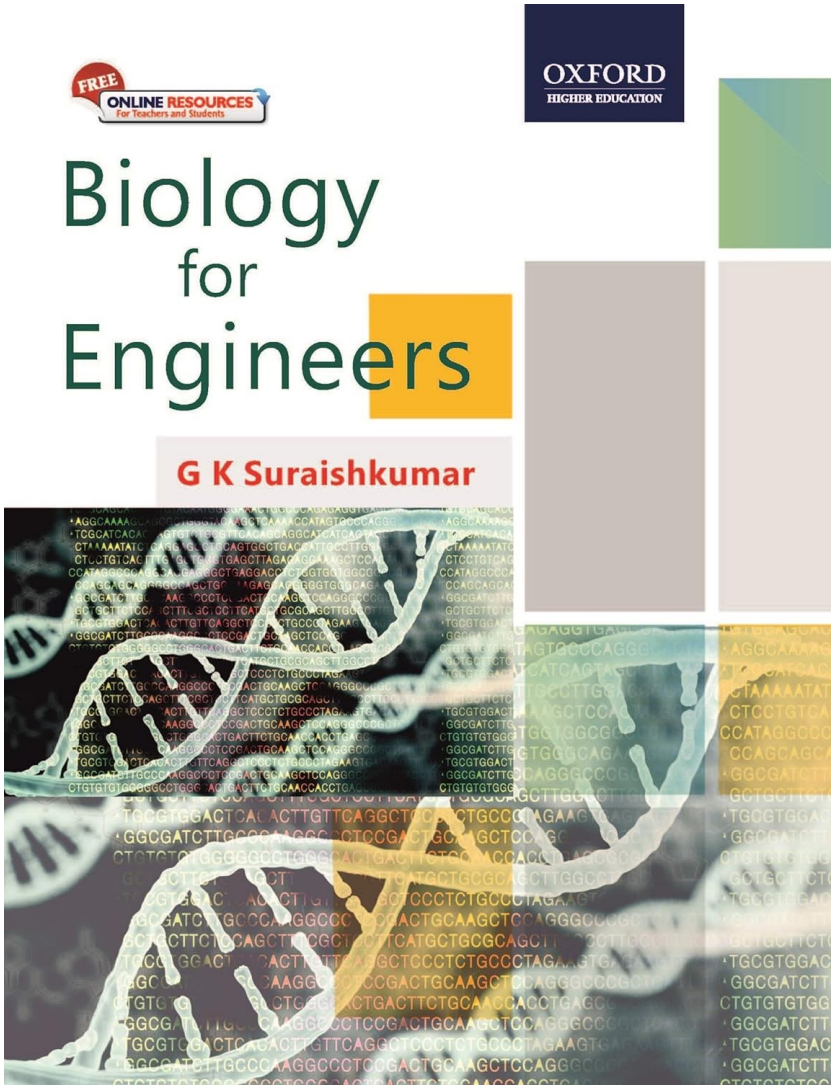
- Origin of life and Evolution. (4 lectures)
- Water (1 lectures)
- Biological molecules:
- ○ Proteins, (3 lectures)
- ○ DNA, (2 lectures)
- ○ RNA, (2 lectures)
- ○ Genes, (2 lectures)
- ○ Carbohydrates (2 lectures)
- ○ Lipids (2 lectures)
- Enzymes and Introduction to metabolism, Nutrients. (3 lectures)
- Introduction to Cells in Biology, Cellular processes, cell organelles and cell structure, Cell
- cycle, Culture growth. (6 lectures)
- The Central Dogma, Chromatin, DNA structure, replication, transcription and translation.
- (5 lectures)
- Respiration and photosynthesis (5 lectures)
- Homeostasis. (2 lectures)
- Basics of human physiology. (3 lectures)

	Weightage
Midterm Examination	40%
2 announced Quiz	10%

- Attendance will be taken.
- Date of the quiz will be informed 1 week prior.
- A whatsapp group will be created where most of information will be shared.
- Questions answer sessions are reserved for first and last 5 minutes of the lecture.
- Class notes will be shared.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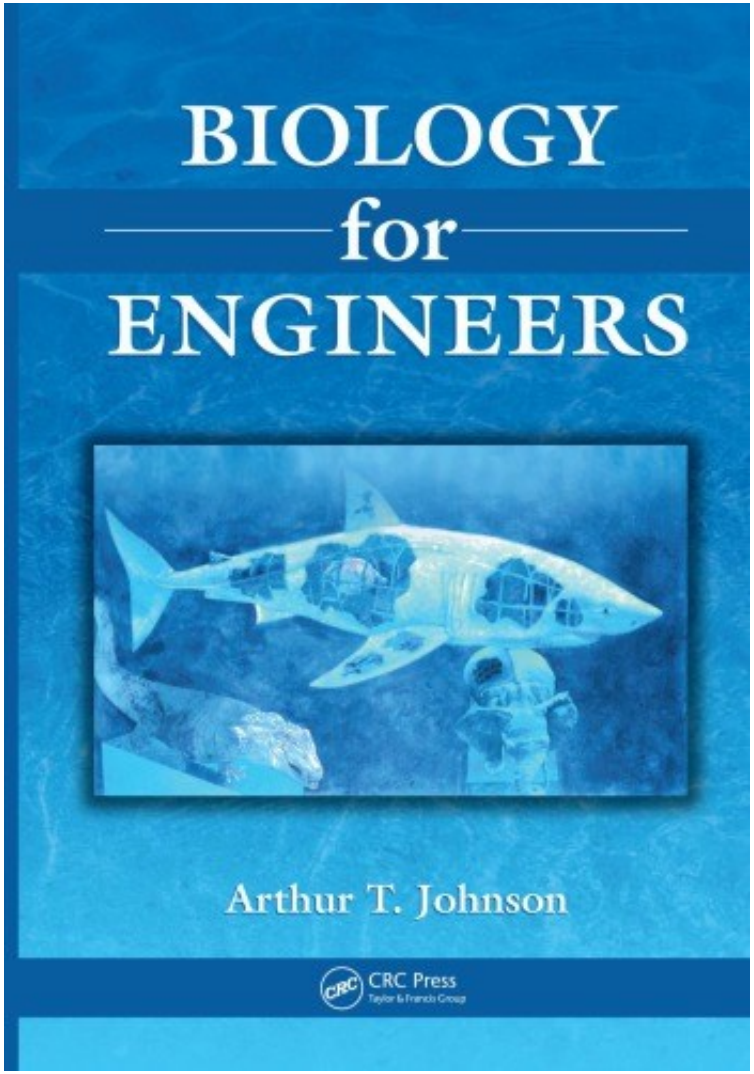
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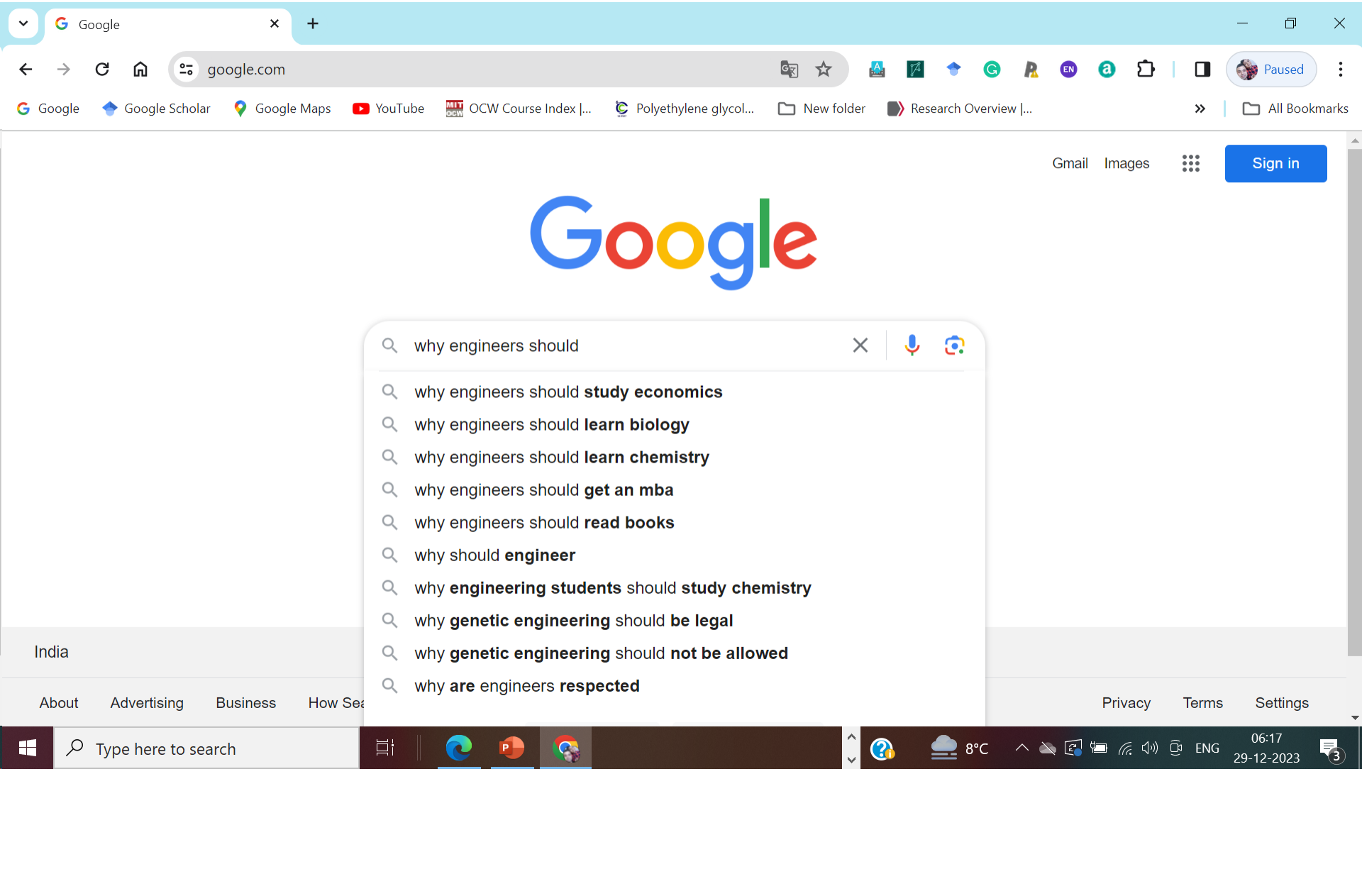
Why Biology for Engineers?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why genetic engineering should be legal
why genetic engineering should not be allowed
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Water desalination

