Biology
ES131

Module 2

Chemistry in Biology (Part 1)

Elements & Biomolecules

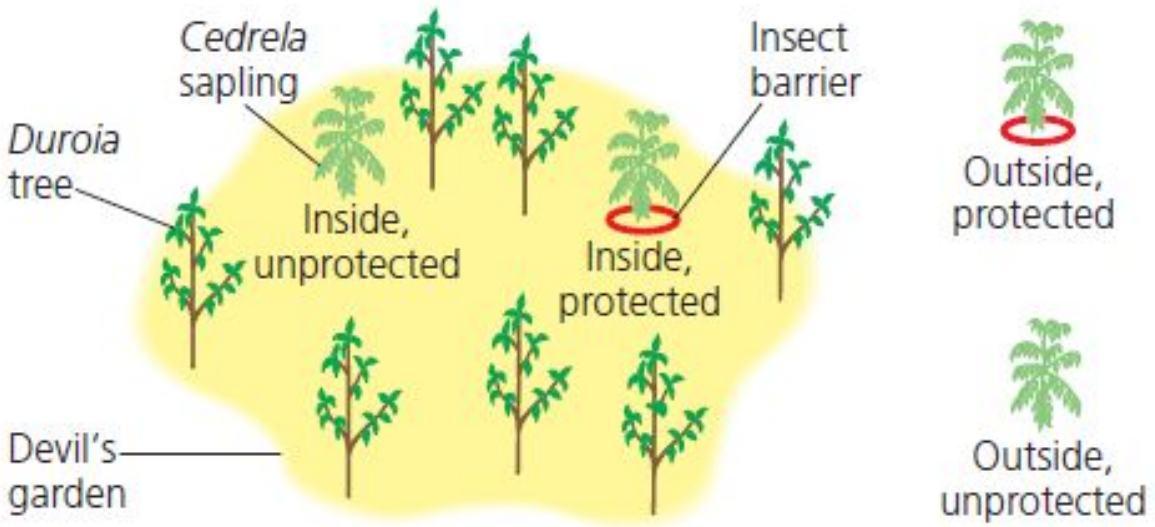
Devil’s Garden

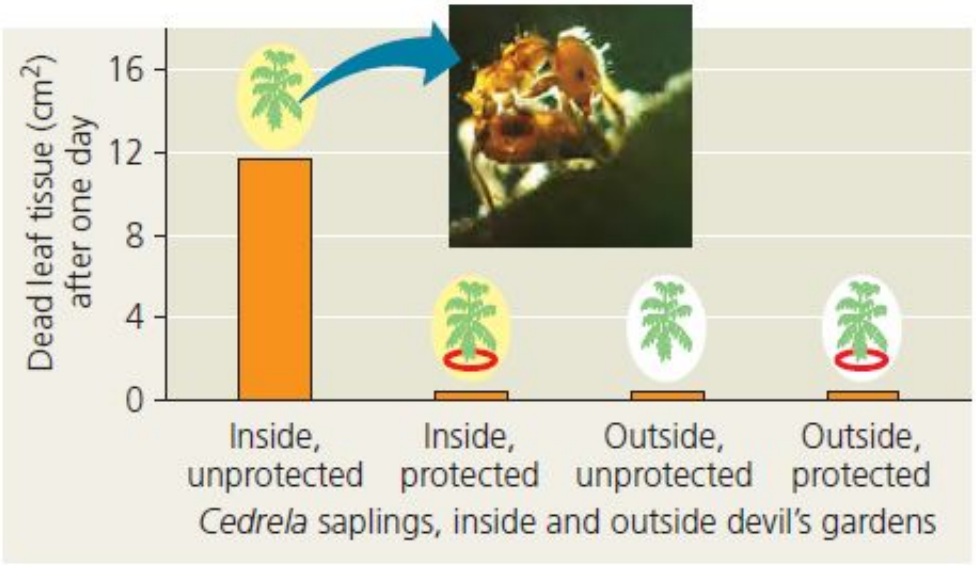
Refer: https://blogs.scientificamerican.com/compound-eye/visiting-the-devils-garden/

Who Controls The Devil's Garden?

- Researchers from Stanford University
- Hypothesis 1: Ants living in these trees, *Myrmelachista schumanni,* produce a poisonous chemical that kills trees of other species
- Hypothesis 2: The *Duroia trees themselves kill competing* trees, perhaps by means of a chemical

Devil's Garden - Experiment





Chemical Basis of Life

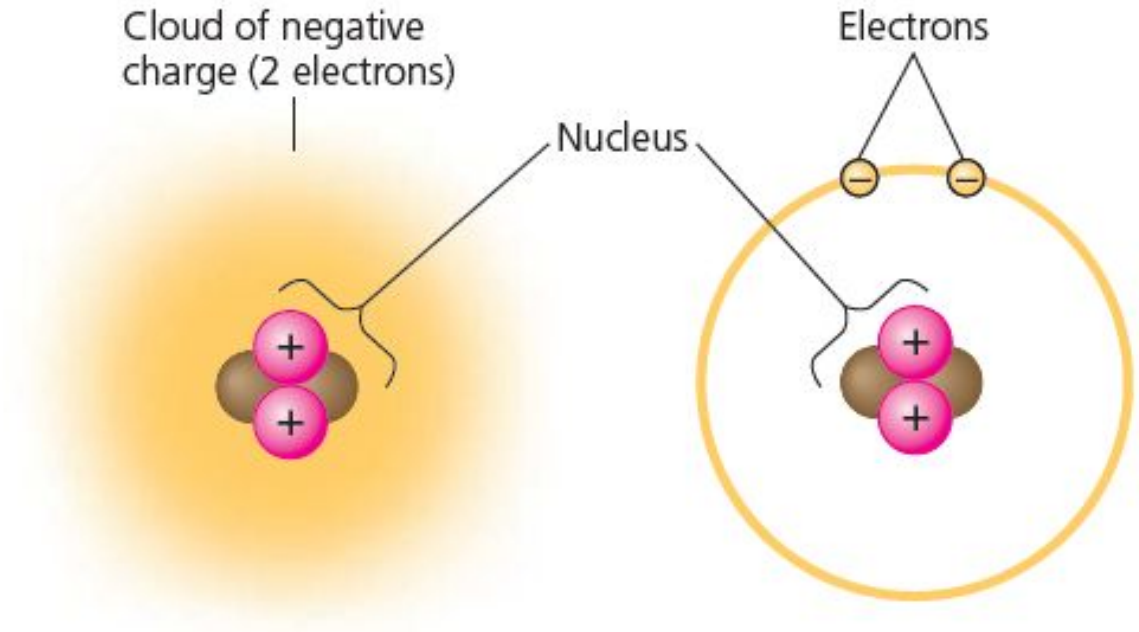
Table 2.1 Elements in the Human Body

Element	Symbol	Percentage of Body Mass (including water)	
Oxygen	O	65.0%	96.3%
Carbon	C	18.5%	
Hydrogen	H	9.5%	
Nitrogen	N	3.3%	
Calcium	Ca	1.5%	3.7%
Phosphorus	P	1.0%	
Potassium	K	0.4%	
Sulfur	S	0.3%	
Sodium	Na	0.2%	
Chlorine	Cl	0.2%	
Magnesium	Mg	0.1%	

Trace elements (less than 0.01% of mass): Boron (B), chromium (Cr), cobalt (Co), copper (Cu), fluorine (F), iodine (I), iron (Fe), manganese (Mn), molybdenum (Mo), selenium (Se), silicon (Si), tin (Sn), vanadium (V), zinc (Zn)

- Essential Elements
- Trace Elements
- CHON makes 96% of living matter
- Some elements are toxic - Arsenic

Chemical Basis of Life

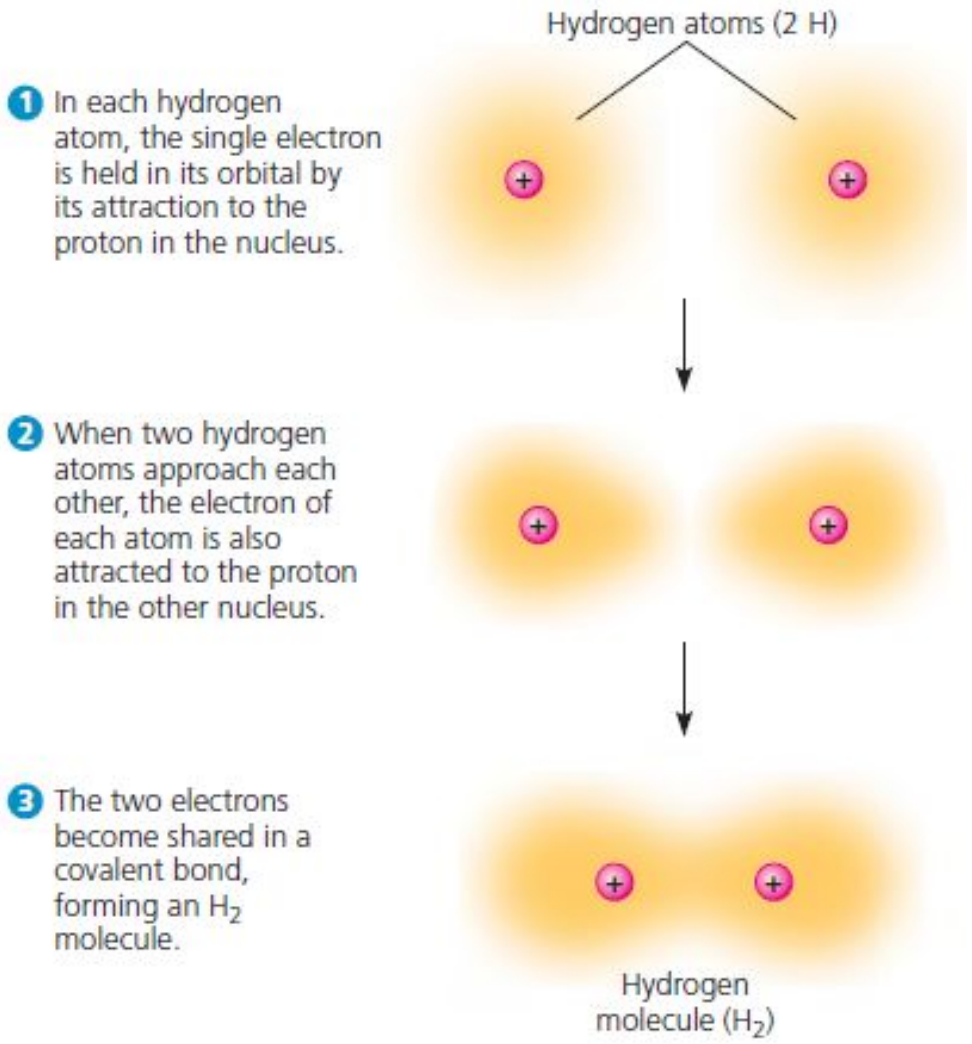


(a) This model represents the two electrons as a cloud of negative charge.

(b) In this more simplified model, the electrons are shown as two small yellow spheres on a circle around the nucleus.

▲ **Figure 2.4 Simplified models of a helium (He) atom.** The helium nucleus consists of 2 neutrons (brown) and 2 protons (pink). Two electrons (yellow) exist outside the nucleus. These models are not to scale; they greatly overestimate the size of the nucleus in relation to the electron cloud.

