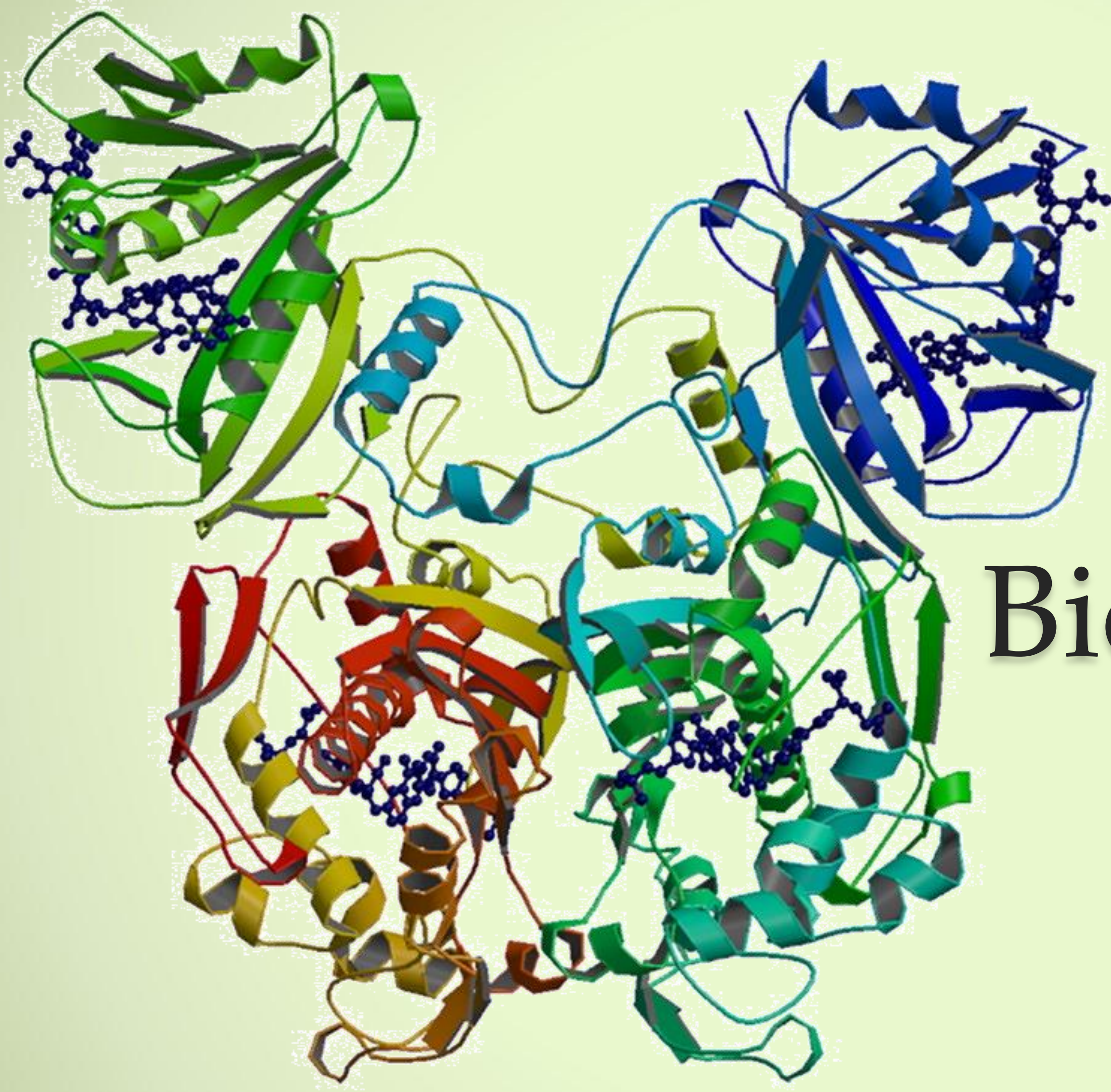


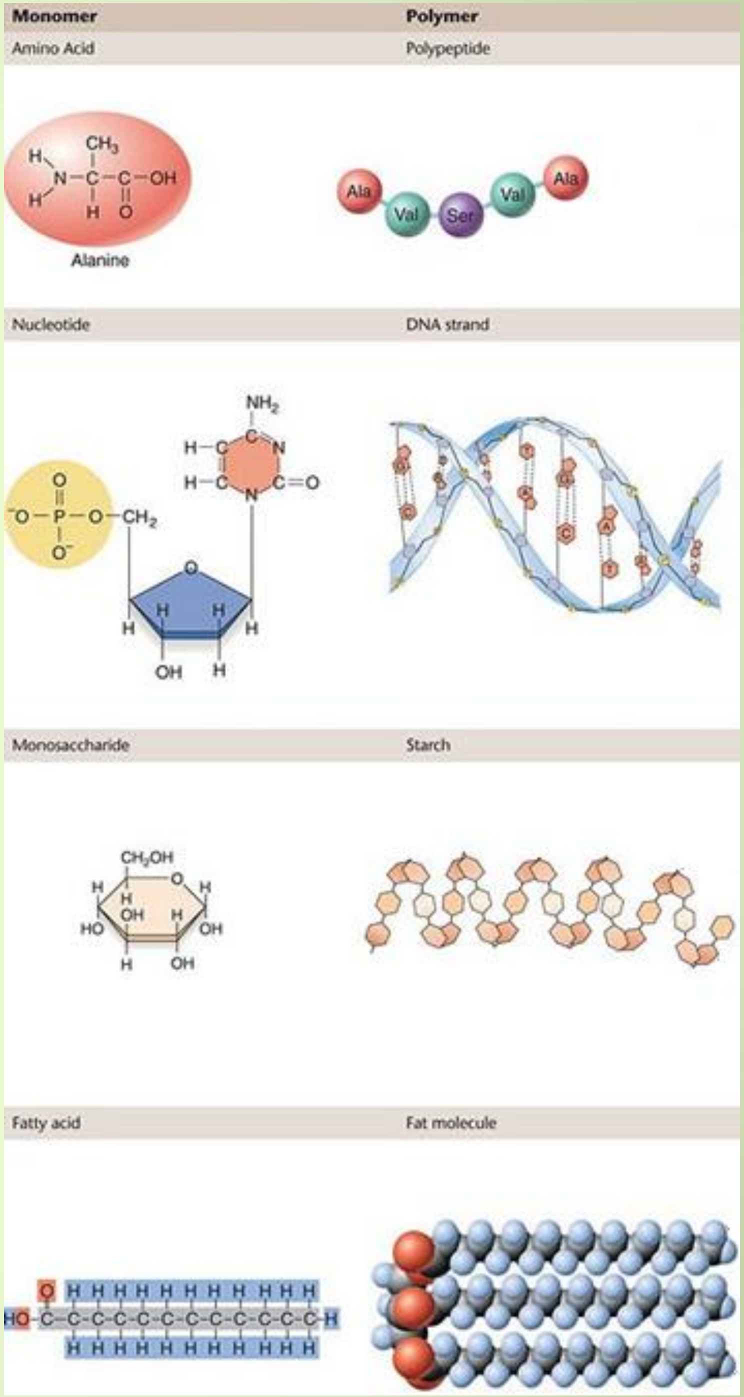
Biochemistry

Biochemistry

- Study of chemical composition and reactions of living matter
  - Biological chemistry
- **Organic compounds**
  - Molecules that contain carbon
    - Except CO_2 and CO (considered inorganic)
    - Carbon is **electroneutral**
      - Shares electrons; never gains or loses them
      - Forms four covalent bonds with other elements
- **Inorganic compounds**
  - All other compounds, not containing carbon
    - Ex: water, salts, acids, and bases

