

Carbohydrates, Lipids, and Health



Carbohydrates and lipids are essential macronutrients.

Carbohydrates and **lipids** are essential macronutrients. Our bodies use them in a variety of different ways, from energy storage to structural support and cell signaling. They are crucial for our health, but some of them can be dangerous in excess. We will explore the many roles of carbohydrates and lipids as well as how to maximize their benefits and minimize their dangers.

Carbohydrates

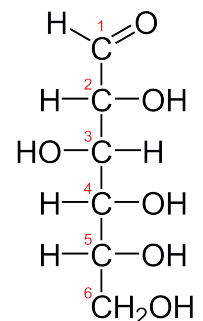
Carbohydrates are organic compounds of carbon, hydrogen, and oxygen. They typically take the form $(CH_2O)_n$. They are the primary source of energy for our muscles, but also help power our central nervous system, assist in metabolizing fat, keep the body from using protein as an energy source (our bodies need protein to build muscle), and promote brain function through their effects on mood, memory, and decision-making. Furthermore, carbohydrates combined with proteins (called **glycoproteins**) are a crucial component of cell membranes, allowing cell types to be identified and serving as specialized attachment sites for certain proteins.

We know carbohydrates as **sugars**, **starches**, and **fibers** and we obtain them from certain foods like fruit, vegetables, and grains. In addition to the health benefits of carbohydrates, whole grains, fruits, and vegetables contain essential antioxidants which protect cells from damage.

When we consume carbohydrates, they are broken down into small units (e.g., glucose, fructose) in our intestines, pass into the bloodstream, and are carried to the liver. The liver converts all the sugars it receives into the sugar **glucose**, which is our cells' primary energy source. Glucose then enters the bloodstream. As the level of sugar in the body increases, the pancreas excretes a hormone called **insulin**, which carries sugar throughout the body to power our muscles. If the blood glucose level is too high, this could mean that the body has difficulty producing insulin.

If we take in excess carbohydrates, our body stores them as **glycogen** (chains of glucose) in muscle and liver cells. We have about a day's worth of energy (in the form of **calories**) stored as glycogen, which our muscles can break down. The resulting glucose can be used in the muscles for exercise, within the liver, or passed back into the bloodstream to be carried to other parts of the body. Any additional carbohydrates consumed can be converted into fat for long-term storage.

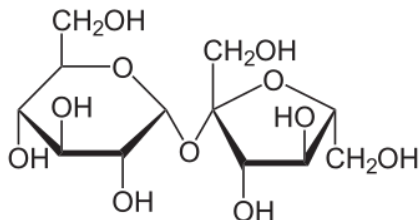
The **energy density** of a macronutrient (how much energy it contains) is measured in calories per gram. Most carbohydrates contain **4 calories of energy per gram**. Fiber, however, which we can't digest, is partially broken down by bacteria in the large intestine, producing about 1.5 to 2.5 calories per gram.



Glucose is the main source of cellular energy.

Types of Carbohydrates

There are two kinds of carbohydrates: simple and complex.



Sucrose is a disaccharide.

Simple carbohydrates are **monosaccharides** (one sugar) or **disaccharides** (two sugars) such as glucose and **sucrose** (table sugar). Simple carbohydrates are small, so they can quickly be broken down and absorbed. In fact, they are the fastest source of energy, able to rapidly increase the level of glucose in the blood

for a burst of energy. Unfortunately, this also means that the energy gets used up quickly, resulting in fatigue soon after. Simple carbohydrates are found in fruit, dairy, honey, and maple syrup, among other sources.

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both heart disease and diabetes. Fiber-rich foods include oatmeal, whole wheat bread, blueberries, brown rice, legumes, apples, beans, nuts, cucumbers, tomatoes, lentils, carrots, and whole grain couscous.

Carbohydrate Preparation

Carbohydrates can be **refined** or **unrefined**.

Refined carbohydrates have been highly processed, resulting in the removal of important components such as fiber, bran, vitamins and minerals. Such foods are low in nutritional value but contain just as many calories as other carbohydrates. To add nutritional value, many refined carbohydrates are enriched by adding back vitamins and minerals. However, diets with lots of refined carbohydrates come with a heightened risk of obesity and diabetes. Refined carbohydrates include white rice, white flour, and table sugar.

