Digestion and absorption of lipids

The average daily intake of lipids by adults is about 81 g, of which more than 90% is normally triacylglycerol. The remainder of the dietary lipids consists primarily of cholesterol, cholesteryl esters, phospholipids, and unesterified fatty acids.

*A/ processing of dietary lipid in the stomach

The digestion of lipids begins in the stomach, catalyzed by an acid stable lipase that originates from glands at the back of the tongue (*lingual lipase*). TAG molecules are primary target of this enzyme. These same TAGs are also degraded by a *gastric lipase*, secreted by gastric mucosa. Both enzymes are acid stable, with pH optimums of pH 4 to pH 6. These acid lipases play a particularly important role in lipid digestion in neonates, for whom milk fat is the primary source of calories. They are also important digestive enzymes in individuals with pancreatic insufficiency, such as those with cystic fibrosis. Lingual and gastric lipases aid these patients in degradation TAG molecules despite a near or complete absence of pancreatic lipase.

Cystic fibrosis: This is the most common lethal genetic disorder in Caucasians of Northern European ancestry. This disorder is caused by mutation to the protein that functions as a chloride channel on epithelium. Defective protein results in decreased secretion of chloride and increased reabsorption of sodium and water. In the pancreas, the decreased hydration results in thickened secretions such that pancreatic enzymes are not able to reach the intestine, leading to pancreatic insufficiency. Treatment includes enzyme replacement therapy.

*B/ emulsification of dietary lipid in the small intestine

The critical process of emulsification of dietary lipids occurs in the duodenum. Emulsification increases the surface area of the hydrophobic lipid droplets so that the digestive enzymes, which work at the interface of the droplet and the surrounding aqueous solution, can act effectively. Emulsification is accomplished by to complementary mechanisms, use the detergent mechanism of bile salts, and mechanical mixing due to peristalsis. Bile salts, made in the liver and stored in the gallbladder, are derivatives of cholesterol. These emulsifying agents interact with the dietary lipid particles and the aqueous duodenal contents, thereby stabilizing the particles as they become smaller, and preventing them from coalescing.

*C/ Degradation of dietary lipids by pancreatic enzymes

The dietary TAG, cholesteryl ester, and phospholipids are enzymatically degraded by pancreatic enzymes, whose secretion is hormonally controlled.

