4.4: Digestion and Absorption of Lipids

Skills to Develop

- Summarize the steps in lipid digestion and absorption.
- Explain how lipids are used for energy and stored in the body.

Lipids are large molecules and generally are not water-soluble. Like carbohydrates and protein, lipids are broken into small components for absorption. Since most of our digestive enzymes are water-based, how does the body break down fat and make it available for the various functions it must perform in the human body?

From the Mouth to the Stomach

The first step in the digestion of triacylglycerols and phospholipids begins in the mouth as lipids encounter saliva. Next, the physical action of chewing coupled with the action of emulsifiers enables the digestive enzymes to do their tasks. The enzyme lingual lipase, along with a small amount of phospholipid as an emulsifier, initiates the process of digestion and starts the breakdown of triacylglycerides. These actions cause the fats to become more accessible to the digestive enzymes. As a result, the fats become tiny droplets and separate from the watery components.
Figure 4.4.1: Lipid Digestion

In the stomach, gastric lipase starts to break down triacylglycerols into diglycerides and fatty acids. Within two to four hours after eating a meal, roughly 30 percent of the triacylglycerols are converted to diglycerides and fatty acids. The stomach’s churning and contractions help to disperse the fat molecules, while the diglycerides derived in this process act as further emulsifiers. However, even amid all of this activity, very little fat digestion occurs in the stomach.

Going to the Bloodstream

As stomach contents enter the small intestine, the digestive system sets out to manage a small hurdle, namely, to combine the separated fats with its own watery fluids. The solution to this hurdle is bile. Bile contains bile salts, lecithin, and substances derived from cholesterol so it acts as an emulsifier. It attracts and holds on to fat while it is simultaneously attracted to and held on to by water. Emulsification increases the surface area of lipids over a thousand-fold, making them more accessible to the digestive enzymes.

Once the stomach contents have been emulsified, fat-breaking enzymes work on the triacylglycerols and diglycerides to severe fatty acids from their glycerol foundations. As pancreatic lipase enters the small intestine, it breaks down the fats into free fatty acids and monoglycerides. Yet again, another hurdle presents itself. How will the fats pass through the
watery layer of mucus that coats the absorptive lining of the digestive tract? As before, the answer is bile. Bile salts envelop the fatty acids and monoglycerides to form micelles. Micelles have a fatty acid core with a water-soluble exterior. This allows efficient transportation to the intestinal microvillus. Here, the fat components are released and disseminated into the cells of the digestive tract lining.

![Figure 4.4.2: Fats can travel through the watery environment of the body due to the process of emulsification.](image)

Just as lipids require special handling in the digestive tract to move within a water-based environment, they require similar handling to travel in the bloodstream. Inside the intestinal cells, the monoglycerides and fatty acids reassemble themselves into triacylglycerols. Triacylglycerols, cholesterol, and phospholipids form lipoproteins when joined with a protein carrier. Lipoproteins have an inner core that is primarily made up of triacylglycerols and cholesterol esters (a cholesterol ester is a cholesterol linked to a fatty acid). The outer envelope is made of phospholipids interspersed with proteins and cholesterol. Together they form a chylomicron, which is a large lipoprotein that now enters the lymphatic system, bypassing the liver, and will soon be released into the bloodstream via the jugular vein in the neck. Chylomicrons transport food fats perfectly through the body's water-based environment to specific destinations such as the liver and other body tissues. Entrance into the bloodstream can last up to 14 hours with the peak 30 to 3 hours post-meal.

Cholesterols are poorly absorbed when compared to phospholipids and triacylglycerols. Cholesterol absorption is aided by an increase in dietary fat components and is hindered by high fiber content. This is the reason that a high intake of fiber is recommended to decrease blood cholesterol. Foods high in fiber such as fresh fruits, vegetables, and oats can bind bile salts and cholesterol, preventing their absorption and carrying them out of the colon.

