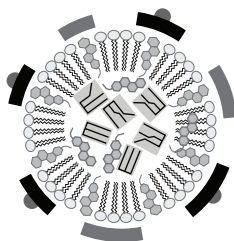


Lipid Digestion

An Introduction to
Lipid Transport and Digestion
with consideration of
High Density and Low Density Lipoproteins



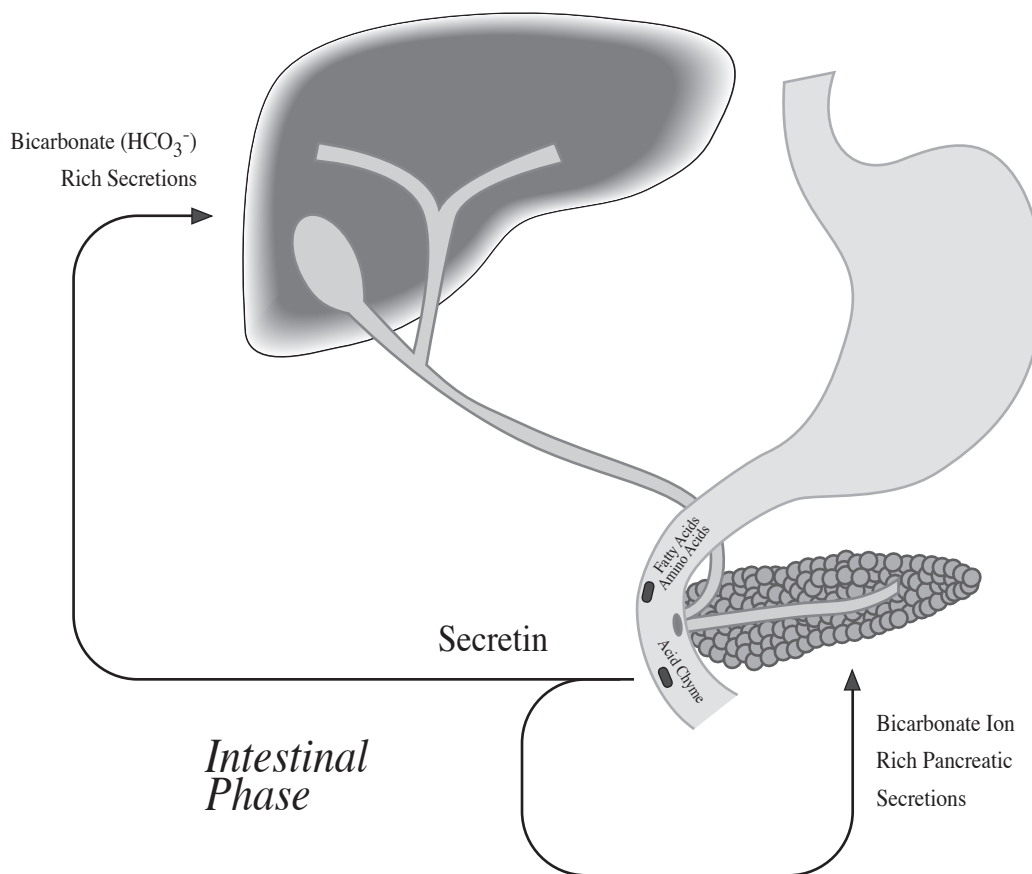
By Noel Ways

Suspension and Neutralization of Chyme pH

Boli containing lipids enters the stomach lumen where stomach churning mechanically breaks the boli down and suspends the lipids in gastric juices. This nutrient rich gastric fluid is called chyme. Without continued churning, however, the lipids and water would separate. As the stomach begins to incrementally empty, the nutrient rich acidic chyme enters into the duodenum where the lipids will be "formally" processed.

The processing of lipids by the digestive system begins with a two-pronged approach. First, acid rich chyme triggers the release of secretin from intestinal enteroendocrine cells of the duodenum into the blood stream. Secretin signals both the liver and the pancreas to secrete a bicarbonate- rich secretion that will neutralize the acid. A neutral pH is important for two reasons:

