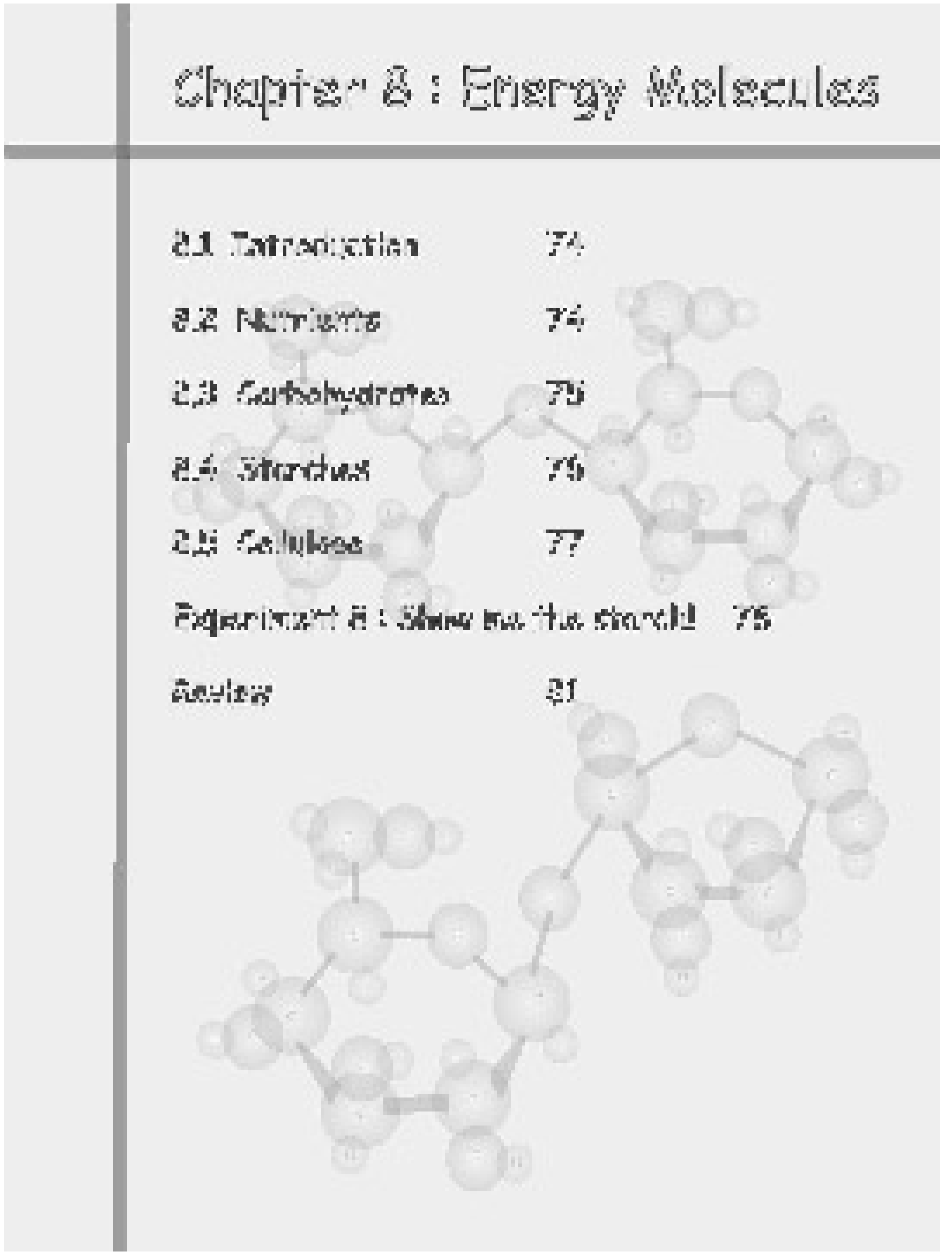


Chapter 8 : Energy Molecules

Time Required:

Text reading - 30 minutes
Experimental - 30 minutes to1 hour

Experimental Pre-setup:

NONE

Additional Materials:

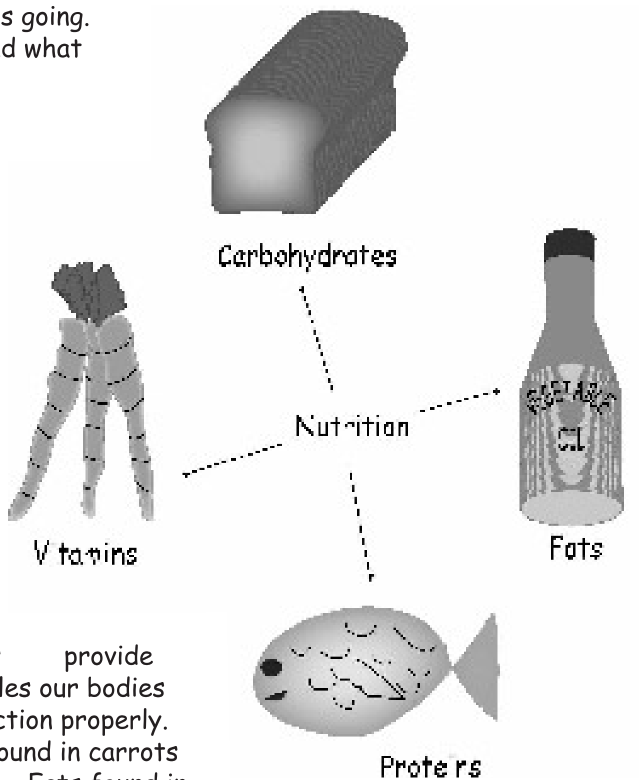
Raw foods such as:
- Bread
- Celery
- Banana
- Potato

8.1 Introduction

Have you ever wondered why we need to eat food? We may know from experience that when we skip a meal or are unable to eat because of illness, we become weak and lack energy. Our bodies require food to help us grow and keep our "engines running." Without food we would not survive.

Unlike plants, we cannot stick our feet in the soil, lift our hands to the sun and make our own food. In fact, we rely on plants and other animals to provide the food our bodies need to keep us going. But what is in food and what does it do for us?

8.2 Nutrients



There are many different kinds of nutrients our bodies require to stay healthy. These include vitamins, proteins, fats and carbohydrates. We get these important nutrients from eating a variety of foods. The nutrients we get from eating foods provide the necessary molecules our bodies need to grow and function properly. Vitamins, like those found in carrots help our eyes to work. Fats found in vegetable oil and butter help our brains and other tissues to function. Proteins from fish and meats help our bones to heal and our muscles to grow. Carbohydrates, like those found in bread, potatoes, and sweets provide us with "energy."

Overall Objectives:

This chapter will introduce "energy" molecules, i.e. those molecules that fuel our bodies including carbohydrates and starches.

Some of the words get difficult to pronounce and can be intimidating. Also, these molecules are more complicated than those we have examined previously. It is not important that the students remember all of the names, or understand all of the chemical structures. The main points are:

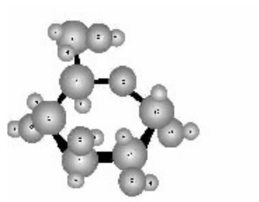
- Carbohydrates are energy molecules.
- Carbohydrates are made mostly of carbon, hydrogen, and oxygen.
- Small carbohydrates are *sugars*.
- Large carbohydrates are *starches and cellulose*.
- Starches and cellulose are long *chains* of smaller carbohydrates (sugars).

Discuss the various types of foods we eat to get our *nutrients*, i.e. those foods that help our bodies grow and live.

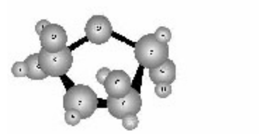
8.3 Carbohydrates

What are carbohydrates and how do they provide *energy* for our bodies?

The name "carbohydrate" is a general term for many different kinds of molecules that contain carbon, oxygen and hydrogen. Carbo means "carbon" and hydrate means "water," so carbohydrate means "a combination of carbon and water."



