• Chapter 5
• The Lipids—Triglycerides, Phospholipids, and Sterols

**The Lipid Family**

**Triglycerides (fats and oils)**
- Predominate in the body (99%) and in foods (95%)
- Composed of Carbon, Hydrogen and Oxygen
  - 9 kcalories per gram

**Phospholipids (such as lecithin)**

**Sterols (such as cholesterol)**

**Chemist’s View of Fatty Acids and Triglycerides**

1. Composed of glycerol + 3 fatty acids
2. Fatty acids may be 4-24 carbons long
   - Even numbers
   - 18 carbons fatty acids most common
3. Saturated or Unsaturated
   - monounsaturated or polyunsaturated
4. Omega-3 and Omega-6 fatty acids are of importance in nutrition.
5. Essential Fatty acids include:
   - Omega-3-linolenic
   - Omega-6 linoleic

**What is a Fatty Acid?**
- Composed of a chain of carbon atoms with hydrogens attached
- Have an acid group at one end and a methyl group at the other end.
- A Fatty Acid

Stearic acid, an 18-carbon saturated fatty acid.

Stearic acid (simplified structure).

**Fatty Acids**

**Chain Length**
- Long-chains are 12 - 24 carbons in length
  - common in meats, fish and vegetable oils
- Medium chains are 6 - 10 carbons
  - coconut and palm oils
- Short chains are < 6 carbons
  - dairy products
- Saturation

**Saturation**
- Saturated fatty acid: contains the maximum possible number of hydrogen atoms
- Stearic acid; 18 carbon saturated fatty acid
- Degree of Unsaturation
• Unsaturated fatty acid:
  – has some hydrogen atoms missing and therefore has at least 1 double bond
• Monounsaturated fatty acid:
  – has 1 double bond (missing 2 hydrogen atoms)
    – oleic acid found in olive oil and canola
• 18 carbon monounsaturated fatty acid; oleic
• Degree of Unsaturation
• Polyunsaturated fatty acid:
  – has 2 or more double bonds
  – linoleic acid has 2
  – linolenic acid found in soybean oil has 3
• 18 carbon polyunsaturated fatty acid
  – linoleic acid
  – found in corn, safflower, sunflower, and soybean oils
• Location of the Double Bonds
  Omega Number
  – Polyunsaturated acids are identified by the location of their double bond:
    – The omega number indicates the position of the 1st double bond in a fatty acid
      – counting from the CH₃ group (methyl group)
• Triglycerides
  – a glycerol molecule
  – 3 fatty acids
• The 3 fatty acids
  – Can be mixed with both saturated and unsaturated
  – A Mixed Triglyceride
• fatty acids (18-c saturated) stearic acid
• Glycerol fatty acids (18-c monounsaturated) oleic
• fatty acids (18-c polyunsaturated) linoleic

Degree of Unsaturation
  Firmness
  Degree of saturation influences firmness at room temperature
  – More saturated fats are solid at room temperature
  – Animal fats (fat on the meat and fat in dairy)
  – Tropical Oils – palm oil, palm kernel oil, coconut oil, cocoa butter
    – Softer due to shorter carbon chain
• Degree of Unsaturation
  Firmness
  • Unsaturated:
    • Liquid at room temperature.
    • Polyunsaturated vegetable oils
• Vegetable oils make up most of the added fat in the U.S. diet
• Fast-food chains use them for frying
• Food manufacturers add them to processed foods
• Degree of Unsaturation

Stability:
– Fat becomes spoiled when exposed to oxygen
– Particularly polyunsaturated
– Saturated fats are most resistant to oxidation

To prevent rancidity food companies:
– Use air-tight seals and refrigeration
– Antioxidants are added - BHA, BHT, Vitamin E
– Hydrogenation

• Degree of Unsaturation
• **Hydrogenation:**
  The process of adding hydrogen to unsaturated fatty acids to make the fat more solid and resistant to the chemical change of oxidation
  – Protects against oxidation
  – Alters texture of the food by making liquid vegetable oils more solid
• Hydrogenation
• Cis- and Trans-Fatty Acids Compared
• Hydrogenated Vegetable Oil
• Hydrogenation
  – Prevents spoilage of unsaturated fats
  – Hydrogenated oil is used in frying
    • Can be heated to high temperature
  – Easy to handle, easy to spread
  – Once fully hydrogenated, an oil loses both its unsaturated character and health benefits
• **Trans** Fatty Acids
• **Trans-Fatty Acids:**
  – Similar in shape to saturated fatty acid
    • Not made by the body
    • Naturally occur in tiny amounts mainly in dairy foods and beef
    • Trans Fatty Acids act like saturated fatty acids in the body.
• **Trans** Fatty Acids
• **Trans** fats and margarine
  – The stick varieties, especially, contain almost 50% of their fat as trans fat
  – Many other foods contribute a greater percentage of trans fat to the diet
• Major Source of Trans Fats in the U.S. Diet
• Phospholipids
• Phospholipids are soluble in both water and fat
– Cell membranes
  – Help lipids move across cell membranes, such as vitamins, and hormones
  – Emulsifiers-keep fat suspended in body fluids

