Lipid Digestion

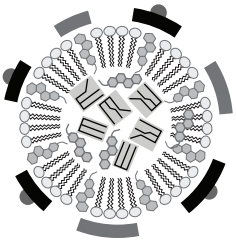
and Human Nutrition

An Introduction to

Lipid Transport and Digestion

with consideration of

High Density and Low Density Lipoproteins



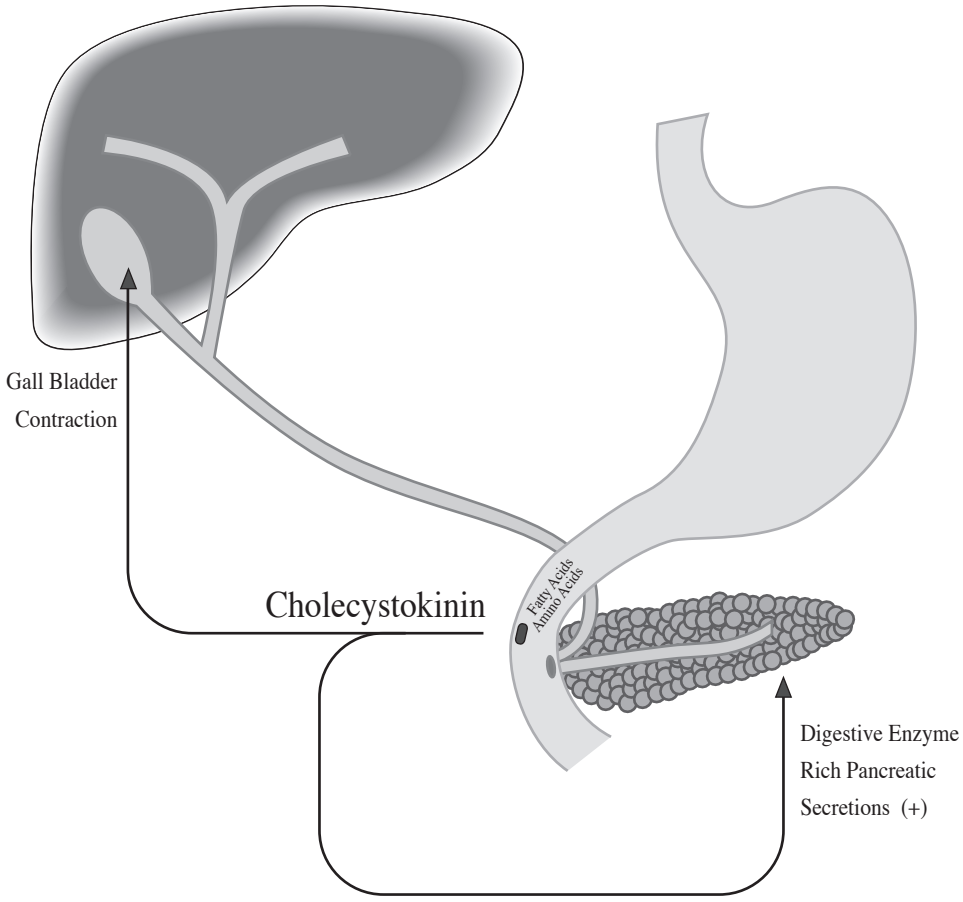
By Noel Ways

Emulsification of Lipids and release of Pancreatic Lipase

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 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:

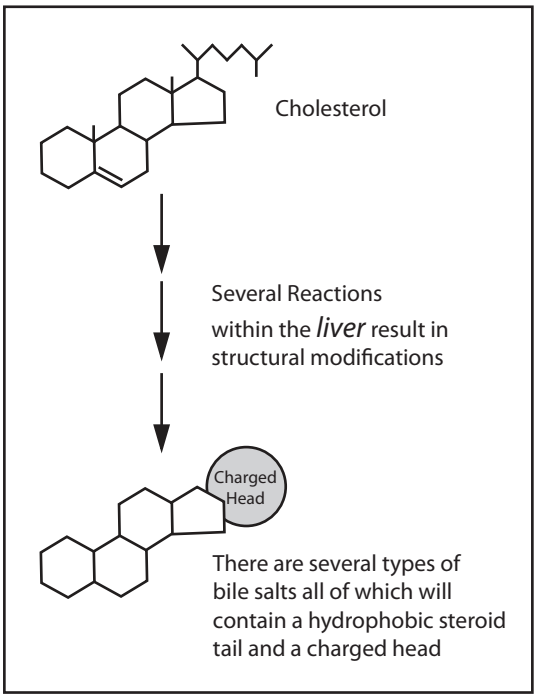
- The gall bladder contracts allowing bile to flow into the lumen of the duodenum. The purpose of the bile contents is to emulsify the lipids.
- Cholecystokinin stimulates the pancreas to secrete digestive enzymes, of which pancreatic lipase is of particular importance for this discussion.