Chemical Basis of Life



▲ **Figure 2.11 Formation of a covalent bond.**

The formation and function of molecules depend on chemical bonding between atoms

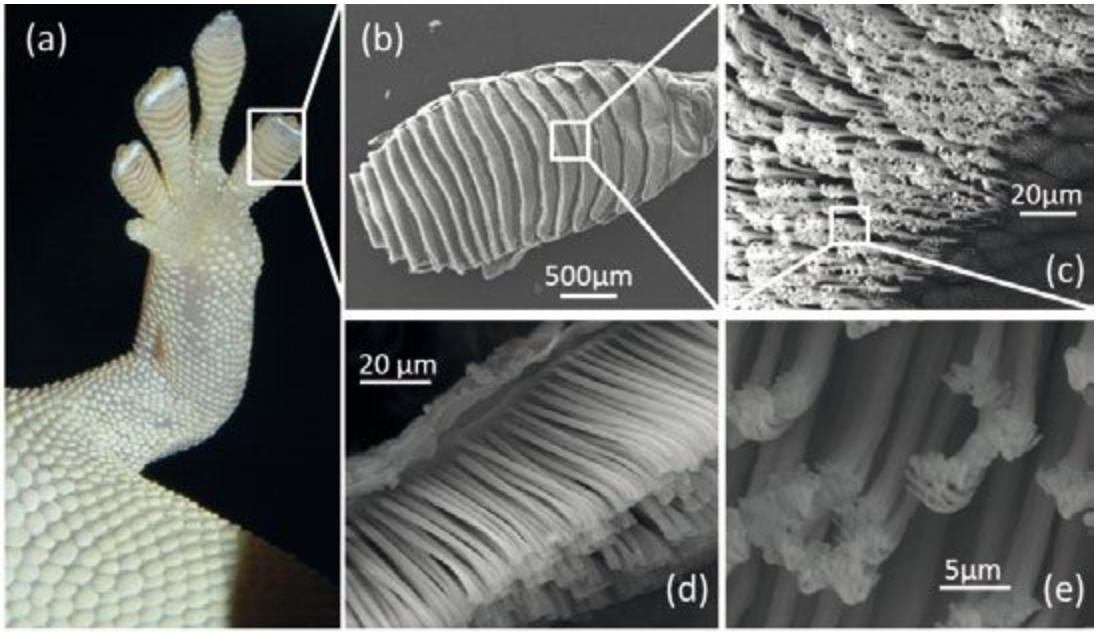
Strong Interactions

- **Covalent bonds**
- **Ionic bonds**

Chemical Basis of Life

Weak Interactions

- **Hydrogen bond**
- **Van der Waals**



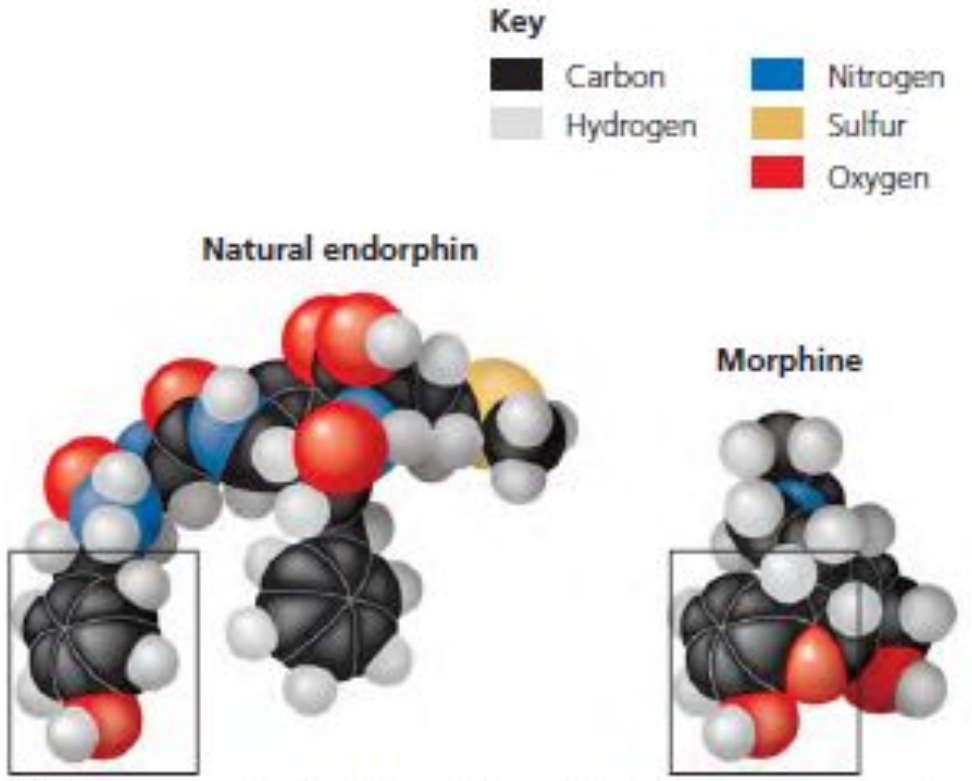
Molecular Shape and Function

- Molecular shape is crucial in biology because it determines how biological molecules recognize and respond to one another with specificity

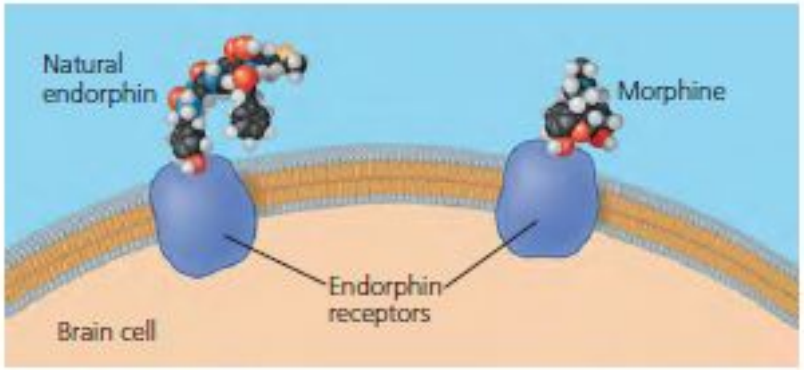
- Why would brain cells carry receptors for opiates, compounds that are not made by our bodies?

"Bugger the sweeties old lady. Got any meth-amphetamine tablets?"

Molecular Shape and Function



(a) **Structures of endorphin and morphine.** The boxed portion of the endorphin molecule (left) binds to receptor molecules on target cells in the brain. The boxed portion of the morphine molecule (right) is a close match.



(b) **Binding to endorphin receptors.** Both endorphin and morphine can bind to endorphin receptors on the surface of a brain cell.

▲ **Figure 2.18 A molecular mimic.** Morphine affects pain perception and emotional state by mimicking the brain's natural endorphins.

Molecular Diversity Arising from Carbon Skeleton Variation

(a) Length

Ethane Propane

Carbon skeletons vary in length.

(b) Branching

Butane 2-Methylpropane (commonly called isobutane)

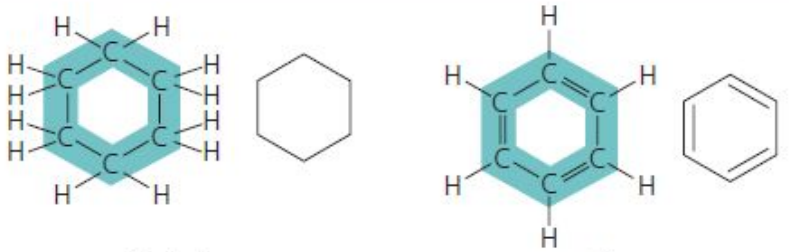
Skeletons may be unbranched or branched.

(c) Double bond position

1-Butene 2-Butene

The skeleton may have double bonds, which can vary in location.

(d) Presence of rings



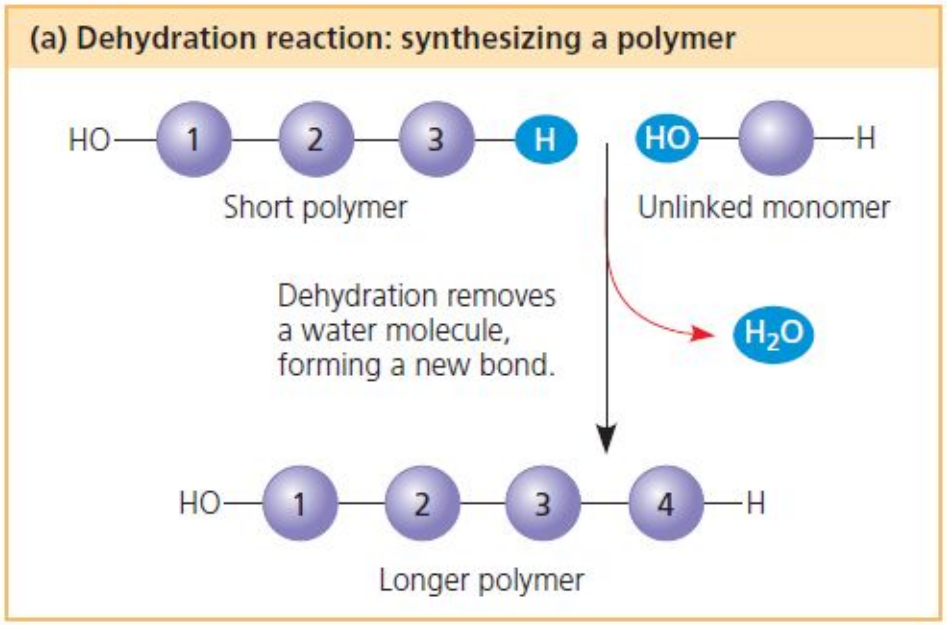
Cyclohexane Benzene

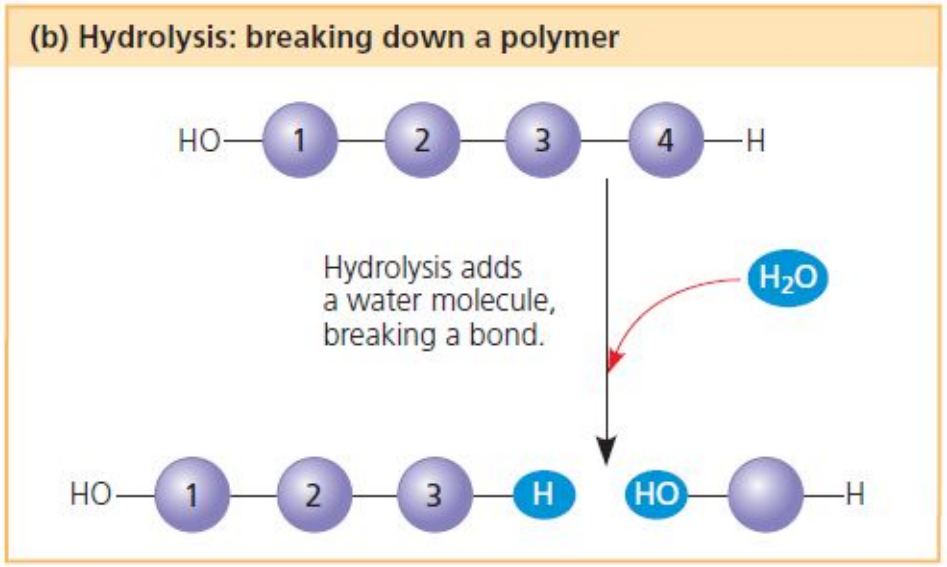
Some carbon skeletons are arranged in rings. In the abbreviated structural formula for each compound (at the right), each corner represents a carbon and its attached hydrogens.