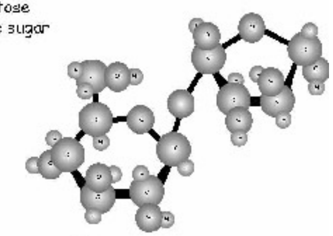
Glucose
a simple sugar



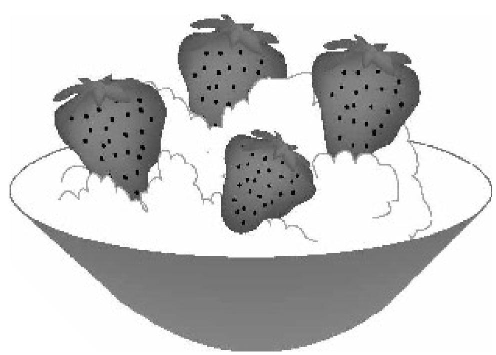
Fructose
a simple sugar

The simplest carbohydrates are the sugars. Sugars are relatively small molecules. They taste sweet and can be easily broken down by our bodies to provide quick energy. The very simplest sugars are called monosaccharides. Mono is Greek and means "single," and saccharide means "sugar," so a monosaccharide is a "single sugar." The single sugars Glucose and Fructose are monosaccharides.

When a few monosaccharides are put together, they are called oligosaccharides. Oligo is Greek for "a few," so an oligosaccharide is a "few sugars." Sucrose is an example of an oligosaccharide. Sucrose is a single molecule of glucose hooked to a single molecule of fructose by a chemical bond. Sucrose is common table sugar; the same sugar that we buy in the store and put on strawberries.



Sucrose
Glucose + Fructose



Carbohydrates are made of carbon atoms and water molecules. For example, glucose, a simple sugar, has 6 carbons, 6 oxygens and 12 hydrogens. A chemical formula for glucose can be written as $C_6(H_2O)_6$. This formula shows that glucose has 6 carbon atoms and 6 molecules of water. This is the origin of the name "carbo-hydrate."

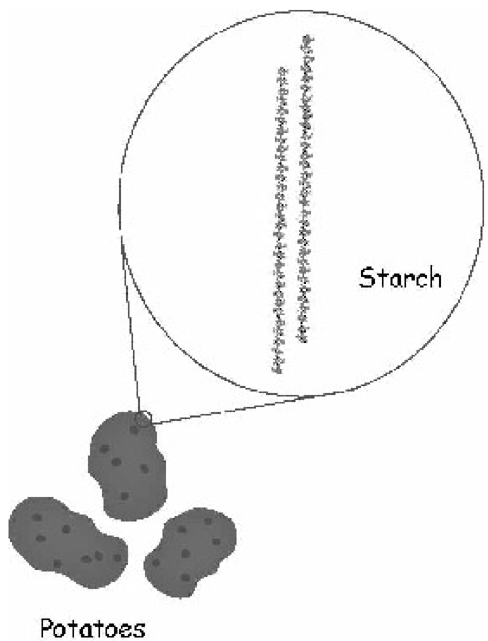
The simple carbohydrates are the *mon-o-sac'cha-rides.*
Larger carbohydrates are the *o-li-go-sac'cha-rides.*

Monosaccharides are very important for our metabolism. They are an essential component in many biologichemical pathways. For humans, simple sugars are essential for brain development. Human milk, for example, has the highest sugar content of all animal milk. Whale and seal milk have lower sugar content and higher fat content than human milk, since fat is essential for protecting these animals from the cold ocean waters.

8.4 Starches

When more than a few saccharides, or sugars, are hooked together the molecule is called a polysaccharide. Poly means "many" so a polysaccharide means "many sugars." Polysaccharide molecules usually contain ten or more monosaccharides.

There are two general types of polysaccharides called starch and cellulose. Starches are the molecules that provide our bodies with most of the energy we need to live and work. Potatoes, pasta, and bread are excellent sources of starches.



There are three main kinds of starches. Glycogen is a starch that animals produce in their livers and store in their muscles. Amylose and Amylopectin are two starches that are made by plants and are the main energy storage molecules found in rice and potatoes.