Emulsifier Classification and Micelle Formation

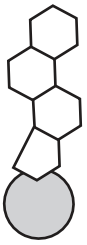
Within the bile there are many emulsifiers:

- *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



Hydrophobic
Tail (Steroid, from cholesterol)

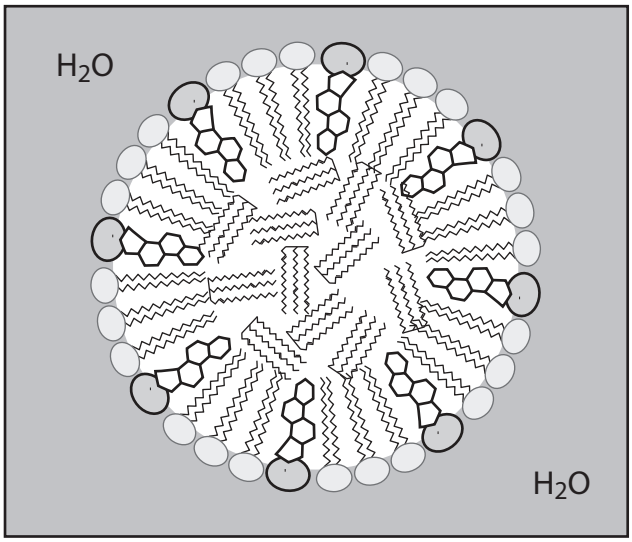
Hydrophilic Head (may be
a variety of charges structures)

Phospholipid

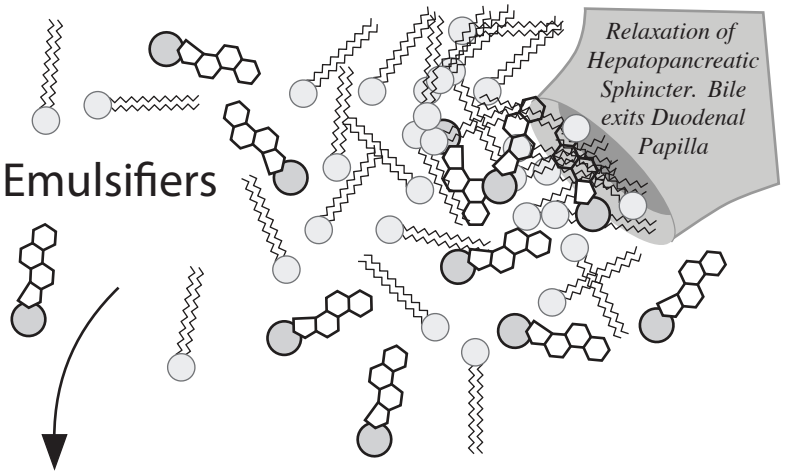
Hydrophobic
Tail (Fatty Acids)

Hydrophilic
Head

Micelle



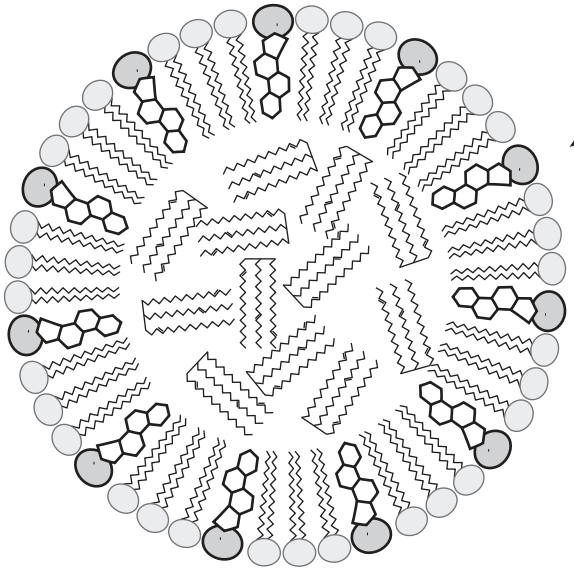
Lipid Mass



Emulsifiers

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.

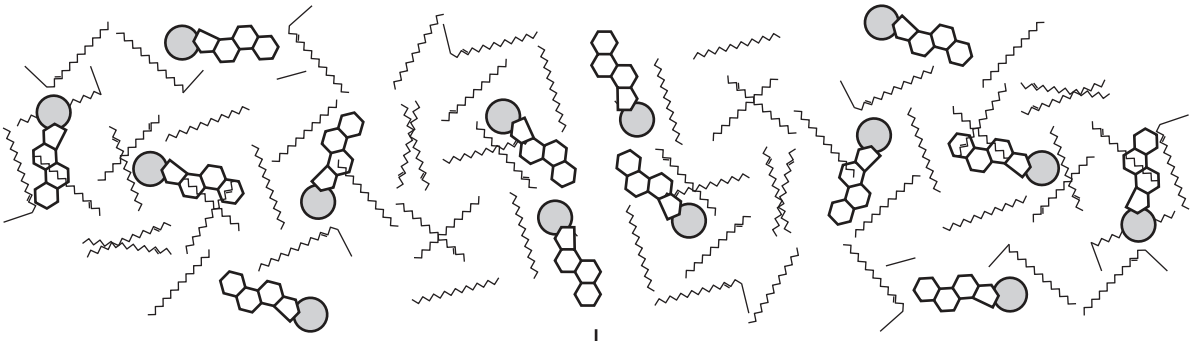


Pancreatic Lipase

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

Once the lipids are digested the micelle spontaneously dissasembles 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 collumnar cells.