Earthquake prediction

Ocean clean up

Renewable Energy And storage

Brain decoding

Universal Vaccine

Embodied AI

Dementia treatment

Carbon sequestration

Self-driving smart vehicle


Neura
link

Overview: Inquiring About the World of Life

- **Evolution** is the process of change that has transformed life on Earth
- **Biology** is the scientific study of life
- Biologists ask questions such as:
  - How a single cell develops into an organism
  - How the human mind works
  - How living things interact in communities

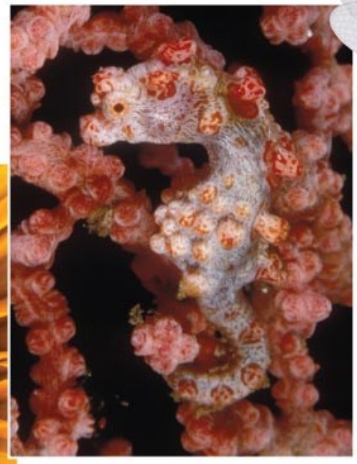
Fig. 1-1

Fig. 1-2

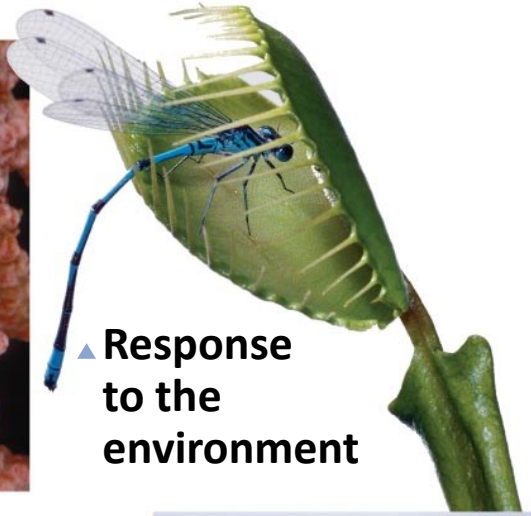
- Life defies a simple, one-sentence definition
- Life is recognized by what living things do

Fig. 1-3

Order



Evolutionary adaptation



Response to the environment

Regulation

Energy processing

Growth and development

Reproduction

Concept 1.1: Themes connect the concepts of biology

- Biology consists of more than memorizing factual details
- Themes help to organize biological information

Evolution, the Overarching Theme of Biology

- Evolution makes sense of everything we know about living organisms
- Organisms living on Earth are modified descendents of common ancestors

Theme: New properties emerge at each level in the biological hierarchy

- Life can be studied at different levels from molecules to the entire living planet
- The study of life can be divided into different levels of biological organization

