CARB CRAZY

No-Carb?
Low-Carb?
High-Carb?

Never before has the role of carbohydrates in our diet been so thoroughly discussed. We'll try to cut through the hype to give you the lowdown on...

MIKE CIESIELSKI

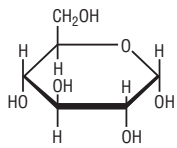
CARBOHYDRATES AND LOW-CARB DIETS.

By Brian Rohrig

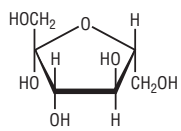
What are carbs?

The word carbohydrate reveals that all carbs are composed of three elements: carbon, hydrogen, and oxygen. There are three main categories of carbohydrates—monosaccharides, disaccharides, and polysaccharides.

Monosaccharides are composed of one sugar unit and are referred to as simple sugars. Their empirical formula is generally CH_2O. Some common monosaccharides are glucose and fructose. Although both have a formula of $C_6H_{12}O_6$, they have a different arrangement of atoms. Such compounds are called isomers. Glucose is produced by plants during photosynthesis. Glucose can be found in sports drinks, providing quick energy when you need it. Glucose is the body's primary fuel source. It is broken down into energy through the process of cellular respiration. Carbon dioxide is released as a waste product. If glucose is not converted into energy, it is converted into glycogen to be stored.

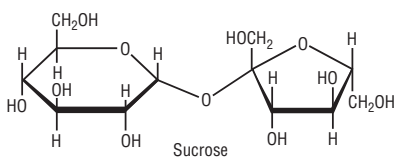


Glucose



Fructose

Disaccharides, also known as double sugars, are composed of two simple sugar molecules. The most common disaccharide is **sucrose** or table sugar. In order to be used by our body as energy, sucrose must first be broken down into **glucose and fructose**. Food manufacturers are more often replacing sucrose in products with fructose, because it is cheaper to produce, and because it is sweeter, less needs to be used. Other common disaccharides are maltose and lactose (milk sugar).



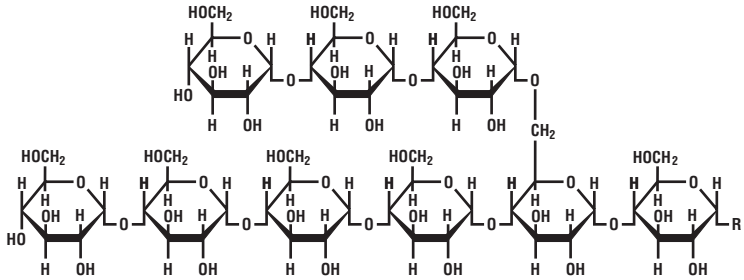
Sucrose

Polysaccharides are complex carbohydrates. They are polymers composed of long chains of sugar units. A common polysaccharide is starch, which is composed of long chains of glucose molecules. Starch is used by plants as a way to store energy, and it can be found in foods such as potatoes, rice, corn, and wheat. Our body must break down starch into glucose, which it then uses for energy.

Other types of complex carbohydrates are not digestible by our body. Chief among these are cellulose, which forms the cell walls of plant cells, giving them structure and support. Its glucose molecules are linked together in such a way that our body lacks the necessary enzymes to break them down. These indigestible polysaccharides are known as fiber, and they contribute no calories because our bodies cannot convert them into energy. High-fiber foods—such as oats, bran, and whole grains—are an essential part of our diet, aiding in digestion.

Carbohydrates and blood sugar

To understand the effect of carbohydrates on our body, it is important to understand their role on blood sugar. Just like a car requires fuel, so does our body. The body's major fuel source is glucose, or blood sugar. However, this blood sugar is not automatically released into the cells. If a car's engine receives too much fuel, the engine becomes flooded, and it will not start. In the same way, the body must regulate how much blood sugar enters our cells. This occurs through the production of the hormone insulin, which is manufactured by the pancreas. Think of insulin as the gatekeeper to the cells—it opens the gates and allows glucose to leave the bloodstream and enter our cells.

