Formation of Macromolecules
Monomers \(\rightarrow\) Polymers \(\rightarrow\) Macromolecules
Smaller \(\rightarrow\) larger

- monomer: single unit
- dimer: two monomers
- polymer: three or more monomers
- macromolecules: extremely large, two or more polymers joined together

### Chapter 5
Structure and Function Of Large Biomolecules

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#### Synthesis and Breakdown of Polymers

**Dehydration synthesis/Condensation**
chemically joining two molecules with loss of H2O
(larger \(\rightarrow\) smaller)

**Hydrolysis**
splitting of polysaccharide into monosaccharide units with addition of water
(smaller \(\rightarrow\) larger)

#### Carbohydrates
(saccharo / Latin or Greek /sweet or sugar)

- Composed of \(\text{C} : \text{H} : \text{O}\)
  - 1 : 2 : 1 ratio
- Function: fuel and structure
- monosaccharide \(\rightarrow\) disaccharide \(\rightarrow\) polysaccharide
- Monosaccharides: monomers/ building blocks
- Polysaccharides: differ in position & orientation of glycosidic linkages
  - Storage (plants: starch, animals: glycogen)
  - Structure (plant: cellulose, arthropod: chitin)

#### Types of Carbohydrates

1. **Monosaccharides:** \((\text{C}_6\text{H}_{12}\text{O}_6)\)
   A. glucose – most important: used for energy
      - all di/polysaccharides broken down into glucose
   B. galactose – milk
   C. fructose – fruits

Trademarks of a sugar:
- Carbonyl group \(\text{C} = \text{O}\)
- Multiple hydroxyl groups \(-\text{OH}\)
- In H2O most 5/6 C sugars form rings
2. Disaccharides: \((C_{12}H_{22}O_{11})\) two monosaccharide units joined by a glycosidic linkage (covalent bond between two monosaccharides)

- sucrose – table sugar
- maltose – malt sugar (beer)
- lactose – milk sugar

* function determined by sugar monomers and position of glycosidic linkages*

3. Polysaccharides: macromolecules (100’s – 1000’s of monosaccharides)

- A. starch – energy storage for plants
  - 100’s of glucose molecules
- B. glycogen – energy storage for animals (muscles and liver)
- C. cellulose – structure for plant stems
  - wood and bark
  - cell walls of plants

**Molecules of starch, cellulose, and glycogen - 1000s of glucose units, no fixed size**

Cellulose vs. Starch

Two Forms of Glucose: \(\alpha\) glucose & \(\beta\) glucose

- Starch: \(\alpha\) glucose
- Cellulose: \(\beta\) glucose

different geometries = different shapes

Storage polysaccharides of plants (starch) and animals (glycogen)

Lipids (fats)

- not polymers (too small)
- waxy or oily compounds
- hydrophobic due to H-C chains
- ratio of H to C is > 2:1
- structure:
  - 1 glycerol + 3 fatty acids
  - 3 H2O lost (triglycerol/ide)
- functions:
  - energy storage
  - membrane formation (phospholipids)
  - chemical messengers (sterols/steroids)

Chitin: structural polysaccharide found in exoskeleton of arthropods.
- differs from cellulose with addition of N
Formation of a Triglyceride via Dehydration Synthesis

Types of Lipids

- **Saturated**: solid at RT - max number of H bonds with C (saturated with bonds)
- **Unsaturated**: liquid at RT - double bonds between C
- **Polyunsaturated**: many double bonds between C - cooking oils

**trans fats**: heating unsaturated fats to become saturated - very bad
**hydrogenated oils**: adding H to unsaturated fats to make solid - very bad

Phospholipids
- Lipid bilayer of cell membrane
- Structure of a phospholipid

Steroids
- Cholesterol and hormones
- Skeleton with 4 fused C rings
- Cholesterol

Proteins
- Proteins\(^\circ\) = first or primary
- 50% dry weight of cells
- Contains: C, H, O, N, S
- Most structurally sophisticated molecules known

Functions of Proteins

- **Enzymatic proteins**: Function: Selective acceleration of chemical reactions
  Example: Digestive enzymes catalyze the hydrolysis of bonds in food molecules.