Fig. 1-4

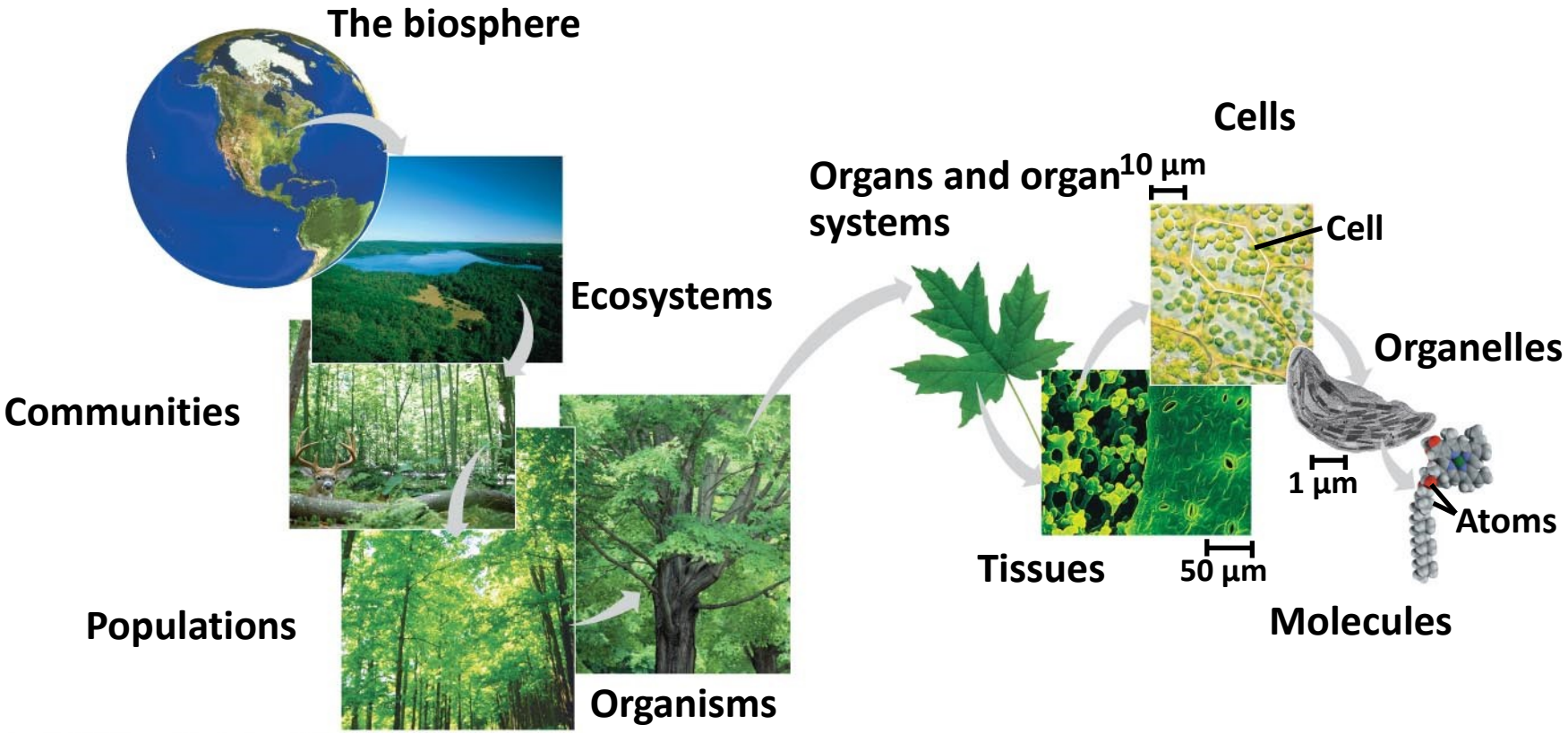


Fig. 1-4a

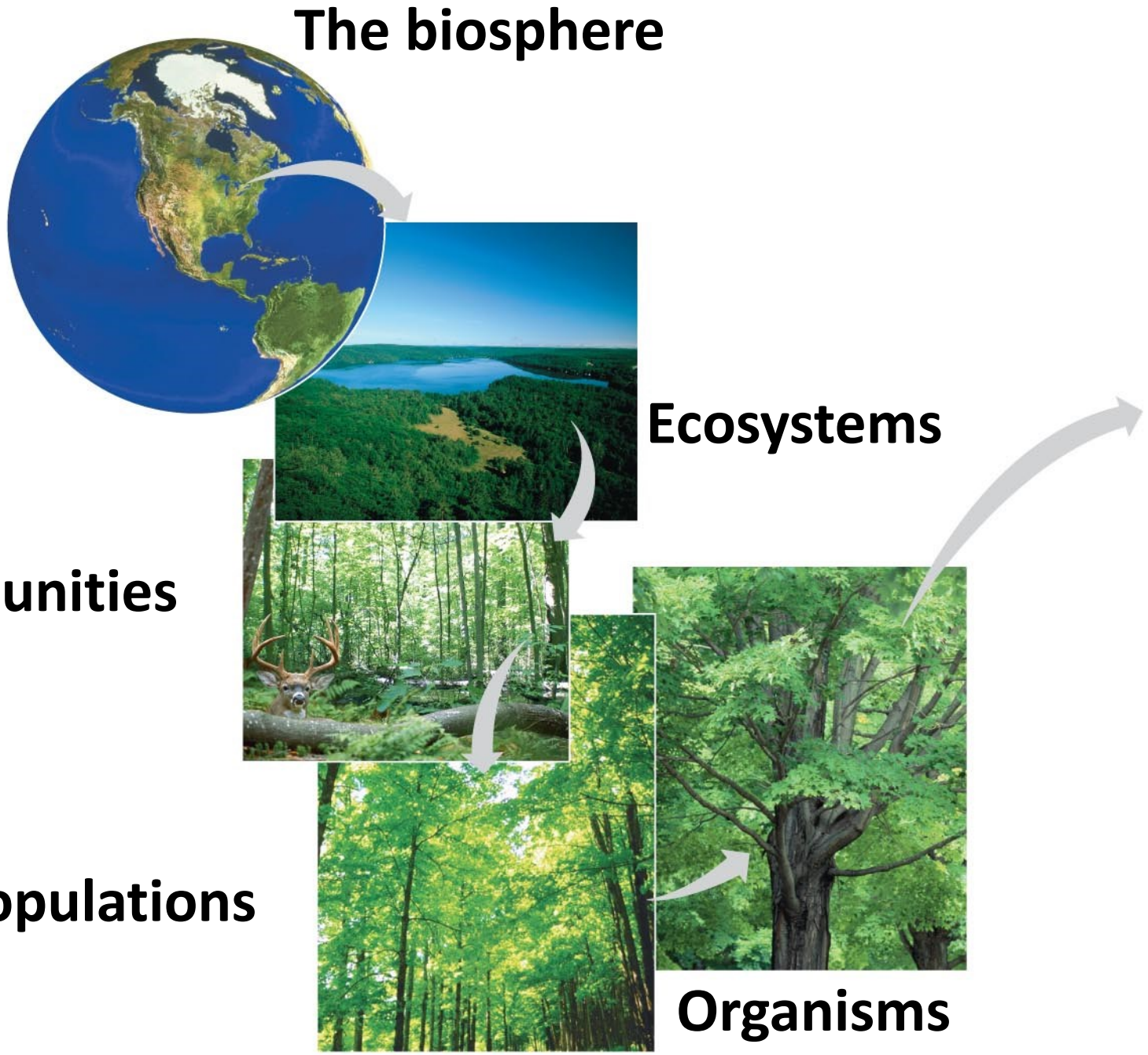


Fig. 1-4b

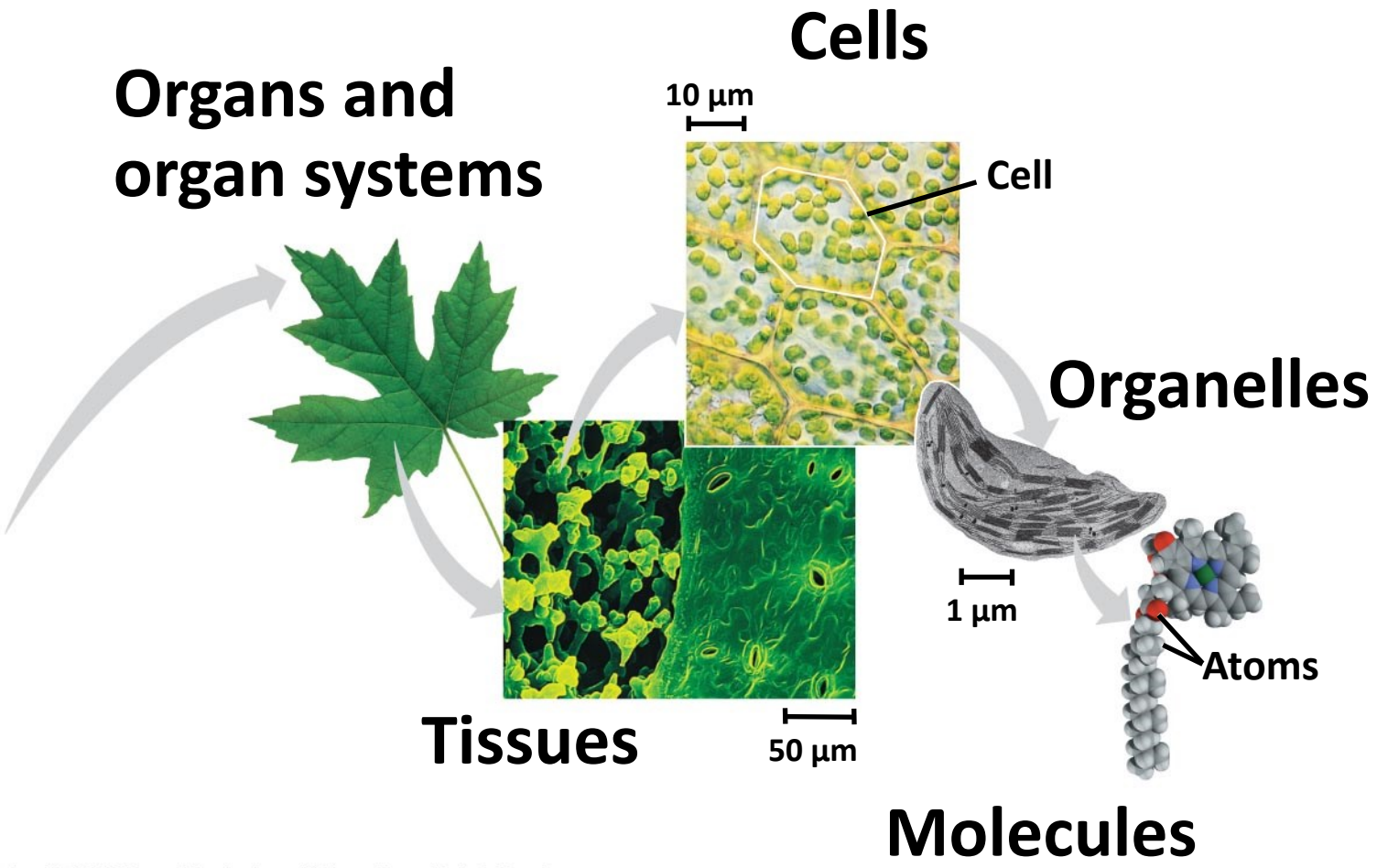


Fig. 1-4c

The biosphere

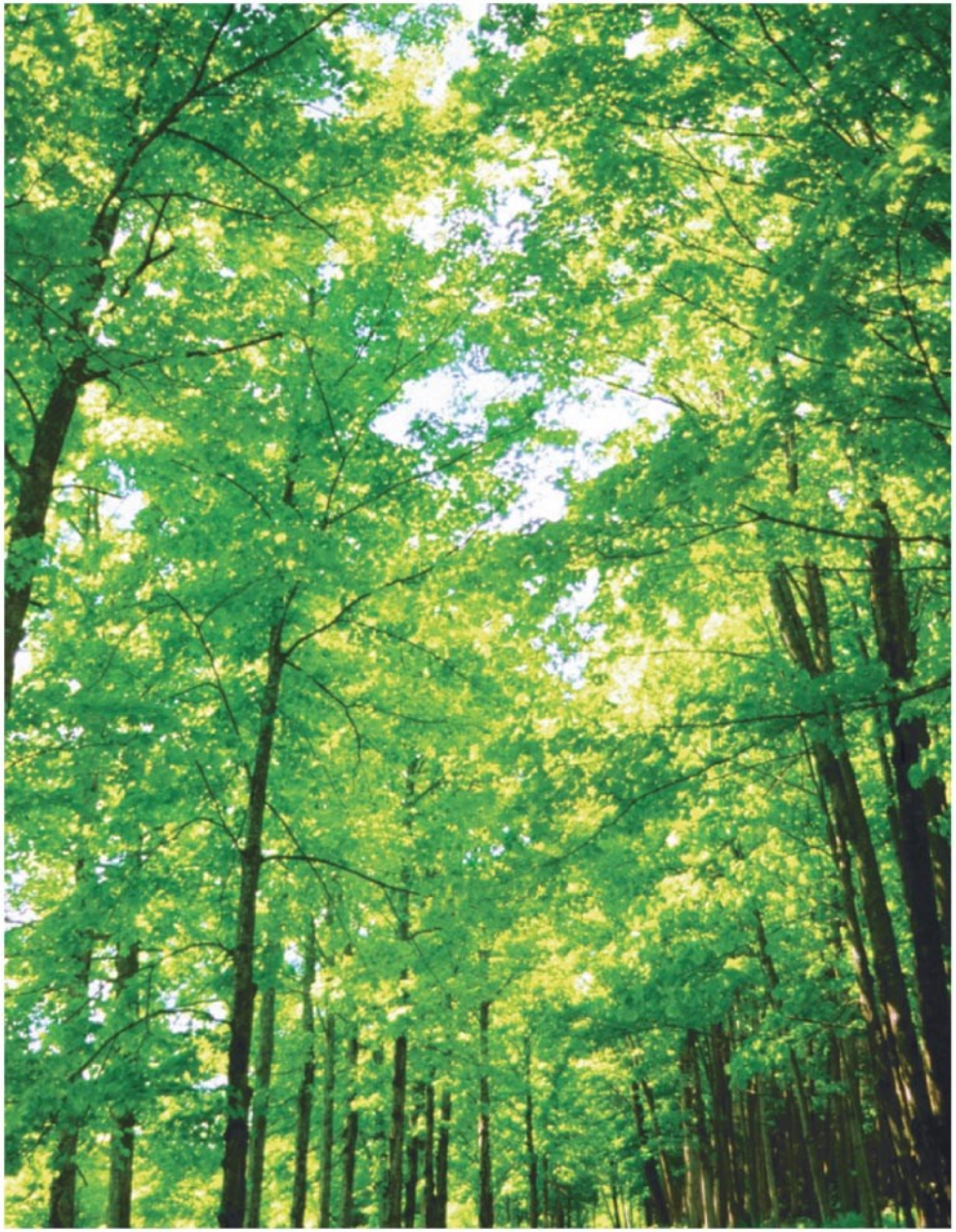
Fig. 1-4d

Ecosystems

Fig. 1-4e

Communities

Fig. 1-4f



Populations

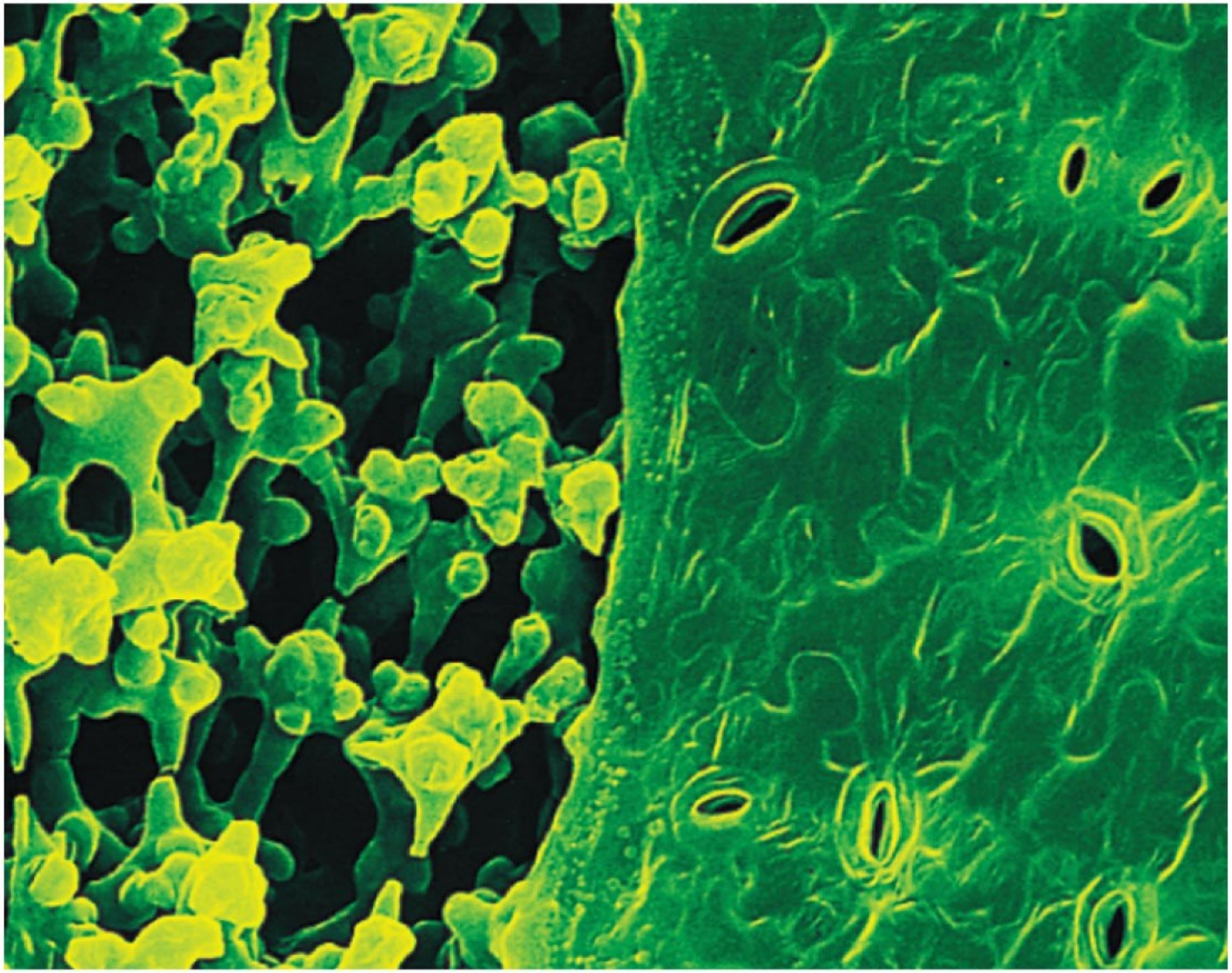
Fig. 1-4g

Organisms

Fig. 1-4h

Organs and organ systems

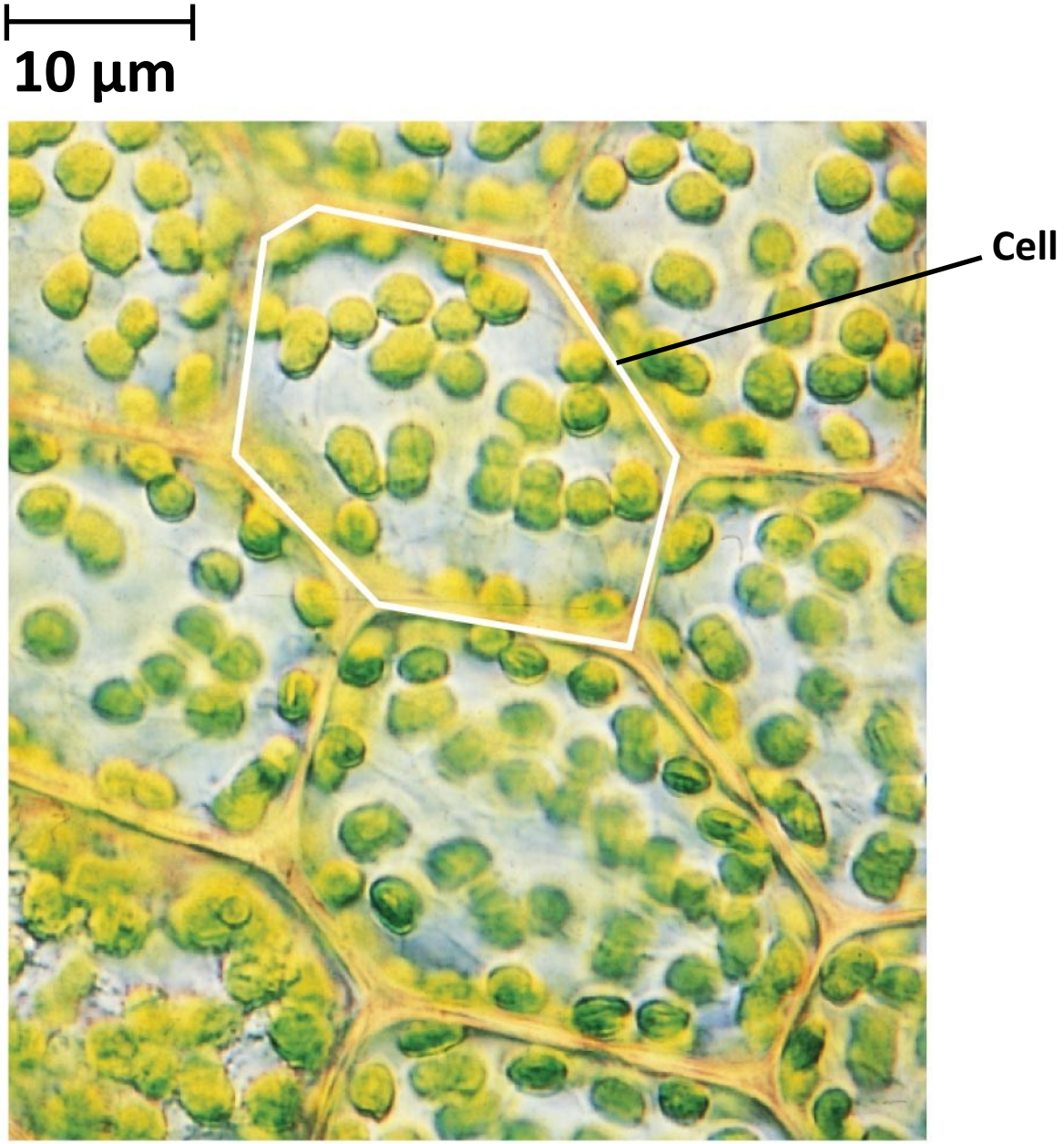
Fig. 1-4i



Tissues

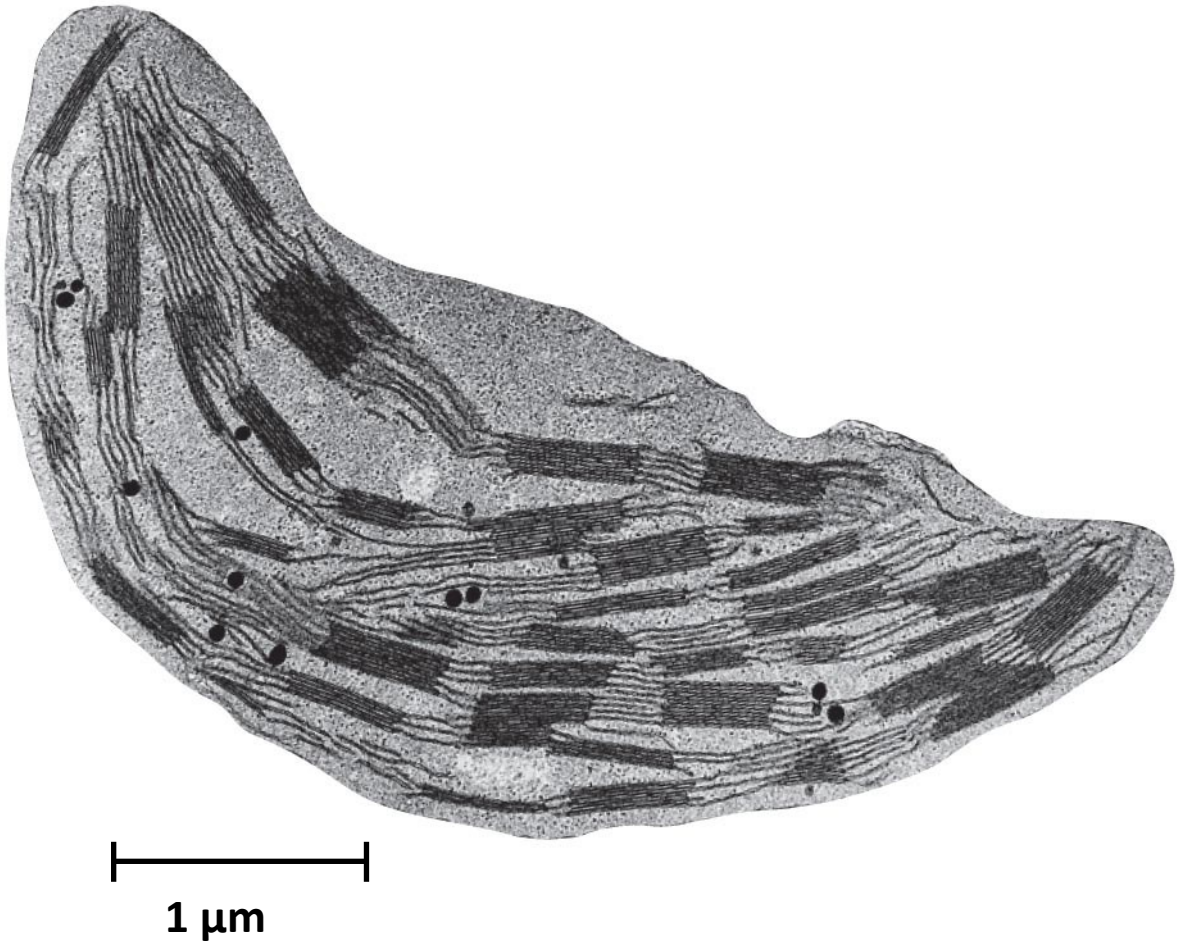
50 µm

Fig. 1-4j



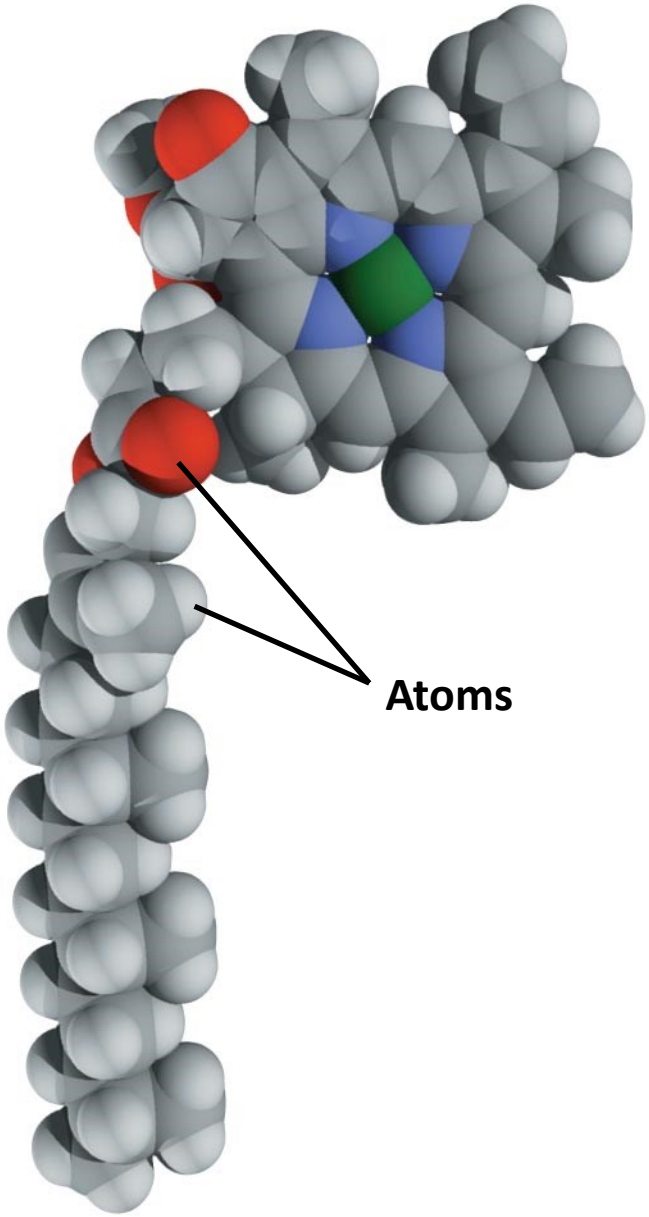
Cells

Fig. 1-4k