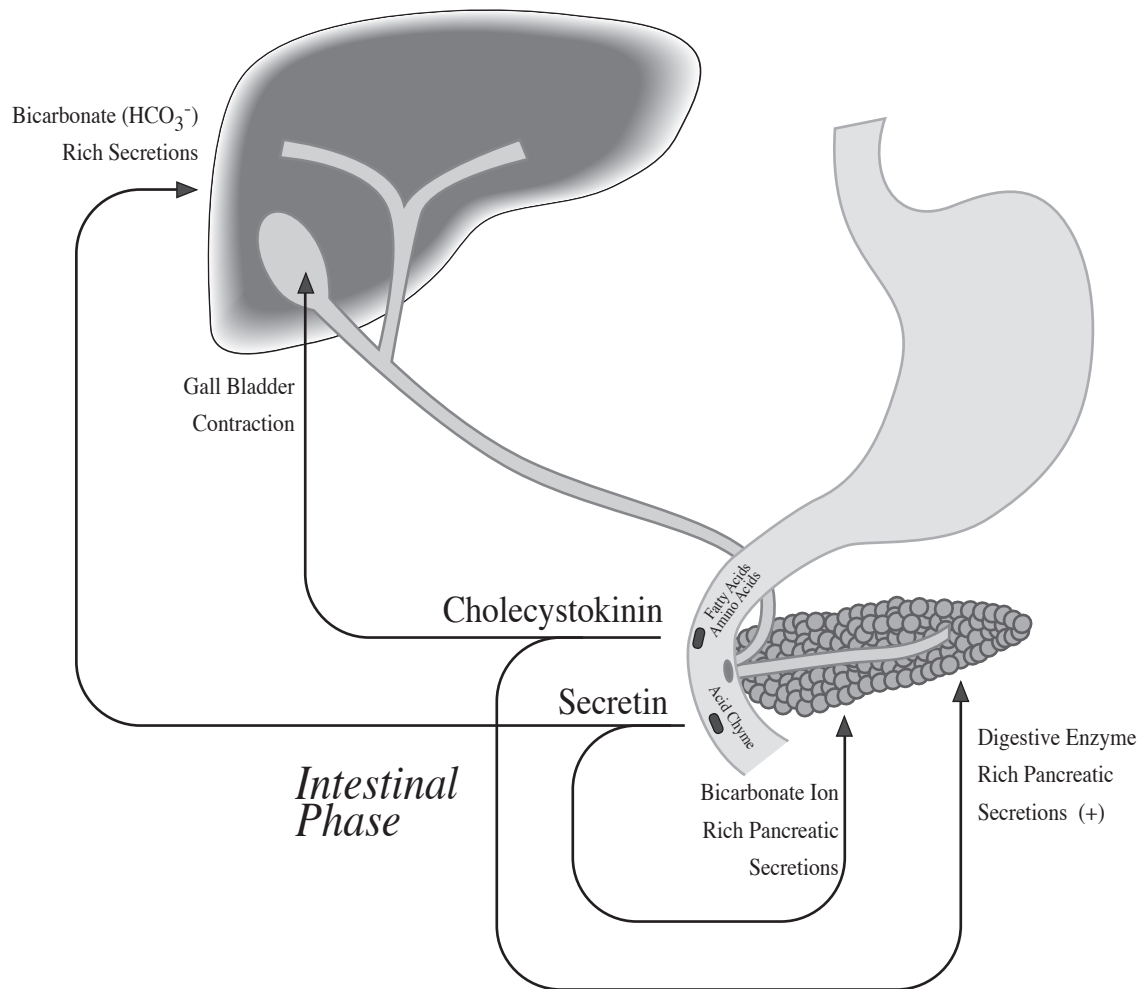
- pancreatic enzymes, such as lipase function at a near neutral pH
- eliminate the need for a thick protective layer of mucous which would otherwise impede absorption.



Emulsification of Lipids and release of Pancreatic Lipase

The presence of nutrients, such as lipids, within the duodenum, will trigger the secretion of cholecystokinin from intestinal enteroendocrine cells of the duodenum into the blood stream. Cholecystokinin will have two effects:

- The gall bladder contracts (and the hepatopancreatic sphincter relaxes) allowing bile to flow into the lumen of the duodenum. The purpose of the bile contents is to emulsify the lipids.

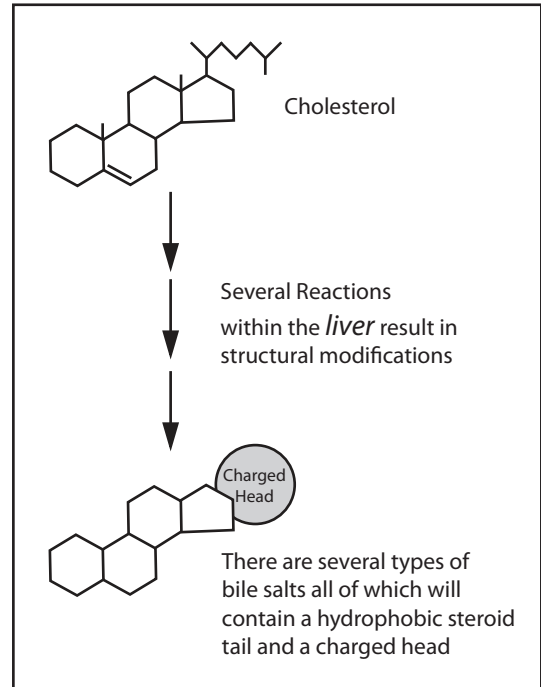


- Cholecystokinin stimulates the pancreas to secrete digestive enzymes, of which pancreatic lipase is of particular importance for this discussion.

