Organic Compounds

What does organic mean?
- We think of organic produce
  - “natural”
- In biology organic refers to molecules of one or more elements covalently bound to one or more carbon atoms
- Chemists thought of organic as coming from plants and animals and inorganic coming from minerals

Outline
- Organic compounds - definition
- Functional Groups
- Biological Molecules
  - Carbohydrates
  - Lipids
  - Amino acids and Proteins
  - Nucleotides and Nucleic Acids (DNA, RNA)

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Carbon

- Carbon has four electrons in its outer shell. It needs eight electrons to be stable
- So, carbon can form up to four covalent bonds.
- Carbons can link together to form a backbone – many other elements can bond to this backbone

Polar functional Groups

- Oxygen containing:
  - Carboxyl = - COOH
  - Hydroxyl (alcohol) = - OH
  - Phosphates = - PO₄
  - Carbonyl
  - Ketone = - CO
  - Aldehyde = - CHO
- Nitrogen containing: Amino (-NH₂)
- Sulfur containing: -SH

Types of Organic Compounds

- Carbohydrates – monosaccharides, disaccharides, polysaccharides
- Lipids – triglycerides, phospholipids, steroids,
- Proteins – Made of amino acids
  - enzymes, channels, pores, transporters, regulatory, structural, eg. keratin, collagen, actin
- Nucleic Acids – Made of Nucleotides
  - DNA & RNA

Macromolecules

- Large molecules are called macromolecules
- Macromolecules that are composed of small, repeated molecules are called polymers.
- The small molecules that form the polymers are called monomers

Biological molecules - functional groups

<table>
<thead>
<tr>
<th>Table 3.1 Functional groups</th>
</tr>
</thead>
<tbody>
<tr>
<td>Group</td>
</tr>
<tr>
<td>Carbonic acid (substance)</td>
</tr>
<tr>
<td>Hydrogen (substance)</td>
</tr>
<tr>
<td>Amine (substance)</td>
</tr>
<tr>
<td>Phosphate (substance)</td>
</tr>
</tbody>
</table>

Macromolecules

- Large molecules are called macromolecules
- Macromolecules that are composed of small, repeated molecules are called polymers.
- The small molecules that form the polymers are called monomers
Carbohydrates

- Contain Carbon, Hydrogen, and Oxygen in a $C_6H_{12}O_6$ ratio for example glucose = $C_6H_{12}O_6$

Simple Carbohydrates
- monosaccharide (one sugar)
- disaccharides (two sugars)

Complex carbohydrates – polysaccharide (many sugars)

Macromolecules – Polymers

- When polymers are made, water is removed, and the reaction is called dehydration synthesis

Polymers - dehydration

- Conversely, when the polymers are broken apart, water is added and the reaction is called hydrolysis

Simple Carbohydrates

- Rapidly Mobilized Source of Energy
  - Glucose
- Energy storage
  - Glycogen (in animals) and Starch (in plants)
- Structural
  - In cell walls bacteria and plants (Cellulose).
- Coupled with protein to form glycoproteins
  - In cell membranes

Complex Carbohydrates

- Polymers
- Monomer of carbohydrate is glucose

Functions of Carbohydrates

1. Rapidly Mobilized Source of Energy
   - Glucose
2. Energy storage
   - Glycogen (in animals) and Starch (in plants)
3. Structural
   - In cell walls bacteria and plants (Cellulose).
4. Coupled with protein to form glycoproteins
   - In cell membranes
Simple Carbohydrates: Function

- Rapidly Mobilized Source of Energy

Glucose Ring Structure

Simple Carbohydrates - Glucose

Simple Carbohydrates - Disaccharides

Lactose Intolerance

- Lactose is a disaccharide made of glucose + galactose.
- The enzyme lactase breaks lactose into the two monosaccharides.
- Some people lack this enzyme and lactose is not digested, it enters the large intestine and is broken down by bacteria, which produce gas and lactic acid
- Symptoms include: cramps, bloating, flatulence & diarrhea