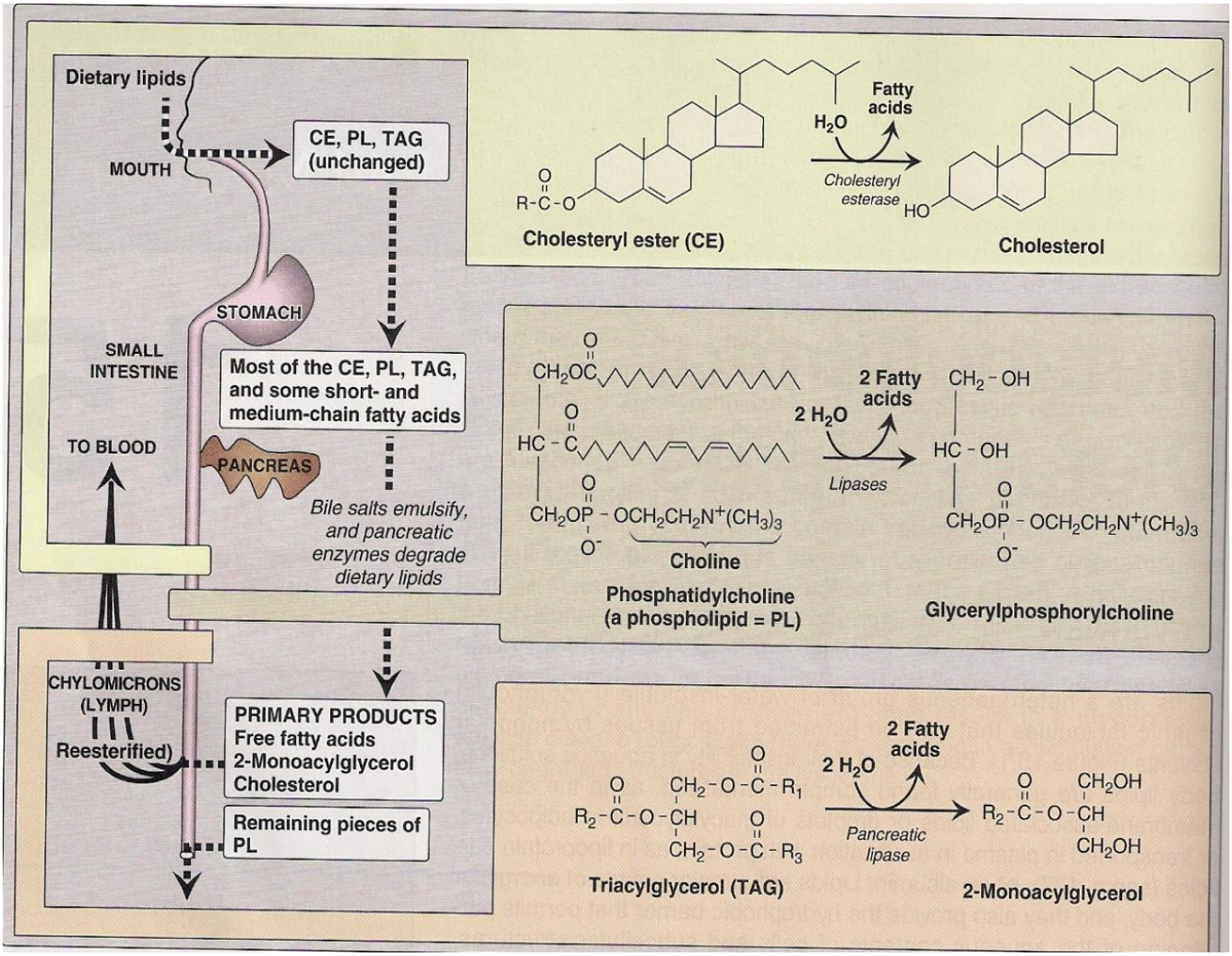
1/ TAG degradation: TAG molecules are too large to be taken up efficiently by the mucosal cells of the intestinal villi. They are therefore, acted upon by a pancreatic lipase, which preferentially removes the fatty acids at carbon 1 and 3. The primary products of hydrolysis are thus a mixture of 2-monoacylglycerol and free fatty acids.

Orlistat, an antiobesity drug, inhibits gastric and pancreatic lipases, thereby decreasing fat absorption, resulting in loss of weight.

2/ Cholesteryl ester degradation: Most dietary cholesterol is present in the free form, with 10-15% present in the esterified form. Cholesteryl esters are hydrolyzed by pancreatic cholesteryl ester hydrolase, which produces cholesterol plus free fatty acids.

3/ Phospholipid degradation

Pancreatic juice is rich in phospholipase which removes one fatty acid from carbon 2 of phospholipid, leaving a lysophospholipid. For example, phosphatidylcholine (the predominant phospholipid during digestion) becomes lysophosphatidylcholine. The remaining fatty acid at carbon 1 can be removed by lysophospholipase, leaving a glycerylphosphoryl base, (for example, glycerylphosphorylcholine, that may be excreted in feces, further degraded or absorbed.



Overview of lipid digestion

*Absorption of lipids by intestinal mucosal cells (enterocytes)

Free fatty acids, free cholesterol, and 2-monacylglycerol are the primary products of lipid digestion in the jejunum. These, plus bile salts and fat soluble vitamins, form mixed micelles-disk-shaped clusters of amphipathic lipids that coalesce with their hydrophobic groups on the outside. Mixed micelles, are therefore, soluble in aqueous environment of the intestinal lumen. These particles approach the primary site of lipid absorption, the brush border membrane of the enterocytes (mucosal cells). This membrane is separated from the liquid contents of the intestinal lumen by an unstirred water layer that mixes poorly with the bulk fluid. The hydrophilic surface of the micelles facilitates the transport of the hydrophobic lipids through the unstirred water layer to the brush border membrane where they are absorbed. Short and medium chain length fatty acids do not require the assistance of mixed micelles for absorption by the intestinal mucosa, therefore they are important in dietary therapy for individuals with malabsorption disorders.

Note: Relative to other dietary lipids, cholesterol is only poorly absorbed by the enterocytes.