Organelles

Fig. 1-4l



Emergent Properties

- **Emergent properties** result from the arrangement and interaction of parts within a system
- Emergent properties characterize nonbiological entities as well
  - For example, a functioning bicycle emerges only when all of the necessary parts connect in the correct way

The Power and Limitations of Reductionism

- Reductionism is the reduction of complex systems to simpler components that are more manageable to study
  - For example, the molecular structure of DNA
- An understanding of biology balances reductionism with the study of emergent properties
  - For example, new understanding comes from studying the interactions of DNA with other molecules

Systems Biology

- A system is a combination of components that function together
- **Systems biology** constructs models for the dynamic behavior of whole biological systems
- The systems approach poses questions such as:
  - How does a drug for blood pressure affect other organs?
  - How does increasing CO_2 alter the biosphere?

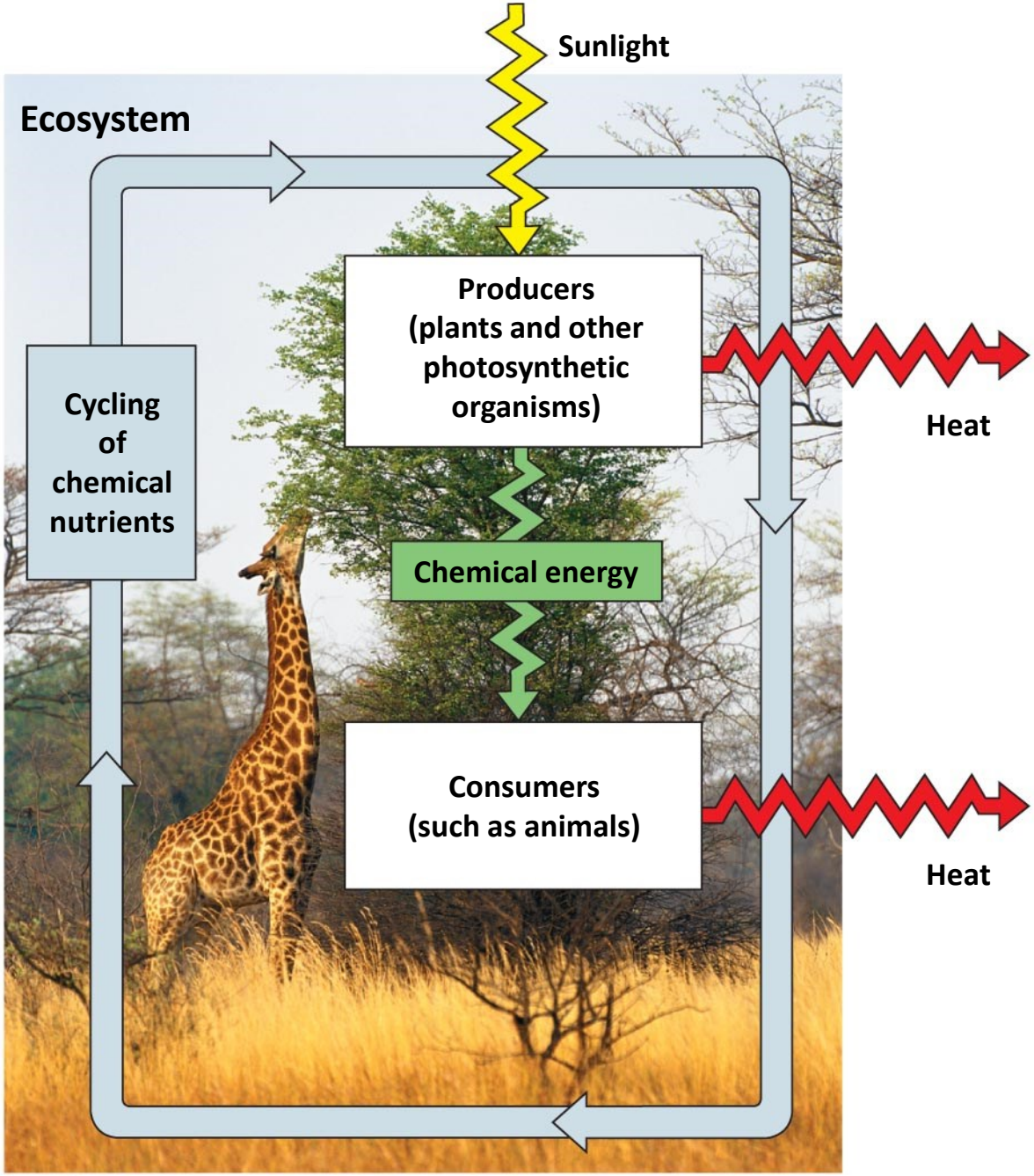
Theme: Organisms interact with their environments, exchanging matter and energy