Emulsifier Classification and Micelle Formation

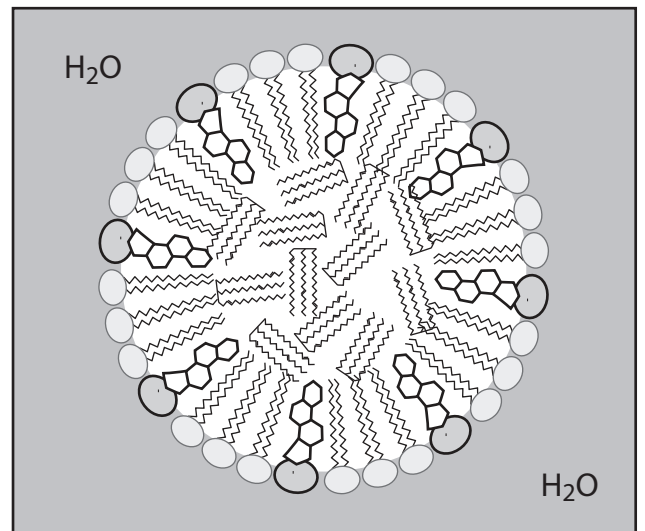
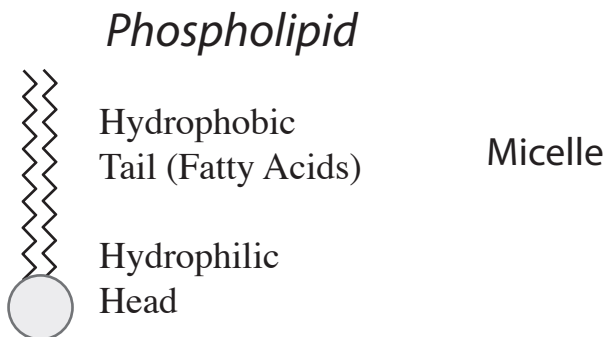
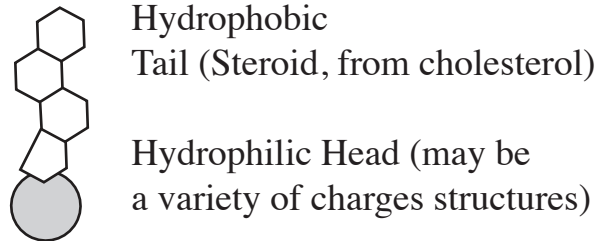
Within the bile there are many emulsifiers:

- *Phospholipids*, a collection of compounds having a hydrophobic fatty acid “tail”, and a hydrophilic head containing P and N with associated charges.
- *Lecithins*, which are phospholipids, but the head also contains a coline molecule.
- *Bile Salts*, another large collection of molecules that contain a hydrophobic steroid tail (derived from cholesterol) and a charged head.



In all cases, these emulsifiers will break apart masses of lipids into small droplets by inserting the hydrophobic end into the lipid and the hydrophilic head will interact with the polar water outside. These emulsifiers form a "bridge" between the water and the lipid, and the lipid droplet remains suspended in the water. The lipid droplet is said to be emulsified. The emulsified lipid droplets are called micelles.

Bile Salt



Lipid Mass

Emulsifiers

Relaxation of Hepatopancreatic Sphincter. Bile exits Duodenal Papilla

Emulsification of the lipid mass into micelles serves two important functions:

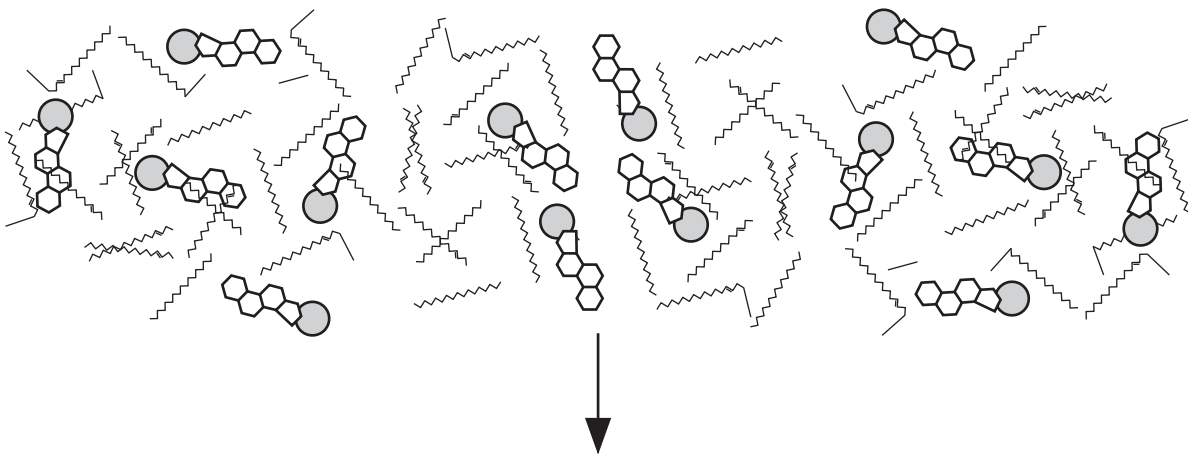
- suspend the lipids within a watery environment.
- emulsification process also dramatically increases the *digestive surface area* of the lipids.

