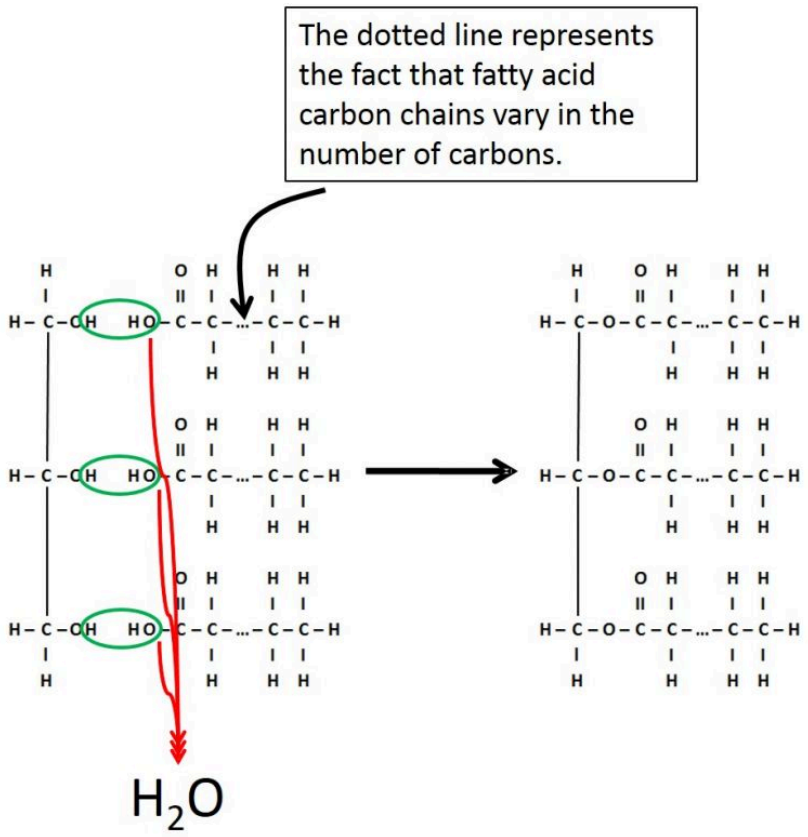
5.2.3

Lipids

Lipid Digestion

The digestion and absorption of lipids presents a whole new set of complexities because most lipids are hydrophobic and the entire digestive tract is full of watery secretions. You could say lipids have a love/hate relationship with our intestinal system. Most of the lipids we eat (> 90%) are in the form of **triacyclglycerols (triglycerides)**. Triacyclglycerols are composed of two molecular building blocks - **glycerol** and **fatty acids**. Fatty acids are chains of carbons that vary in length and the number and type of double bonds between carbons.