• Phospholipids
• Phospholipids in food
  – Found in foods such as eggs, liver, soybeans, wheat germ, peanuts
  – Used in food industry as emulsifiers (salad dressings)

• Sterols
  • Sterols in Food:
    – Most common one is cholesterol;
      • Found only in foods of animal origin
      • meat, eggs, fish and poultry, dairy
    – Plant sterols (phytosterols)
      • Naturally found plants but in very low levels
      • Plant sterols block cholesterol absorption
      • Plant sterols have been added to common foods such as vegetable oil spreads, dairy drinks, snack bars
    – Sterols

• Roles of sterols:
  – Bile acids
  – Sex hormones
  – Adrenal hormones
  – Vitamin D
  – Cholesterol (component of cell membranes)
    • Made in the liver
• Cholesterol can be used as the starting material to make these compounds
• Cholesterol and Vitamin D3
• Cholic Acid and the Sex Hormones
• Emulsification of Fat by Bile
• Hydrolysis of a Triglyceride
• Absorption of Lipids
• Absorption of Fat
Micelle
Fat Absorption
Lipid Transport

**Chylomicrons:**
- Largest & Least Dense
- Transport diet derived lipid (Trig) from the intestine, through the lymph, to the blood and the rest of the body
- As chylomicrons pass through bloodstream, cells remove lipids from them
- Liver cells remove the remnants from the blood and reassemble them into new triglycerides
- Size Comparisons of the Lipoproteins
- Lipid Transport

**VLDL:**
- Very Low Density Lipoprotein
- Transport mainly triglyceride (50%)
- Made in Liver.....The most active site of Lipid Synthesis
- As VLDL travel throughout the body, cells remove triglyceride
- As they lose triglyceride, the proportion of cholesterol increases and they become LDL.
- Lipid Transport

**LDL: “Bad Cholesterol”**
- Low Density Lipoprotein
- Composed primarily of cholesterol
- Circulate throughout the body and release triglyceride, cholesterol and phospholipid to body cells.
- Body cells collect the lipids and use them to make cell membranes, hormones, or store for later use.
- Liver removes LDL from circulation
- Often termed “Bad Cholesterol” because this is the lipoprotein that is linked to heart disease.
- Lipid Transport

**HDL: “Good Cholesterol”**
- High Density Lipoprotein
- Transports cholesterol and phospholipids from the cells back to the liver for recycling or disposal

Lipoproteins with a low protein-to lipid ratio have a low density: those with a high protein-to-lipid ratio have a high density
- The Lipoproteins Compared
- Lipid Transport
- Health Implications
- Factors that lower LDL and or Raise HDL
  - Weight control
  - Mono or polyunsaturated fat instead of saturated
  - Soluble fiber
  - Physical Activity
Moderate Alcohol
• The Usefulness of Fats
• Essential Fatty Acids

Fatty acids that the body cannot make or cannot make in sufficient quantities

**Linoleic Acid**
• Omega-6 fatty acid
• Found in plant and animal sources
• Vegetable Oils, Meats, Fish
• With adequate linoleic acid, the body can make other members of the omega-6 family (such as arachidonic)
• Essential Fatty Acids

**Linolenic Acid**
• Omega-3 fatty acid; must be supplied by food
  – Canola, Soybean, Nuts, Seeds
  – Fish Oils-Salmon, Mackerel, Menhaden, Tuna, Sardines, and Lake Trout
• Essential for normal growth and development, especially eyes and brain
• May help with prevention and/or treatment of heart disease, hypertension, arthritis, and cancer.
• Omega -3 Fatty Acids
• With adequate linolenic acid, the body can make other members of the omega-3 family such as:
  – DHA: docosahexaenoic acid
  – EPA: eicosapentaenoic acid
    • Used to make “eicosanoids” - biologically active compounds
    • Help lower blood pressure
    • Prevent clot formation
    • Protect against regular heartbeats
    • Reduce inflammation
• Essential Fatty Acids