Hydrocarbons and Isomers

Large Biological Molecules

Macromolecules are polymers, built from monomers





Diversity of Biological Molecules

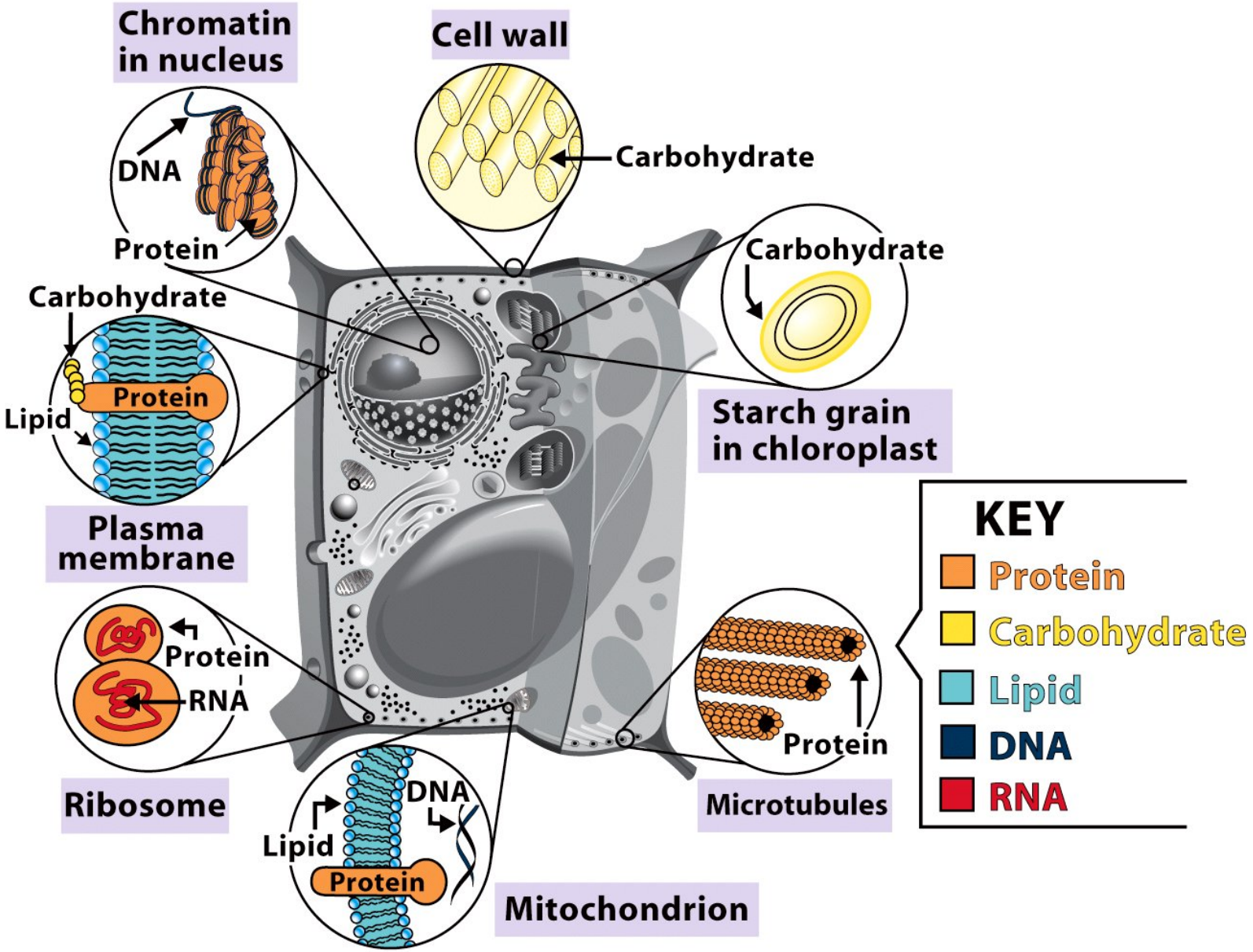


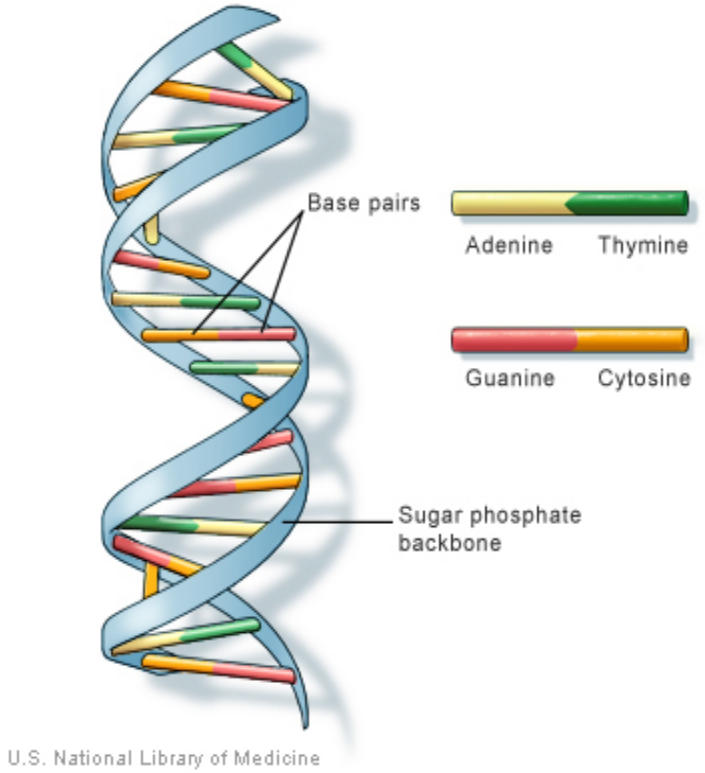
Figure 2-11 Cell and Molecular Biology, 4/e (© 2005 John Wiley & Sons)

Basic Functions

	Carbs	Lipids	Nucleic Acids	Proteins
Functions	• Energy • Storage • Structure	• Long term storage • Insulation • Protection	• Inheritance • Blueprint for metabolism	• Catalysts • Hormones • Structure
Forms	• Starch • Glycogen • Glucose • Sucrose • Cellulose	• Lipid • Fats • Oils • Waxes	• DNA • RNA • ATP	• Proteins • Enzymes

DNA (Deoxyribonucleic acid)

DNA as a CPU of the cell



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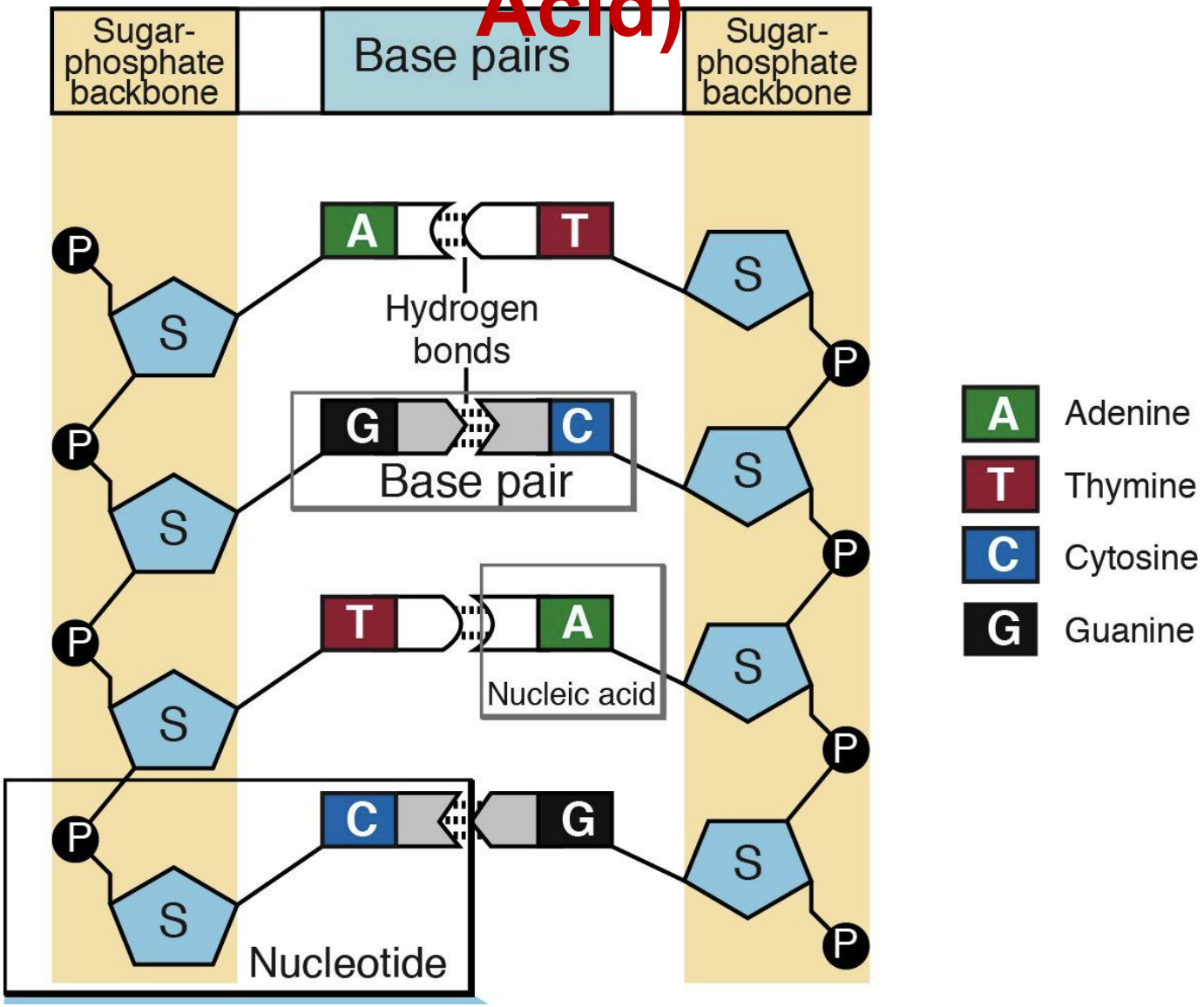
AAAGCGCGGGAATTACAGATAAATTAAAACTGCG
ACTGCGCGGCGTGAGCTCGCTGAGACTTCCTGG
ACGGGGGACAGGCTGTGGGGTTTCTCAGATAAC
TGGGCCCCTGCGCTCAGGAGGCCTTCACCCTCT
GCTCTGGGTAAAGGTAGTAGAGTCCCGGGAAAG
GGACAGGGGGCCCAAGTGATGCTCTGGGGTAC
TGGCGTGGGAGAGTGGATTTCCGAAGCTGACAG
ATGGGTATTCTTTGACGGGGGGTAGGGGCGGAA
CCTGAGAGGCGTAAGGCGT

DNA (Deoxyribonucleic Acid)



DNA (Deoxyribonucleic acid)