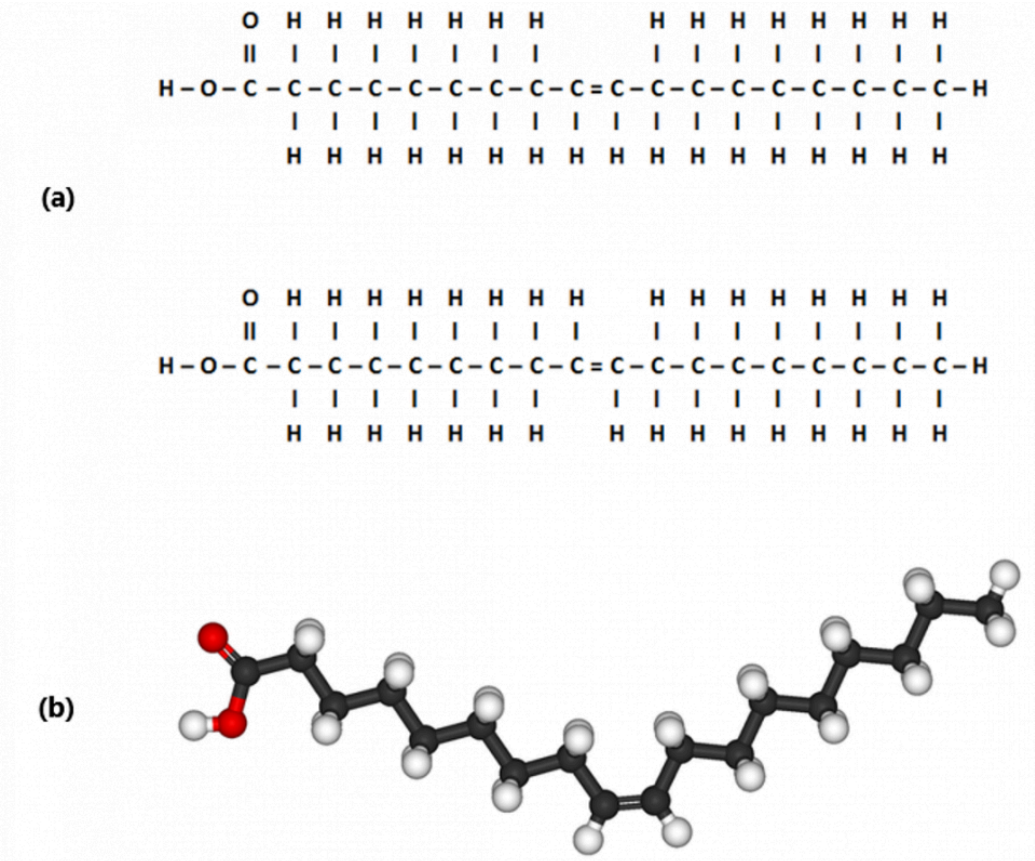


Bonding of Glycerol and Three Fatty Acids by Dehydration Synthesis Reaction to Form Triglyceride

Image created by JS at BYU-Idaho 2014

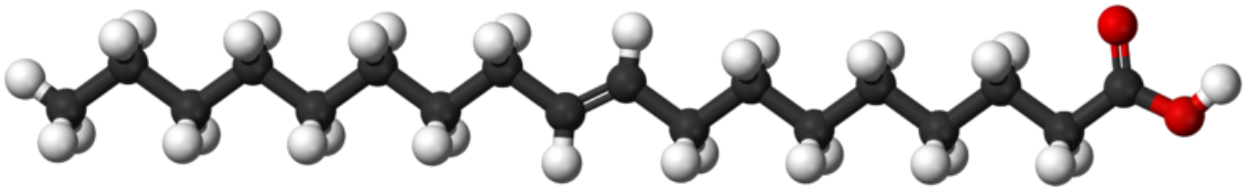
Fatty acid chains with no double bonds are referred to as saturated. This means that every carbon - carbon bond in the chain is a single bond which allows the linking of 2 hydrogen atoms to every carbon in the chain and 3 hydrogen atoms bonded to the last carbon. If a double bond occurs between two carbons in the hydrocarbon chain, then the carbon atoms connected by a double bond will each bond with one less hydrogen atom in order to maintain 4 bonds per carbon atom. We could say that because of the double bond, the fatty acid hydrocarbon chain is no longer "saturated" with

hydrogen atoms at every carbon. Therefore, an unsaturated fatty acid will contain one or more double bonds. A fatty acid with one double bond is referred to as a monounsaturated fat and fatty acids with two or more double bonds are polyunsaturated fats. Additionally, some fats are named after the location of the double bond, such as omega 3 or omega 6 fats. This nomenclature refers to the location of the double bond on the carbons counting from the bottom of the chain up. All lipid containing foods have a specific mixture of saturated and unsaturated fatty acids. Saturated fatty acids tend to be straight and do not have "kinks" or angles that would make "packing" or "stacking" together more difficult. The more tightly packed molecules of fat are, the more likely to be a solid at room temperature. Unsaturated fats can have either "cis" or "trans" double bonds in the hydrocarbon chains. "Cis" bonds allow for a kinked or angled geometry that makes it more difficult to "pack" together. Unsaturated fats with "cis" bonds include vegetable oils.



(a) Cis & Trans Double Bond in Monounsaturated Fatty Acid; (b) Cis Double Bond in Unsaturated Fatty Acid creating kink.

Image created by JS at BYU-Idaho 2014: Modified File: Oleic-acid-3D-ball-&-stick.png; Author: Benjah-bmm27; Site: https://commons.wikimedia.org/wiki/File:Oleic-acid-3D-ball-%26-stick.png; License: Public Domain



Trans Double Bonds in Unsaturated Fatty Acid.