- **Storage proteins**: Function: Storage of amino acids
  Examples: Casein, the protein of milk, is the major source of amino acids for baby mammals. Plants store proteins in their seeds. Osinibin is the protein of egg white, used as an amino acid source for the developing embryo.

- **Defensive proteins**: Function: Protection against disease
  Example: Antibodies inactivate and help destroy viruses and bacteria.

- **Transport proteins**: Function: Transport of substances
  Example: Hemoglobin, the iron-containing protein of vertebrate blood that transports oxygen from the lungs to other parts of the body. Other proteins transport molecules across cell membranes.

- **Contractile and motor proteins**: Function: Movement
  Examples: Motor proteins are responsible for the undulations of cilia and flagella. Actin and myosin proteins are responsible for the contraction of muscles.

- **Structural proteins**: Function: Support
  Example: Keratin is the protein of hair, horns, feathers, and other skin appendages. Insects and spiders use silk fibers to make their cocoons and webs, respectively. Collagens and elastin proteins provide a fibrous framework in animal connective tissues.
**Structure**
- **Amino acids** - building blocks
  - 20 different amino acids
  - polymer = polypeptide
- protein can be one or more polypeptide chains folded & bonded together
- large & complex molecules complex 3-D shape

**Amino acid**
- Side chain (R group)
- R group (side chain)
  - Variable group
  - Confers unique chemical properties of a.a.
  - Alpha C is asymmetric

**Non-polar Amino Acids**
- nonpolar and hydrophobic

**Polar Amino Acids**
- polar or charged and hydrophilic

**Peptide Bond**
- Covalent bond between two amino acids
- Dehydration synthesis reaction
  - H from amino group bonds with OH (hydroxyl) of carboxyl group of another amino acid
  - water molecule is removed
  - repeated sequence (N-C-C) is the polypeptide backbone

**Levels of Protein Structure and Function**
- Function depends on structure
  - 3-D structure
  - twisted, folded, coiled into unique shapes

**Basic Principles of Protein Folding**
A. Hydrophobic AA buried in interior of protein (hydrophobic interactions)
B. Hydrophilic AA exposed on surface of protein (hydrogen bonds)
C. Acidic + Basic AA form salt bridges (ionic bonds)
D. Cysteines can form disulfide bonds
Primary (1°) Structure

- Linear chain of amino acids
- Order of amino acids in chain
  - amino acid sequence determined by gene (DNA)
  - slight change in amino acid sequence can affect protein’s structure & it’s function
  - even just one amino acid change can make all the difference!

Example of 1° Structure Change

Sickle Cell Anemia

Secondary (2°) Structure

- Gains 3D shape (folds, coils) by H bonding
  - folding along short sections of polypeptide
  - Interaction between adjacent amino acids
- Alpha (α)
  - helix
  - H bonding between every 4th amino acid
- Beta (β)
  - pleated sheet
  - H bonds between parts of 2 parallel polypeptide backbones

Tertiary (3°) Structure

- Whole molecule folding
- Bonding between side chains (R groups) of amino acids
- Hydrophobic interaction: hydrophobic AA in clusters in core of protein, out of contact with water
- van der Waals forces hold them together
- Anchored by disulfide bridges (H & ionic bonds)
- Include 1° and 2° structures

Models of Tertiary Proteins

Quaternary (4°) Structure

More than one polypeptide chain joined together.
Chaperonins (chaperone proteins) assist in proper folding of proteins
- keep new polypeptide segregated from cytoplasmic environment

Prions: misfolded proteins- mad cow disease

Denaturation
Unfolding of a protein (disruption of 3° structure)
- pH, salt, temperature
- disrupts H bonds, ionic bonds & disulfide bridges
- destroys functionality (sometimes permanently)

Nucleic Acids
- composed of C, O, H, N plus P
- very large molecules
- polymers of nucleotides (polynucleotides)

DNA
RNA
ATP

Review
- Primary
  - aa sequence (peptide bonds)
  - determined by DNA
- Secondary
  - R groups (H bonds)
- Tertiary
  - R groups (hydrophobic interactions, disulfide bridges)
- Quarternary
  - multiple polypeptides
  - hydrophobic interactions