Unrefined carbohydrates have not been processed and thus still have many essential nutrients and are high in fiber. Whole grains are unrefined carbohydrates.



Blueberries and oatmeal are good sources of fiber.

Glycemic Index and Glycemic Load

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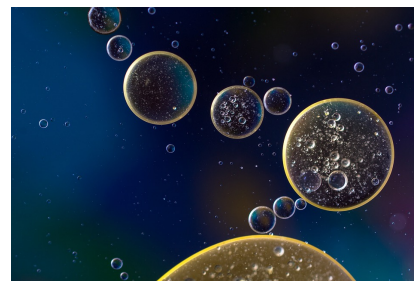
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Lipids

Lipids are organic compounds of carbon, hydrogen, and oxygen that don't mix well with water. In fact, most are **hydrophobic**, meaning they repel or are repelled by water. Although they are composed of the same elements as carbohydrates, they are configured differently and are combined in different ratios. Of macronutrients, lipids have the widest structural variety and can sometimes be difficult to define. However, all have at least one hydrocarbon chain with an acidic end.



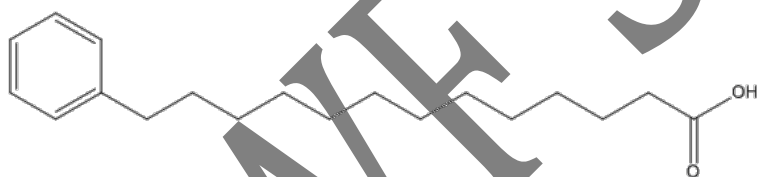
Lipids are united by their inability to mix well with water.

Lipids play three major roles in the body. They **store energy**, make up cell membranes, and assist in **cell signaling**. In their energy storage capacity, they further provide insulation for organs and the body as a whole. As cell membrane components, they support the growth of the cell. They help absorb important nutrients and vitamins, as well as producing hormones.

Our bodies would be unable to process (and thus obtain nutrition from) certain vitamins without the aid of lipids. Vitamins A, D, E, and K are only soluble in fat and can only be absorbed after being dissolved. Vitamin A is necessary for vision, as well as skin, teeth, and bone health. Vitamin D helps our bodies absorb other nutrients like calcium and iron. Vitamin E is an antioxidant that is vital to the immune system. Vitamin K helps blood clot properly and assists with maintaining bone health.

In their cell signaling role, lipids help proteins join specific other proteins and assist in the initiation of chemical reactions that maintain growth, the immune response, and reproduction, among other metabolic processes.

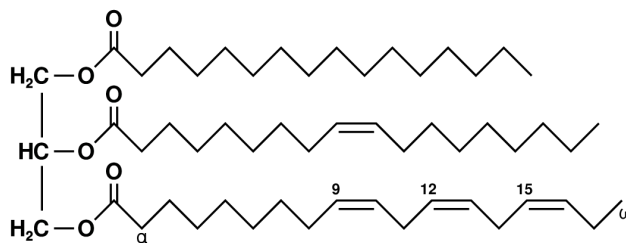
Triglycerides



Fatty acids are the simplest lipids.

amphipathic, which means that one end, the carboxyl group, is **hydrophilic** (mixes well with water), while the other end, the hydrocarbon chain, is hydrophobic.

We consume fatty acids called **triacylglycerols**, or **triglycerides**, lipid compounds that store energy. They are composed of three fatty acids joined to a **glycerol molecule** (three hydroxyl (OH) groups). Triglycerides are insoluble in water. When we consume triglycerides, they are broken down within the small intestine into small



We consume triglycerides.

units called **micelles**, spherical units with hydrophilic exteriors and hydrophobic interiors. Enzymes called **lipases** further break down the micelles into monoglycerides and free fatty acids, which are absorbed into cells lining the small intestine and recombined into triglycerides. These

triglycerides are carried through the bloodstream to the organs, where they are broken down to produce energy. Fat supplies more energy than carbohydrates, with **9 calories per gram**. Thus, energy can be stored in less than half the body weight of fat compared with glycogen. In addition, fat supplies energy more slowly even than complex carbohydrates for sustained energy.

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should come from polyunsaturated fats. It has been shown that increasing that to 15% (in place of saturated fats, not in addition to), can lower the risk of heart disease.