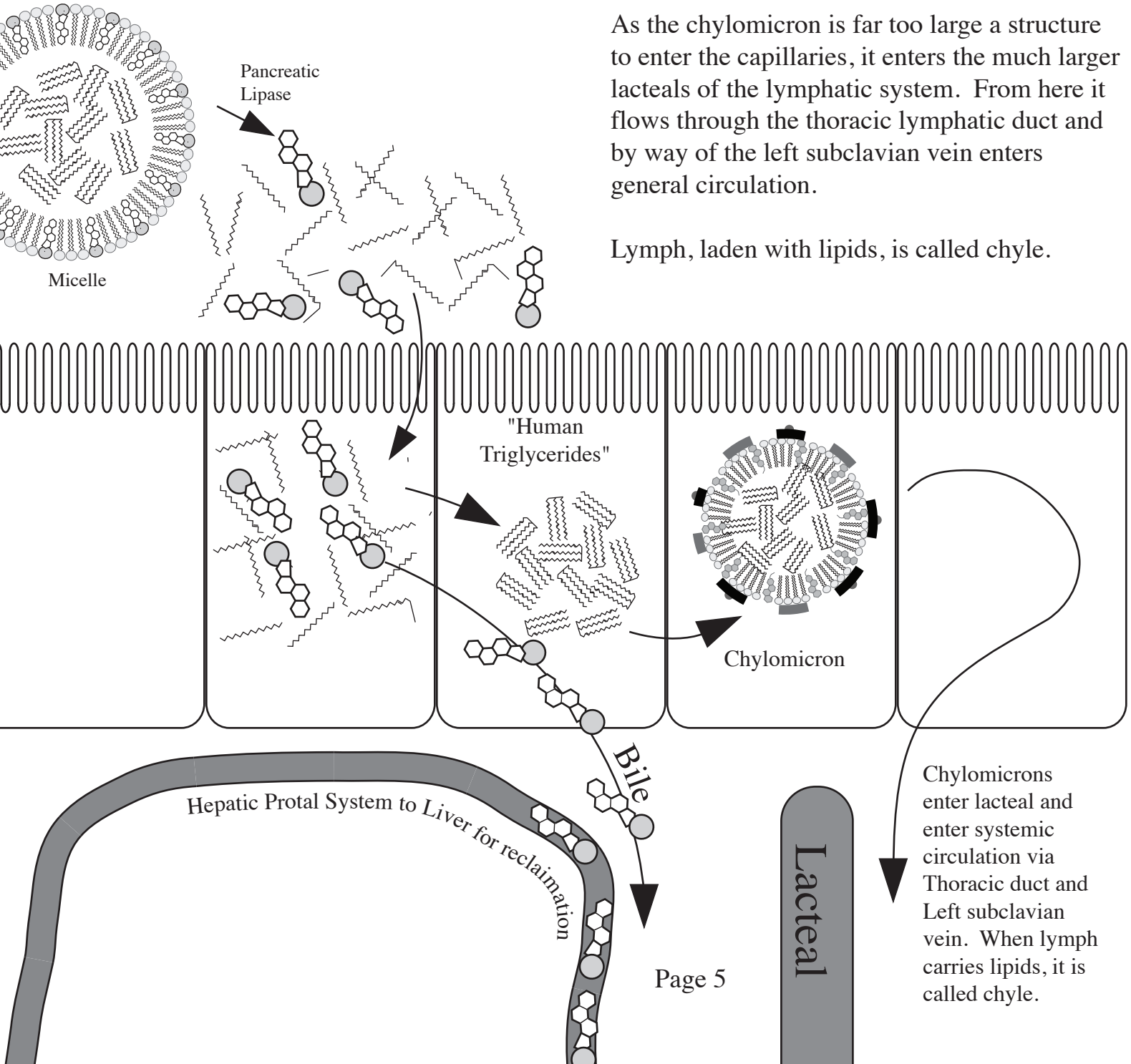


Absoprtion into columnar cells of small intestine

Processing of Lipids by Intestinal Mucosa and Enterohepatic Circulation

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

On the other hand, the lipid components are re-synthesized into "human triglycerides" within the cells of the small intestine, and then emulsified into a structure called a chylomicron. A chylomicron consists of phospholipid emulsifiers with embeded 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.