- Every organism interacts with its environment, including nonliving factors and other organisms
- Both organisms and their environments are affected by the interactions between them
  - For example, a tree takes up water and minerals from the soil and carbon dioxide from the air; the tree releases oxygen to the air and roots help form soil

Ecosystem Dynamics

- The dynamics of an ecosystem include two major processes:
  - Cycling of nutrients, in which materials acquired by plants eventually return to the soil
  - The flow of energy from sunlight to producers to consumers

Fig. 1-5



Energy Conversion

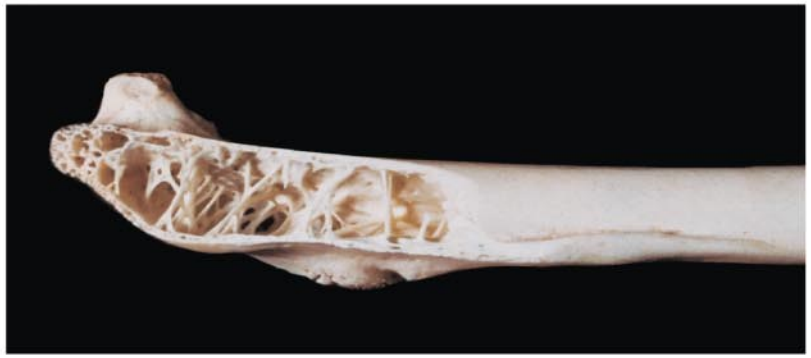
- Work requires a source of energy
- Energy can be stored in different forms, for example, light, chemical, kinetic, or thermal
- The energy exchange between an organism and its environment often involves energy transformations
- Energy flows *through* an ecosystem, usually entering as light and exiting as heat

Theme: Structure and function are correlated at all levels of biological organization

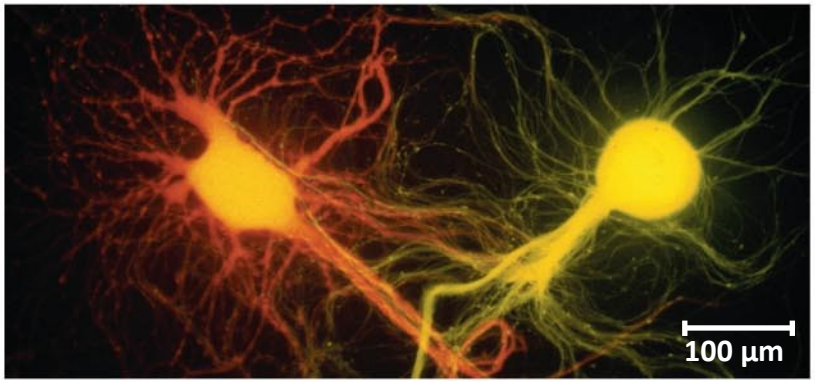
- Structure and function of living organisms are closely related
  - For example, a leaf is thin and flat, maximizing the capture of light by chloroplasts