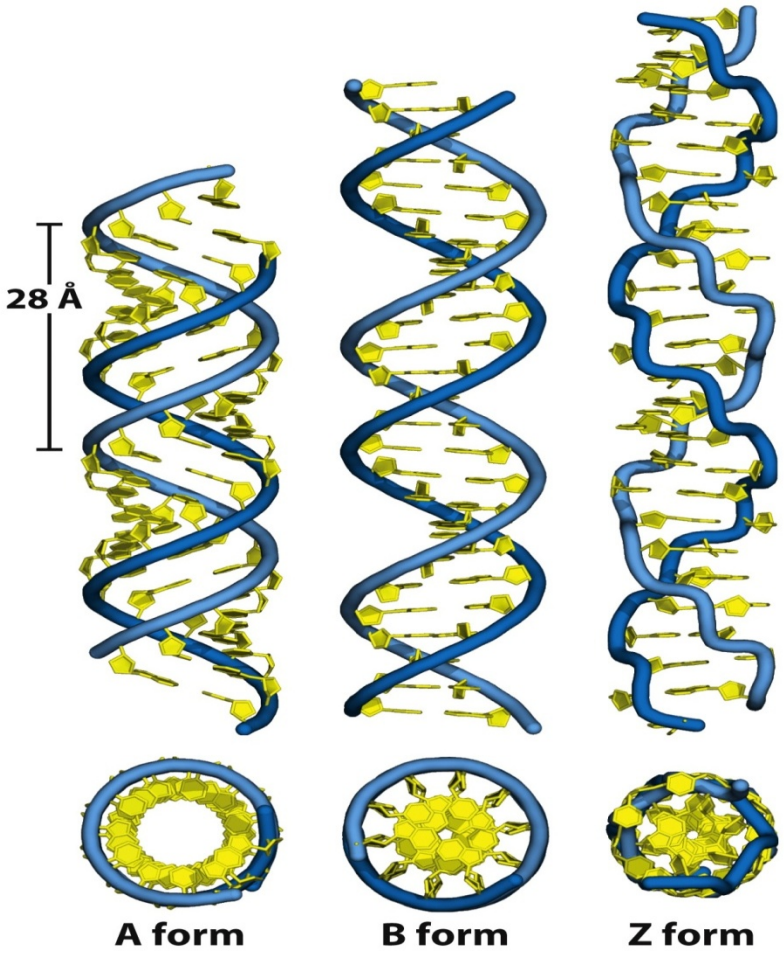


Figure 8-17 part 1
Lehninger Principles of Biochemistry, Sixth Edition
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Crick, Watson, and Wilkins were awarded the Nobel Prize for Franklin's work.

Rosalind Franklin Francis Crick James Watson Maurice Wilkins

	A form	B form	Z form
Helical sense	Right handed	Right handed	Left handed
Diameter	~26 Å	~20 Å	~18 Å
Base pairs per helical turn	11	10.5	12
Helix rise per base pair	2.6 Å	3.4 Å	3.7 Å
Base tilt normal to the helix axis	20°	6°	7°
Sugar pucker conformation	C-3′ endo	C-2′ endo	C-2′ endo for pyrimidines; C-3′ endo for purines
Glycosyl bond conformation	Anti	Anti	Anti for pyrimidines; syn for purines

Figure 8-17 part 2
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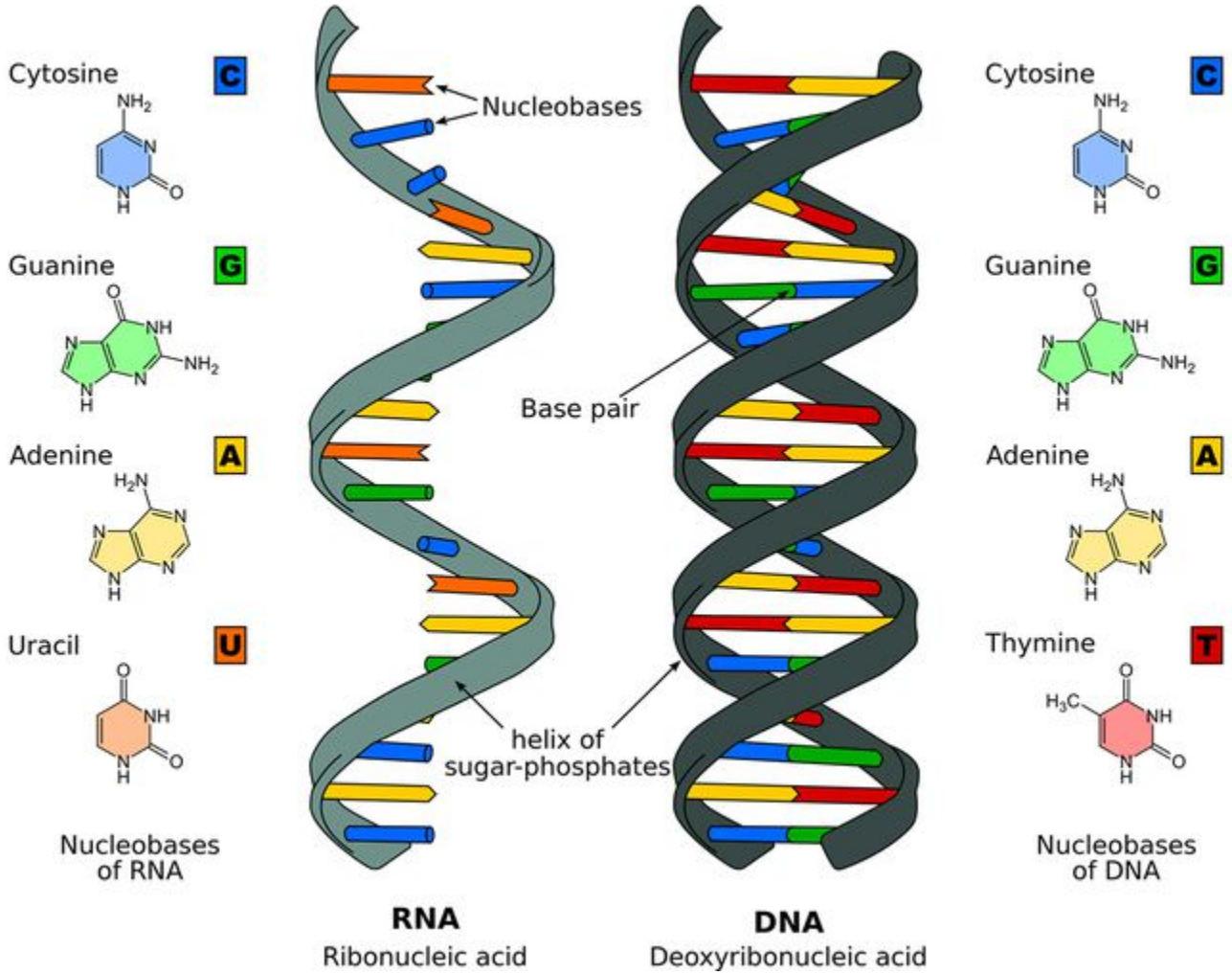
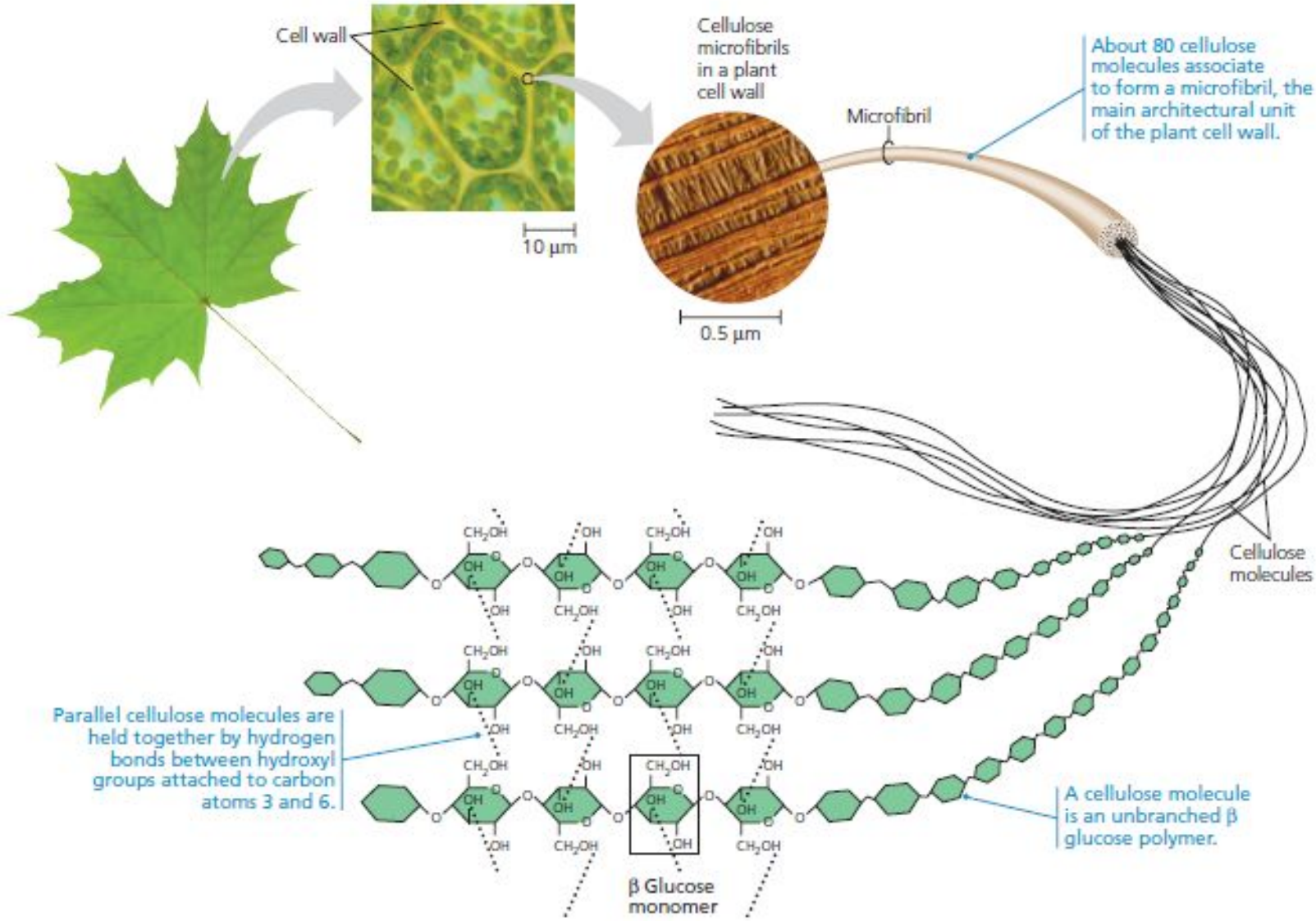
RNA (Ribonucleic Acid)



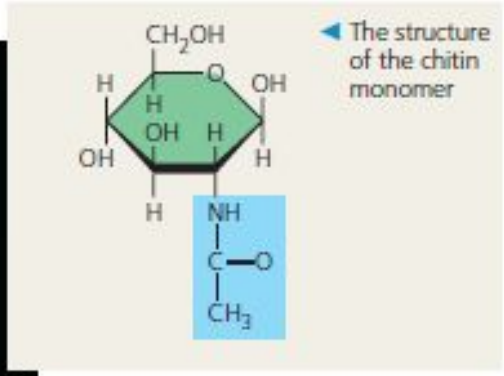
RNA molecules perform a variety of roles in the cell but are mainly involved in the process of **protein synthesis (translation)** and its regulation

Carbohydrates



▲ **Figure 5.8 The arrangement of cellulose in plant cell walls.**

Carbohydrates



◀ The structure of the chitin monomer

◀ Chitin forms the exoskeleton of arthropods. This cicada is molting, shedding its old exoskeleton and emerging in adult form.