All of these polysaccharides are composed of only glucose molecules linked together to make long chains. They can have as many as 3000 glucose units hooked together in a row.

So how do our bodies use these long chains of glucose for energy? We have special proteins in our bodies that break the long chains up into individual glucose molecules. The single glucose molecules are used directly by our bodies for energy. So if it is only the glucose our bodies need, why not eat only the simple sugars and have a diet rich in candy coated sugar bomb cereal?

The largest carbohydrates are the *pol-y-sac'cha-rides*.

These include the *starches* and *cellulose*.

The two main energy molecules found in plants, that can be used by humans, are *am'-y-lose* and *am'y-lo-pec-tin*. These are the two main starches found in potatoes, breads, and pasta.

Amylose has several thousand glucose units hooked together into a long chain or *polymer*. For simplicity these are shown as straight chains in the picture, but the real amylose chains are twisted around to form an irregular helical coil.

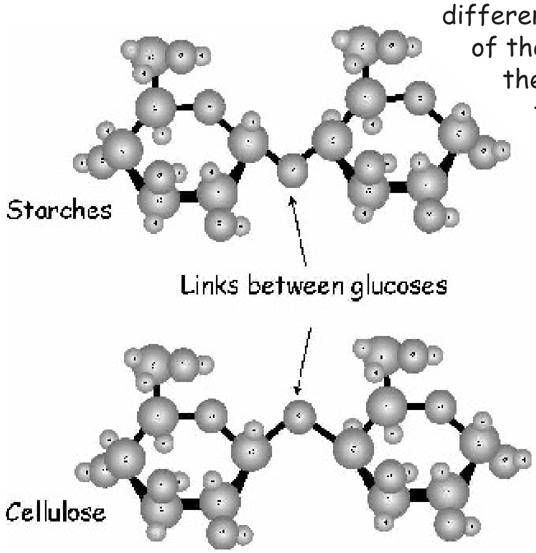
Amylopectin also contains several thousand glucose units, but instead of being a helical coil, it is branched. The structure for glycogen is very similar to that of amylopectin.

In the experiment that the students will perform for this chapter, it is amylose that is detected by iodine. Amylopectin, glycogen and cellulose cannot be detected by iodine. The helical coil of amylose interacts with the iodine molecules to give a deep purple or black color. The other starches do not form this coil and therefore cannot be detected by iodine.

If we ate only simple sugars, our bodies would use up all of the energy in these molecules too quickly and we would get tired. The long chains in the polysaccharides provide "storage" for the energy molecules which menas that long after we eat we will have enough energy to ride bikes, swim, or run.

8.5 Cellulose

Cellulose differs from the starches only in how the glucose molecules are hooked together. The links between the glucose molecules in cellulose are different from the links between those of the starches. For the starches, the oxygen atom that connects the two glucose molecules is pointing "down." However, the oxygen between two glucose molecules in cellulose is pointing "up." The direction of this bond is the only difference between these two molecules, but it makes a huge difference to us.



Cellulose is the main ingredient of wood, cotton, flax, wood pulp, and other plant fibers. It is even in grass. However, wood and grass are not main staples of our diet and not often served for Sunday brunch. In fact, although cellulose has the same glucose molecules that the starches have, humans cannot use cellulose for food energy at all.

Many animals, including humans, do not have the enzyme (protein) required to break the bonds between the glucose molecules in cellulose. Our enzymes only recognize the bonds in the starches; so we cannot graze the lawn for breakfast. Some animals, like cattle and horses, have bacteria that provide the necessary enzymes to break cellulose links, so these animals can eat grass for food energy, but we cannot.

Cellulose is the main structural molecule for plants. Because plants need to have rigid cell walls for support (since they don't have bones), the structure for cellulose is very different from that of starches.

The main difference between the bonding for the starches and cellulose is the orientation of the linkage between individual glucose units. For the starches, the term "down" is given for the students. The actual name of this type of bond is *alpha* and is given the symbol α. Starches have α bonds between their glucose units.