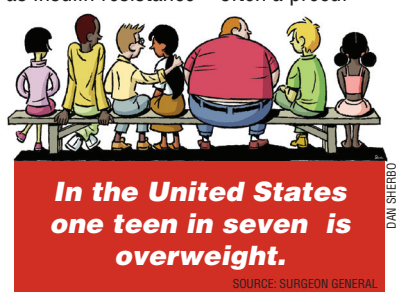


The polysaccharide glycogen is a stored form of glucose.

Once sugar enters our cells, it can do one of three things. It can be converted into energy through cellular respiration. Or it can be converted into glycogen in the liver and muscles, for use as an emergency fuel. **Glycogen** is similar to starch but is more extensively branched. Finally, it can be converted into fat if there is more sugar available than is needed.

Consider what happens when you wash down a glazed doughnut with a sugary soda. As your bloodstream is inundated with sugar, a temporary spike in blood sugar will occur. Your pancreas responds by producing a surge of insulin to quickly rid the bloodstream of this excess sugar. This quick release of insulin will cause your blood sugar to then drop suddenly. The sudden drop in blood sugar can cause weakness, fatigue, and intense hunger—often leading to a craving for more delicious glazed donuts. This can create a vicious cycle, where our blood sugar constantly rises and falls, leading to overeating and eventual weight gain. A well-balanced diet can help to reduce these sudden peaks and falls in blood sugar.

Over the long term, constant spikes in blood sugar and insulin are not a good thing. When so much insulin is produced for so long, your body may become immune to the effects of it, creating a condition known as insulin resistance—often a precursor to type 2 diabetes. For reasons not yet fully understood, the cells can become desensitized to the effects of insulin, with the result that glucose is not effectively taken into the cells and converted into energy. The liver then takes over, taking this excess blood sugar and converting it into fat—leading to obesity. And the overworked pancreas may get worn out from producing so much insulin.



Why not radically cut carbohydrates from the diet?

Eat as much bacon and eggs as you want as long as you forget about the toast and orange juice?! Such a suggestion is at the very least culinary, if not dietary, heresy. But as a result of two decades of rising obesity rates and the sheer popularity of low-carb diets, researchers, doctors, and dietitians began re-examining the theories of Dr. Robert Atkins, who published Dr. Atkins' Diet Revolution in 1972. He advocated eating all of the fats and proteins you wanted, and said that if you only cut out all those carbohydrates, you would lose weight.

PHOTO BY STAFF

Numerous modifications of the Atkins' diet, such as the South Beach Diet and the Zone, have since appeared. Many of these modified diets have a more balanced approach, stressing the importance of avoiding unhealthy saturated fats found in red meat and dairy products, and emphasizing healthier unsaturated fats found in nuts, fish, and vegetable oils.

Millions have tried the diet with success and testimonials abound. By now, you've probably heard a friend or family member give the low-carb dieter litany: "'I failed on other diets, but this diet worked for me because I wasn't hungry all the time.'" "'I lost weight faster than on other diets, and I wasn't hungry all the time.'" Or even, "'I failed on this diet, but at least I wasn't hungry all the time!'"

How do low-carb diets work?

All diets work according to one basic principle: You must burn more calories than you consume. How many calories you burn depends on both metabolism and exercise. You cannot lose weight if you consume more calories than your body uses. By cutting out carbs, you are cutting back on a lot of calories. Cutting out just sugared sodas, potato chips, and candy bars can reduce your overall calorie consumption dramatically.

Another reason low-carb diets are successful is that fats and protein have better "staying power". Because carbohydrates are rapidly converted into glucose and then utilized by your body as energy, they do not keep us satiated for long. Fat and protein are absorbed more slowly by the body, so they stay with us longer. Even though low-carb diets claim you can eat all the fat and protein you want, in truth these foods fill us quicker, causing us to ultimately eat less.


MIKE CIESIELSKI

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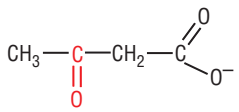
Ketosis: An inefficient way to burn fat

Although some claim that a reduced-carbohydrate diet is nothing more than a reduced-calorie diet in disguise, low-carb diets actually do one thing that is radically different than any other diet. The majority eliminate most, if not all, carbohydrates in the initial induction phase of the diet. When the body becomes carbohydrate-starved, it must find an alternate energy source.