**Fatty Acid Deficiency**
• U.S. diets meets essential fatty acid needs
• Historically, deficiencies developed in children fed fat-free milk or in hospitalized patients fed fat free formulas
  • Symptoms:
  Growth retardation
  Reproductive Failure
  Skin lesions
  Kidney Disease
  Neuro and visual problems
• Lipid Metabolism

**Storing Fat as Fat:**
• Fat is stored as triglyceride in adipose tissue.
• Adipose tissue has an unlimited capacity to store fat.
• Lipoprotein Lipase-An enzyme on the surface of the adipose cell that hydrolyzes the triglycerides to fatty acids and monoglycerides and passes them into the cell.
• Inside the cell the pieces are reassembled into triglyceride for storage or energy use
• Adipose Tissue
• Lipid Metabolism

Making Fat from CHO or Protein:
• Fat can be made from 2-carbon fragments from carbohydrate or protein
• Requires energy

Making Fat from Fat:
• Most efficient
• Fat is eaten as triglyceride and stored as triglyceride
• Lipid Metabolism

Using Fat for Energy:
• Fat provides 60% of energy needs during rest
• Glycerol and fatty acids are released directly into the bloodstream.
• 1 pound of fat = 3500 kcal.
• Only the glycerol portion of triglyceride can be converted to glucose for brain, nerve and RBCs
  – the fatty acids cannot be converted to glucose.

• Health Effects of Lipids

Heart Disease
• Leading cause of death in adults
• Elevated cholesterol is a major risk factor for heart disease
• Cholesterol based plaque buildup restricts and blood flow and raises blood pressure
• Saturated fats raise LDL cholesterol levels much more dramatically than food cholesterol.
• Health Effects and Recommended Intakes of Lipids
• Health Effects of Lipids
  – Blood lipid profile
    • Reveals concentrations of lipids in the blood
    • Desirable levels
    – Total cholesterol < 200 mg/dL
    – LDL cholesterol < 100 mg/dL
    – HDL cholesterol ≥ 60 mg/dL
    – Triglycerides < 150 mg/dL
• Health Effects of Lipids

Risks from Saturated Fats
• Saturated fats raise LDL Cholesterol
• LDL Cholesterol raises heart disease risk
• The more saturated fat in the diet, the more LDL
• Sources of Saturated fats:
  – Whole milk, cream, butter, cheese
  – Fatty cuts of beef and pork
  – Coconut, palm and palm kernel oils-candies, pastry, pies, doughnuts, cookies
• Health Effects and Recommended Intakes of Lipids
• Risks from *Trans* Fats
  • *Trans*-fatty acids in the diet
    – increase LDL cholesterol and decrease HDL cholesterol.
  • Food sources include deep-fried foods using vegetable shortening, cakes, cookies, doughnuts, pastry, crackers, snack chips, margarine, imitation cheese, and meat and dairy products.
  • Butter versus margarine
    – Soft – liquid or tub
    – *Trans fat free*
    – Liquid vegetable oil as 1st ingredient
    – <2 grams saturated fat
• Health Effects of Lipids
• Risks from Cholesterol
  – Raises blood cholesterol
    • Dietary cholesterol has less effect on cholesterol level
  – Increases heart disease risk
  – Food sources of cholesterol include:
    • egg yolks, milk products, meat, poultry and shellfish.
• Health Effects of Lipids
• Benefits of Mono and Polyunsaturated Fats
  – Replace both saturated and *trans* fats with monounsaturated and polyunsaturated fats
  – Monounsaturated
    • Olive oil, canola oil, peanut oil, avocados
  – Polyunsaturated
    • Safflower, sesame, soy, corn, sunflower oils, nuts, seeds
• Health Effects of Lipids

**Benefits from Omega-3 Fatty Acids**
Reduced risk of heart disease and stroke
  – Diets high in fish oils (ie, salmon, tuna) decrease cholesterol levels
  – Helps prevent blood clots, lowers blood pressure
  – Sources include canola, soybean, flaxseed oils, walnuts, fatty fish (mackerel, salmon, sardines)
• Health Effects of Lipids
• **Balance Omega-3 & Omega-6 Intakes**
• Eat more fish & less meat
• Two 3 ounce servings of fish per week
• Routine fish oil supplements are **not** recommended:
  ~ Can increase bleeding time
  ~ Can interfere with wound healing
  ~ Impairment of immune function
• May be beneficial in people with heart disease (consult MD first)
• Health Effects of Lipids

Cancer
• Does not seem to initiate cancer but may promote it once it has arisen
• Colon Cancer- associated with animal fat
• Breast Cancer-association is unclear
• Health Effects of Lipids

Obesity
• Fat 2 x kcal of Protein or Carbohydrate
• High fat diets may exceed energy needs and lead to weight gain
• Health Effects and Recommended Intakes of Lipids