Pancreatic lipase enters the micelle and quickly catabolizes the lipids into free fatty acids, monoglycerides, and glycerol.

Pancreatic Lipase

Once the lipids are digested the micelle spontaneously disassembles as all components can adequately interact with the polar water and exist in a dissolved form.

The lipid components can now enter into the intestinal columnar cells.

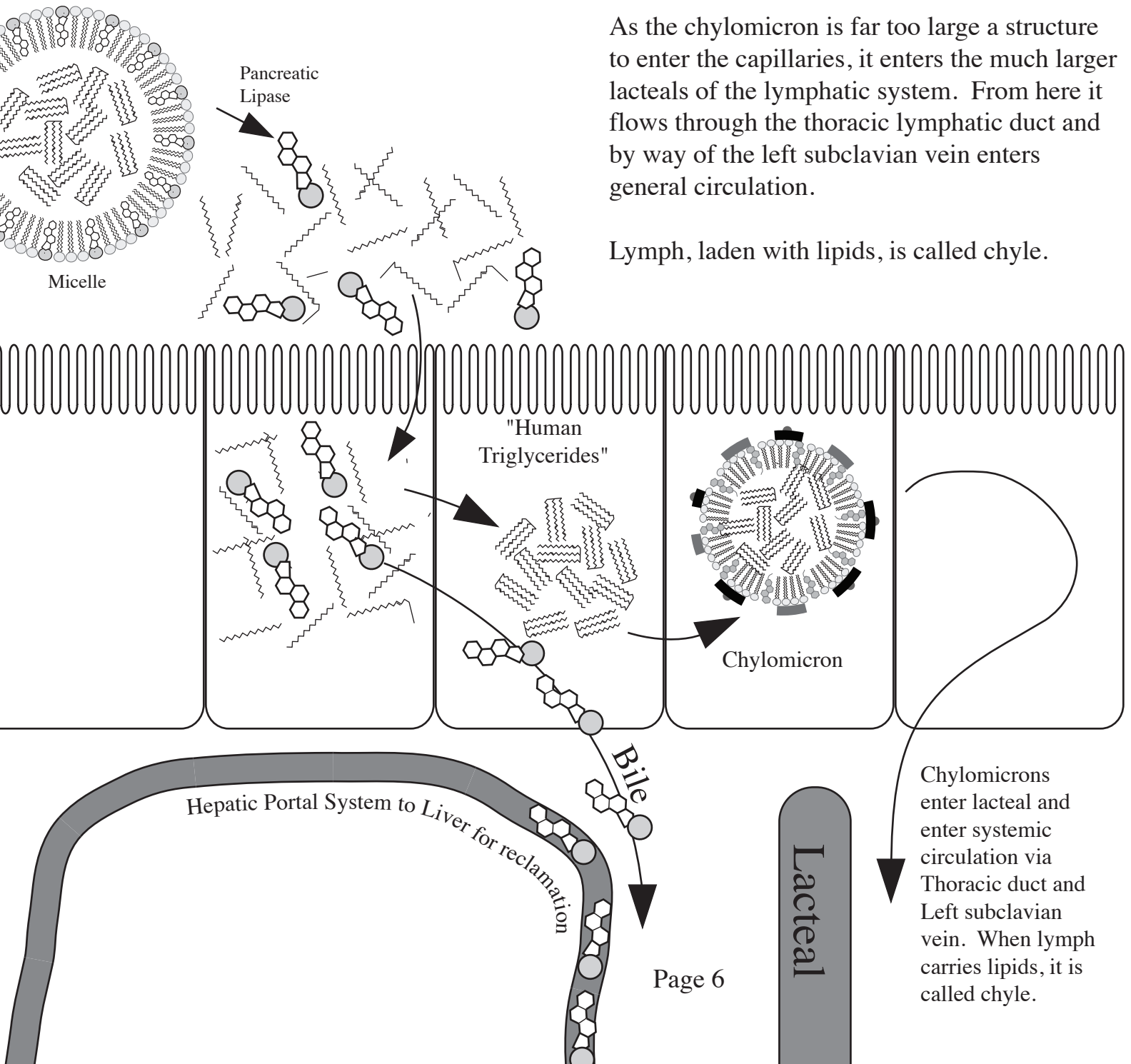


Absorption into columnar cells of small intestine

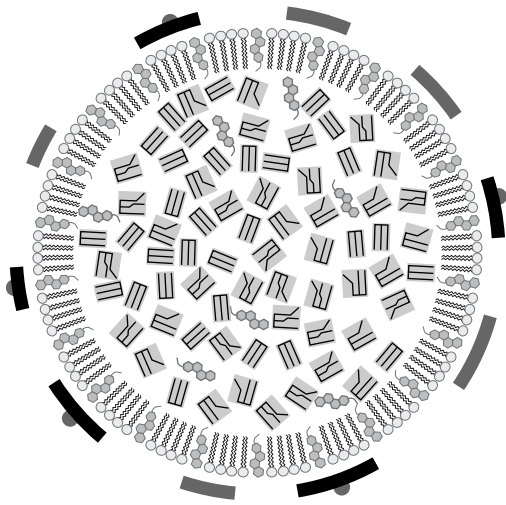
Processing of Lipids by Intestinal Mucosa and Enterohepatic Circulation