If fats are not absorbed properly as is seen in some medical conditions, a person’s stool will contain high amounts of fat. If fat malabsorption persists the condition is known as steatorrhea. Steatorrhea can result from diseases that affect absorption, such as Crohn’s disease and cystic fibrosis.

**Brief Overview of Triacylglyceride Metabolism**

Fat cells are located in special depots in your body and there are many different locations, for example, abdominal (belly fat) or the hips. Also, a small amount of fat is stored in skeletal muscle too. See Figure 4.4.3 to see an adipocyte in skeletal muscle.
Figure 4.4.3: Adipocyte or fat cell within skeletal muscle.

Once stored in the adipocyte (fat cell), the fat will remain there until it is needed to produce energy. Lipolysis is the process by which the triacylglyceride is removed from the lipid droplet with the fat cells, broken into 3 fatty acids and glycerol. The glycerol is secreted from the cells along with some but not all of the fatty acids. These are transported to the liver where the glycerol may be converted to glucose. The fatty acids may be converted to ketones or transported to other cells and burn to produce ATP.

The Truth about Storing and Using Body Fat

Before the prepackaged food industry, fitness centers, and weight-loss programs, our ancestors worked hard to even locate a meal. They made plans, not for losing those last ten pounds to fit into a bathing suit for vacation, but rather for finding food. Today, this is why we can go long periods without eating, whether we are sick with a vanished appetite, our physical activity level has increased, or there is simply no food available. Our bodies reserve fuel for a rainy day.

One way the body stores fat involves the body transforms carbohydrates into glycogen that is in turn stored in the muscles for energy. When the muscles reach their capacity for glycogen storage, the excess is returned to the liver, where it is converted into triacylglycerols and then stored as fat.

In a similar manner, much of the triacylglycerols the body receives from food is transported to fat storehouses within the body if not used for producing energy. The chylomicrons are responsible for shuttling the triacylglycerols to various locations such as the muscles, breasts, external layers under the skin, and internal fat layers of the abdomen, thighs, and buttocks where they are stored by the body in adipose tissue for future use. How is this accomplished? Recall that chylomicrons are large lipoproteins that contain a triacylglycerol and fatty-acid core. Capillary walls contain an enzyme called lipoprotein-lipase that dismantles the triacylglycerols in the lipoproteins into fatty acids and glycerol, thus enabling these to enter into the adipose cells. Once inside the adipose cells, the fatty acids and glycerol are reassembled into triacylglycerols and stored for later use. Muscle cells may also take up the fatty acids and use them for muscular work and for generating energy. When a person’s energy requirements exceed the amount of available fuel presented from a recent meal or extended physical activity has exhausted glycogen energy reserves, fat reserves are retrieved for energy utilization.

As the body calls for additional energy, the adipose tissue responds by dismantling its triacylglycerols and dispensing glycerol and fatty acids directly into the blood. Upon receipt of these substances, the energy-hungry cells break them
down further into tiny fragments. These fragments go through a series of chemical reactions that yield energy, carbon
dioxide, and water.

Key Takeaways

• In the stomach fat is separated from other food substances. In the small intestines, bile emulsifies fats while
  enzymes digest them. The intestinal cells absorb the fats.
• Long-chain fatty acids form a large lipoprotein structure called a chylomicron that transports fats through the lymph
  system.
• Chylomicrons are formed in the intestinal cells and carry lipids from the digestive tract into circulation.
• Short- and medium-fatty chains can be absorbed directly into the bloodstream via the portal system from the
  intestinal microvillus because they are water-soluble.
• Cholesterol absorption is hindered by foods high in fiber.
• When energy supplies are low the body utilizes its stored fat reserves for energy.

Discussion Starters

• Explain the role of emulsifiers in fat digestion.
• Name the part of the digestive system where most fat digestion and absorption occurs.
• Describe the role of bile salts in the digestion of triacylglycerols and phospholipids.
• Define chylomicron.
• Explain how fiber-rich foods affect cholesterol absorption.
• Discuss the body’s processes for using energy.