The first source it taps is the glycogen found in the liver and muscle. But the body's glycogen stores can only last about two days. After this, our body turns to fat for energy. However, the breakdown of fat in this case does not produce glucose. Instead, the fat is broken down into ketones, through an unusual process known as ketosis. Normally, people burn fats without making ketones. Ketosis only occurs when people are carbohydrate-starved.

During ketosis, fat is not completely broken down and you don't receive the "normal" caloric value from burning it. The excess ketones produced during ketosis are secreted in our urine and breath. Sometimes this gives your breath a fruity odor, since acetone—a ketone—may be released by the breath during ketosis. Because the kidneys flush out these ketones from the body, it is important to drink a lot of water on a low-carb diet. Dieters often confirm their body is in ketosis by checking their urine with ketone test strips (*see "Lab on a Stick" in this issue*).



Acetoacetate
(a ketone body)

Considerable debate has arisen among medical experts as to whether or not ketosis is dangerous. Some confuse ketosis with a more serious condition known as ketoacidosis, which is an extreme form of ketosis sometimes suffered by type 1 diabetics. During ketoacidosis, the pH of the blood falls to dangerous levels, because of excessive buildup of acidic ketones. This can lead to coma and death if left untreated.

Some argue that the body functions even better when using ketones as fuel. Others claim that the brain cannot function as well on ketones, and the body will turn to muscle and organ tissue to try to scavenge glucose for fuel. However, most medical authorities today are leaning toward the view that ketosis is a safe bodily process as long as ketones are not produced faster than the body can get rid of them.

Are low-carb diets good for you?

The low-carb diet phenomenon is still too new to judge its long-term effects. However, two studies recently published in the *New England Journal of Medicine* offered some promising news for adult low-carb dieters. These studies found that participants who lost weight on low-carb diets had higher levels of HDL (good) cholesterol and lower levels of triglycerides, or fats, than those who lost weight on different diets.

PHOTO BY STAFF

There's no specific research on teenagers, but you should be wary of going on the diet, especially if you are still growing. Many participants sacrifice the health benefits of the nutrients found in milk, fruit, and whole grains. Osteoporosis can result from a long-term deficiency of calcium in the diet, which could result if milk was totally eliminated from the diet. Pregnant women should definitely not be on the diet, because the developing fetus can be harmed by the lack of nutrients. Athletes should also avoid low-carb diets, since peak athletic performance is dependant on the quick availability of glucose for energy, as well as relying on glycogen reserves.

Any diet is only as successful as the ability to remain on it for life. And make sure you incorporate plenty of exercise in any weight-loss plan you choose.

Brian Rohrig is a chemistry teacher at Jonathan Alder High School in Plain City, OH. His last article for *ChemMatters*, "Lightning: Nature's Deadly Fireworks" appeared in the April 2004 issue.

October 2004 Teacher's Guide

"Carb Crazy"

Student Questions

Carb Crazy

1. What three elements are in a carbohydrate?
2. How is glucose used in the body?
3. What polysaccharide is a storage form of glucose?
4. What is the relationship between insulin and blood sugar?
5. By what basic principle do all diets work?
6. How is ketoacidosis different than ketosis?
7. Why would an athlete want to avoid a low carb diet?

Answers to Student Questions

Carb Crazy

1. What is a carbohydrate? Carbohydrates are composed of three elements: carbon, hydrogen, and oxygen.
2. How is glucose used in the body? Glucose is the body's primary fuel source. It is broken down during cellular respiration to release energy. Carbon dioxide is released as a waste product.
3. What polysaccharide is a storage form of glucose? Glycogen.
4. What is the relationship between insulin and blood sugar? Insulin can be thought as the gatekeeper for blood sugar entering cells. When insulin is released by the pancreas, blood sugar levels drop.
5. By what basic principle do all diets work? You must burn more calories than you consume.
6. How is ketoacidosis different than ketosis? During ketosis, fat is not completely broken down and your body produces and excretes ketone bodies. Ketoacidosis is an extreme form of ketosis where acid ketone bodies build up faster than they can be excreted. The result is a dangerous drop in blood pH and, if left untreated, coma and death.
7. Why would an athlete want to avoid a low carb diet? Athletes rely on glucose and glycogen reserves for quick energy. Most low-carb diets have an induction phase that consumes available glycogen reserves.