With the contents of the micelles broken down, the lipid components and emulsifiers are absorbed into the columnar cells of the intestinal mucosa. The bile enters the vasculature and by way of the hepatic portal system is returned to the liver for retrieval. From there it will make its way to the gallbladder for concentration and temporary storage.

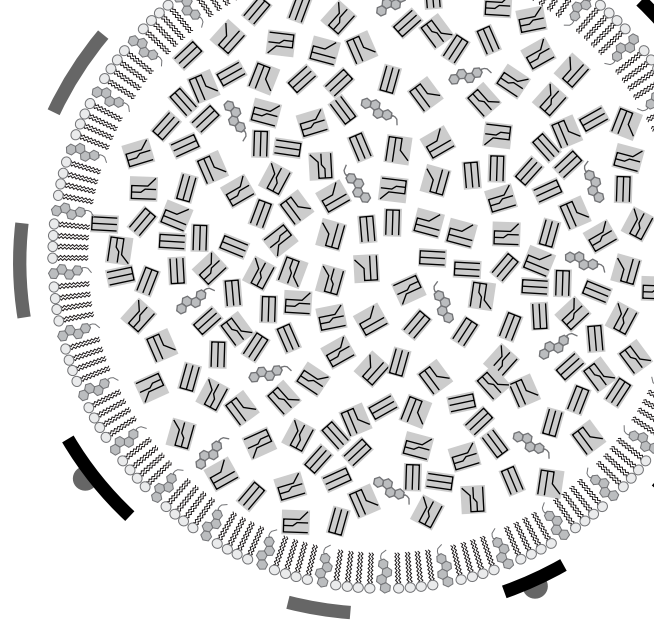
On the other hand, the lipid components are re-synthesized into "human triglycerides" within smooth endoplasmic reticulum and then are emulsified into a structure called a chylomicron. A chylomicron consists of phospholipid emulsifiers with embedded cholesterol and protein on the structure surface. This is a type of lipoprotein. The proteins will have receptors by which lipids can be delivered to tissues "signaling" for them.



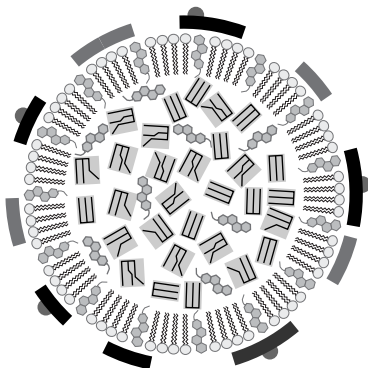
Cast of Characters in Lipid Transport



VLDL
Triglyceride Rich
Cholesterol Poor



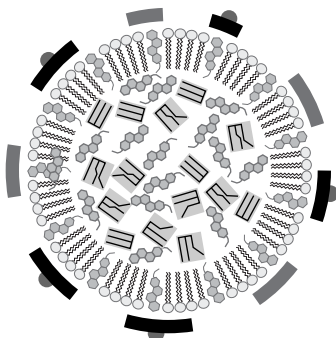
CHYLOMICRON
Triglyceride Rich
Cholesterol Poor



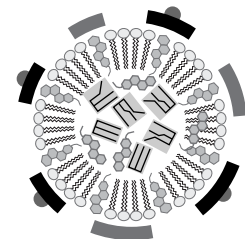
IDL
Triglyceride Moderate
Cholesterol Moderate

Note, the designations Rich, Moderate, Poor refer to percentages, not quantity.

Illustrations and designations are relative, and not to scale.



LDL
Triglyceride Poor
Cholesterol Rich




HDL
Triglyceride Poor
Cholesterol Moderate

Resources:

Perspectives in Nutrition, 4th edition by Gordon M. Wardlaw

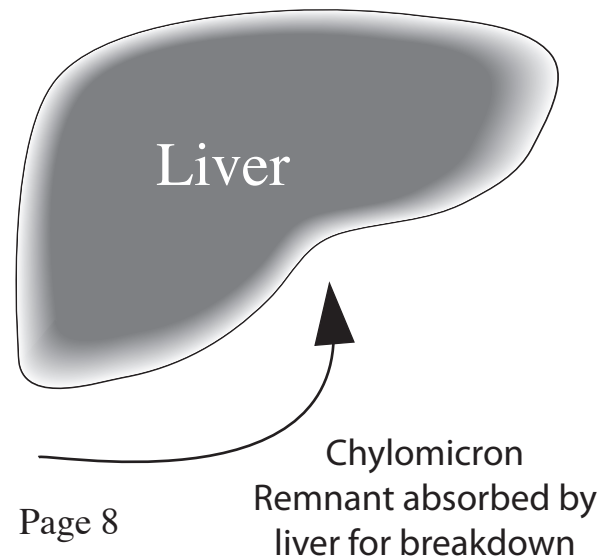
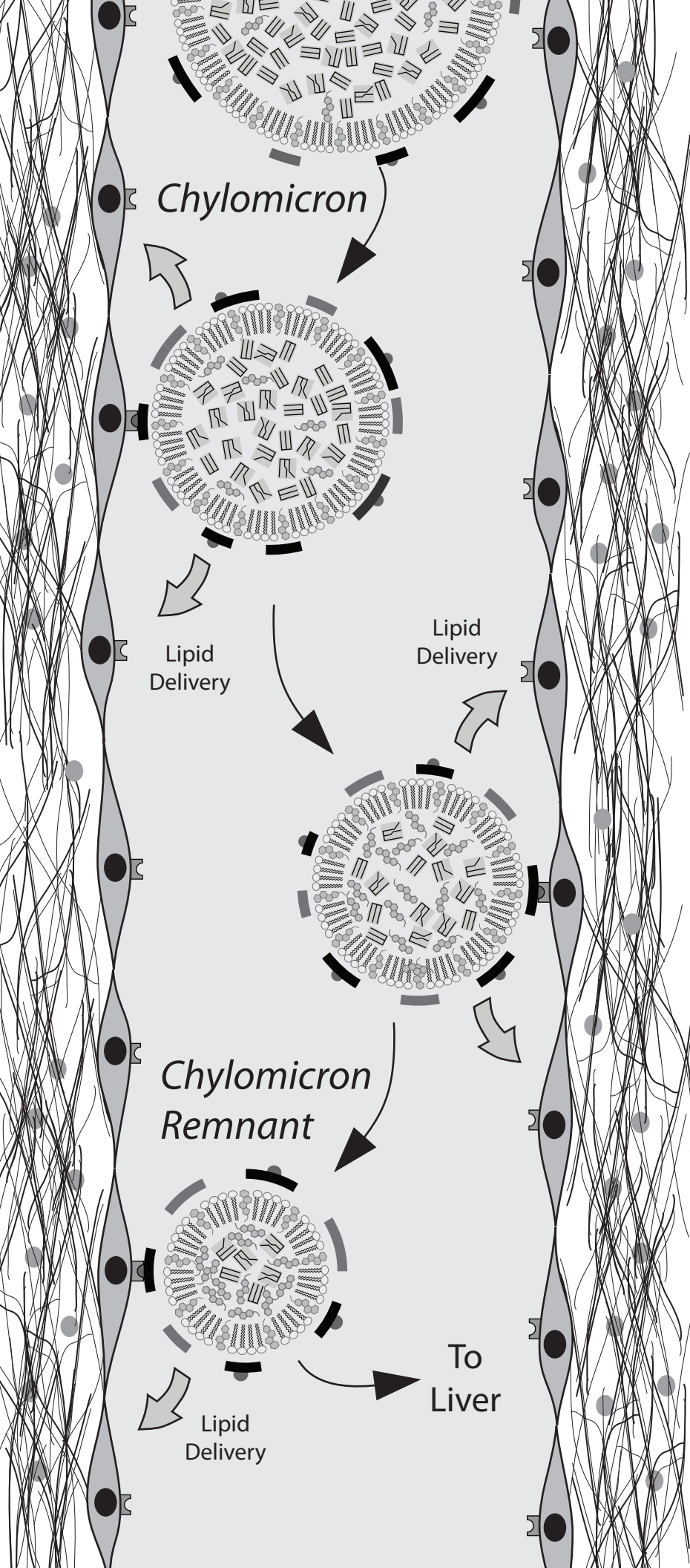
<http://www.softchalk.com/lessonchallenge/lesson/Cholesterol/index.html>

Lipid Transport *From Small Intestine*

As the chylomicrons enter the circulatory system from the lymph, they "feed" lipid components to endothelial cells according to the needs of the adjacent interstitium. More specifically, tissues that require lipids induce production of receptor/enzymes () on adjacent endothelial cells that will trigger the digestion and release of fatty acids from the chylomicron to the cells that require them. This occurs once the chylomicron binds to the receptor.

Whatever lipids are not used in this manner, the chylomicron remnant will be absorbed by the liver and broken down.