▲ Chitin is used to make a strong and flexible surgical thread that decomposes after the wound or incision heals.

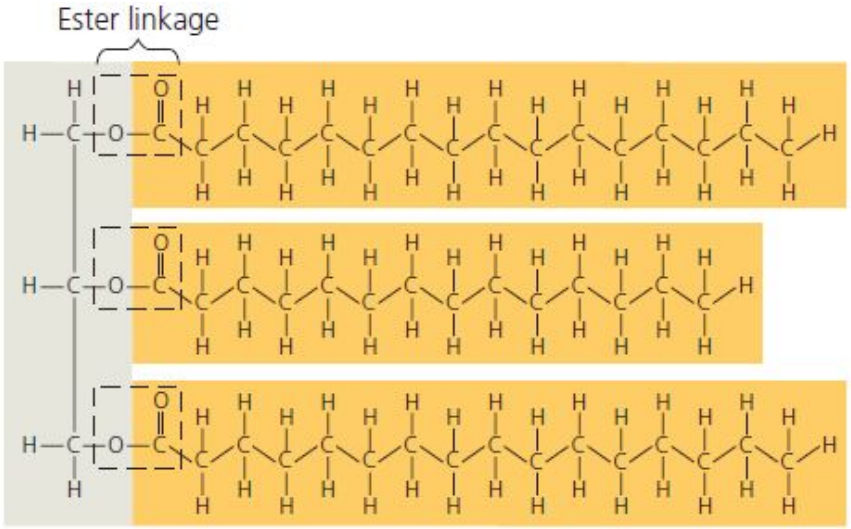
▲ **Figure 5.9 Chitin, a structural polysaccharide.**

Several functions

- **Cellulose**
- **Chitin**
- **Starch**

Lipids

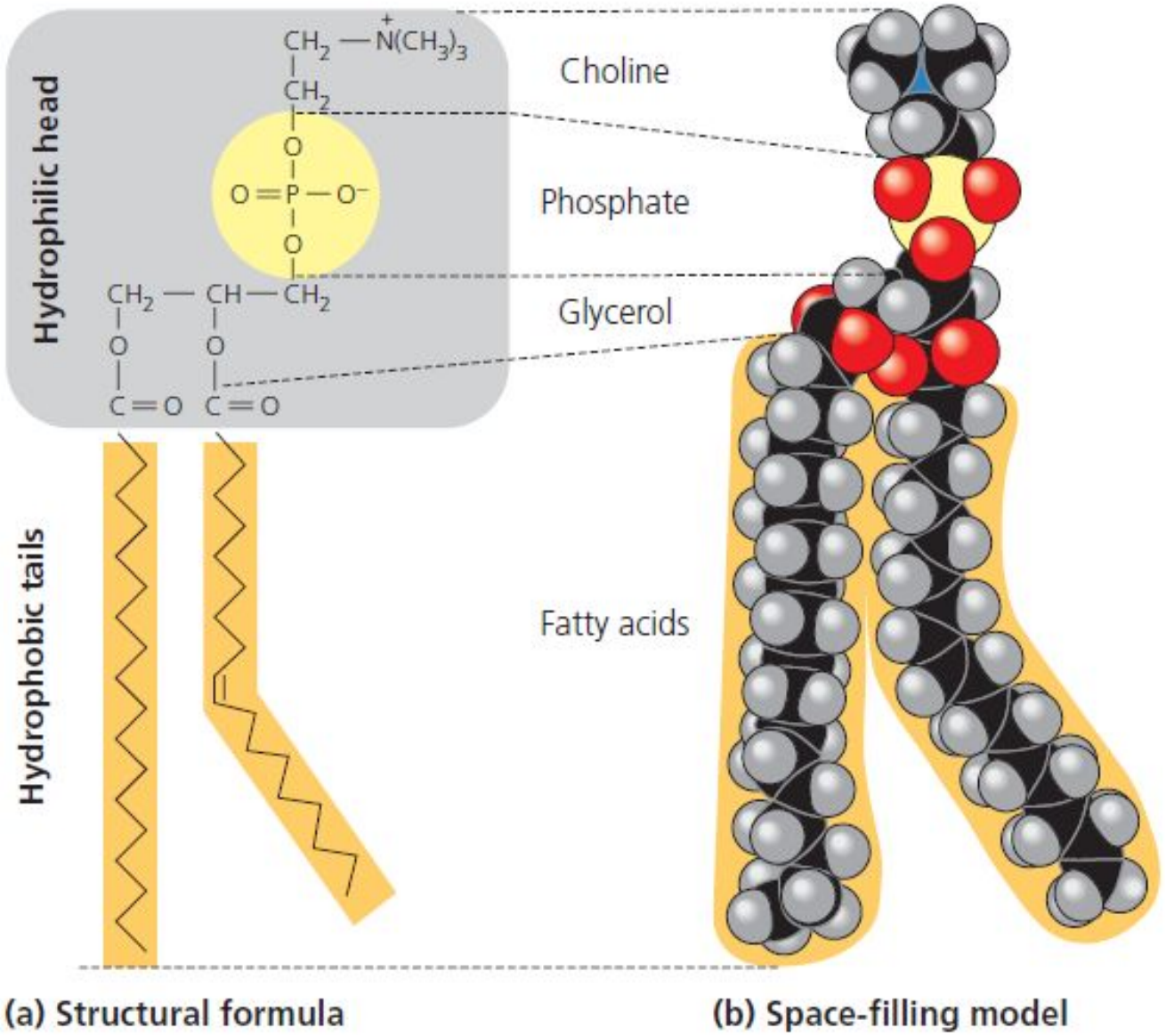
Fats in Practice



Fat in Theory

Fatty acids, oils, phospholipids, and steroids

Phospholipids



Phospholipids – Lipid Bilayer

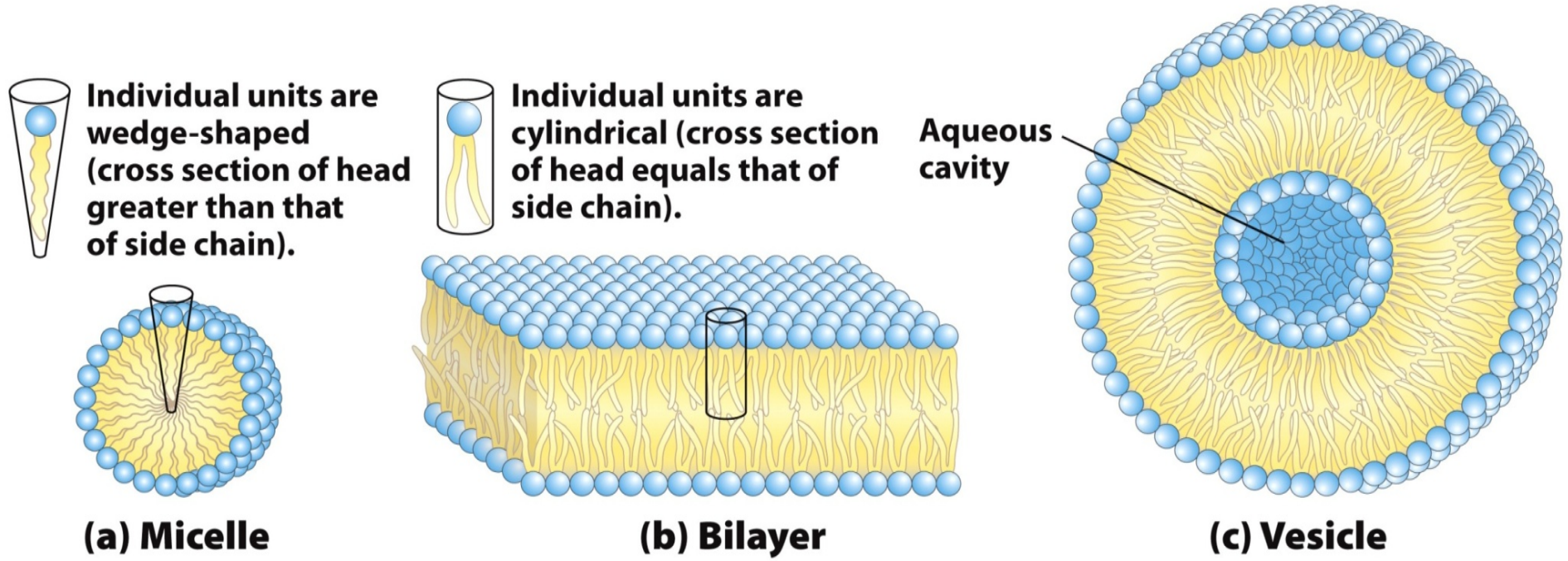


Figure 11-4
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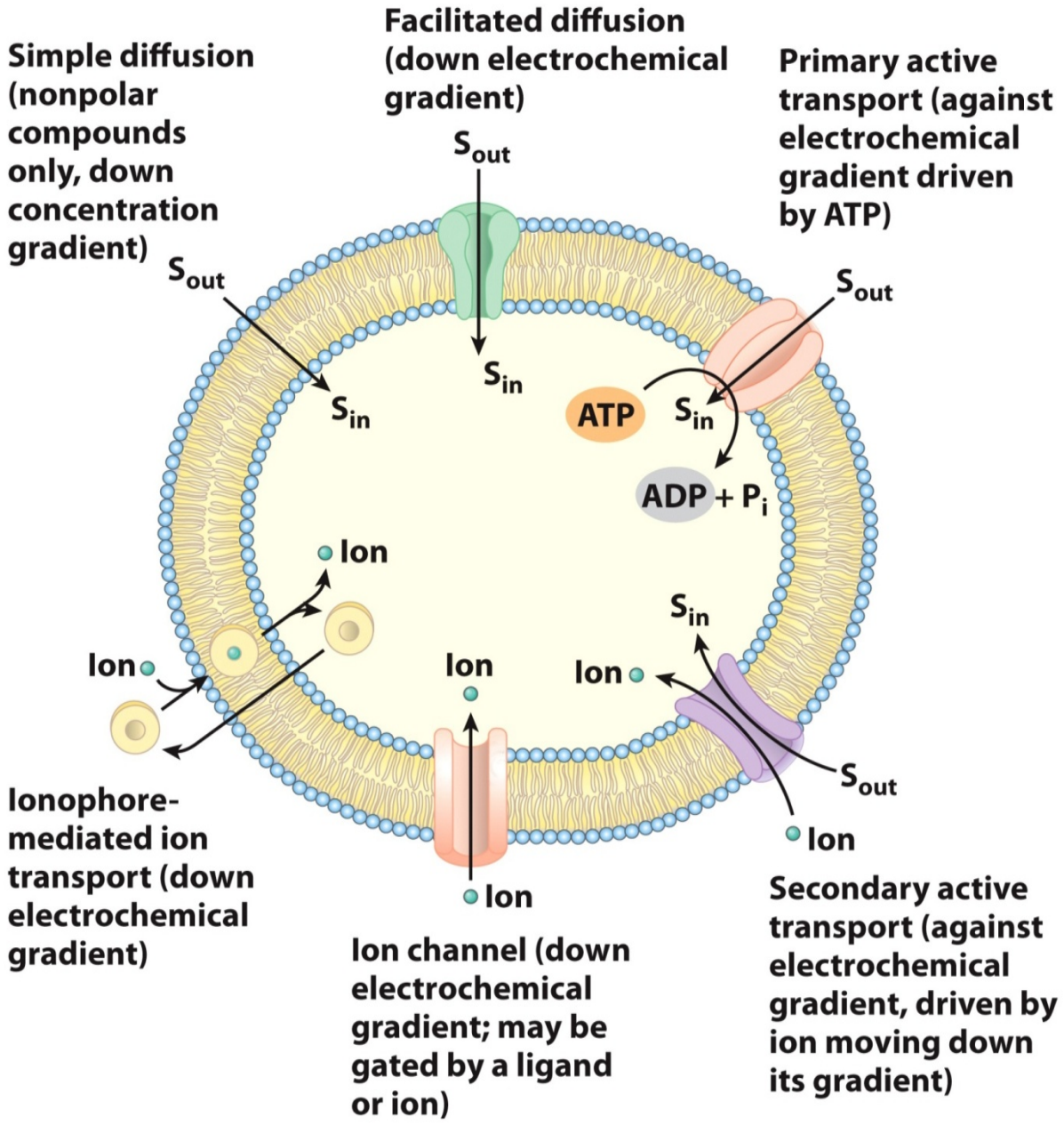
Cell Membrane