The term given to the students for the bonds between the glucose units for cellulose is "up." The actual name for this type of bond is *beta* and is given the symbol β. Starches have β bonds between their glucose units.

This small difference in how the units are hooked to each other makes a huge difference in their overall shape. As mentioned on the last page, the starches are either coils or large branched molecules. In contrast, cellulose forms large sheets which can stack on one another. The cell walls in plants are made of layers of parallel cellulose sheets. These layers make the cell wall rigid .

Humans cannot use cellulose for energy molecules. We do not have the necessary enzymes required to break the β linkages of cellulose glucose units. Certain animals have bacteria that break the cellulose linkages for them, and so they can eat grasses and other plants for their diet.

Experiment 8: Show me the Starch Date:

Objective: *To determine which foods contain starch.*

Hypothesis: *Potatoes conatin starch. Celery does not.*

Materials:

- tincture of iodine
- variety of foods including:
  - pasta
  - bread
  - celery
  - banana
  - potato
  - other fruits
- laundry starch
- absorbent paper
- eye dropper

[Iodine is VERY poisonous, do not eat any food items with iodine]

Experiment:

1. Take several food items and place them on a cookie sheet.

2. Take the liquid starch and with the eye dropper put a small amount on a piece of absorbent paper and label it "Control." Let it dry.

3. Add a droplet of iodine to the starch on the control paper. Record the color.

4. Add iodine to each of the food items and record the color.

5. Compare the color on the "control" to the color of each food item.

6. Note those food items that change color and those that do not.

In this experiment the students will determine which foods contain starch (amylose) and which do not.

Have the student write the objective and hypothesis. Have them guess which foods might have starch and which might not, based on the text for this chapter. Some examples are given.

Only amylose is detected by iodine, so technically they will be observing only those foods that contain amylose. Iodine is very poisonous, do not let the student eat any foods that have iodine on them.

Select a variety of food items. Include some that contain amylose, like potatoes or bread.

Laundry starch is used as a control. Laundry starch is made of corn starch (which contains amylose) and borax and can be used as a positive control. Some papers also have amylose in them, so also test the paper alone. Use a paper that does not turn black.

Explain the use of a *controls* to the students Controls test the experimental method to see if it's working. If the control does not work, something is wrong with the experiment and any other results are not valid. If the control works, then it is more likely that the results of the experiment are *real* and can be used to draw final conclusions. For example, if the iodine solution were bad, old, or just not working, then even the laundry starch would not turn black. But if no control was performed, it might be determined by the results that nothing has starch in it. These results would be incorrect and the conclusion that "potatoes have no starch" would be incorrect. Control experiments are a very important part of real scientific investigation and essential for determining the validity of individual experiments.

Results:

Food Item	Color
Control	

Have the students record their results. Those items containing starch should have a deep purple, almost black color. Everything else will stay light brown.

Conclusions:

Help the students write *valid* conclusions based on the data they have collected. Have them write down if they *proved* or *disproved* their hypothesis.

Some example are:

- *Raw potatoes turn black with iodine.*
- *Potatoes contain starch.*
- *Raw celery does not turn iodine black.*
- *Celery does not have starch.* [starch here meaning amylose]

OPTIONAL:

Test several items before and after cooking them. Ask the students to predict whether or not cooking will affect the outcome of their results.

Cooking breaks the bonds between glucose units and they should see a difference with cooked foods. Cooked foods should not turn purple.

Review

Define the following terms:

nutrients	*Essential molecules we get form the foods we eat.*
carbohydrates	*Molecules made with carbon, oxygen and hydrogen.*
monosaccharide	*Single sugars like glucose.*
oligosaccharide	*A "few" sugars, like sucrose; table sugar.*
polysaccharide	*"Many" sugars, like starches and cellulose.*
starch	*Long chains of sugar units found in plants and animals.*
cellulose	*Long chains of sugar units found mostly in plants.*
amylose	*A common polysaccharide found in plants like potatoes.*
amylopectin	*A polysaccharide found in plants.*

NOTES