Fig. 1-6

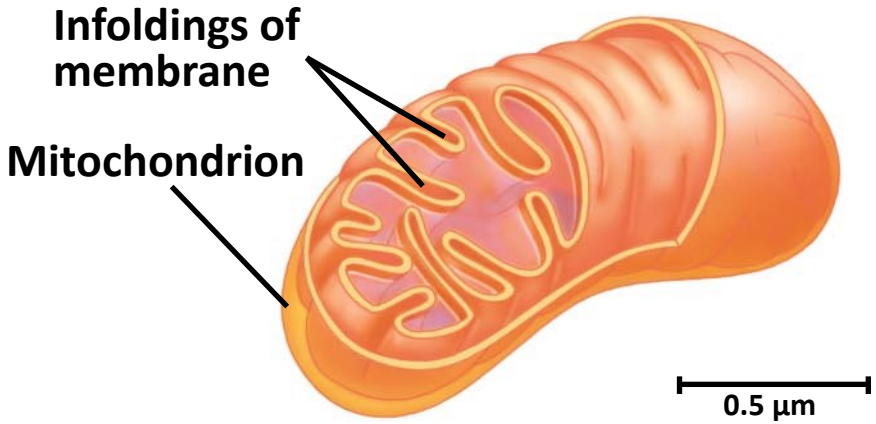
(a) Wings



(b) Bones



(c) Neurons

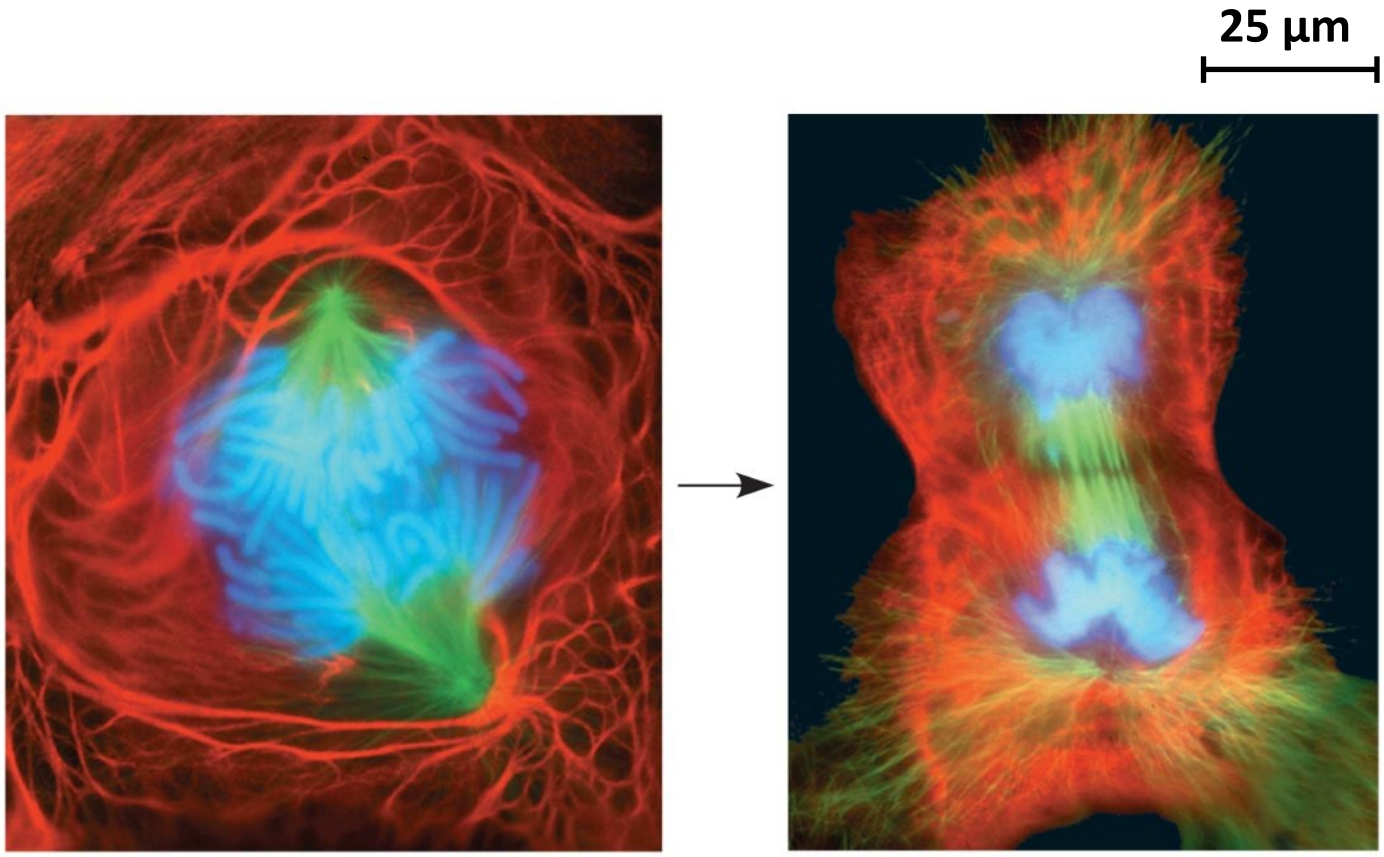


(d) Mitochondria

Theme: Cells are an organism's basic units of structure and function

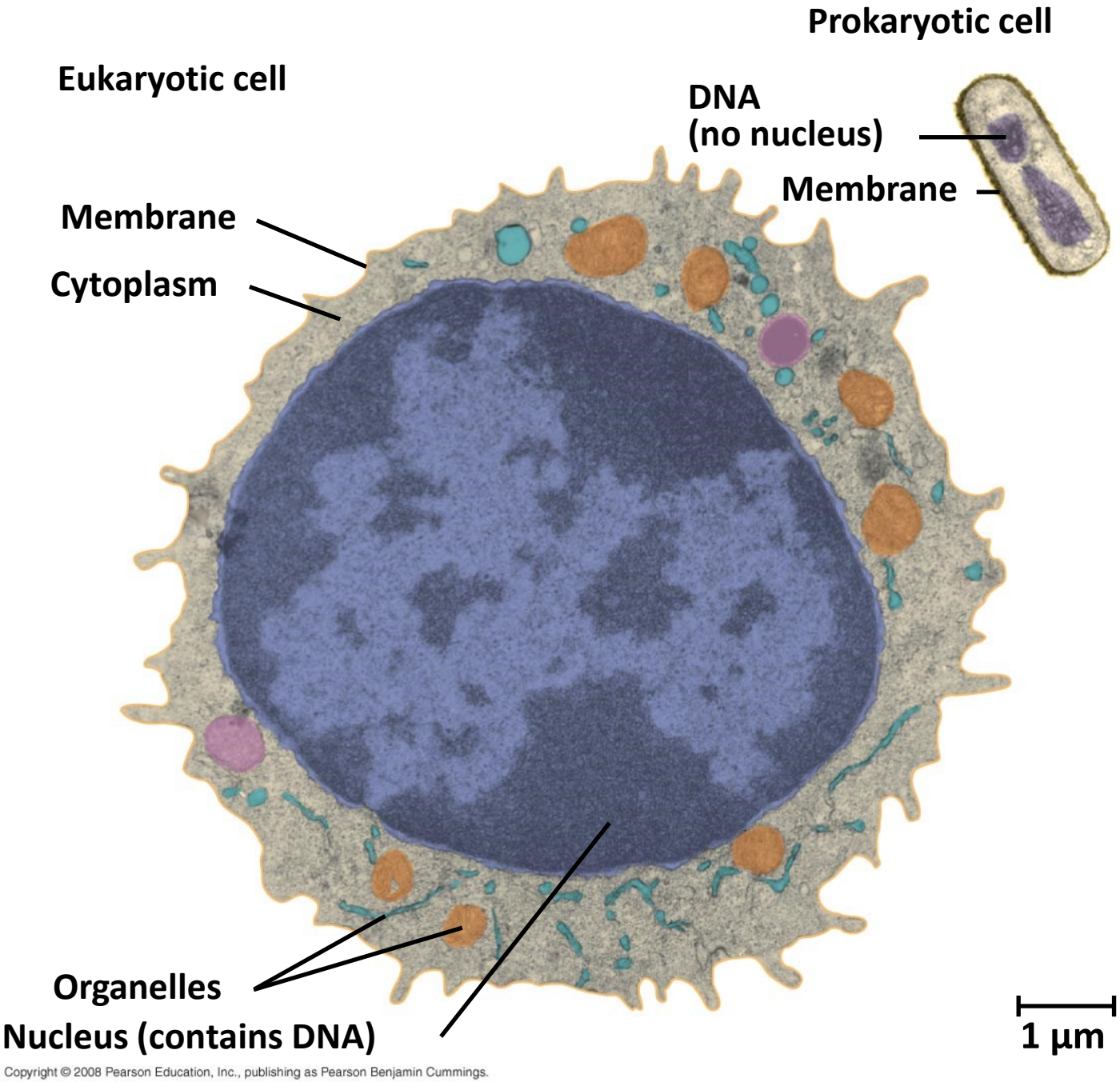
- The cell is the lowest level of organization that can perform all activities required for life
- All cells:
  - Are enclosed by a membrane
  - Use DNA as their genetic information
- The ability of cells to divide is the basis of all reproduction, growth, and repair of multicellular organisms

Fig. 1-7



- A **eukaryotic cell** has membrane-enclosed organelles, the largest of which is usually the nucleus
- By comparison, a **prokaryotic cell** is simpler and usually smaller, and does not contain a nucleus or other membrane-enclosed organelles
- Bacteria and Archaea are prokaryotic; plants, animals, fungi, and all other forms of life are eukaryotic

Fig. 1-8



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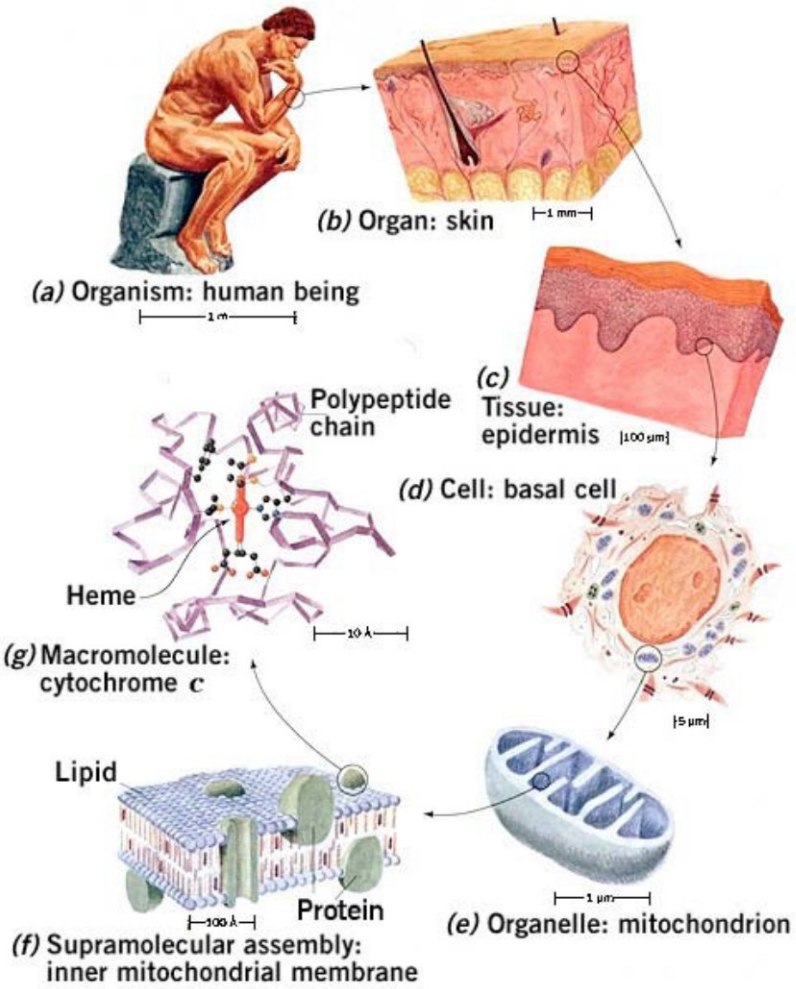
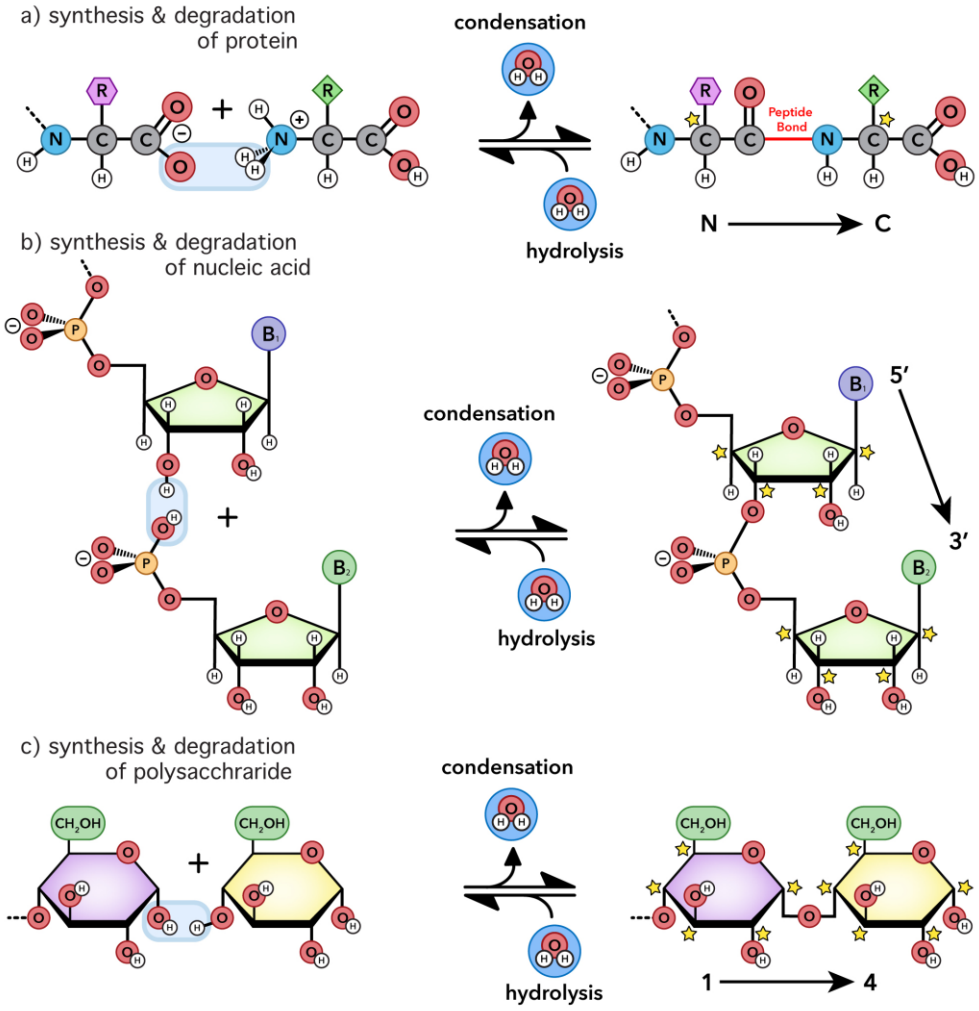