Organic Compounds

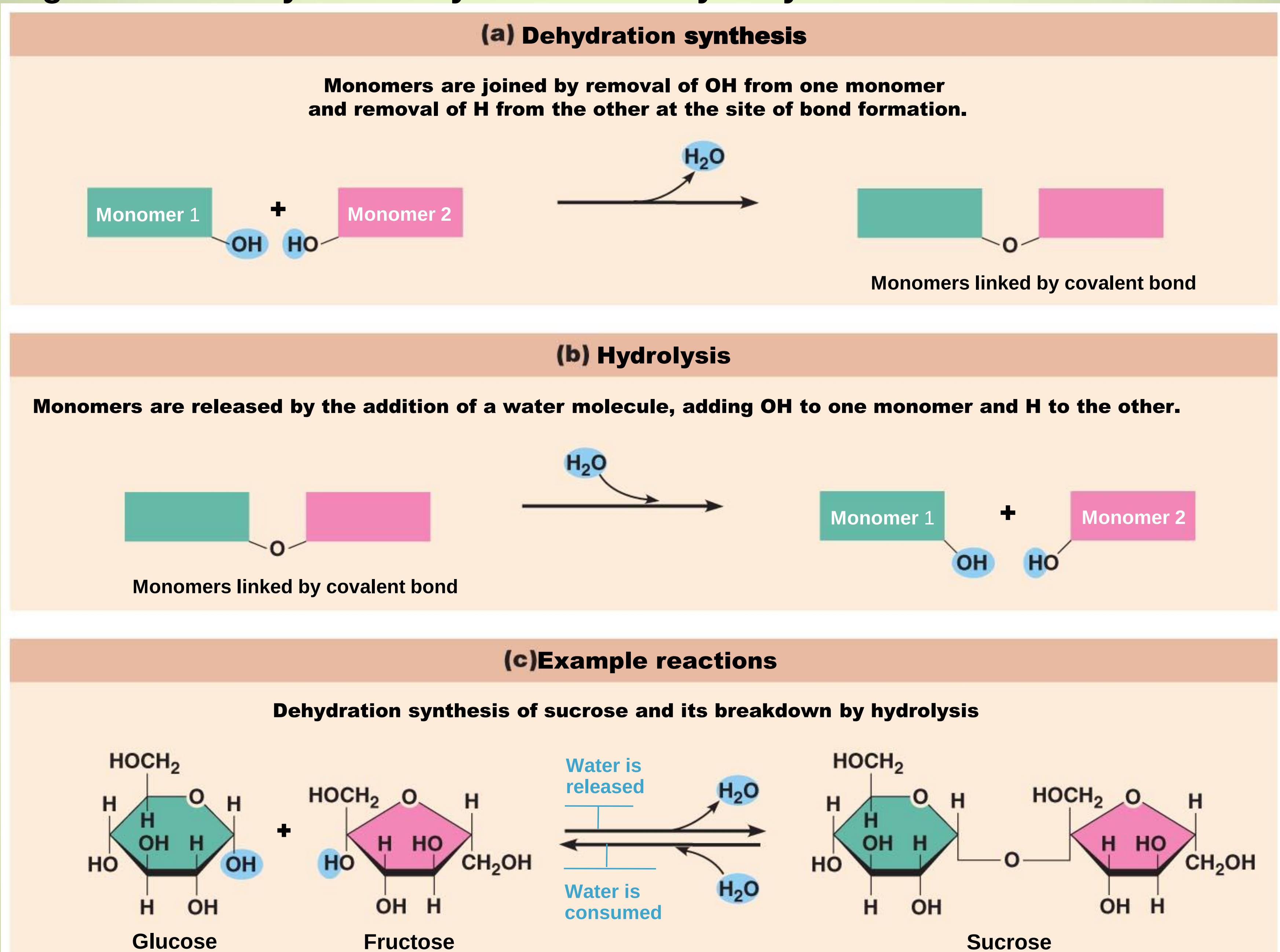
- Unique to living systems
- Includes
  - Carbohydrates
  - Lipids
  - Proteins
  - Nucleic acids
- Often found as **polymers** made up of chains of similar units
  - **Monomers**
    - Serve as building blocks for larger polymers



Organic Compounds

- Attached **functional groups**
  - Change physical and chemical properties
- Synthesized by
  - **Dehydration synthesis**
- Broken down by
  - **Hydrolysis reactions**

Figure 2.14 Dehydration synthesis and hydrolysis.



Carbohydrates

- Sugars and starches
- Contain C, H, and O
  - [$(CH_20)_n$]
- Functions of carbohydrates
  - Major source of cellular fuel (e.g., glucose)
  - Structural molecules (e.g., ribose sugar in RNA)
- Three classes:
  - ***Monosaccharides*** – one sugar
  - ***Disaccharides*** – two sugars
  - ***Polysaccharides*** – many sugars

Monosaccharides

- Simple sugars containing three to seven C atoms
- $(CH_20)_n$ – general formula; n = # C atoms
- Monomers of carbohydrates
- Important monosaccharides
  - Pentose sugars
    - Ribose and deoxyribose
  - Hexose sugars
    - Glucose (blood sugar)

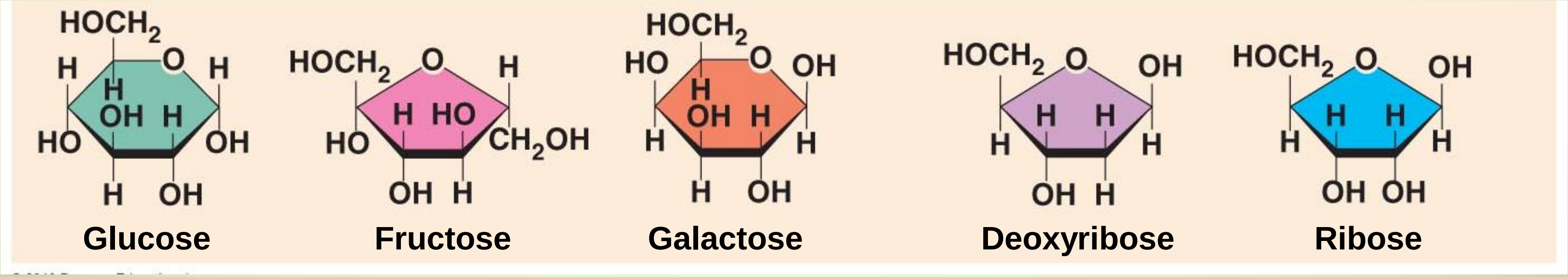


Figure 2.15a Carbohydrate molecules important to the body.

Disaccharides

- Double sugars
- Too large to pass through cell membranes
- Important disaccharides
  - Sucrose, maltose, lactose

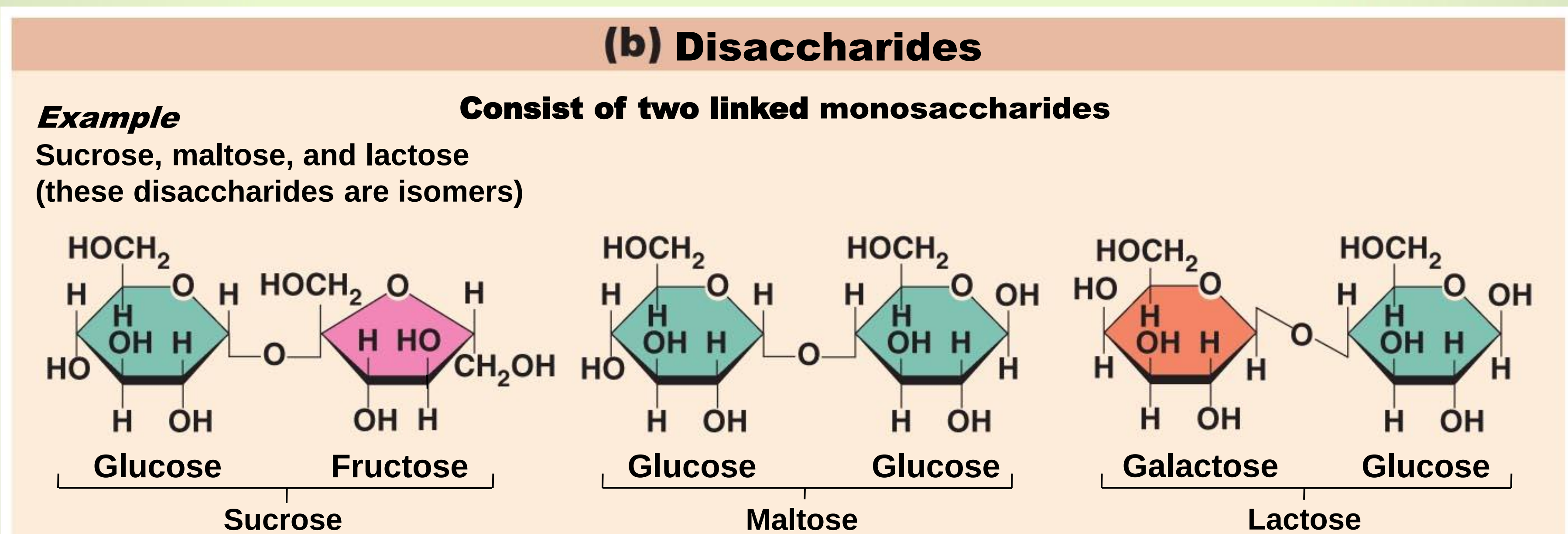


Figure 2.15b Carbohydrate molecules important to the body.