Complex Carbohydrates

Complex Carbohydrates - Functions

1. Energy storage
   - Glycogen (in animals)
   - Starch (in plants)

2. Structural
   - In cell walls bacteria and plants (Cellulose)

Structure of Complex Carbohydrates

- Polysaccharides - Long chains of saccharides (sugars) – 100s to 1000s
  - Monomer: glucose
  - Polymer: Starch, glycogen, cellulose

Structure of Complex Carbohydrates

- The differences between the complex carbohydrates is in the structure: branched, unbranched, coiled, hydrogen-bonded.
  - Cellulose is tightly packed, uncoiled and hard to digest
  - Starch is coiled and may be branched and is easier to digest
  - Glycogen is coiled with extensive branching and is even easier to digest.
**Glycogen**

- **Function:** Carbohydrate stored in animals for energy
- **Structure:** Coiled and branched
- **Very easy to digest (break down)**
- **Stored mainly in liver and muscle**

**Starch**

- **Function:** Carbohydrate stored in plants for energy
- **Stored in structures in the plant cell called:** amyloplasts
- **Structure:** Coiled may have some branching
- **Used for energy**
- **Examples of plants that are high in starch:** Potatoes, rice, carrots, corn

**Cellulose**

- **Structure:** Hydrogen bonds stabilize chains into tight bundles
- **Function:** Carbohydrate used by plants for structure
- **Humans don't have the enzyme that breaks cellulose down into individual glucose molecules.**
- **Important for fiber in our diet**

**Table 2.4 Complex Carbohydrates**

<table>
<thead>
<tr>
<th>Carbohydrate</th>
<th>Monomer</th>
<th>Molecule Formula</th>
<th>Source</th>
<th>Function</th>
</tr>
</thead>
<tbody>
<tr>
<td>Starch</td>
<td>Glucose</td>
<td>C6H12O6</td>
<td>Potatoes, rice, corn</td>
<td>Energy storage</td>
</tr>
<tr>
<td>Glycogen</td>
<td>Glucose</td>
<td>C6H12O6</td>
<td>Muscle and liver cells</td>
<td>Energy storage</td>
</tr>
<tr>
<td>Cellulose</td>
<td>Glucose</td>
<td>C6H12O6</td>
<td>Cell walls of plants</td>
<td>Structural support</td>
</tr>
</tbody>
</table>

**What monomer is starch composed of?**

1. Amino acids
2. Glycogen
3. Fructose
4. Glucose

**The complex carbohydrate stored in animals is?**

1. Starch
2. Glycogen
3. Cellulose

**Complex Carbohydrate - Glycogen**

- **Glycogen is stored in the liver and muscle.**
- **Glycogen granules are stored in cells of the liver.**

**Complex Carbohydrate - Cellulose**

- **Cellulose is a structural polysaccharide found in the cell walls of plants.**
Lipids

- Like carbohydrates, lipids are mainly made of carbon, hydrogen and oxygen, but usually have many carbons and hydrogens.
- They are not soluble in water.
- Types:
  1. Triglycerides
  2. Phospholipids
  3. Steroids

I. Triglycerides

- Function
  1. Energy storage
  2. Insulation
  3. Protection of vital organs
- Structure: Triglycerides are three fatty acids joined to one glycerol.

Fatty acid

Triglycerides

- Butter, lard (animal fat), and vegetable oils are all triglycerides.
- Differences are in the structure of the fatty acids.