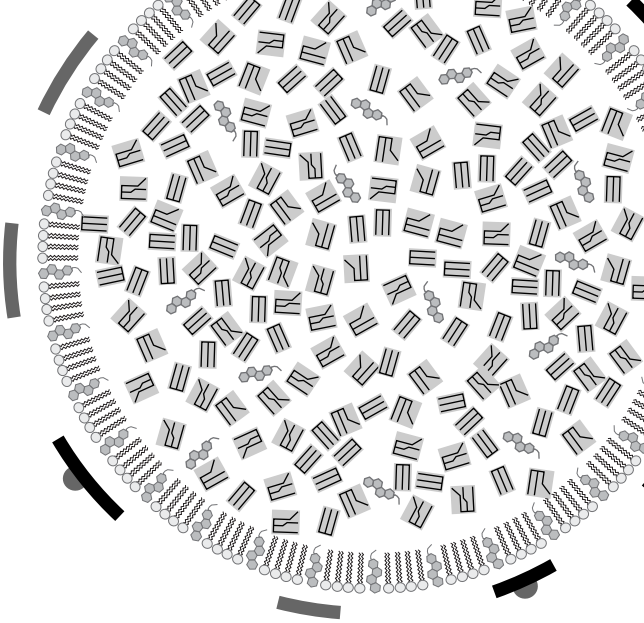


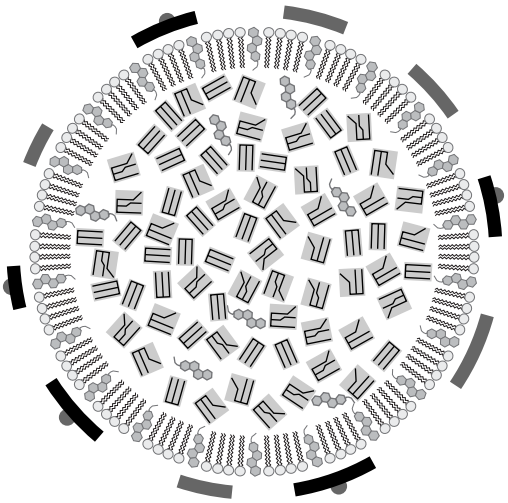
As the chylomicron is far too large a structure to enter the capillaries, it enters the much larger lacteals of the lymphatic system. From here it flows through the thoracic lymphatic duct and by way of the left subclavian vein enters general circulation.

Lymph, laden with lipids, is called chyle.

Chylomicrons enter lacteal and enter systemic circulation via Thoracic duct and Left subclavian vein. When lymph carries lipids, it is called chyle.

Cast of Characters in Lipid Transport





VLDL

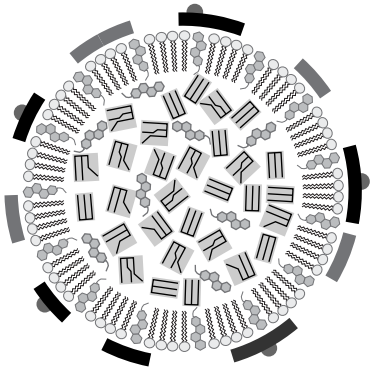
Triglyceride Rich
Cholesterol Poor

CHYLOMICRON

Triglyceride Rich
Cholesterol Poor

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

Illustrations and designations are relative, and not to scale.