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Proteins

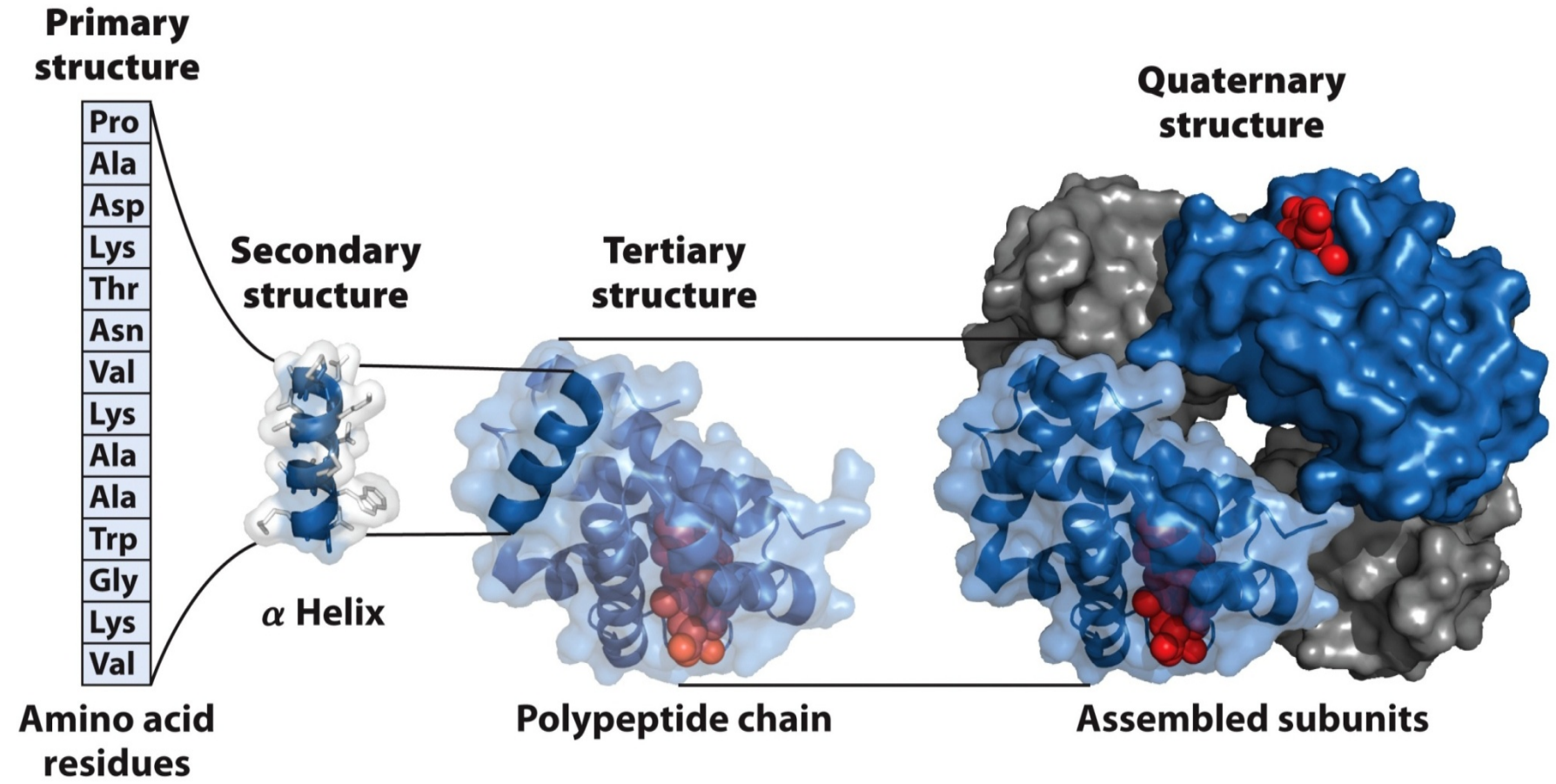

Figure 3-23
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Proteins are made up of Amino Acids (building blocks for proteins)

Amino Acids

- Proteins make up more than 50 % of the dry mass of animals and bacteria, and perform important functions in living organisms.

- Essential amino acids: can not be synthesized by animals, so must be taken in diet. In humans such amino acids are 8, in other animals are 7.

- Non Essential Amino acids: Can be synthesized by animals, so may not be taken in diet

Structural Organization of Proteins

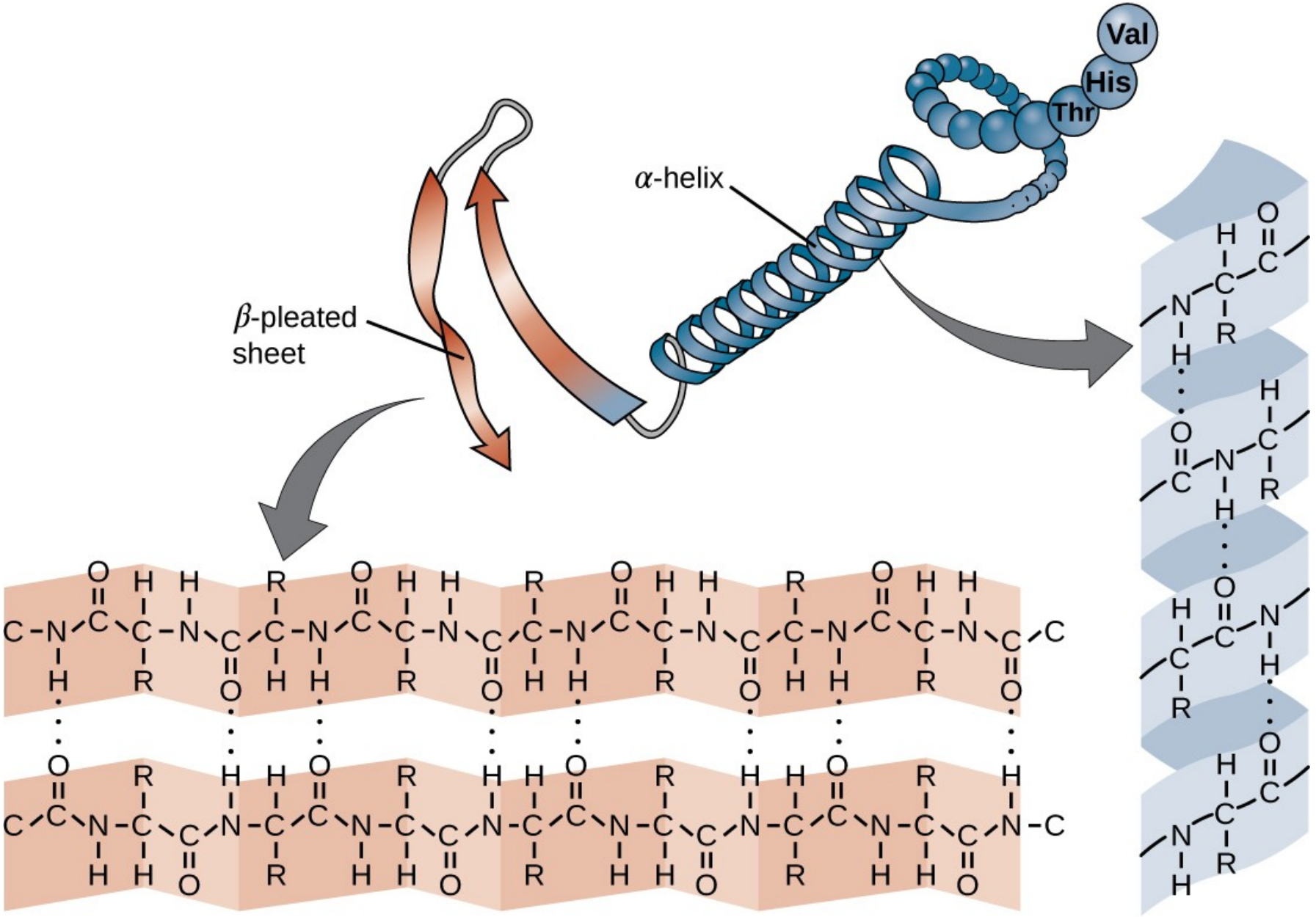
- **Primary Structure**: two dimensional, simple chain of AA with peptide (covalent) bond e.g. Insulin

- **Secondary Structure**: Various functional groups exposed on outer surface interact with hydrogen bonds
  α-helix – e.g. keratin, hair, fur, clans, hooves
  β-pleated – B. keratin of feathers, silk fibroin
  Collagen Helix: 3 α-helices coiled around one another

- **Tertiary Structure**: Additional bonds between functional groups, twisting of secondary structure, weak covalent and high energy disulphide bonds are formed e.g. Myoglobin

- **Quaternary** Structure: Formed as a result of 2-more polypeptide chain and have specific orientation