Polysaccharides

- **Polymers** of monosaccharides
- Important polysaccharides
  - Starch and glycogen
- Not very soluble

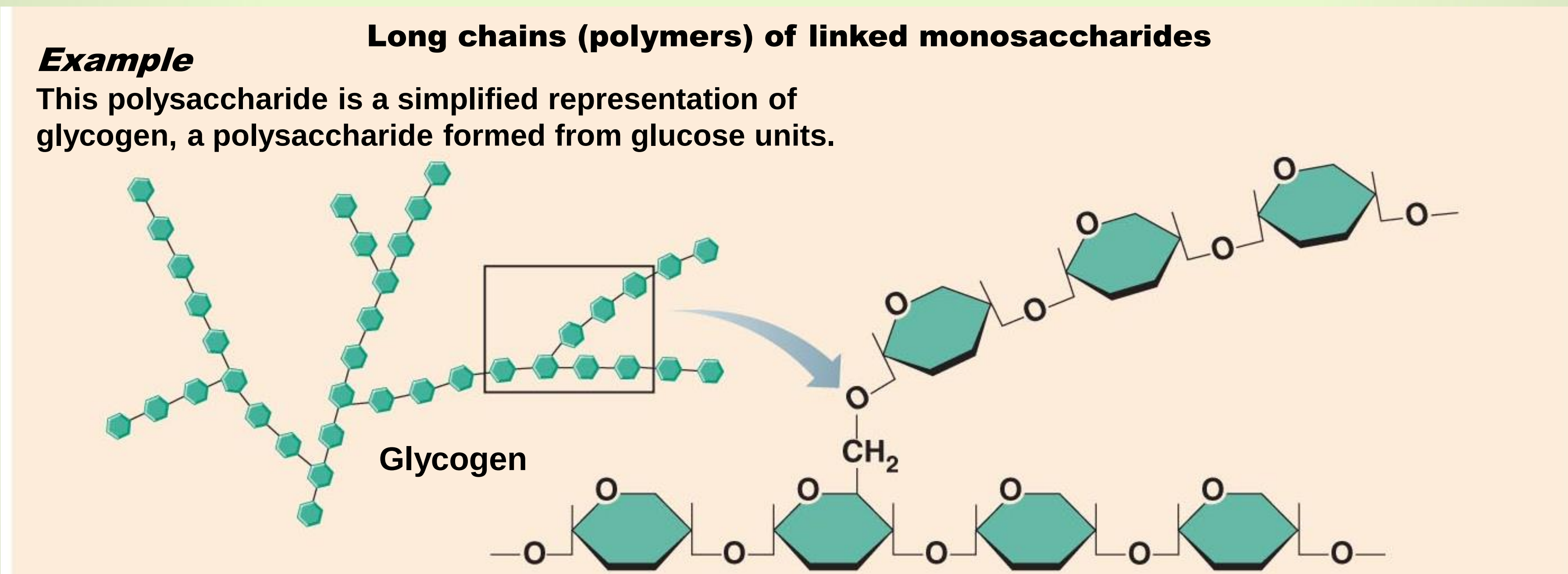


Figure 2.15c Carbohydrate molecules important to the body.

Lipids

- Contain C, H, O, and sometimes P
- Insoluble in water
- Main types:
  - **Triglycerides**
    - aka **neutral fats**
  - **Phospholipids**
  - **Steroids**
  - **Eicosanoids**

Triglycerides
(aka Neutral Fats)

- Called fats when solid and oils when liquid
- Composed of three fatty acids bonded to a glycerol molecule

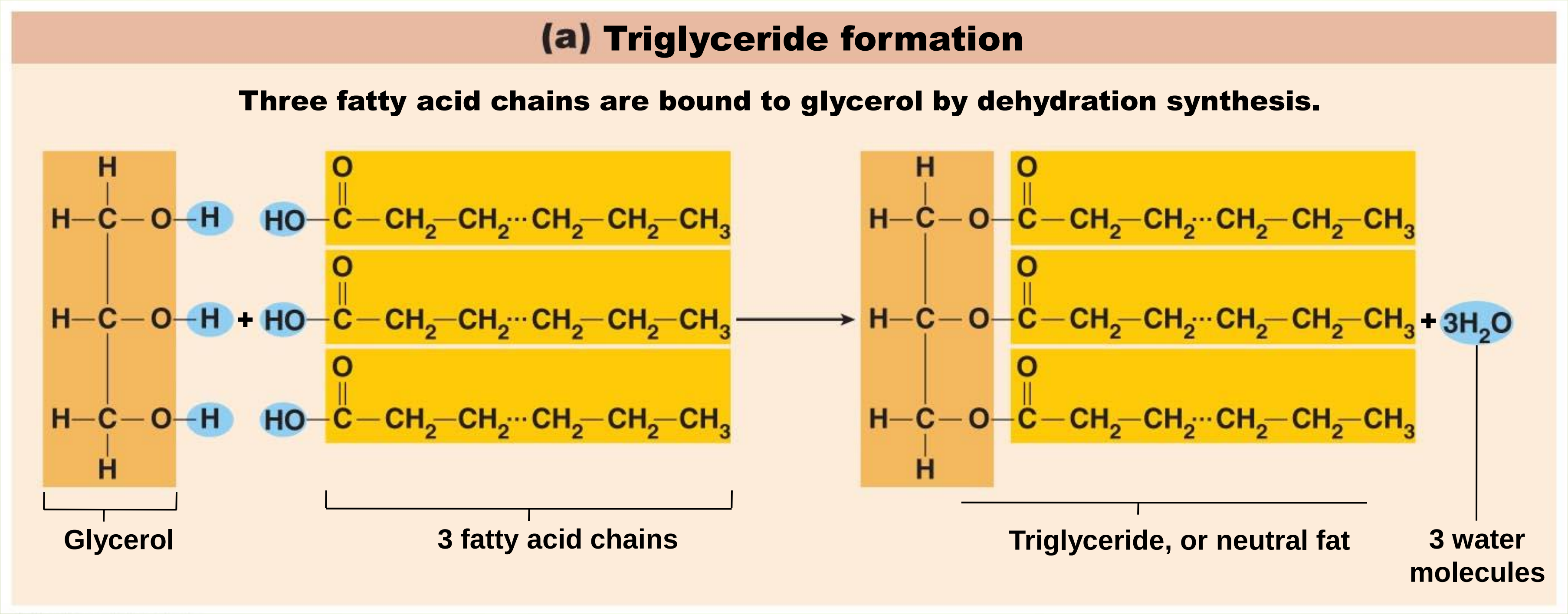
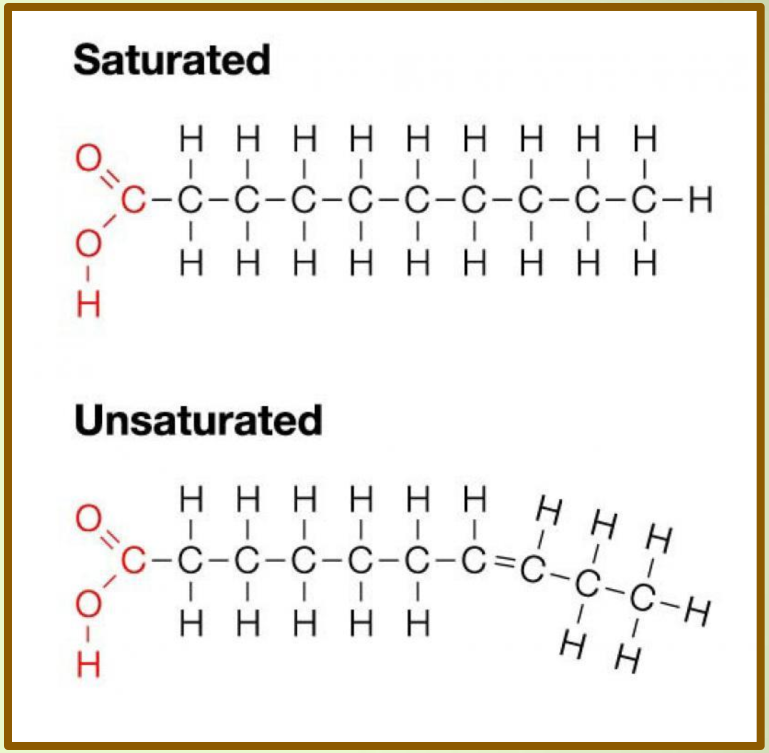


Figure 2.16a Lipids.

Saturation of Fatty Acids

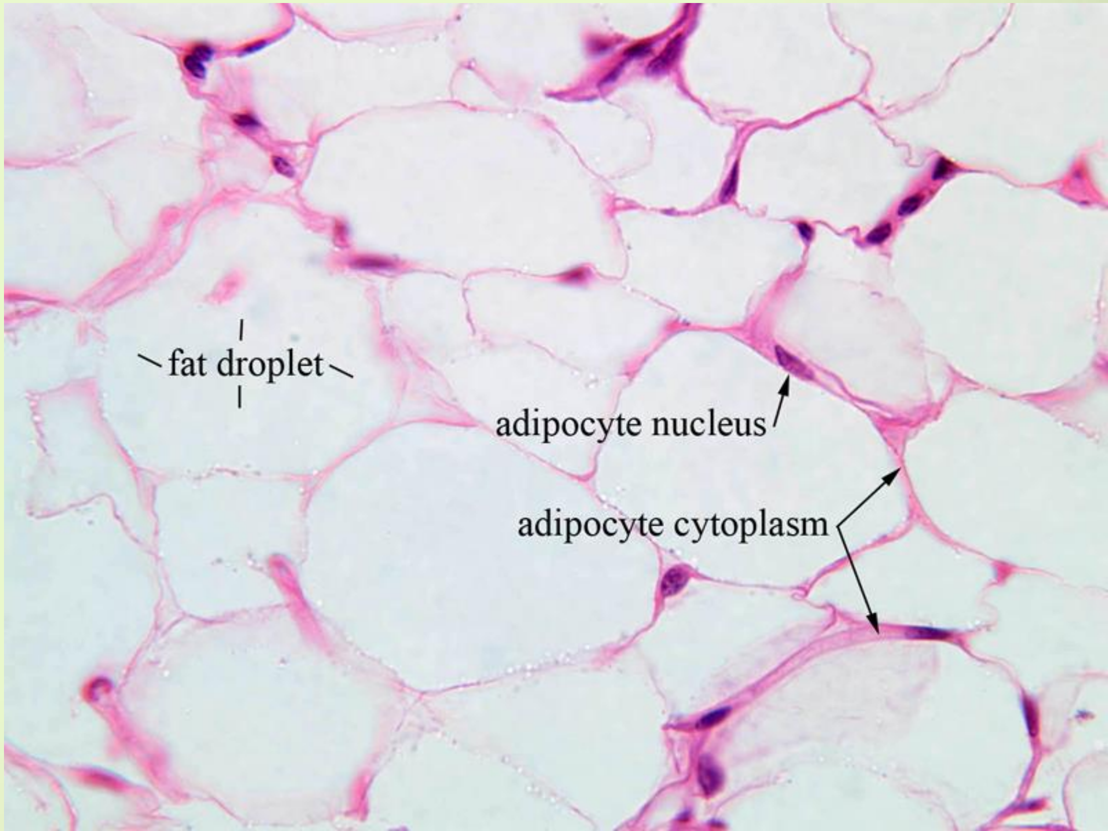
- Saturated fatty acids
  - Single covalent bonds
    - Between C atoms
  - Maximum number of H atoms
  - Solid animal fats, e.g., butter
- Unsaturated fatty acids
  - One or more double bonds
    - Between C atoms
  - Reduced number of H atoms
  - Plant oils, such as olive oil, considered "heart healthy"
- Trans fats – modified oils – unhealthy
- Omega-3 fatty acids – "heart healthy"
  - Polyunsaturated fatty acids (FUFA's)