Fatty Acids

- Saturated fatty acids
  - Saturated fatty acids – carbon chain has no double bonds: \( CH_2-(CH_2-CH_3)_n-COOH \)
- Unsaturated fatty acids – carbon chain has at least one double bond:
  - Monounsaturated fatty acids have one double bond
  - Polyunsaturated fatty acids – more than one double bond.
**Triglycerides**

- Animal fats – contain mainly saturated fatty acids
- Vegetable oils – mainly unsaturated and polyunsaturated fatty acids
- Hydrogenated oils – unsaturated oils that have been chemically saturated so they will be solid at room temperature (Crisco) = trans fats

**Triglycerides**

- Animal fats – These chains are flat so they pack tightly together, they are solid at room temperature
- Vegetable oils – Liquid at room temperature

**Trans Fats**

- Hydrogenation is the process of adding hydrogen to the monounsaturated and polyunsaturated oils to saturate them.
- This process can also create unsaturated fats that now have a different configuration than the original oil
- Sources of trans fats:
  - cookies, french fries, cakes, popcorn, many other packaged foods
  - Labeled “partially hydrogenated oil”

**Fatty acids and Health**

- Heart disease is caused by plaque collecting in the blood vessels leading to the heart.
- Plaque is from oxidized cholesterol
- Cholesterol in the blood leads to more plaque building up in the vessels.
- LDL (bad cholesterol) – transports cholesterol from the liver and to the heart
- HDL (good cholesterol) – transports cholesterol to the liver and away from the heart

**Fatty acids and Cholesterol**

- Trans fats – worst type of fat, raise the bad cholesterol (LDL) and lower the good cholesterol (HDL)
- Saturated fats raise the bad cholesterol
  - Sources – animal fats, dairy products, and some plant oils (palm and coconut)
- Polyunsaturated fats – do not raise the bad cholesterol but slightly lower good cholesterol
  - Sources – many vegetable oils (corn and safflower)
- Monounsaturated fats – Do not increase either
  - Sources – olive, canola and peanut oils; avocado

**Omega-3 Fats**

- Omega-3s are a type of unsaturated fat
- This fat has a carbon double bond located three carbons from the end (end = omega)
- This is the healthiest type of fat
- Protect against heart disease by reducing bad cholesterol
  - Sources – fatty fish (salmon, tuna), walnuts, flax
Which of these fats are the least healthy?

1. Polyunsaturated
2. Omega 3 unsaturated
3. Trans fat
4. Saturated

Which type of fatty acid does not contain a double bond?

1. Polyunsaturated
2. Omega 3 unsaturated
3. Trans fat
4. Saturated

Triglycerides are so named because they are formed by a reaction between three fatty acid molecules and one ________.

1. Amino acid
2. Glucose
3. Glycerol
4. Glycogen

II. Lipid - Phospholipids

- Function
  - Backbone of cell membranes

- Structure: glycerol + two fatty acids + a charged phosphate group + "R" group

II. Lipid - Phospholipids

- They are amphipathic:
  - Phosphate end of molecule polar, soluble in water.
  - Lipid (fatty acid) end is nonpolar, not soluble in water.

III. Steroids

- Examples: hormones and cholesterol
- Functions
  1. Signaling between cells (hormones), control metabolic processes and cellular functions
  2. Part of cell membrane (cholesterol)
- Structure is a four ring backbone, with side chains attached
**Steroid Structure**

(a) Four-ring steroid structure

**Lipids - Steroids**

![Steroid Structure](image1)

![Lipids - Steroids](image2)

**Anabolic Steroids**

- Some athletes take testosterone-like compounds to enhance their performance.
- There is a downside to taking steroids:
  - Increase in body odor, baldness, acne, breast enlargement in men, kidney disease, decreased testicular size, low sperm count, impotence, high cholesterol, high blood pressure, heart damage, liver dysfunction, liver cancer, stunted growth if taken during development, personality changes including rage and delusions.

**Proteins**

- Functions—numerous and varied, including
  - Facilitate chemical reactions (enzymes)
  - Transport
  - Movement of muscles
  - Structure
  - Cell signaling
  - Nutrition
  - Defense
  - Components of cell membrane
  - Immune response
  - Hormones (insulin)

**Proteins**

- Proteins are polymers made up of amino acids
- Amino acids are monomer units
- There are 20 amino acids, each with a different substitution for R. (remember functional groups)

**Amino Acid Structure**

![Amino Acid Structure](image3)
Proteins

- Amino acids that form proteins are linked by bonds called **peptide bonds**.
- **Peptide bonds** which are formed through dehydration synthesis.