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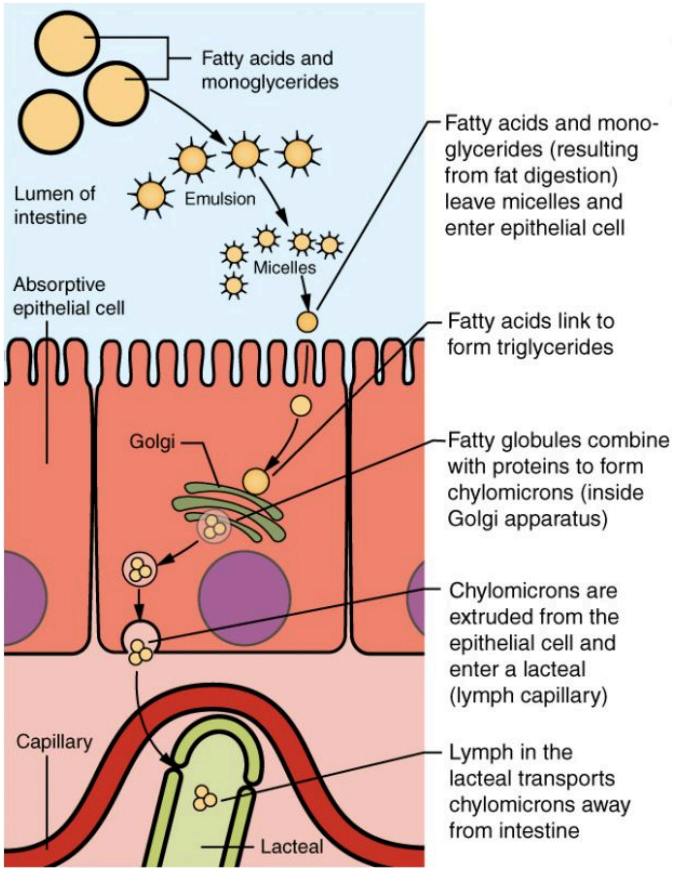
Unsaturated fats with "Trans" bonds contain a geometry that resembles the straight line of a saturated fat. This geometry allows for trans unsaturated fats to pack together tightly enough that they will be found as a solid at room temperature. Products like Crisco and Margarine often have substantial quantities of "trans fats". Cis fats are the most common type found in nature, although there are some naturally occurring trans fats. Although trans fats are rare in nature they have appeared in the American diet as a product of oil processing. Food manufacturers take naturally occurring oils and use high pressures, high temperatures and hydrogen gas to artificially "hydrogenate" unsaturated fats, making them a creamy solid. A byproduct of this process is the formation fats with rearranged double bonds (trans fats). This type of fat is usually listed as "partially hydrogenated oil" in the food ingredients list. Food companies are interested in the "hydrogenation" of oils so that they might get fat that has the texture, flavor and chemistry necessary for many of the food products we enjoy (i.e. many pastries, puddings, sauces, creamers, and confectioneries). Unfortunately, this switch of hydrogen arrangement has been shown to increase the risk of coronary heart disease (discussed further below).

The hydrophobic nature of lipids presents problems for the digestive process. Because lipids do not interact well with water they tend to form large fat droplets. These droplets make it difficult for the enzymes to access the molecular structure of the fat. To alleviate this problem the fats are **emulsified** (dispersed) by the actions of bile released from the liver and gallbladder into the small intestine. Components of bile act like detergents and help to break up the large masses of fat into smaller more manageable pieces. The emulsified products form small vesicles called micelles. Micelles increase the surface area for digestion but a side effect is that the bile salts inhibit the digestive enzymes (**Lipases) need to breakdown the fat.** As a result, the pancreas secretes colipase in addition to various lipases. The colipase helps the lipases overcome the inhibitory action of the bile salts.