Triglycerides (Neutral Fats)

Main functions in human body:

- Energy storage
- Insulation
- Protection



Phospholipids

- Modified triglycerides:
  - Glycerol + two fatty acids and a phosphorus (P) group
- “Head” and “tail” regions have different properties
- Important in cell membrane structure

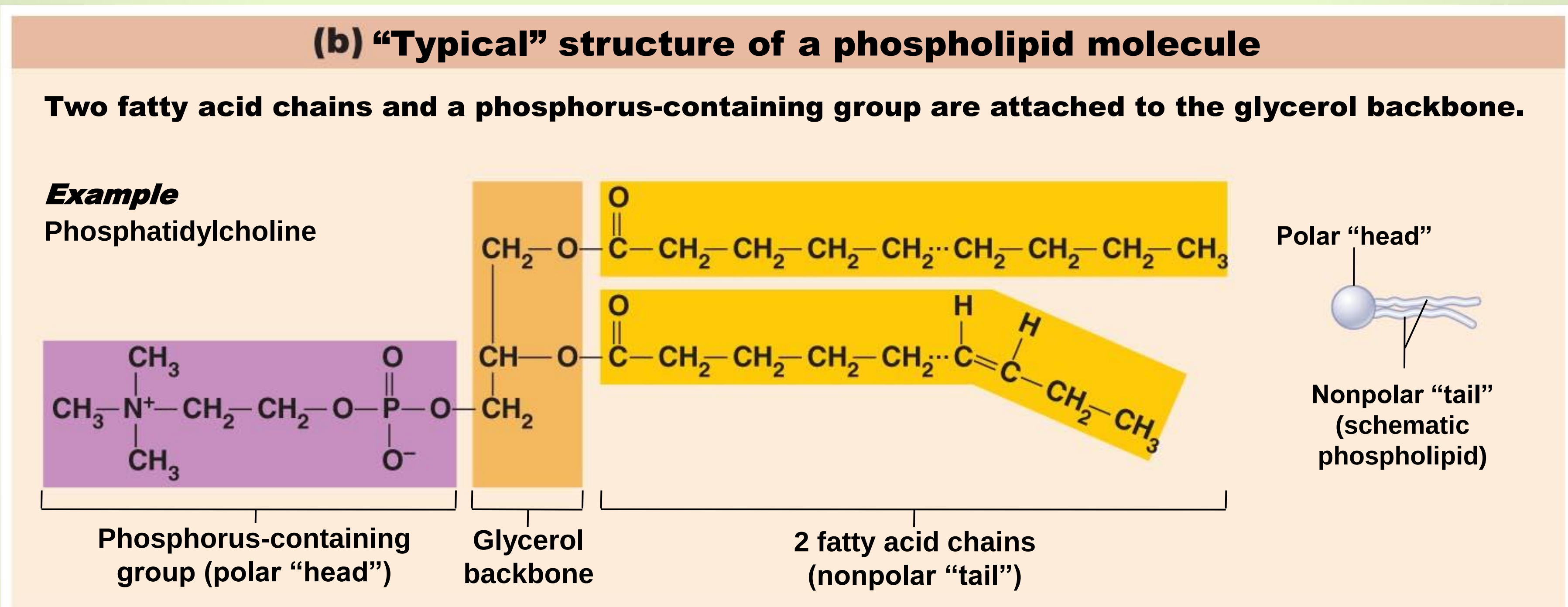


Figure 2.16b Lipids.

Steroids

- Interlocking four-ring structure
- Cholesterol, vitamin D, steroid hormones, and bile salts
- Most important steroid = **cholesterol**
  - Important in cell membranes, vitamin D synthesis, steroid hormones, and bile salts

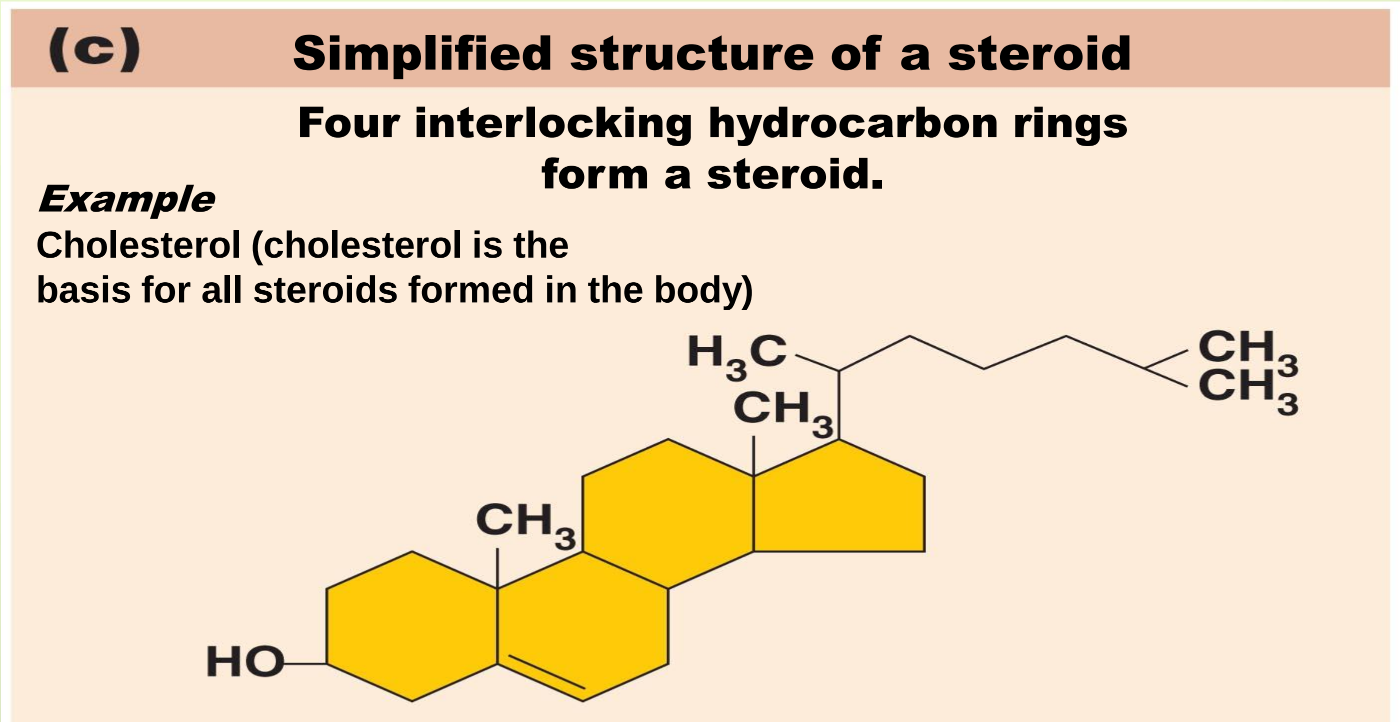
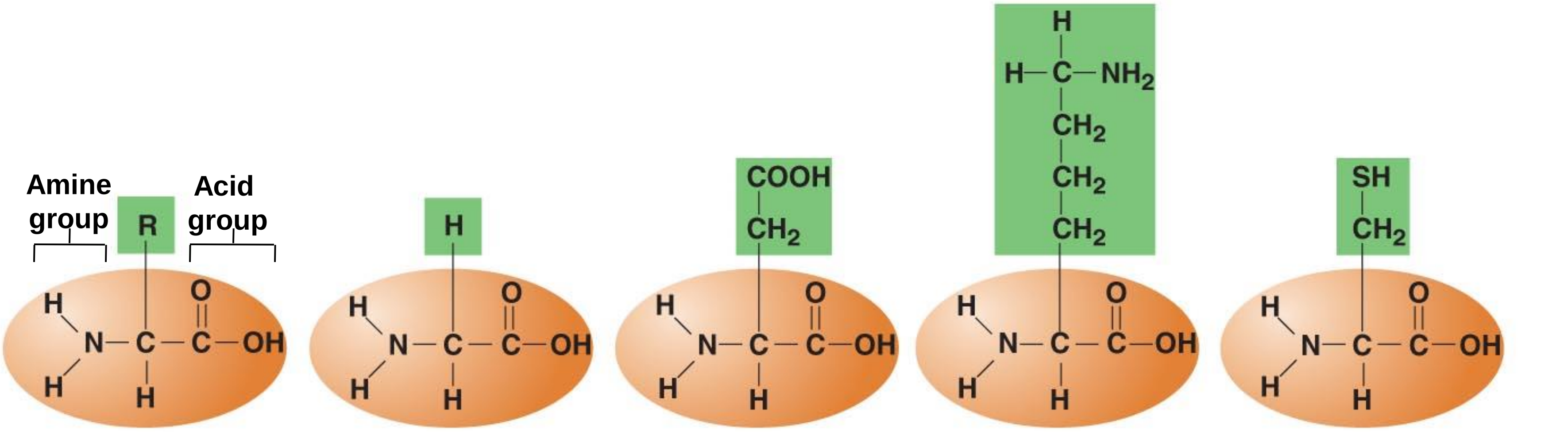