Proteins

- Chains of only a few amino acids are called **peptides**.
- Chains of 10 or more amino acids are called **polypeptides**.
- Polypeptide chains of at least 50 amino acids are called **proteins**.
- Proteins are usually folded.

Protein structure

- Proteins have four distinct levels of structure that affect their function in the body:
  - Primary
  - Secondary
  - Tertiary
  - Quaternary

Primary Structure

- Primary Structure – Amino acid sequence
  - This sequence determines its function and structure. The amino acids have different properties and structures.
  - Amino acids are bound together by a **peptide bond**.

1. Primary Structure – Amino acid sequence
2. Secondary Structure – Structural features within a polypeptide chain
   - Alpha helix and Beta pleated sheets
3. Tertiary Structure – Overall folding
4. Quaternary Structure – Multiple polypeptides interacting
Proteins – Primary structure

- Primary structure is the specific sequence of amino acids. Each amino acid is depicted here as a bead within the polypeptide chain.

Secondary Structure

- Structural features within a polypeptide chain
- Do the amino acids form coils or sheets?
  - This is determined by the primary structure.
  - Hydrogen bonding between amino acids in the protein shape α-helix or β-pleated sheets.
  - A polypeptide chain can contain both α-helix and β-pleated sheets

Proteins

- Secondary structure, such as the helix shown here, results from the bending and coiling of the chain of amino acids.

Tertiary Structure

- Overall folding
  - Determined by size and placement of amino acids in protein
  - Chaperone proteins aid in the folding of polypeptide chains
  - A protein can lose its shape under some conditions = denaturation

Proteins - tertiary structure

- Tertiary structure is the three-dimensional shape of proteins.

Quaternary Structure

- Multiple chains of amino acids (polypeptide chains) interacting or binding together to function as one protein

Proteins – quaternary structure

- Some proteins have two or more polypeptide chains, each chain forming a subunit. Quaternary structure results from the attractive forces between two or more subunits.

Hemoglobin
**Shape of Protein and Health**

- Hemoglobin and Sickle Cell Anemia
  - The change of one amino acid in the sequence

**Proteins - Enzymes**

- Enzymes are proteins that help reactions to happen – they speed up chemical reactions
- They can only speed up reactions that would happen eventually (may take years)
- Some enzymes need cofactors to function. Example = iron

**Enzyme Properties**

1. They are usually specific for their substrates
2. They are not consumed (destroyed) in the process
3. They have optimal conditions
   - pH
   - Temperature

**Melanin is the pigment that gives the black color to the fur. The enzyme that controls the melanin production is heat sensitive, it works best at cooler temperatures**

**Enzyme Properties**

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**Enzymes are a type of ___, which function to _____.**

1. carbohydrate; build strength
2. gland; form hormones
3. cell; repair tissue
4. protein; speed up chemical reactions

**Nucleotides**

- Their functions include:
  - Energy (ATP)
  - Coenzymes that aid enzyme function (NAD+) or are messengers between and within cells (ADP)
- Small compounds consisting of a sugar, with attached phosphate groups, and a nitrogenous base.
- There are 5 nucleotides because the bases are different:
  - Adenine, Thymine, Uracil, Guanine, Cytosine
Nucleotide Examples

- Adenosine Tri and Diphosphate (ATP & ADP)
  - Energy transferring molecules.
- Guanosine Tri and Diphosphate (GTP & GDP)
  - Intracellular signaling molecules + energy transferring molecules.
- Nicotinamide Adenine dinucleotide (NAD)
  - Energy transfer

Nucleic Acids

- Nucleic Acids (polymer)
  - Chain or chains of Nucleotides (monomer)
- Two Types Nucleic Acids
  - Deoxyribonucleic Acid (DNA)
  - Ribonucleic Acid (RNA)
- Functions –
  - Blueprint to make proteins (DNA)
  - Protein synthesis (RNA)