Recommended Intakes of Fat
– The DRI and the Dietary Guidelines recommend:
  • fat at 20-35% of energy intake (400-700 kcalories of a 2,000-kcalorie diet).
– FDA Daily Values recommends:
  • limiting 10% of energy intake from saturated fat
  • 30% of energy intake total fat
– Daily Value for cholesterol is 300 mg per day
• Health Effects and Recommended Intakes of Lipids

Recommended Intakes of Fat
– Daily Values
  • 65 g fat based on 30% of 2000-kcal diet
  • 20 g saturated fat based on 10% of 2000-kcal diet
  • 300 mg cholesterol
– USDA Food Guide considers saturated fats discretionary kcalories.
– Too little fat can be detrimental to health.

• Recommended Intakes

Provide 20-35% of your daily energy intake as fat
• Decrease fat as a seasoning
• Remove fat from high fat foods
• Use low fat alternatives
• Reduce fat from animal sources and processed foods
• Reduce saturated fat to < 10% of energy intake

Reduce Cholesterol Intake to Less than 300 mg per Day
• Less fat from animal products
• From Guidelines to Groceries
• Choose fat-free and low-fat milks and milk products
• Vegetables, fruits, and grains
  • Lowers consumption of various fats in the diet
• Invisible fat
  • Fried and baked goods
• Choose wisely
  • Unprocessed foods
• Fat in Ground Meats
• Fast Food: Breakfast/Pizza Choices
• Fast Food: Taco/Burger Choices

• Counting College Calories
• Krispy Creme glazed doughnut: 200 Kcal 12 g fat
• Starbucks Grande Frappuccino: 270 Kcal 4 g fat
• McDonald’s Big Mac: 530 Kcal 33 g fat
• Super size fries: 610 Kcal 29 g fat
• Jack in Box taco: 170 Kcal 9 g fat
• Subway steak and cheese: 412 Kcal 18 g fat
• 2 large pieces of Dominos pizza pepperoni 614 kcal 24 g fat

• Health Effects and Recommended Intakes of Lipids
• Guidelines to Groceries
  – Fat Replacers
    • Ingredients derived from carbohydrate, protein or fat
    • Replace fat in foods
    • Artificial fats offer sensory and cooking qualities but no kcalories.
    • Research on olestra supports its safety but it decreases the absorption of fat-soluble vitamins and may cause digestive distress in some consumers.

• Fat Replacers
  Olestra:
  Artificial fat.
  Sucrose molecule with 6-8 fatty acids attached
  Digestive enzymes are unable to break bonds.
  Passes through undigested.
  Looks, feels, tastes like fat
  High heat stable-fry, cook, bake
  Provides 0 kcal.
  Used in snack foods, chips, crackers
  May cause digestive distress: cramps, bloating, gas, diarrhea, fecal urgency, and anal leakage.
• Calculate Personal Daily Value for Fat

1800 total kcal X 0.30 from fat = 540 kcal

540 fat kcal

9 kcal/g = 60 g fat

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• Alternatives to Fat

Problems with Olestra:

Binds with fat soluble vitamins (A, D, E, K)

Vitamins are unabsorbed.

To compensate - Olestra is fortified with fat soluble vitamins to saturate its bonds and avoid binding with vitamins in the body

May cause digestive distress: cramps, bloating, gas, diarrhea, fecal urgency, and anal leakage.

• Alternatives to Fat

Oatrim: Made from digestible oat fiber

Forms a gel when water added

Heat stable-used in baking (not frying)

4 kcal/gram

Used in ice cream, frozen desserts

salad dressing and mayonnaise

Z-Trim: Made from crushed hulls of grain

Insoluble fiber-passes undigested

0 kcal, adds fiber

Used in baked goods, cheeses, meats and milks

• Alternatives to Fat

Simplesse: Made from egg white or milk protein

Gels at high temps

OK for baking, not frying.

Provides 1-2 kcal/g

Used in frozen desserts, cheese, yogurts, salad dressing, coffee, coffee creamer, and pastries

Salatrim: Fat Based (short & long chains f.a.)

5 kcal/gram

OK baking, not frying

• Alternatives to Fat

Caprein: Triglyceride made with short chain acids and
one long chain fatty acid
5 kcal/g
Used in chocolate, confections, cookies crackers, sour cream, frozen desserts.

Olestra: Artificial fat.
Sucrose molecule with 6-8 fatty acids attached
Digestive enzymes are unable to break bonds.
Passes through undigested.
Looks, feels, tastes like fat
High heat stable-fry, cook, bake
Provides 0 kcal.
Used in snack foods, chips, crackers