Triglyceride Digestion and Absorption

- **Mouth**
  - *Lingual lipase* begins emulsification of lipids (negligible)
  - also emulsification from dietary phospholipids
  - emulsification especially important, because digestive secretions all water-based

- **Stomach**
  - Gastric lipase produced
  - Stomach churning helps to physically separate fats

- **Small intestine**: Primary site of fat digestion: broken down to *monoglycerides* and *fatty acids*
  - *Pancreatic lipase* (actually joins bile just before dumped into duodenum)
    - *CCK hormone* stimulates pancreas to release *pancreatic lipase*
    - Pancreatic *colipase* is released to help facilitate lipase enzyme action
  - Bile contains: salts, cholesterol and a phospholipid called *lecithin* -> major emulsification
    - *CCK* stimulates the release of *bile* to help emulsify fat

- **Phospholipid digestion**
  - broken into glycerol, fatty acids, phosphoric acid, other (e.g. choline)
  - enzyme = phospholipase from pancreas
**Lipid Digestion**

Large fat droplets enter intestine after meal

Bile acids & lecithin emulsify fats into smaller particles

Lipase breaks down fat into fatty acids & monoglycerides

MGs and FAs are absorbed through villi via micelles & then re-form into triglycerides

Triglycerides aggregate & are combined with cholesterol, protein & phospholipids to form chylomicrons

Bile acids from gall bladder

Lipase from pancreas

Bile acids from gall bladder

Lipase from pancreas

Glycerol

- goes directly into intestinal cells -> to bloodstream

Free fatty acids

- short chain and medium chain pass directly into intestinal cells (remember that cell membranes are lipid-based so lipids can pass through them -> to bloodstream

Monoglycerides and long-chain fatty acids

- surrounded by bile salts -> form MICELLES -> carry lipids to microvilli surface

  - they pass through cell membranes

  - bile salts return to lumen to pick up more fats

    - in ileum, bile salts absorbed and passed back through portal vein for recycling

  - one inside intestinal cells, monoglycerides and fatty acids reform triglycerides which are then absorbed by the lacteals
• reformed triglycerides, plus phospholipids and cholesterol packaged together to form CHYLOMICRONS

• Lipoproteins = packages of fat (must be packaged specially because fats are hydrophobic)
• chylomicrons are lipoproteins made by the intestine

**chylomicrons** carry reformed triglycerides and cholesterol with a protein rich “shell” made of phospholipids

• They enter the **lymphatic** system
  • travel through thoracic duct
  • eventually merge with subclavian vein in neck and get dumped into the general circulation at that point

• lipoprotein lipase lining blood vessels releases fatty acids from the chylomicrons, which can then be taken up by cells
  • most of the triglycerides are used up
  • whatever is left over goes to the liver
• VLDL - carries mostly triglycerides and a little Cholesterol made by the liver
  • lipoprotein lipase (from capillaries) breaks down some of the triglycerides
  • eventually becomes an IDL (intermediate density lipoprotein) - this returns to liver
    where it’s converted into LDL

• LDL - carries mostly cholesterol
  • this is what’s left over from the VLDLs after most of the triglycerides are gone
  • delivers cholesterol to cells (away from liver)
  • liver also has LDL receptors (good for controlling blood cholesterol levels)
    • NOTE: saturated fats appear to block cellular receptors for LDL (thus raising
      blood cholesterol)

• if LDLs are taken up by white blood cells (via “scavenger pathway”) - ultimately leads
  to atherosclerosis
  • WBCs bury themselves in blood vessels, oxidize the LDL - builds up plaque
    over time

• HDL - scavenges cholesterol from arterial plaques and dying cells - ultimately return
  cholesterol to liver
Sterol digestion & absorption

• little digestion
• poorly absorbed
  – dietary fat influence
  – dietary fiber influence

• sterols undergo little or no digestion
  • sterol esters (sterols with fatty acids attached) are broken into sterol + fatty acid

• poor absorption
  • usually only absorb ~50% dietary cholesterol
    • if increase dietary cholesterol, will absorb <50%
  • if ingested with other dietary fat, increases absorption
  • if ingested with dietary fiber or plant sterols, decreases cholesterol absorption

• Cholesterol is made in adequate quantities by the liver and is NOT an essential nutrient
What the heck is Olestra®?