Figure 2.16c Lipids.

Proteins

- Contain C, H, O, N, and sometimes S and P
- Amino acids (20 types)
  - Monomers in proteins
    - Joined by covalent bonds called peptide bonds
- Contain
  - **Amine group** (--NH_2)
  - **Acid group** (--COOH)
- Can act as either acid or base
- Vary by "R group"

Figure 2.17 Amino acid structures.



(a) Generalized structure of all amino acids.

(b) Glycine is the simplest amino acid.

(c) Aspartic acid (an acidic amino acid) has an acid group (—COOH) in the R group.

(d) Lysine (a basic amino acid) has an amine group (—NH_2) in the R group.

(e) Cysteine (a basic amino acid) has a sulfhydryl (—SH) group in the R group, which suggests that this amino acid is likely to participate in intramolecular bonding.

Proteins

- Proteins are polymers
  - Links amine end of one to the acid end of another
  - Results in a **peptide bond**
  - Linkage of 100s to 1000s of amino acids = **macromolecule**

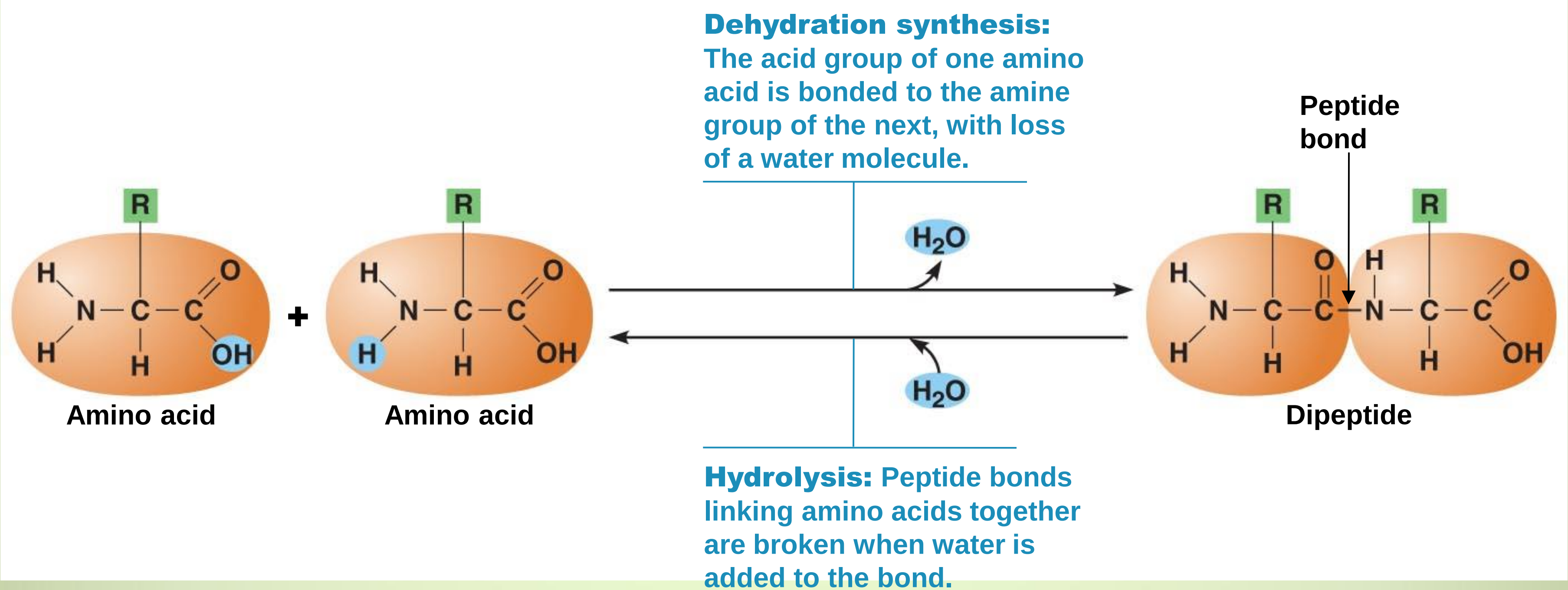


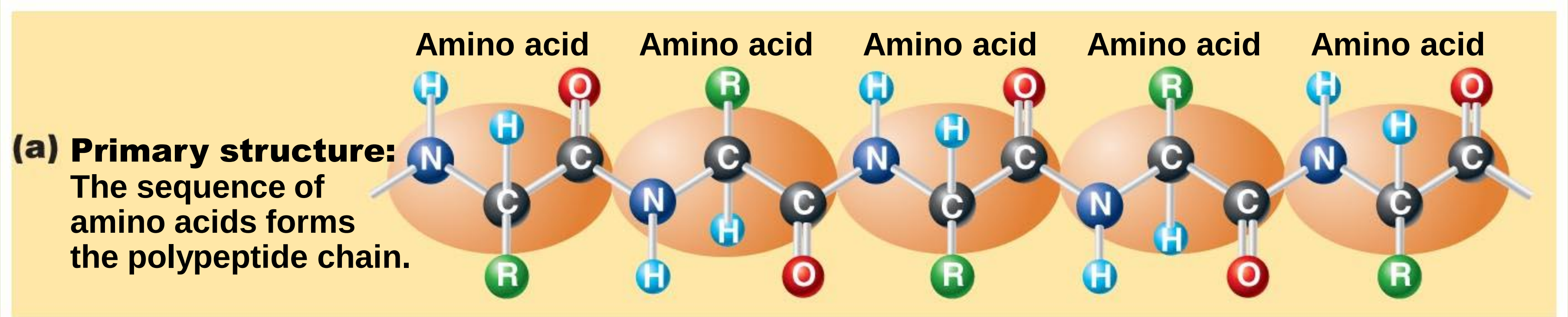
Figure 2.18 Amino acids are linked together by peptide bonds.

Proteins

- Proteins vary widely in structure and function
  - *All* are constructed from different combinations of 20 common amino acids
- Two major factors contribute to uniqueness
  - Each amino acid has distinct properties
    - R groups
  - Sequence of amino acids bound together
    - Varying combinations lead to distinct proteins
    - Changes in types or positions of amino acids
- Sequence also affects levels of protein structure
- Overall structure determines its biological function

Structural Levels of Proteins

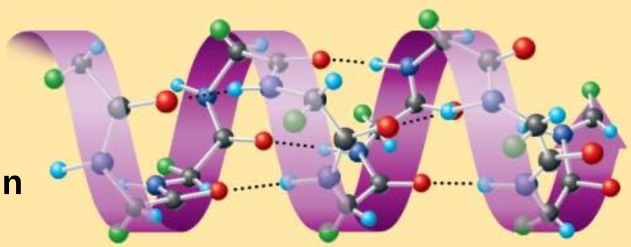
Figure 2.19a Levels of protein structure.



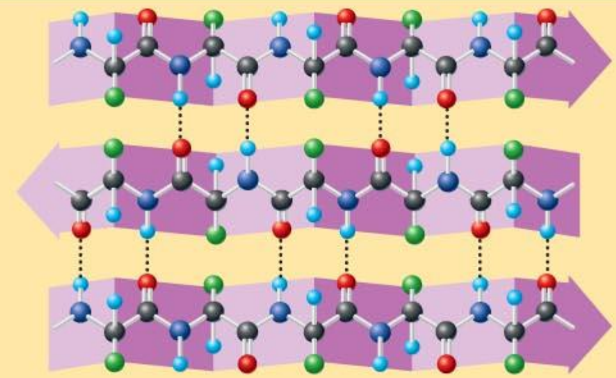
Structural Levels of Proteins

Figure 2.19b Levels of protein structure.

(b) Secondary structure: The primary chain forms spirals (α-helices) and sheets (β-sheets).