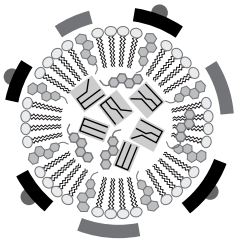


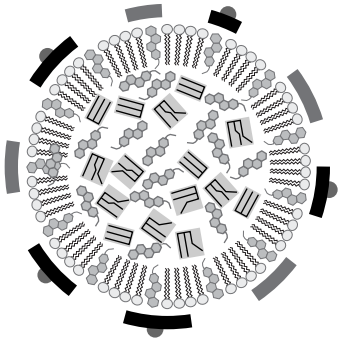
IDL

Triglyceride Moderate
Cholesterol Moderate

HDL

Triglyceride Poor
Cholesterol Moderate

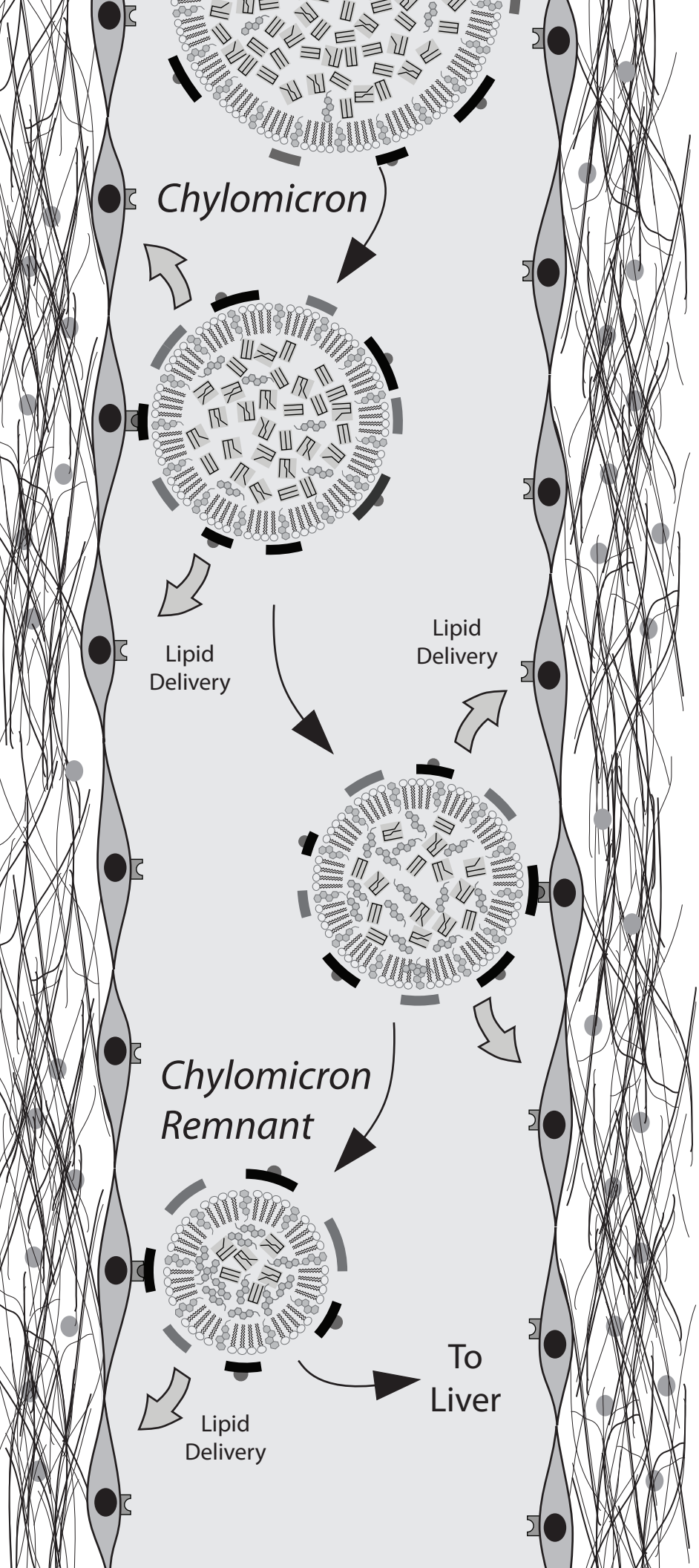




LDL

Triglyceride Poor
Cholesterol Rich

Resources:
Perspectives in Nutrition, 4th edition by Gordon M. Wardlaw
http://www.softchalk.com/lessonchallenge/lesson/Cholesterol/index.html

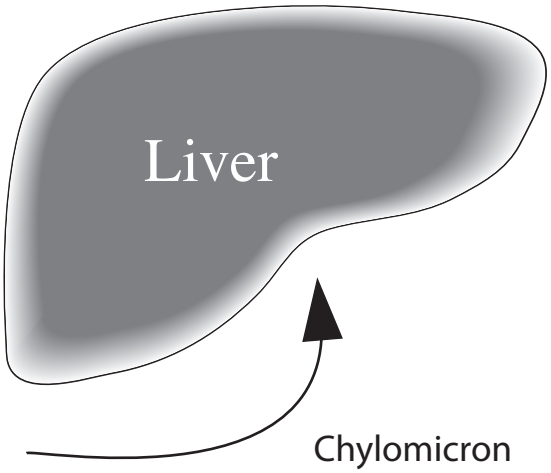


Lipid Transport
From Small Intestine

As the chylomicrons enter the circulatory system, they "feed" lipid components to capillary cells according to the needs of the adjacent tissues. More specifically, tissues that require lipids induce production of receptor/enzymes ( ) 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.