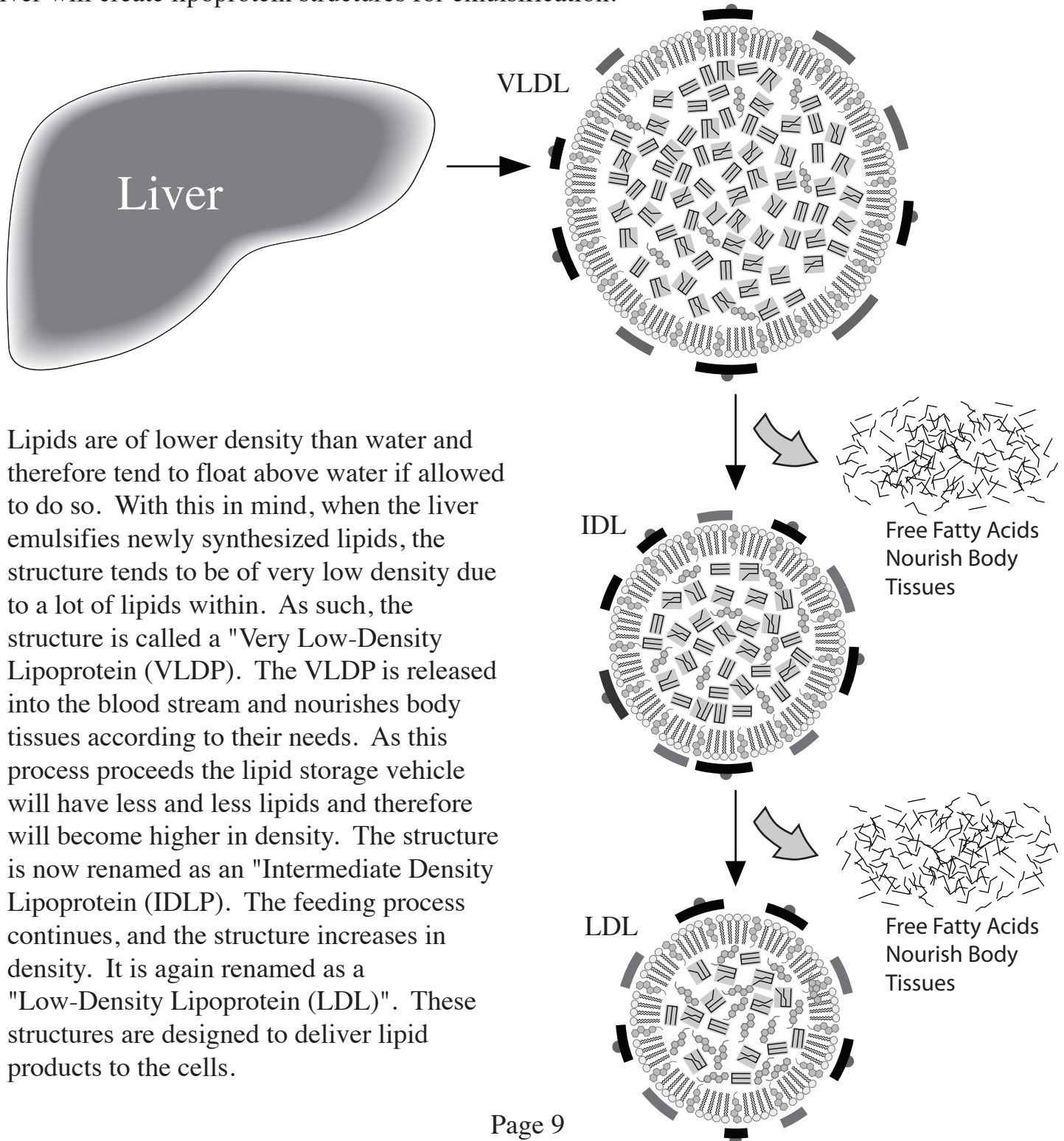
Note that as the chylomicron gets smaller the cholesterol concentration rises.






Lipid Transport

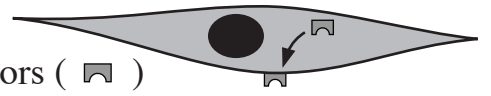
From Liver to Interstitium

The Liver may be considered the "grand central station" of lipid metabolism; which will include the production of cholesterol, phospholipids, triglycerides, and bile salts. The liver will also store lipid soluble vitamins such as A, D, E, and K. When body tissues are in need of any such components or substances, it is the liver that will synthesize them, and then package them for transport within the water based blood. For transport purposes, the liver will create lipoprotein structures for emulsification.