Lipid Absorption

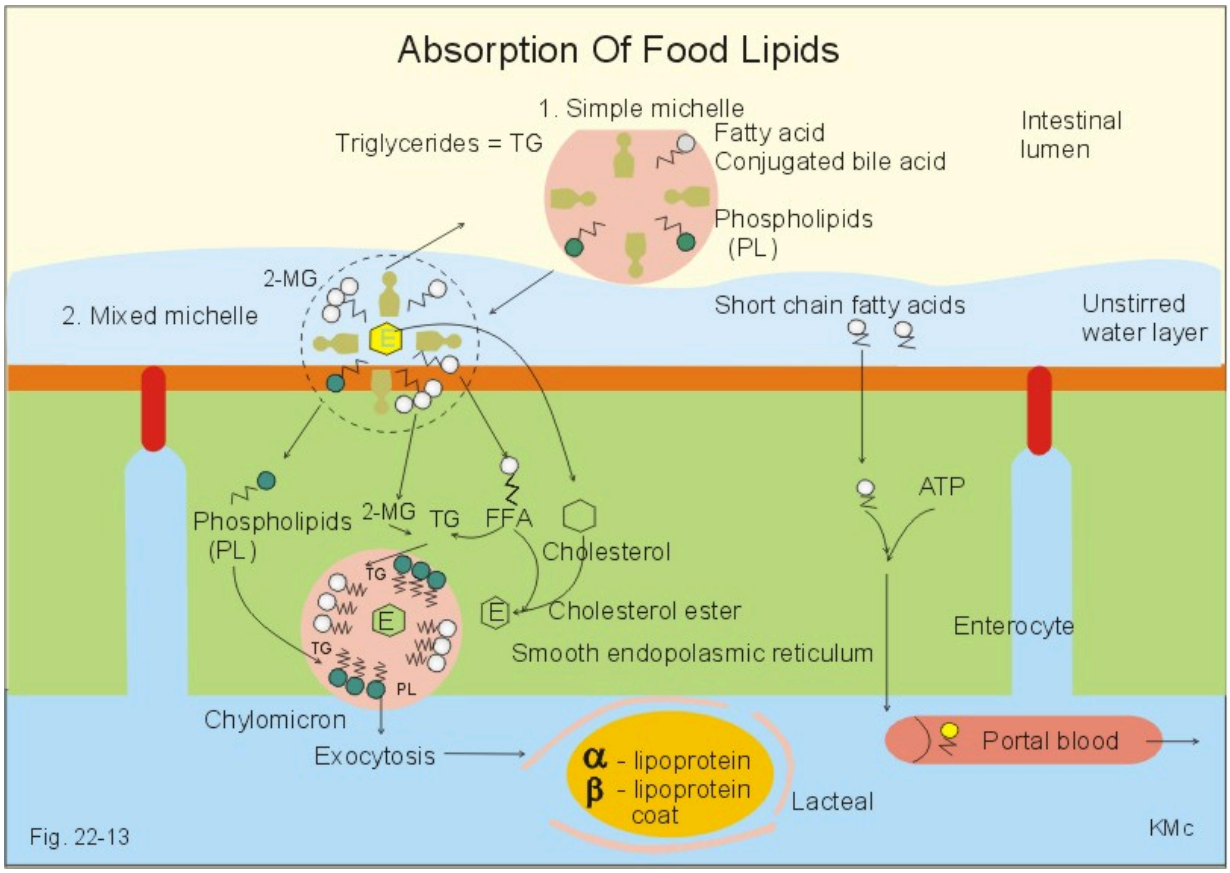
Because the partially digested products inside the micelles are lipophilic, absorption across the lipid bilayer of the small intestinal cell occurs primarily through diffusion.



Lipid Absorption

Author: OpenStax License: License: Creative Commons Attribution License 4.0 Link: https://cnx.org/resources/ee5d4d78da8a6418debe94999ced693451cd30c0/2431_Lipid_Absorption.jpg

However, once inside the cell, the lipids are again forced to interact with water. This issue is solved through the use of intracellular proteins called fatty acid-binding proteins that bind the digested lipids and transport them to the smooth endoplasmic reticulum. Once inside the smooth endoplasmic reticulum the fats are "reassembled" into triacyclglycerols, phospholipids or cholesterol esters. The newly re-synthesized fats are packaged into new vesicles called chylomicrons that are formed from the smooth endoplasmic reticulum and modified in the Golgi apparatus. The chylomicron vesicles are then exocytosed from the basal portion of the small intestinal cell. Because of the rather large size of the chylomicrons they cannot be directly absorbed by the capillaries of the lamina propria, therefore they must pass through the larger channels of the associated lymphatic capillaries found in the center of the villi and enter the lymphatic system. The chylomicrons will eventually enter the blood circulation through the left subclavian vein. Once in the blood, chylomicrons will go through a complex regulatory pathway illustrated below.



Absorption of Lipids

Image by BYU-I Student Tabitha D. 2015