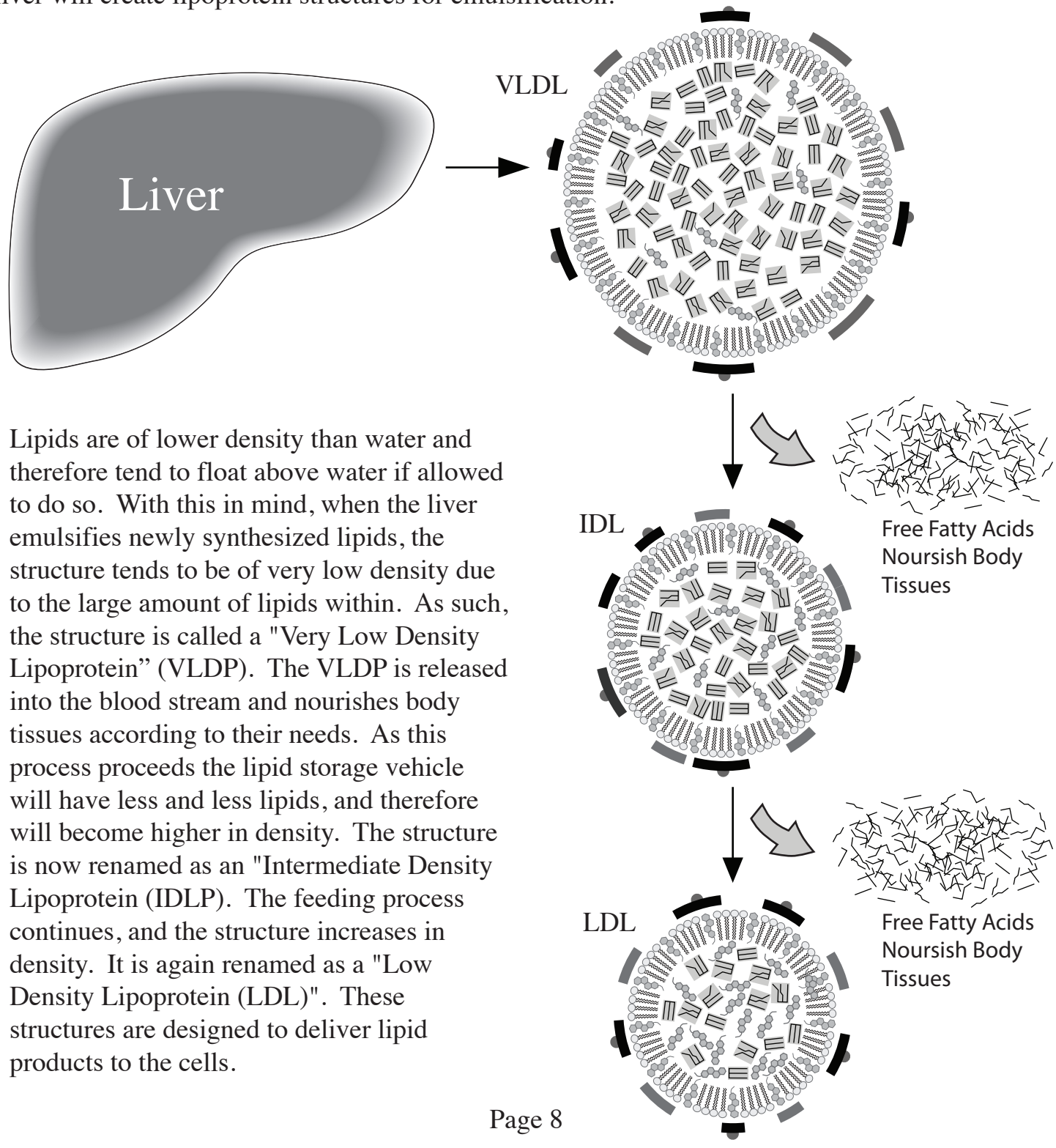


Chylomicron Remnant absorbed by liver for breakdown

Lipid Transport

From Liver to Interstitium

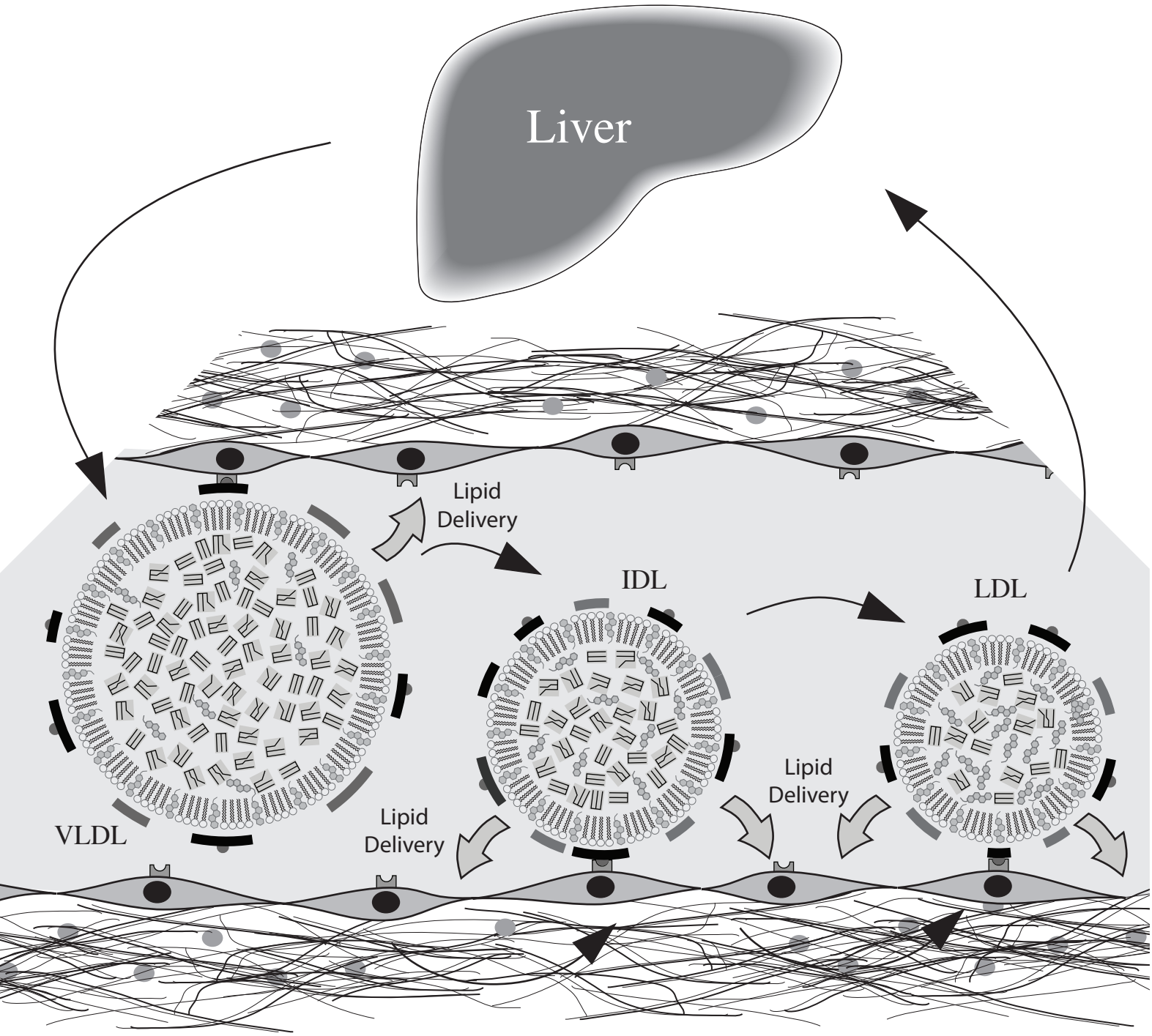
The Liver may be considered the "grand central station" of lipid metabolism; which will include the production of cholesterol, phospholipids, triglycerides, and bile salts. The liver will also store lipid soluble vitamins such as A, D, E, and K. When body tissues are in need of any such components or 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 the large amount 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 (IDLP). 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 capillary cells. 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 the by liver.



