition problems occur when alcohol calories are substituted for food calories? What damaging effects may occur?
8. A 154 lb person can metabolize ____ ml of alcohol per hour.