Saturated fats, such as coconut oil, are solid at room temperature.

Saturated fats are solid at room temperature and are generally considered unhealthy. Their hydrocarbon chains contain only single bonds, meaning that all carbon atoms are bonded to the maximum number of hydrogen atoms. They are found mainly in foods derived from animals, but also occur in some plants as well. Sources of saturated fats include coconut; coconut oil; palm oil; cheese; whole and reduced fat milk, butter, and dairy desserts; meat (e.g. sausage, bacon, beef); and cookies and other desserts

made from grains; among others. Saturated fats can increase bad cholesterol in the blood (see **Steroids** section), which raises the risk of cardiovascular disease. It can also increase the likelihood of developing type 2 diabetes. Dietary Guidelines for Americans suggest obtaining less than 10% of daily calories from saturated fats. The American Heart Association suggests no more than 7%. Replacing saturated fats with good, unsaturated fats can help prevent insulin resistance (which precedes diabetes).

Trans fats are mainly manufactured, but some are naturally-occurring (found in beef and dairy fats). These fats are created by a process called **hydrogenation**: liquid vegetable oil is heated in the presence of hydrogen gas and a catalyst (a substance that speeds up a reaction). Partial hydrogenation increases the stability of oils, so they last longer before going bad; makes oils once liquid at room temperature solid (e.g. margarine, shortening); and makes them more resistant to heat, so they are good for frying. Trans fats are commonly used in restaurants and food manufacturing.

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Fats should make up 25-35% of daily calorie intake, with only 5-10% of that from saturated fats.

Phospholipids

Phospholipids are lipid compounds consisting of two fatty acids linked to a polar head group. The fatty acid “tails” of phospholipids are hydrophobic, while the polar heads are hydrophilic. Thus, like triglycerides, phospholipids are amphipathic. Phospholipids are the primary building block of cell membranes, the envelopes that protect the cytoplasm and contents of cells, only allowing certain materials to pass through. They are also an important part of **myelin**, the material that

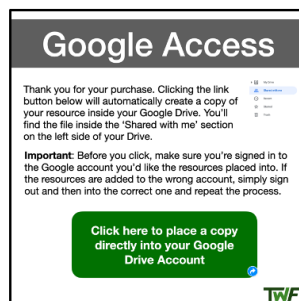
insulates nerves and speeds up nerve impulses. Phospholipids are also used to synthesize messenger molecules that carry signals from cell surface receptors to targets within the cell.

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Cholesterol must be transported throughout the body to where it is needed. **Lipoproteins**, lipid-protein complexes, are cholesterol's means of transportation. Lipoproteins are structurally like micelles and there are two major types: **high-density lipoprotein** (HDL) and **low-density lipoprotein** (LDL). Typically, HDL is considered “good cholesterol” while LDL is “bad cholesterol”. However, the cholesterol itself has little to do with good or bad; it’s how much cholesterol is carried by which type of lipoprotein. HDL has the highest protein-to-lipid ratio and its main role is to carry excess cholesterol from the cells to the liver for removal from the body. High levels of HDL are linked to lowered risk of heart disease and stroke. LDL, on the other hand, carries cholesterol to the body’s tissues. The higher the level of LDL, the more cholesterol exists in the bloodstream and the more likely it is to build up in artery walls, potentially leading to a blood clot and/or heart attack. High-fiber foods (e.g., beans) and those containing unsaturated fats (e.g., avocado, olive oil) increase HDL levels. LDL levels increase with diets containing large amounts of sugars and refined carbohydrates.

As mentioned previously, cholesterol is a building block for the steroid hormones estrogen and testosterone. These hormones carry signals through the body that are necessary for growth, sexual development, the immune response, and metabolic regulation.

Reading Comprehension Questions

1. What are
2. What does insulin do?
3. What
4. What is
5. List two reasons fiber is important.
6. What
7. What is the glycemic index and why is it important?
8. What are
9. What
10. What are the health benefits of essential fatty acids?
11. What
12. What are phospholipids and what is their main role in the body?
13. What are steroids?
14. Explain

Extension Questions

15. Why
16. What
17. Choose one of the carbohydrate or lipid classes discussed above and create an infographic detailing how it moves through the body and what its role(s) is(are). Check out canva.com for templates.

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