Content Reading Materials

National Science Education Content Standard Addressed As a result of activities in grades 9-12, all students should develop understanding	**Carb Crazy**
Science as Inquiry Standard A: of abilities necessary to do scientific inquiry	
Science as Inquiry Standard A: about scientific inquiry.	✔
Physical Science Standard B: of the structure and properties of matter.	✔
Physical Science Standard B: of chemical reactions.	✔
Life Science Standard C: of the cell.	✔
Life Science Standard C: of matter, energy, and organization in living systems.	✔
Science and Technology Standard E: about science and technology.	✔
Science in Personal and Social Perspectives Standard F: of personal and community health.	✔
Science in Personal and Social Perspectives Standard F: of science and technology in local, national, and global challenges.	
History and Nature of Science Standard G: of science as a human endeavor.	✔
History and Nature of Science Standard G: of the nature of scientific knowledge.	✔
History and Nature of Science Standard G: of historical perspectives.	

*QFTC-Question From the Classroom

Reading Strategies

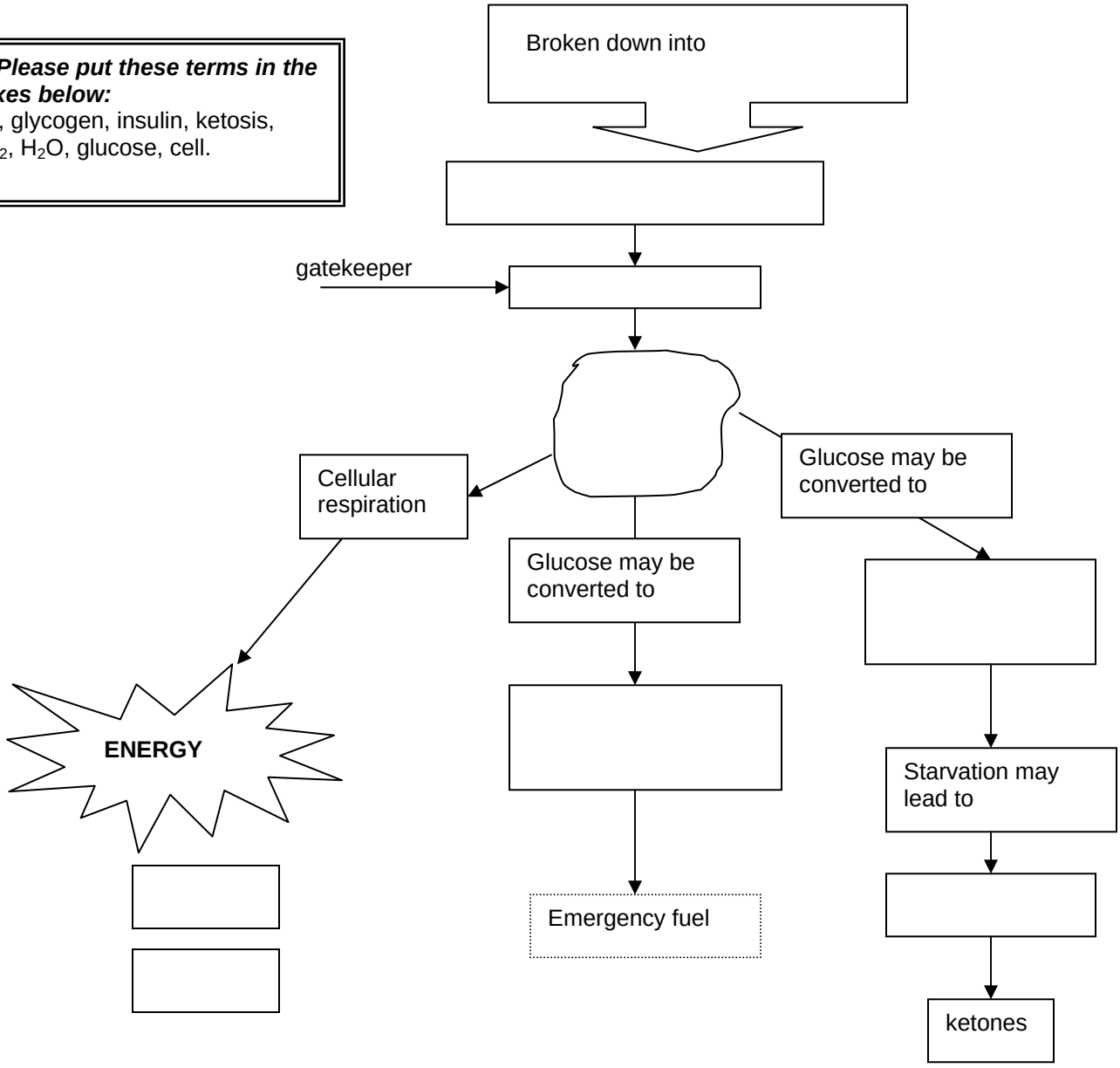
These content frames and organizers are provided to help students locate and analyze information from the articles. Student understanding will be enhanced when they explore and evaluate the information themselves, with input from the teacher if students are struggling. If you use these reading strategies to evaluate student performance, you may want to develop a grading rubric such as the one below.