*Lipid malabsorption

Lipid malabsorption, resulting in increased lipid (including the fat soluble vitamins A, D, E, and K, and essential fatty acids) in the feces (that is steatorrhea), can be caused by disturbance by lipid digestion and/or absorption. Such disturbances can result from several conditions, including CF (causing poor digestion) and shortened bowel (causing decreased absorption)

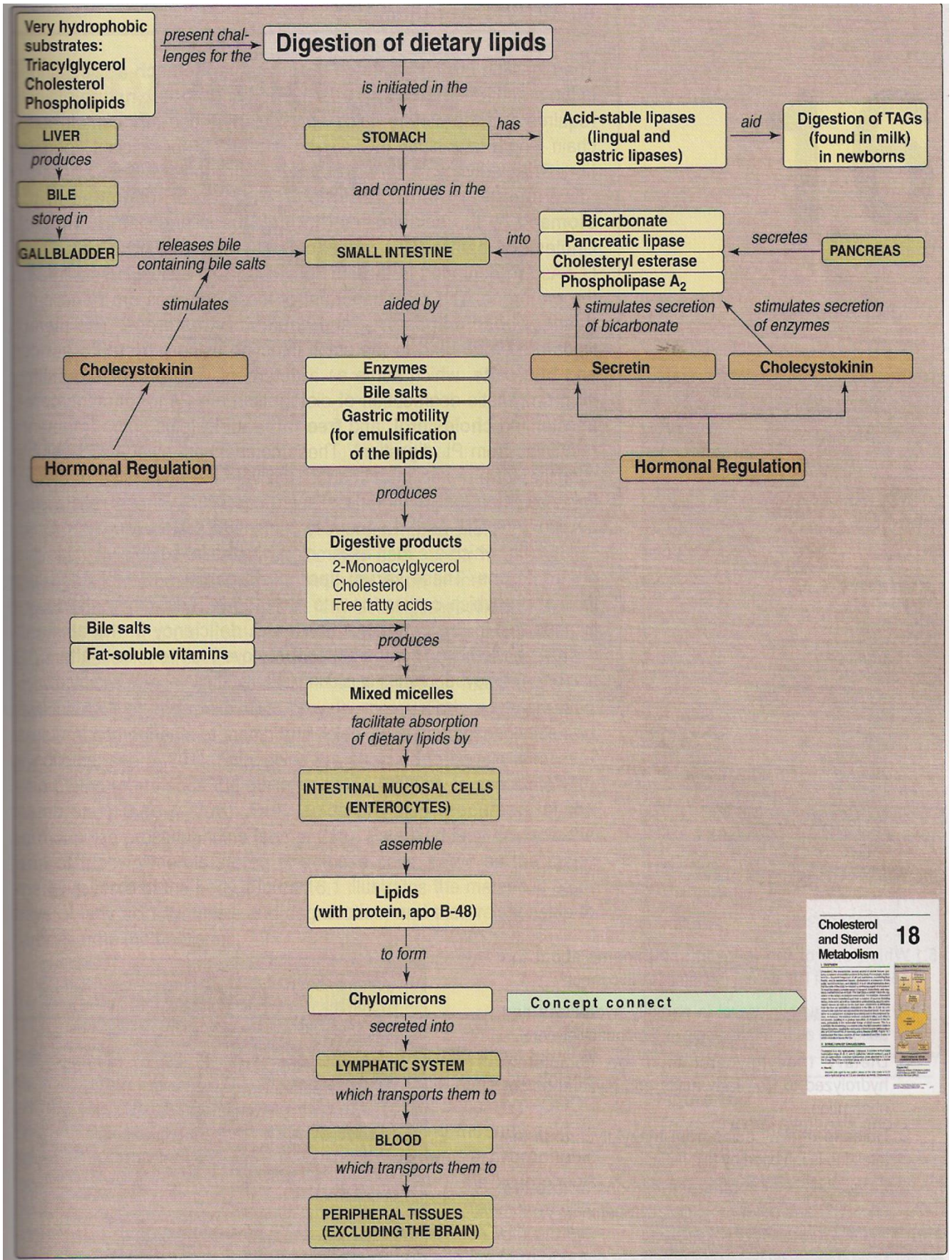


Figure 15.8
Key concept map for metabolism of dietary lipids. apo = apolipoprotein; TAGs = triacylglycerols.