α-Helix: The primary chain is coiled to form a spiral structure, which is stabilized by hydrogen bonds.

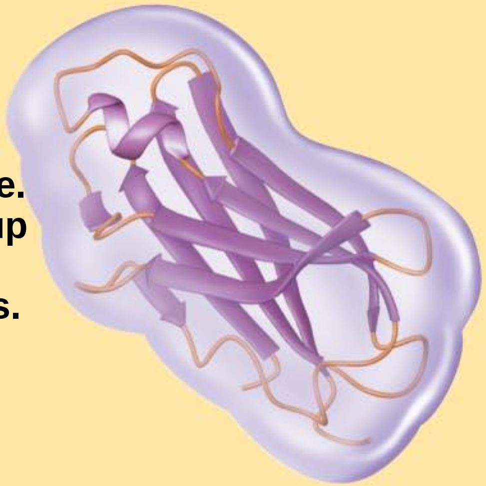


β-Sheet: The primary chain “zig-zags” back and forth forming a “pleated” sheet. Adjacent strands are held together by hydrogen bonds.

Structural Levels of Proteins

Figure 2.19c Levels of protein structure.

(c) Tertiary structure:
Superimposed on secondary structure. α-Helices and/or β-sheets are folded up to form a compact globular molecule held together by intramolecular bonds.

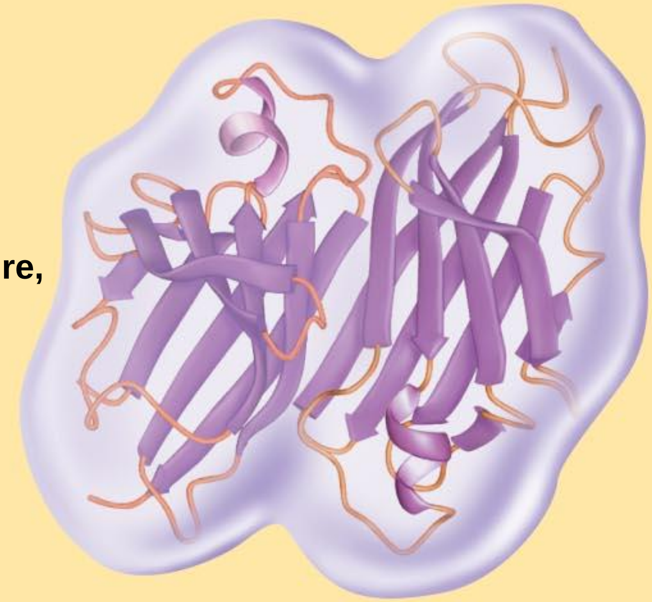


Tertiary structure of prealbumin (transthyretin), a protein that transports the thyroid hormone thyroxine in blood and cerebrospinal fluid.

Structural Levels of Proteins

Figure 2.19d Levels of protein structure.

(d) Quaternary structure:
Two or more polypeptide chains, each with its own tertiary structure, combine to form a functional protein.



Quaternary structure of a functional prealbumin molecule. Two identical prealbumin subunits join head to tail to form the dimer.

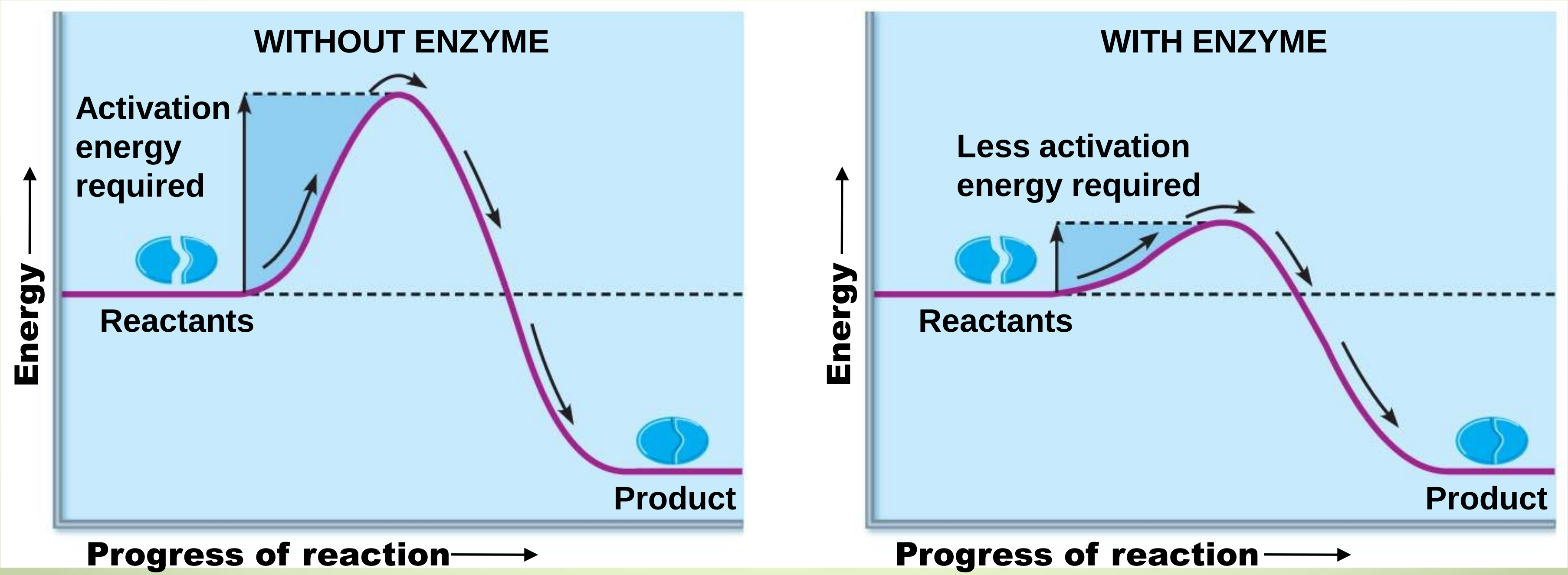
Protein Denaturation

- Globular proteins unfold and lose functional, 3-D shape
  - **Active sites** destroyed
- Can be cause by decreased pH or increased temperature
- Usually reversible if normal conditions restored
  - Re-folded back to *native* structure
- Irreversible if changes extreme
  - E.g., cooking an egg

Enzymes

- Globular proteins that act as biological **catalysts**
- Regulate and increase speed of chemical reactions
  - Lower the activation energy, increase the speed of a reaction (millions of reactions per minute!)
  - Allow reactions to occur under normal physiological conditions
- Do <u>not</u> force reactions to happen
  - Highly specific in terms of reactants (**substrates**)

- Activation energy = energy required to prime a reaction
- Enzyme overcomes energy barrier
  - Doesn't add energy → ↑ rate by lowering energy barrier
- Metabolic reactions can occur quickly and precisely



Characteristics of Enzymes

- Enzymes are specific
  - Act on specific **substrate**
- Reactions are highly regulated
- Usually end in *-ase*