Structural Organization of Proteins



Different Types of Proteins

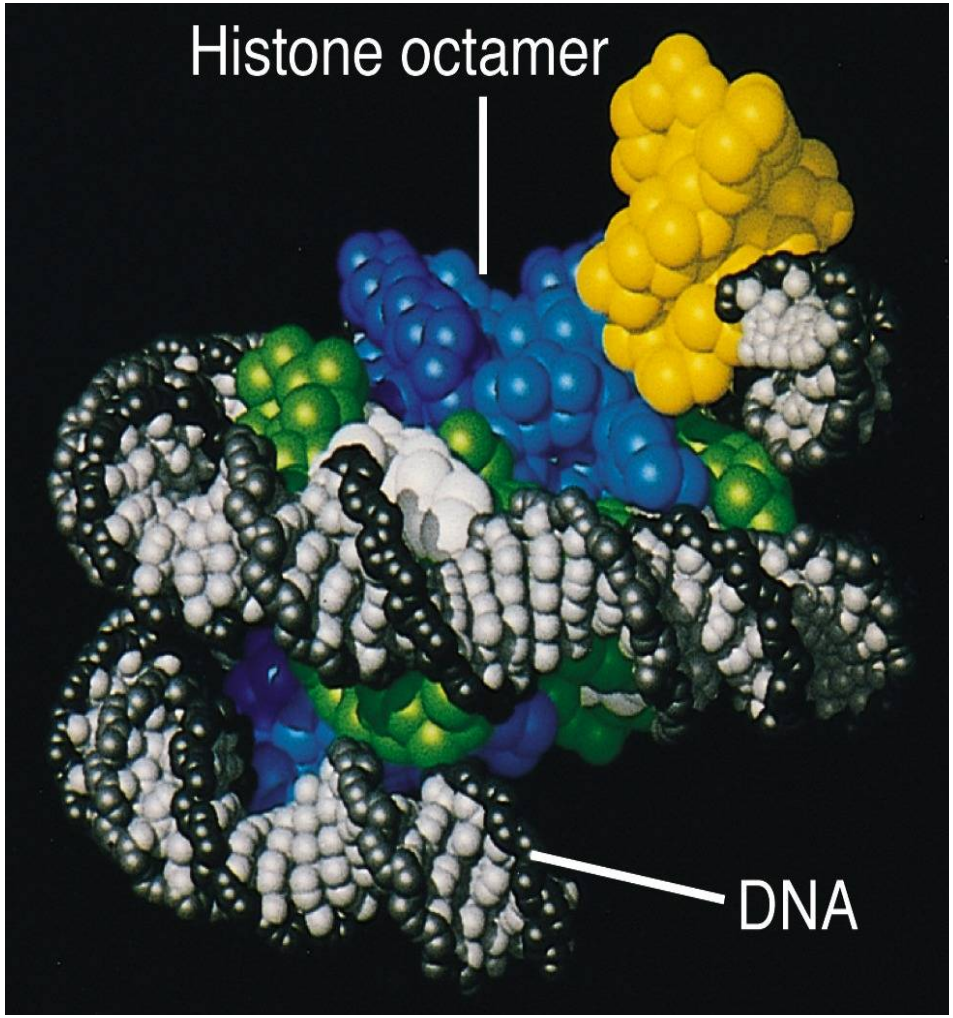
Types of proteins according to structure

1. **Fibrous** – collagen fibres, keratin, elastin, fibrin, fibroin, actin, myosin
2. **Globular** – glutelin, protemine, globulin, albumin, glutenin, orygemin.
3. **Intermediate** – myosin, fibrinogen

Types of proteins according to chemical nature

1. **Simple** – only AA. Albumin, globulin, protanine, fish, prolamine (corn, pl, wheat), histone (corn, wheat), glutelin (glutenin), keratin.
2. **Conjugated** – protein + non protein (prosthetic group) e.g. **Nucleoprotein** (nucleic acid), **chromoprotein** (Hb, cytochrome), **metallo** (with metals Zn, Fe), **lipoprotein**, **glycoprotein** etc.

Structural Proteins



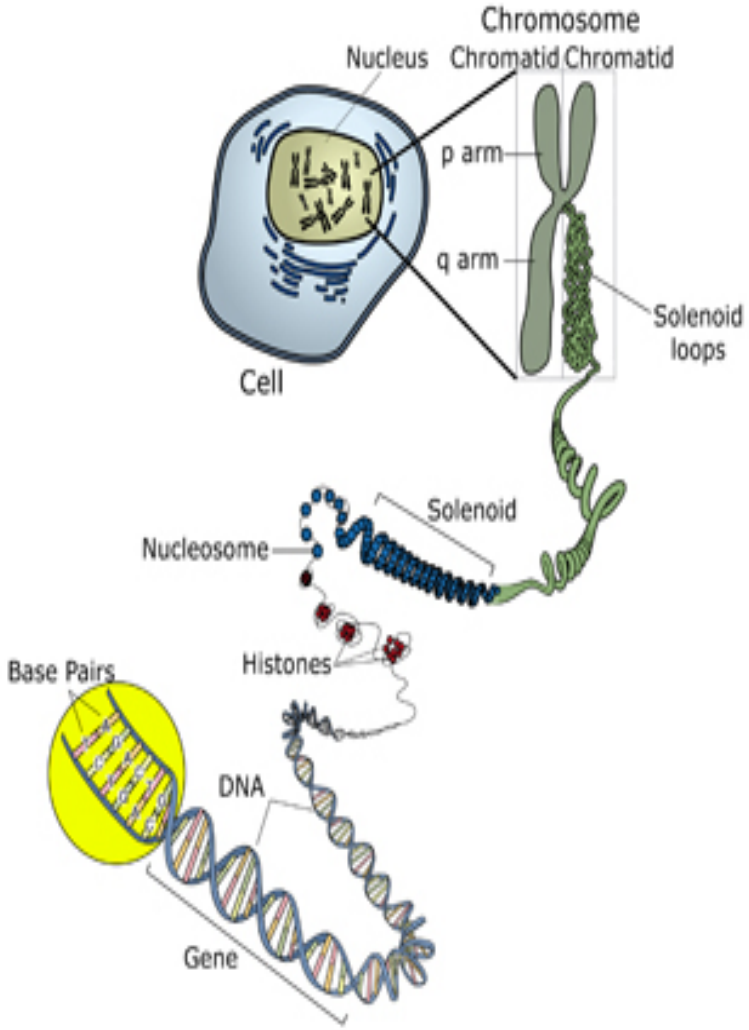
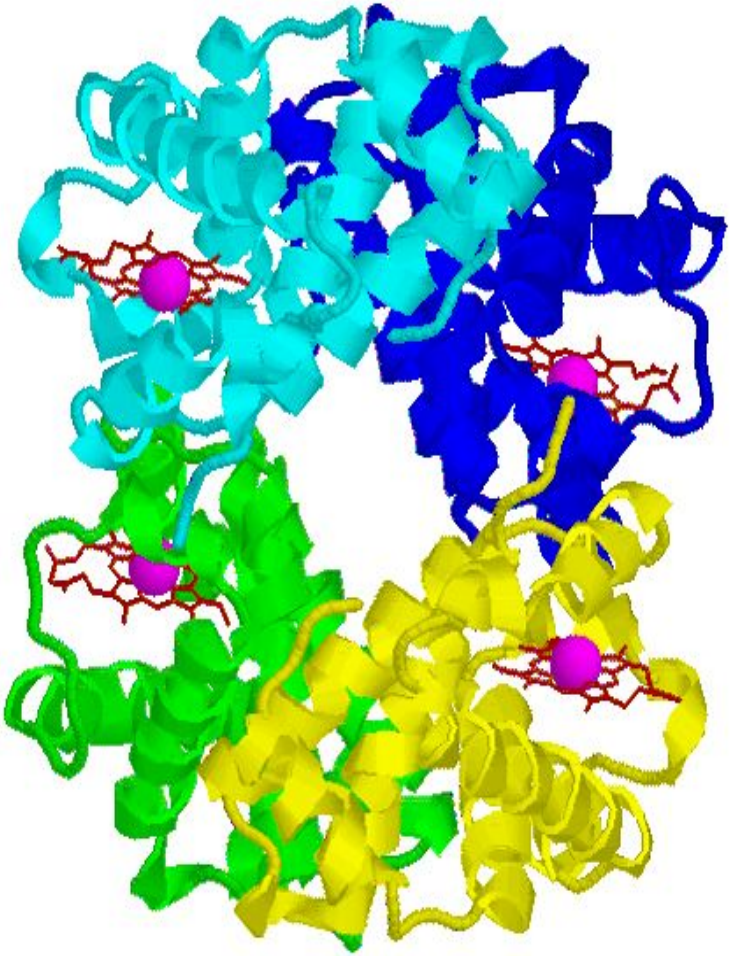
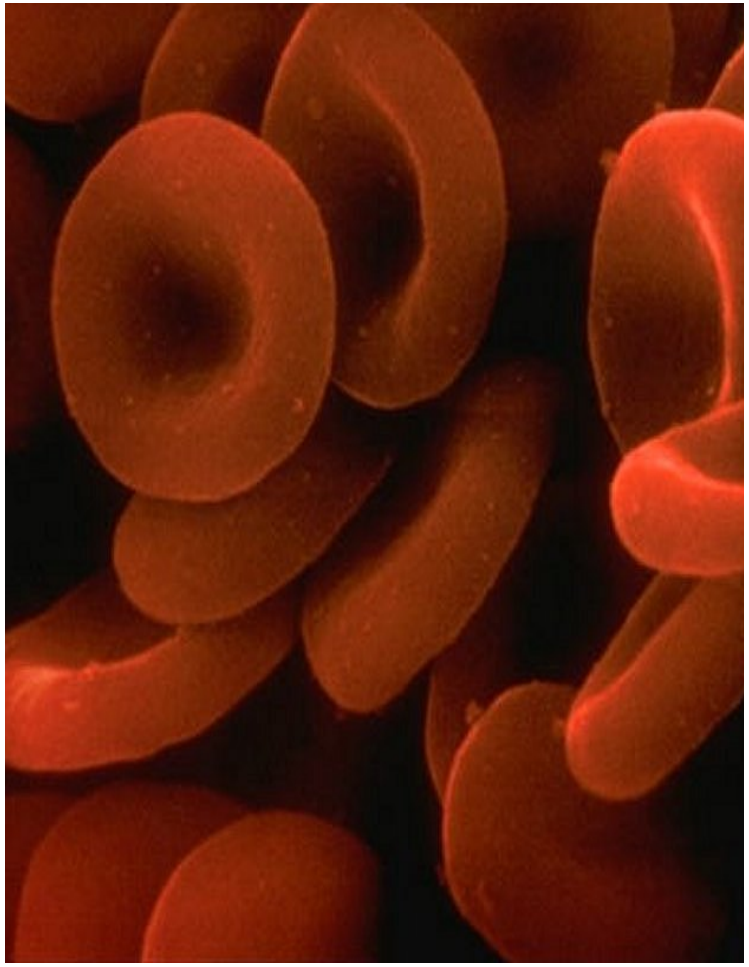


Image adapted from: National Human Genome Research Institute.