Score	Description	Evidence
4	Excellent	Complete; details provided; demonstrates deep understanding.
3	Good	Complete; few details provided; demonstrates some understanding.
2	Fair	Incomplete; few details provided; some misconceptions evident.
1	Poor	Very incomplete; no details provided; many misconceptions evident.
0	Not acceptable	So incomplete that no judgment can be made about student understanding.

Carb Crazy

	Carbohydrates		
	Monosaccharides	**Disaccharides**	**Polysaccharides**
Brief Description			
Examples			

➔ ***Please put these terms in the boxes below:***
Fat, glycogen, insulin, ketosis, CO_2, H_2O, glucose, cell.



Anticipation Guides

Anticipation guides help engage students by activating prior knowledge and stimulating student interest before reading. If class time permits, discuss their responses to each statement before reading each article. As they read, students should look for evidence supporting or refuting their initial responses.

Directions for all Anticipation Guides: In the first column, write "A" or "D" indicating your agreement or disagreement with each statement. As you read, compare your opinions with information from the article. In the space under each statement, cite information from the article that supports or refutes your original ideas.

Carb Crazy

Me	Text	Statement
		1. All digestible carbohydrates are broken down into glucose so the body can use them.
		2. Fructose is more expensive and less sweet than sucrose.
		3. Indigestible carbohydrates are unhealthy.
		4. Eating sugary snacks can actually make you hungry sooner.
		5. To lose weight, you must burn more calories than you eat.
		6. Your body burns fat before glycogen.
		7. People on low-carb diets should restrict water intake.
		8. Proteins and fats are absorbed more quickly in the body than carbohydrates.
		9. Low carb diets are good for teenagers.

Carb Crazy

Background Information

Both starch and glycogen are important polysaccharides which act to store the simple sugar monomers composing them. Both starch and glycogen polymerize within cells by a form of condensation synthesis in which a hydroxyl group of one monomer reacts with the anomeric carbon at the opposite end of a second monomer. Molecules of water are eliminated in the process. Simple sugars are released from storage when the polysaccaride undergoes the reverse process, hydrolysis, in which molecules of water are restored.

Starch is made by plant cells, and glycogen, by animals. Both of the polysaccarides, with their many exposed hydroxyl groups, become heavily hydrated in their cellular environments. Starch molecules— huge polysaccarides (m.w. often exceeding 1 million)—are generally of two types: amylose consisting of long, unbranched chains of D-glucose, and amylopectin, highly branched. Glycogen, similar to amylopectin, is even more highly branched. It generally appears in granules that also contain enzymes ready to degrade the molecule when conditions are right.

Both starch and glycogen are essentially insoluble. If the point is to have glucose ready for instant use as cellular fuel, why don't cells simply store the glucose molecules in solution? It turns out that having that many particles in solution would create a severe osmotic imbalance that would either cause the cells to swell and burst, or, at the very least, would reach an equilbrium state in which no additional net gain in glucose molecules would occur.