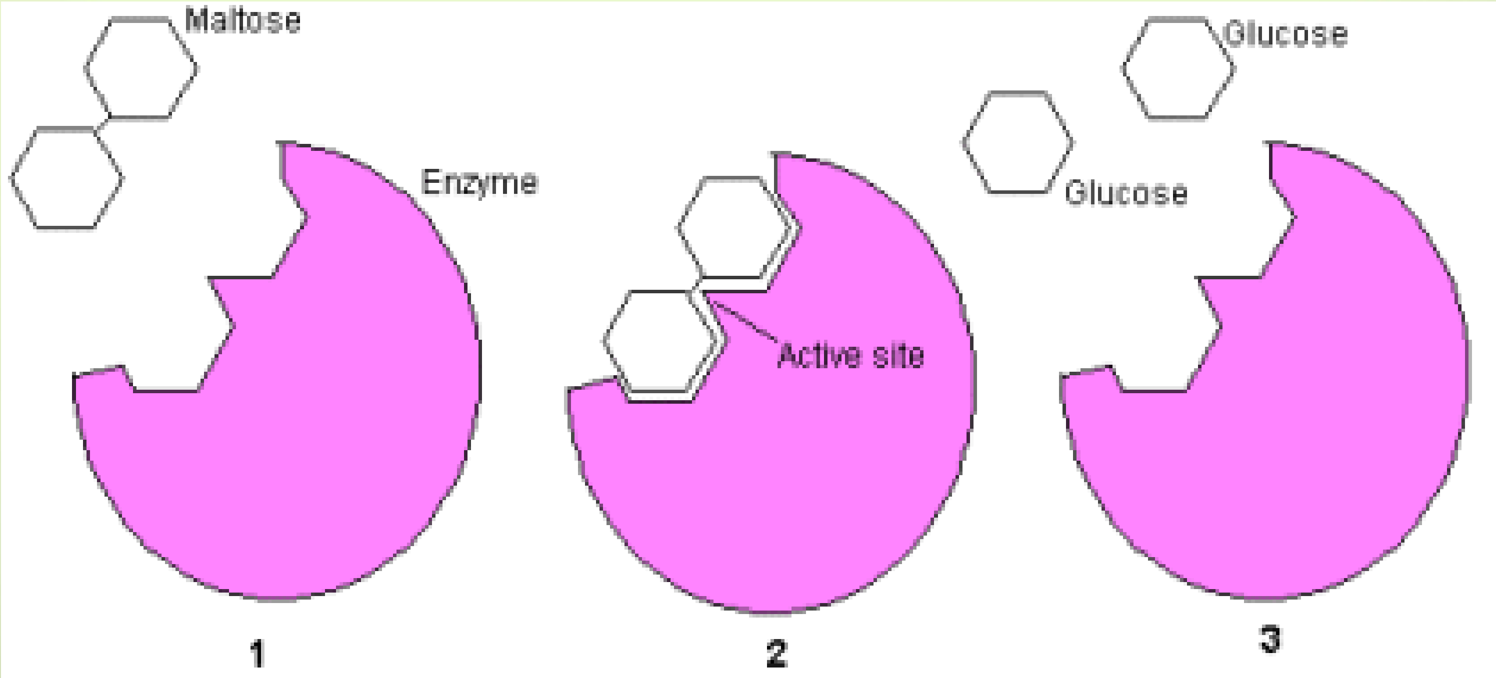
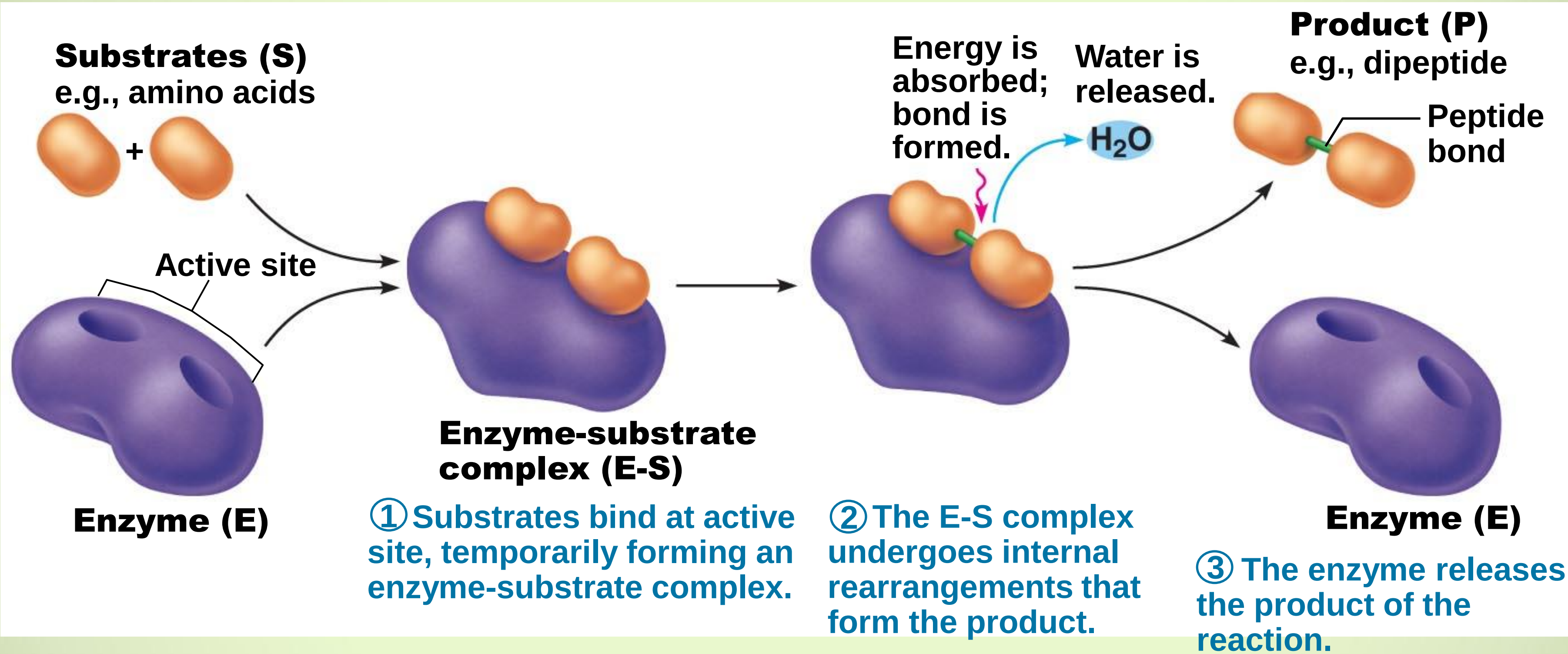


Figure 2.21 Mechanism of enzyme action.



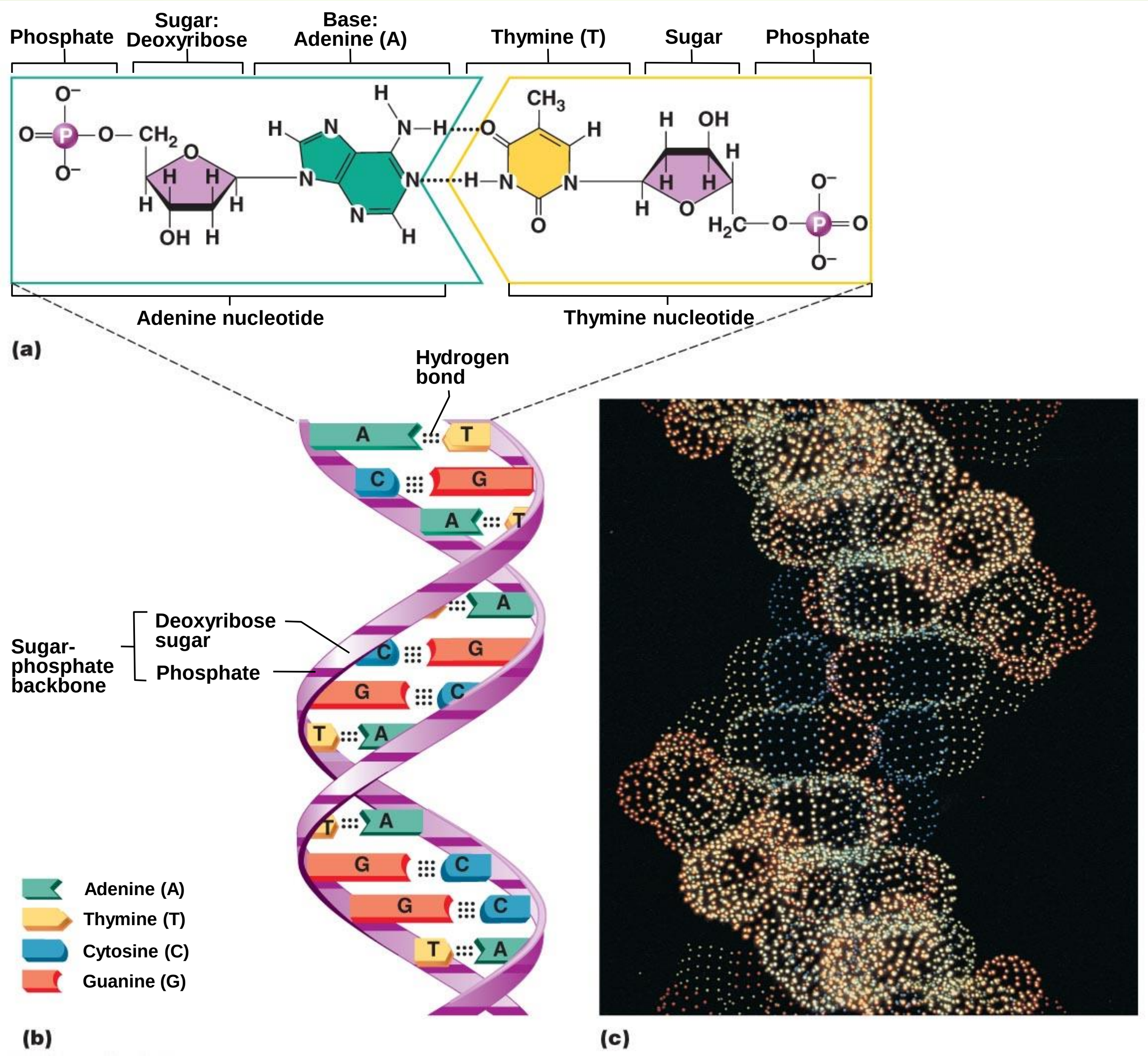
Nucleic Acids

- Deoxyribonucleic acid **(DNA)** and ribonucleic acid **(RNA)**
  - Largest molecules in the body
- Contain C, O, H, N, and P
- Polymers
  - Monomer = **nucleotide**
    - Composed of nitrogen base, a pentose sugar, and a phosphate group

Deoxyribonucleic Acid (DNA)

- Four nitrogen bases:
  - Purines: Adenine (A), Guanine (G)
    - Two-rings
  - Pyrimidines: Cytosine (C), and Thymine (T)
    - Single ring
  - **Base-pair rule** = each base pairs with its complementary base
    - A always pairs with T; G always pairs with C
- Double-stranded helical molecule **(double helix)** in the cell nucleus
- Pentose sugar is **deoxyribose**
- Provides instructions for protein synthesis
- Replicates before cell division ensuring genetic continuity

Figure 2.22 Structure of DNA.