- Olestra = “Olean”
- fat replacement molecule
- same sensory qualities as triglycerides, can withstand high temperatures
- rather than glycerol backbone, has SUCROSE backbone
  - 6 - 8 fatty acids attached instead of 3
  - NO ENZYME FOR US TO DIGEST THIS
  - goes right through- YAH REALLY!!
- problem - also prevents us from absorbing fat soluble vitamins
• this is based on Dietary Guidelines for Americans
• another plan: NCEP’s Therapeutic Lifestyle Changes
• [NCEP = National Cholesterol Education Program]
  • recommend <200 mg cholesterol qd
  • allows up to 35% total calories from fat but <7% saturated
    • LOWERING SATURATED FAT INTAKE HAS GREATEST EFFECT ON BLOOD
      CHOLESTEROL
  • only ~5% intake needs to come from essential fatty acids (two servings/week of fish is enough)
• used to advise eating lots of polyunsaturated fats - not anymore! Also tends to lower HDL
• currently advise MONOunsaturated - doesn’t lower HDL cholesterol but DOES help lower total and LDL levels

•Recommended intake
  • Reduce saturated and trans fat intake
  • Total fat: 20-35% of calories
  • Need ~ 2% of calories as essential fatty acids
  • Improve balance of
    omega-3: omega-6 fatty acids
Risks associated with high dietary fat intake

• Obesity

Obesity
• excessive accumulation of body fat
  • BMI $\geq 30$ or $>20\%$ above range on height-weight table
• est. 55% Americans overweight - obese
• excess fat intake contributes - fat is calorie-dense, often hidden in foods
• obesity itself linked to disease - hypertension, heart disease, stroke, diabetes, cancer, sleep apnea, osteoarthritis, gout, gallbladder disease
• overweight = BMI 25-29.9
Risks associated with high dietary fat intake

• **Heart disease**
  – Saturated fats!

- Hypercholesterolemia principal risk factor for CVD (b/c promotes atherosclerosis)
- High LDL and low HDL are risk factors
- Elevated blood triglycerides are associated with low HDLs
HEART DISEASE
Risks associated with high dietary fat intake

- Cancer? 
  - evidence inconclusive

\[ \uparrow \text{fat intake} \rightarrow \text{obesity} \rightarrow \text{cancer} \]

- Cancer: link?
- higher CA rates in countries with higher fat consumption
  - more related to calorie intake? Not sure - seems to be more related to body fat than caloric intake
TEXT pages 122-123

• Glycerol
  • liver can convert into glucose or pyruvate (for processing via glycolytic pathways)
  • relatively small amount of energy

• fatty acids
  • transported to mitochondria by CARNITINE
Lipid catabolism: beta-oxidation

- Catabolism of fatty acids = “beta-oxidation”
- Enzymes snip off two carbons at a time
  - Results in acetyl CoA -> feeds into Kreb’s cycle
  - Also produces lots of reduced electron carriers (NADH and FADH2)
- One 18-C fatty acid yields ~120 ATP (so a triglyceride would yield 360 ATP)
Lipid anabolism

- lipogenesis
- storage

Text page 124

- can make long chain fatty acids and combine them to form triglycerides = lipogenesis
- mostly happens in liver
- excess carbs and proteins can be converted to triglycerides
- Requires ATP, biotin, niacin and pantothenic acid

- essentially reversal of beta-oxidation but different enzymes, occurs in cytosol rather than mitochondria
- storage form of fat = triglyceride in adipose