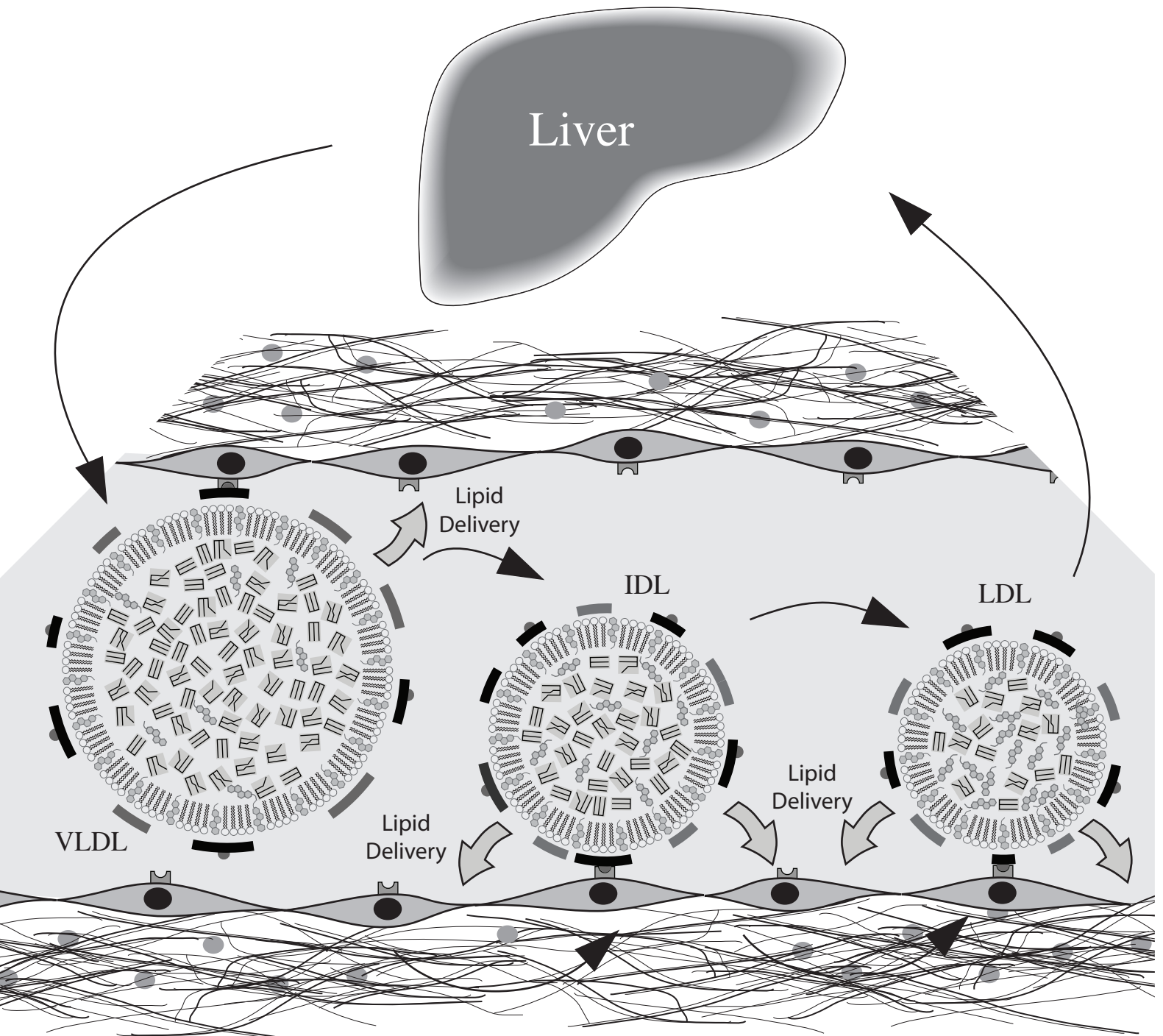


Lipids are of lower density than water and therefore tend to float above water if allowed to do so. With this in mind, when the liver emulsifies newly synthesized lipids, the structure tends to be of very low density due to a lot of lipids within. As such, the structure is called a "Very Low-Density Lipoprotein (VLDP)". The VLDP is released into the blood stream and nourishes body tissues according to their needs. As this process proceeds the lipid storage vehicle will have less and less lipids and therefore will become higher in density. The structure is now renamed as an "Intermediate Density Lipoprotein (IDL)". The feeding process continues, and the structure increases in density. It is again renamed as a "Low-Density Lipoprotein (LDL)". These structures are designed to deliver lipid products to the cells.

This system of lipid delivery is highly regulated. Any tissue in need of lipids will induce the synthesis of appropriate receptors () on adjacent endothelia. These receptors will be inserted on the cell surface. This receptor will correspond to a molecule on the lipoprotein (). And when they bind (), triglycerides will be digested and received by the adjacent tissues/cells.



As the process continues, the lipoprotein gets increasingly dense and has an appropriate name change. Any remaining lipoprotein/triglycerides not so used will be absorbed by the liver.



Lipid Transport

From Interstitium to Liver

Whereas the low-density lipoproteins are the means by which the liver transports lipid products to the tissues, the liver will likewise produce another distinct structure to retrieve unneeded lipids from tissue sources and bring them back to the liver for breakdown. This structure consists of lipoproteins with fewer lipids within. In other words, it has a capacity to enlarge as lipids are absorbed. Due to the initial lack of low-density lipids, the structure is relatively high in density and is therefore called, "High-Density Lipoproteins (HDL)".

The HDL leaves the liver, picks up lipids from cells and tissues where the lipids are no longer needed, as well as LDL in the blood stream, and brings them back to the liver for breakdown.

Unique receptors will trigger this process and will be distinct from those involved with delivery.