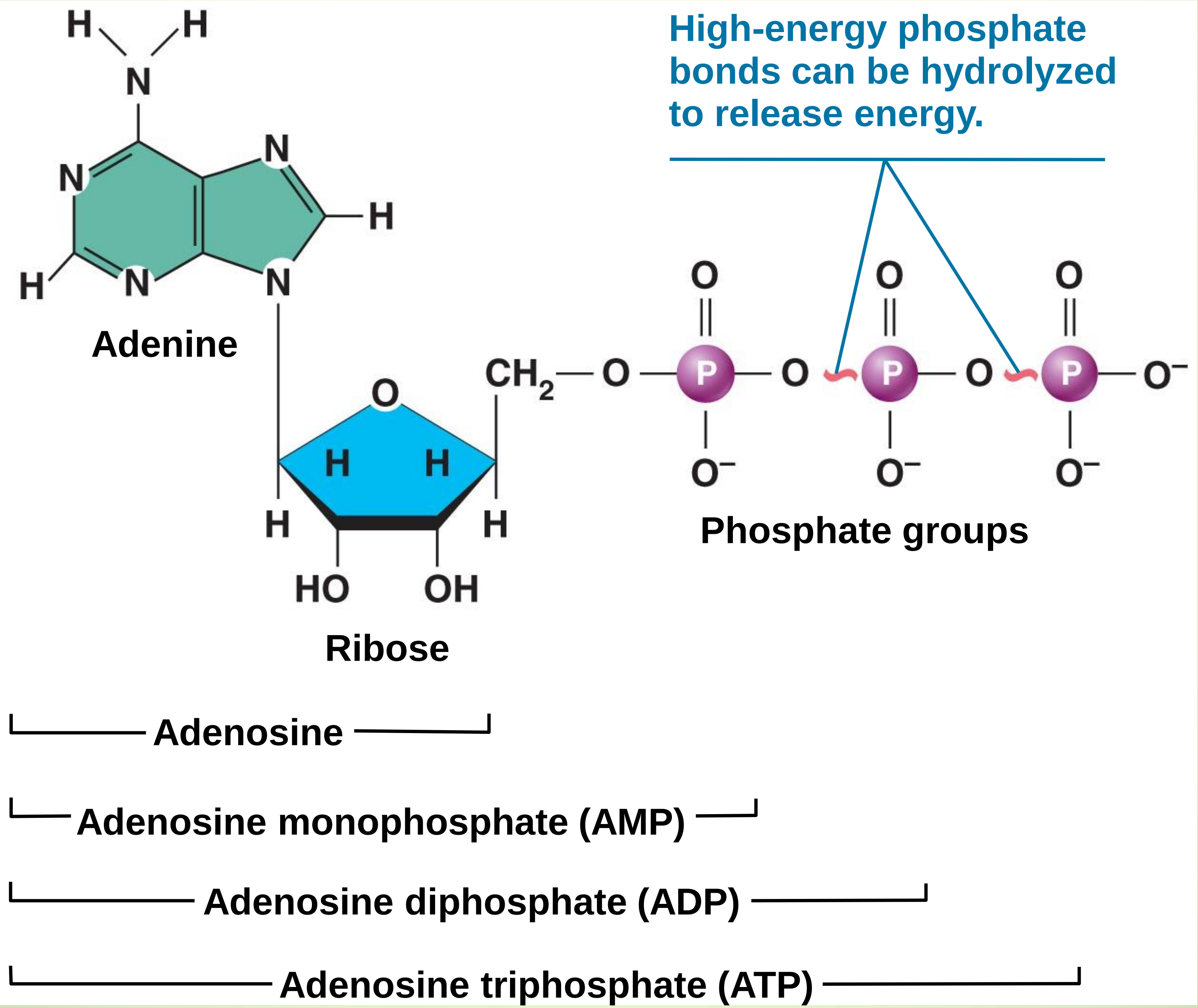
Ribonucleic Acid (RNA)

- Four nitrogen bases:
  - Adenine (A), Guanine (G), Cytosine (C), and Uracil (U) (single ring)
- Pentose sugar is **ribose**
- Single-stranded molecule mostly active outside the nucleus
- Three varieties of RNA carry out the DNA orders for protein synthesis
  - Messenger RNA (mRNA)
  - Transfer RNA (tRNA)
  - Ribosomal RNA (rRNA)

Adenosine Triphosphate (ATP)

- Captures chemical energy in glucose
- Directly powers chemical reactions in cells
- Energy form immediately useable by all body cells

Figure 2.23 Structure of ATP (adenosine triphosphate).

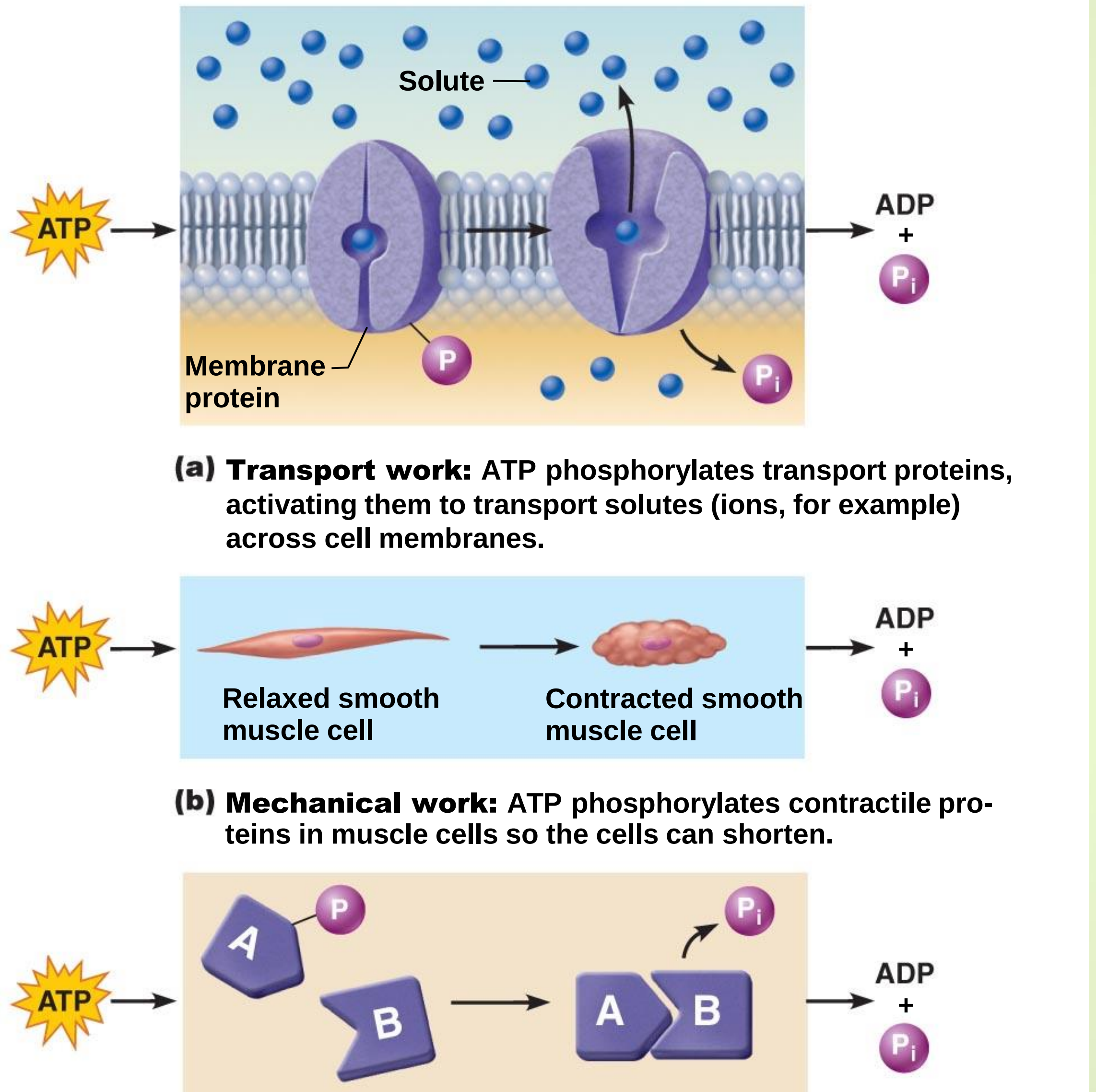


Function of ATP

Phosphorylation

- Terminal phosphates are enzymatically transferred to and energize other molecules
  - Coupled to reactions to provide energy
- Such “primed” molecules perform cellular work (life processes) using the phosphate bond energy
  - Amount of energy released and transferred during ATP hydrolysis drives most reactions

Figure 2.24 Three examples of cellular work driven by energy from ATP.



(a) Transport work: ATP phosphorylates transport proteins, activating them to transport solutes (ions, for example) across cell membranes.

(b) Mechanical work: ATP phosphorylates contractile proteins in muscle cells so the cells can shorten.

(c) Chemical work: ATP phosphorylates key reactants, providing energy to drive energy-absorbing chemical reactions.