Are all carbohydrates created equal?
Do all carbohydrates contribute equally to a rise in blood sugar? Fortunately, no. There are "good" and "bad" carbohydrates, depending on how quickly that carbohydrate is converted to glucose in the bloodstream, as measured by the glycemic index (GI). The GI rates glucose at 100, and foods are ranked according to how fast they enter the bloodstream, relative to glucose. For example, if a food has a GI of 50, it is absorbed into the bloodstream half as fast as that of glucose. Good carbohydrates have a low GI, and bad carbohydrates have a high GI. White bread, for example, has a GI of 70, while pumpernickel has a GI of 41. Watermelon has a GI of 72, but a plum has a GI of only 24. Instant white rice has a GI of 91, while brown rice only has a GI of 55. Generally, the more refined the food, the quicker it can be broken down and the higher its GI. The more work our body must do to break down a substance, the slower it will be absorbed into the bloodstream. Apple juice has a higher GI than apples. Baked potatoes have the highest GI of all potatoes at 85. To avoid spikes in blood sugar, with the resultant insulin spike followed by a crash in blood sugar, choose carbohydrates with a low GI.

The GI is not a perfect measure of what foods to eat, however. Fructose, for example, has a GI of only 20. Scientists actually give rats large does of fructose to make them insulin resistant.

Connections to Chemistry Concepts

Relating the Caloric values of foods to the concepts surrounding Heats of Combustion is relevant to the article's discussions about diet plans.

Possible Student Misconceptions

Students frequently mistake food Calories (actually kilocalories) for the unit of energy the calorie. The "kilo" portion is of course very important. Just warming a 200 g cup of water from room temperature to normal body temperature (25 ^{o}C to 37 ^{o}C) requires 2400 calories. Is a 2400 calorie (not 2400 Calorie or 2400 kilocalorie) diet sufficient to maintain human body temperature for 24 hours?

Students may also wonder about the term “burning” food for calories. Misconceptions are compounded by hearing foods described as “fuels”. The way the cells depend on enzymes to lower the activation energy necessary for breaking chemical bonds during metabolism is a basic topic in many modern biology curricula. A brief discussion may clear up the confusion if it occurs.

Demonstrations and Lessons

The *ACS Chemistry in the Community, 4th Ed.* textbook as well as other basic high school chemistry textbooks, has a laboratory investigation in which students construct a calorimeter using a soda can containing 100 ml of water. Students relate the temperature increase in the water to the weight of paraffin consumed by a burning candle in order to determine the Heat of Combustion of paraffin in kJ/g. A similar procedure might be devised to determine the heat of combustion of small piece of wood. Comparisons between paraffin (lipid) and wood (carbohydrate) heats of combustion would be relevant to a discussion about the relative roles of fats and carbohydrates in a diet plan.

Connections to the Chemistry Curriculum

Organic chemistry, thermal energy, and polymers are topics that relate to the content of the article. In addition, the ways in which information is collected and analyzed for making informed consumer choices is a critical goal of every good high school science program.

Suggestions for Student Projects

1. Students can run analyses of their own diets. The analysis can be a quick and simple activity such as keeping a list of what is eaten on one typical day and then placing each food into the appropriate place on the food pyramid. A more complex analysis might involve a record of what was eaten over several days followed by a detailed analysis of Caloric content, as well as carbohydrate, fat, and protein content (on a percent by Calorie basis), including even the amounts of vitamins and minerals. *ChemCom* provides a rather extensive table of foods showing this type of nutritional information. See also the list of suggested Web sites for this article.
2. Students can perform “blind taste tests” of “low-carb” or “sugar-free” food products to compare them to their sugary counterparts
3. Students could examine one of the current “fad” diets and either prepare a paper or give a class presentation on the rationale behind the diet. Different teams of students could debate the merits of the diet—one side arguing in its favor, the other opposing the diet.

Anticipating Student Questions

Students will want to know if a diet like the Atkins diet is good for them. As the article points out, there have been no significant long-term studies to find out whether minimizing carbs in a teenager’s diet plan advisable or even safe for losing weight.

Websites for Additional Information and Ideas

Students will be interested in finding out about, and perhaps, comparing other diet plans. For an informative and entertaining account of several diet fads of the past go to

http://www.dietbites.com/article0159.html

More of diet plans are found at this site. Be sure to check out the Paleolithic Diet!
http://www.channel4.com/science/microsites/B/bodystory/fat_diets.html#fplan