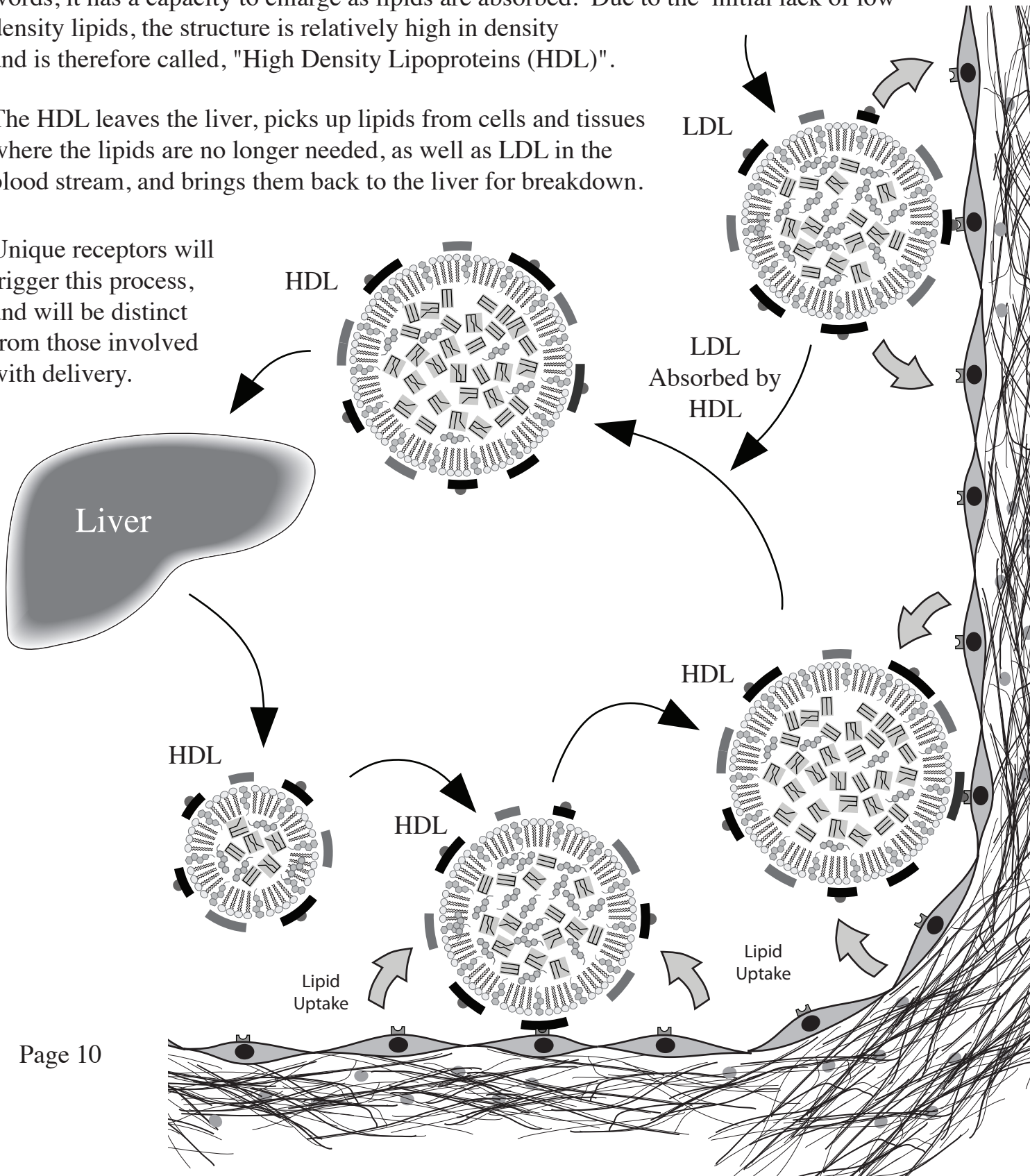
Lipid Transport

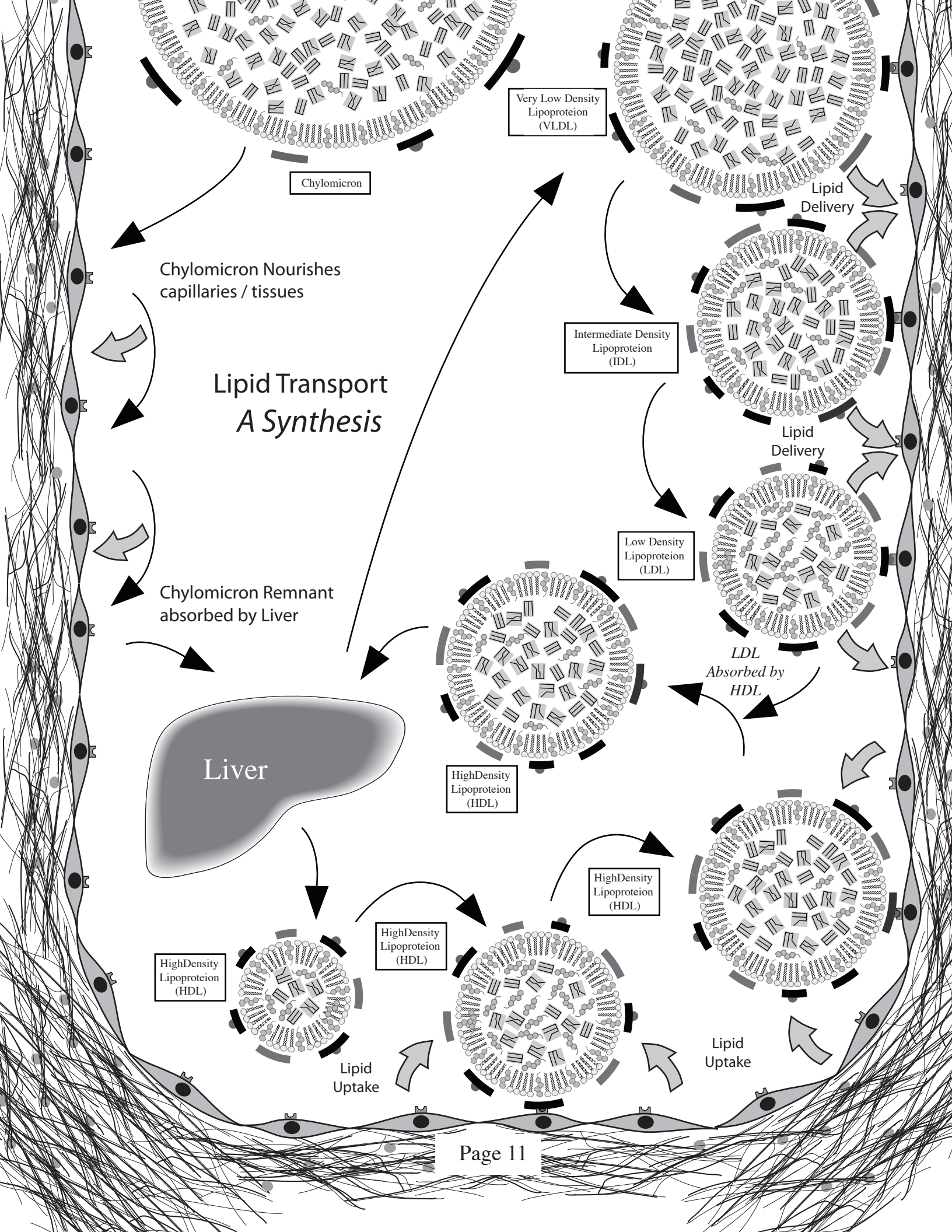
From Tissues to Liver

Whereas the low density lipoproteins are the means by which the liver transports lipid products to the tissues, the liver will likewise produce an 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 very less 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.




Chylomicron
Very Low Density Lipoproteion (VLDL)
Lipid Delivery
Chylomicron Nourishes capillaries / tissues
Intermediate Density Lipoproteion (IDL)
Lipid Transport
A Synthesis
Lipid Delivery
Low Density Lipoproteion (LDL)
Chylomicron Remnant absorbed by Liver
LDL Absorbed by HDL
Liver
HighDensity Lipoproteion (HDL)
HighDensity Lipoproteion (HDL)
HighDensity Lipoproteion (HDL)
HighDensity Lipoproteion (HDL)
Lipid Uptake
Lipid Uptake