Nucleic Acids

- RNA
  - Is single-stranded
  - Has the sugar ribose
  - Has the nitrogenous bases:
    - adenine, guanine, cytosine, and uracil

Nucleic Acids - DNA

- DNA
  - Has two strands that form a distinctive double helix
  - Has the sugar deoxyribose
  - Has the nitrogenous bases adenine, guanine, cytosine, and thymine
Nucleic Acids

<table>
<thead>
<tr>
<th>Characteristic</th>
<th>RNA</th>
<th>DNA</th>
</tr>
</thead>
<tbody>
<tr>
<td>Sugar</td>
<td>Ribose</td>
<td>Deoxyribose</td>
</tr>
<tr>
<td>Bases</td>
<td>Adenine, guanine, cytosine, uracil</td>
<td>Adenine, guanine, cytosine, thymine</td>
</tr>
<tr>
<td>Number of strands</td>
<td>One</td>
<td>Two, twisted to form double helix</td>
</tr>
</tbody>
</table>

Monomer and Polymer

- **Monomer** is the individual unit that makes up a polymer
- **Examples**: Starch is a polymer made up of the monomer units of glucose

<table>
<thead>
<tr>
<th>Polymer</th>
<th>Monomer</th>
</tr>
</thead>
<tbody>
<tr>
<td>Starch</td>
<td>Glucose</td>
</tr>
<tr>
<td>Cellulose</td>
<td>Glucose</td>
</tr>
<tr>
<td>Glycogen</td>
<td>Glucose</td>
</tr>
<tr>
<td>Protein</td>
<td>Amino acids</td>
</tr>
<tr>
<td>Nucleic Acids – DNA and RNA</td>
<td>Nucleotides</td>
</tr>
</tbody>
</table>

Important Concepts

- What are the functions of all the biological molecules?
- What are the types of carbohydrates
- What is the function of each of the carbohydrate
- Know what types of organisms the complex carbohydrates are found in, the digestibility of the different complex carbohydrates.

Important Concepts

- Know what parts of the body is glycogen mainly stored in
- Know the cause and symptoms of lactose intolerance
- Know what monomers join to form the complex carbohydrates, know the structure of the complex carbohydrate (branched, tightly packed and stabilized by H-bonds, etc, coiled)
- Know the types of lipids, their functions, and their structures

Important Concepts

- What is the general structure of triglycerides, what are the molecules that make up the triglycerides
- Know the general structure of phospholipids and the molecules that make up the phospholipids, know the properties of phospholipids
- Know the general structure of steroids, i.e., that it is a four ring structure, be able to identify the structure but you don’t need to draw it.

Important Concepts

- What are the monomers are joined to make proteins and the type of bond that joins them
- What is the primary, secondary, tertiary, and quaternary structure of proteins.
- What monomer units comprise nucleic acids, know the general structure of nucleotides. Know the molecules the form nucleotides
- Be able to identify from a picture any of the biological molecules

Important Concepts

- What are the different types of fatty acids and which are healthy, which are not as healthy – what is the order from healthiest to least healthy.
- Know the structure of trans fat and the source of trans fat and what is the effect of trans fat on the body. What is trans fat called on ingredient labels.
- Know the functions of the 3 types of lipids
- Know the functions of proteins

Important Concepts

- What are enzymes, what is their functions and their properties
- What are the structural differences between RNA and DNA.
- What is the function of DNA and RNA
- Which molecules join together to form what molecules (monomer and polymers)
Definitions

- Monosaccharide, disaccharides, polysaccharide, amyloplasts, saturated fatty acids, unsaturated fatty acids, monounsaturated fatty acids, polyunsaturated fatty acids, omega-3s, trans fats, peptide, polypeptide, protein, peptide bond, polypeptide, enzyme, active site, substrate, product, cofactors, lactose, lactase, alpha helix, beta pleated sheets, amphiphatic, chaperone, denaturation, dehydration synthesis, hydrolysis, monomer, polymer