Transport Proteins



Hemoglobin

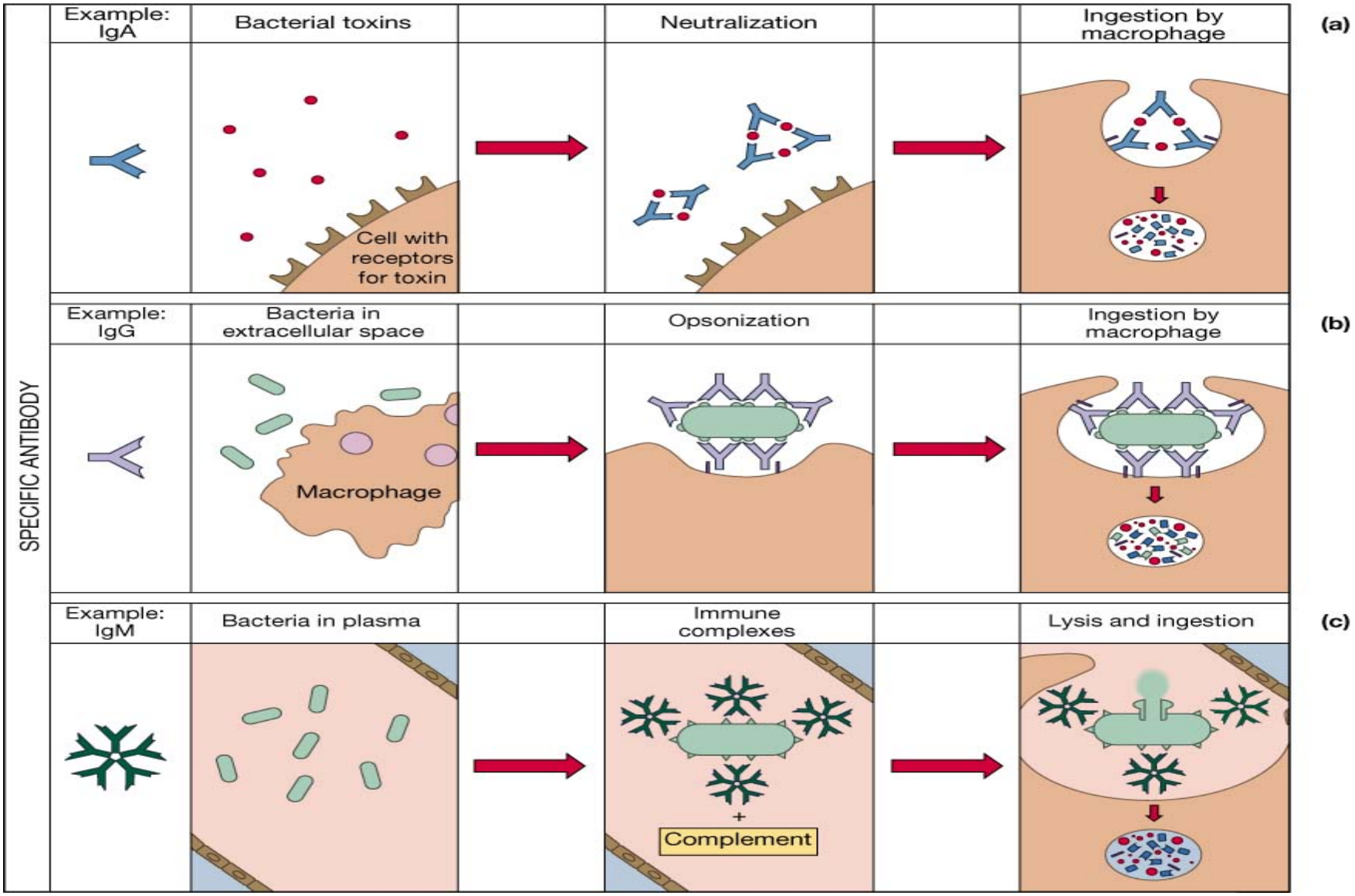


Red Blood Cell

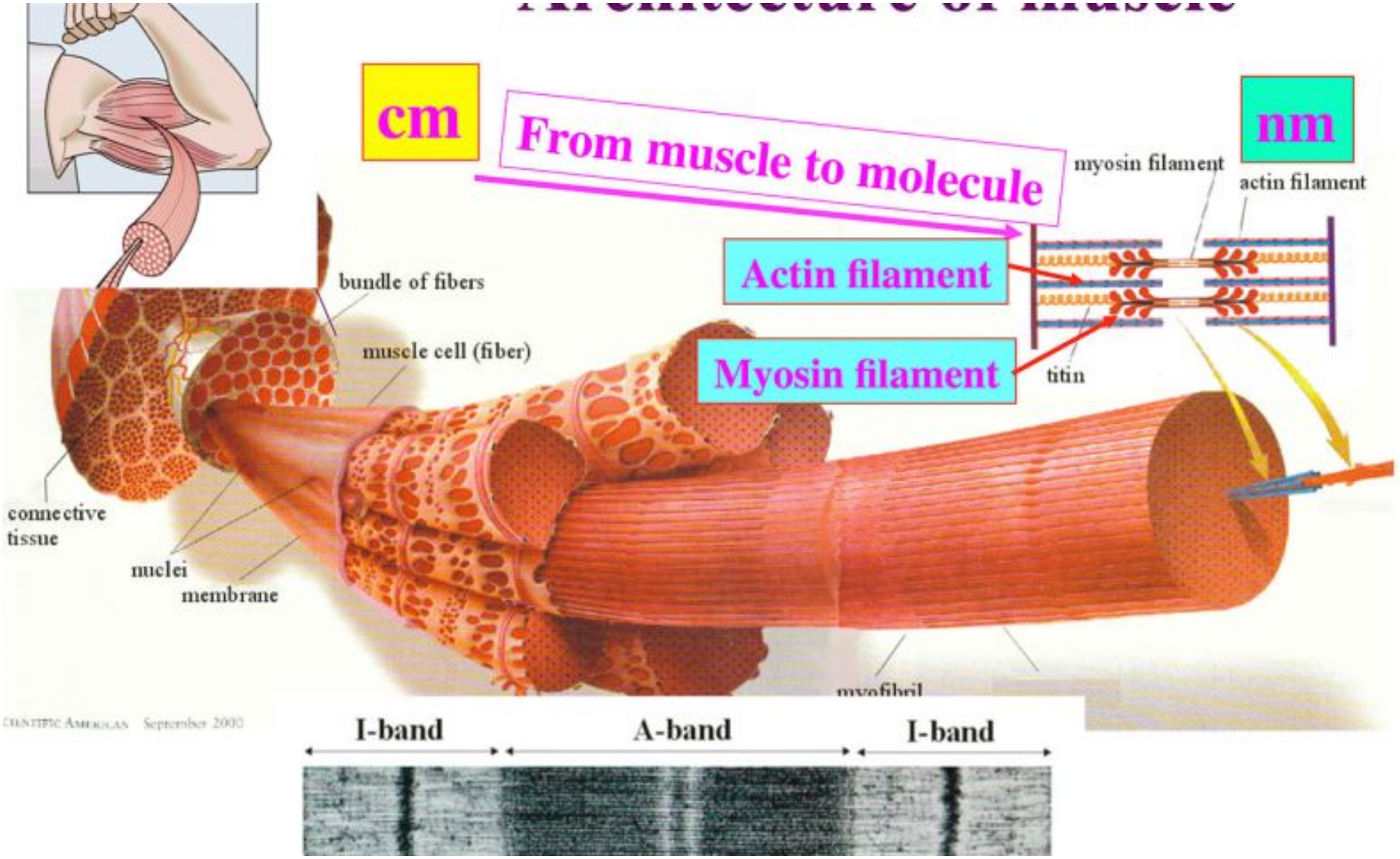
Sickle-cell Anemia

	Primary Structure	Secondary and Tertiary Structures	Quaternary Structure	Function	Red Blood Cell Shape
Normal hemoglobin	1 Val 2 His 3 Leu 4 Thr 5 Pro 6 Glu 7 Glu	β subunit	Normal hemoglobin α β α β	Molecules do not associate with one another; each carries oxygen.	Normal red blood cells are full of individual hemoglobin molecules, each carrying oxygen. 10 μm
Sickle-cell hemoglobin	1 Val 2 His 3 Leu 4 Thr 5 Pro 6 Val 7 Glu	Exposed hydrophobic region β subunit	Sickle-cell hemoglobin α β α β	Molecules interact with one another and crystallize into a fiber; capacity to carry oxygen is greatly reduced.	Fibers of abnormal hemoglobin deform red blood cell into sickle shape. 10 μm

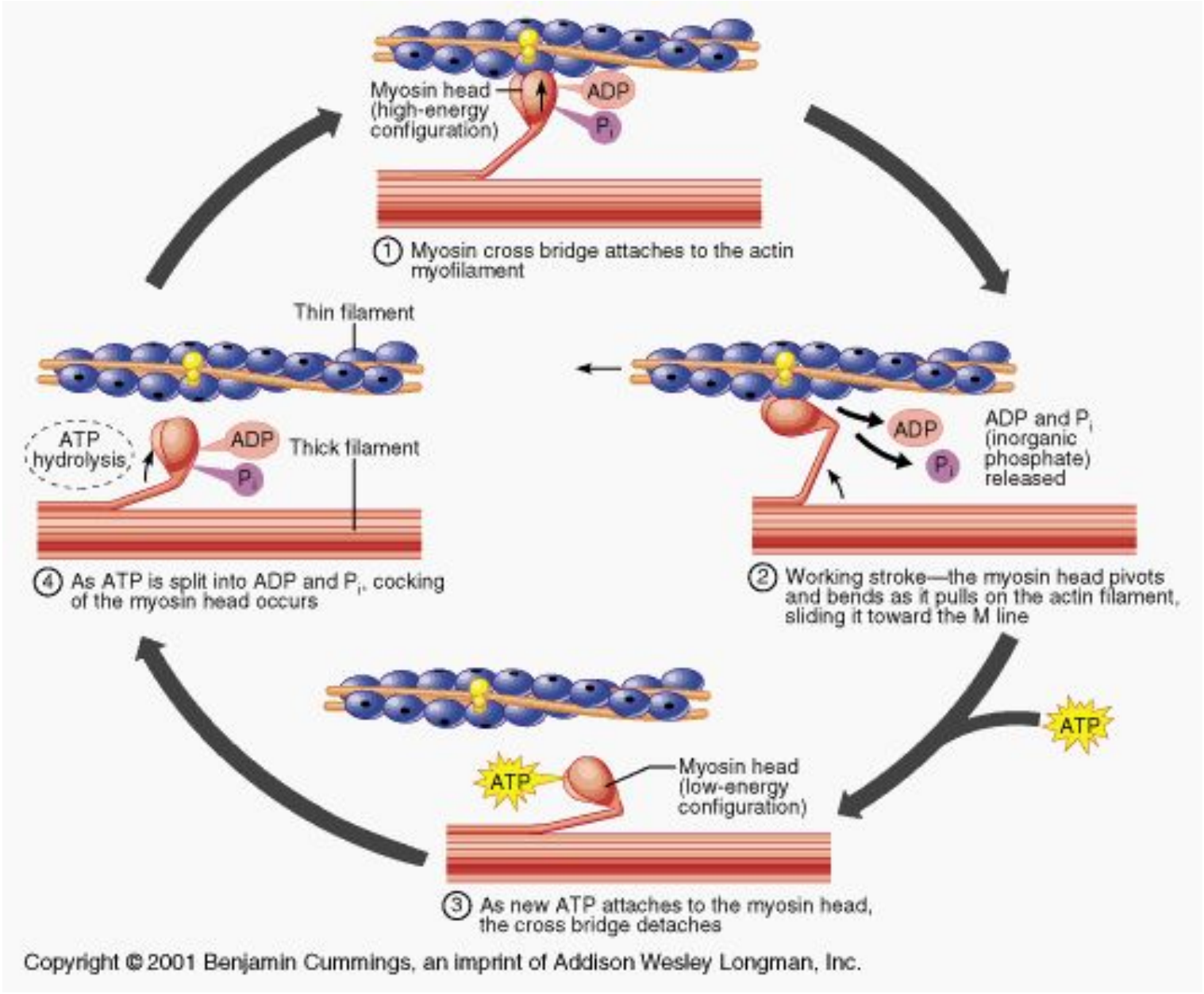
Immunity: Antibodies



Contractile Function: Actin & Myosin



Contractile Function: Actin & Myosin



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