(a) Organism: human being
1 m
(b) Organ: skin
1 mm
(c) Tissue: epidermis
100 μm
(d) Cell: basal cell
5 μm
(e) Organelle: mitochondrion
1 μm
(f) Supramolecular assembly: inner mitochondrial membrane
Lipid
Protein
100 Å
(g) Macromolecule: cytochrome c
Polypeptide chain
Heme
10 Å


a) synthesis & degradation of protein
condensation
hydrolysis
Peptide Bond
N
C
b) synthesis & degradation of nucleic acid
condensation
hydrolysis
5′
3′
c) synthesis & degradation of polysacchraride
condensation
hydrolysis
1
4

The Cell: The Universal Building Block

- Living organisms are made of cells.
- The simplest living organisms are unicellular (single-celled).
- Larger organisms are multicellular (many-celled), with different functions for different cells.
- Cells have some common features but can contain unique components for different organisms.

All Cells Share Some Common Features

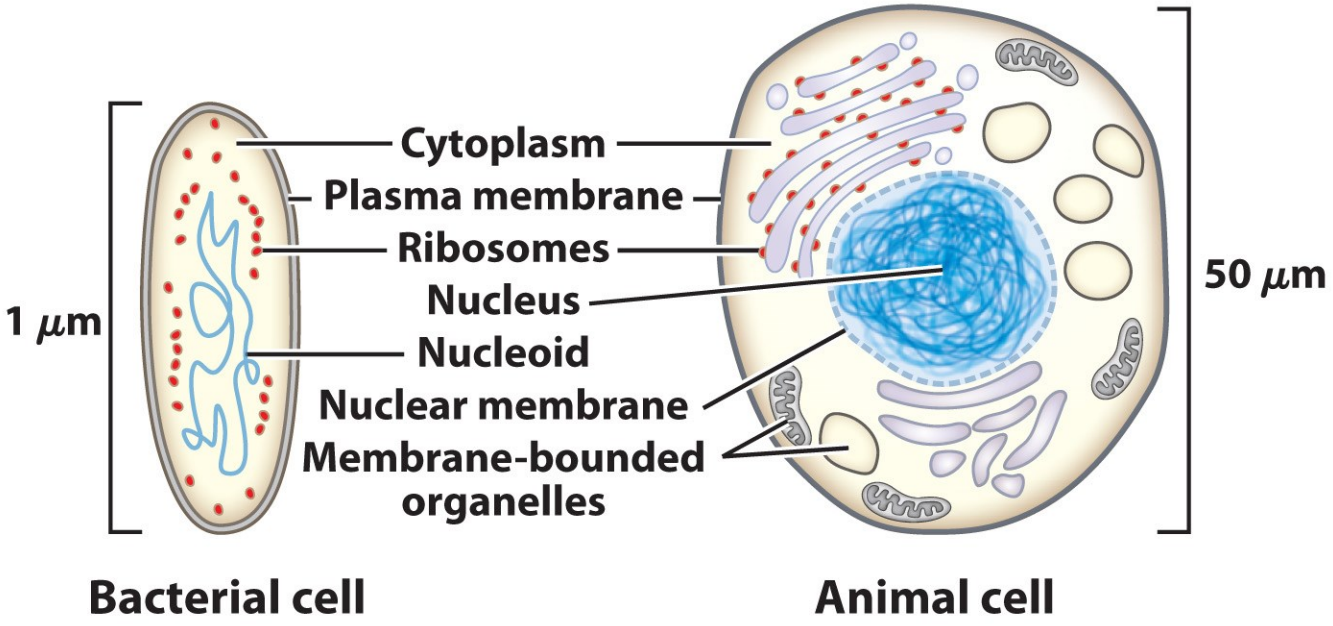


Figure 1-3
Lehninger Principles of Biochemistry, Seventh Edition

The Cytosol Is Very Crowded

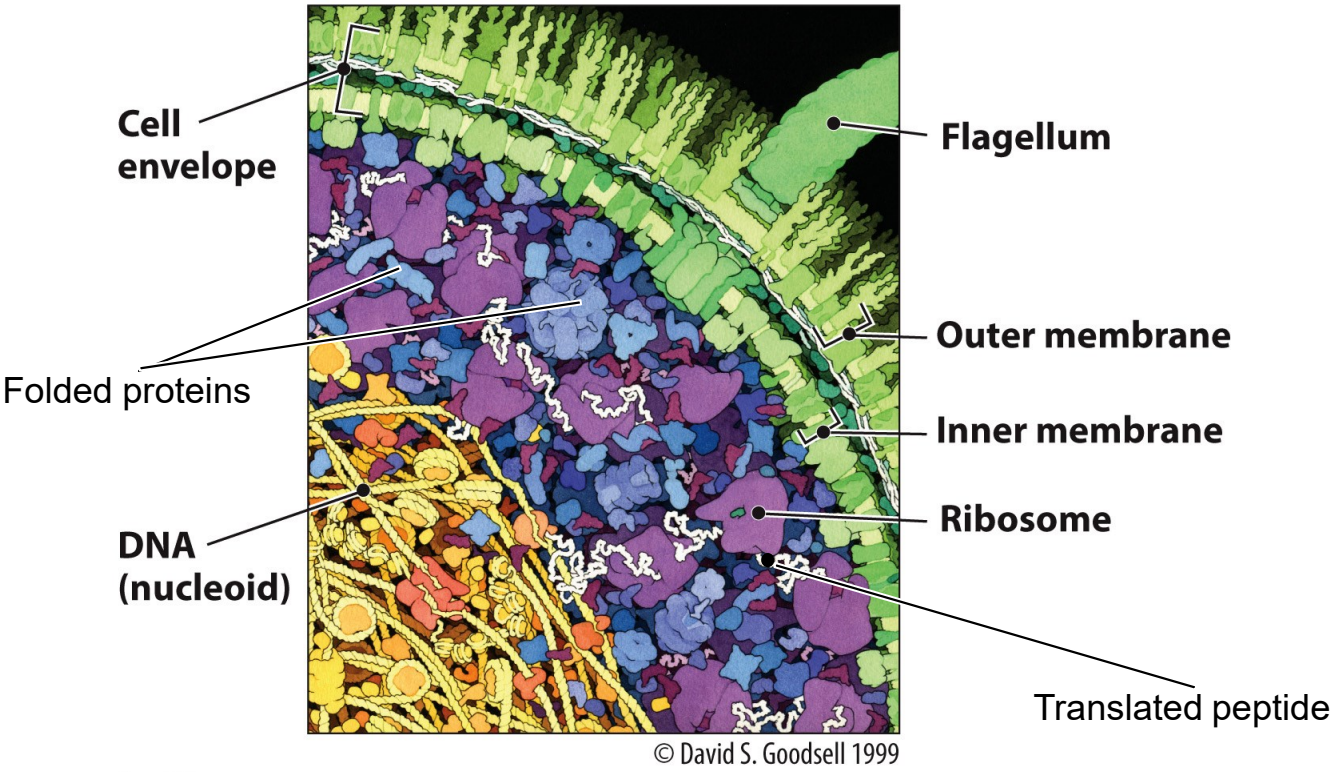
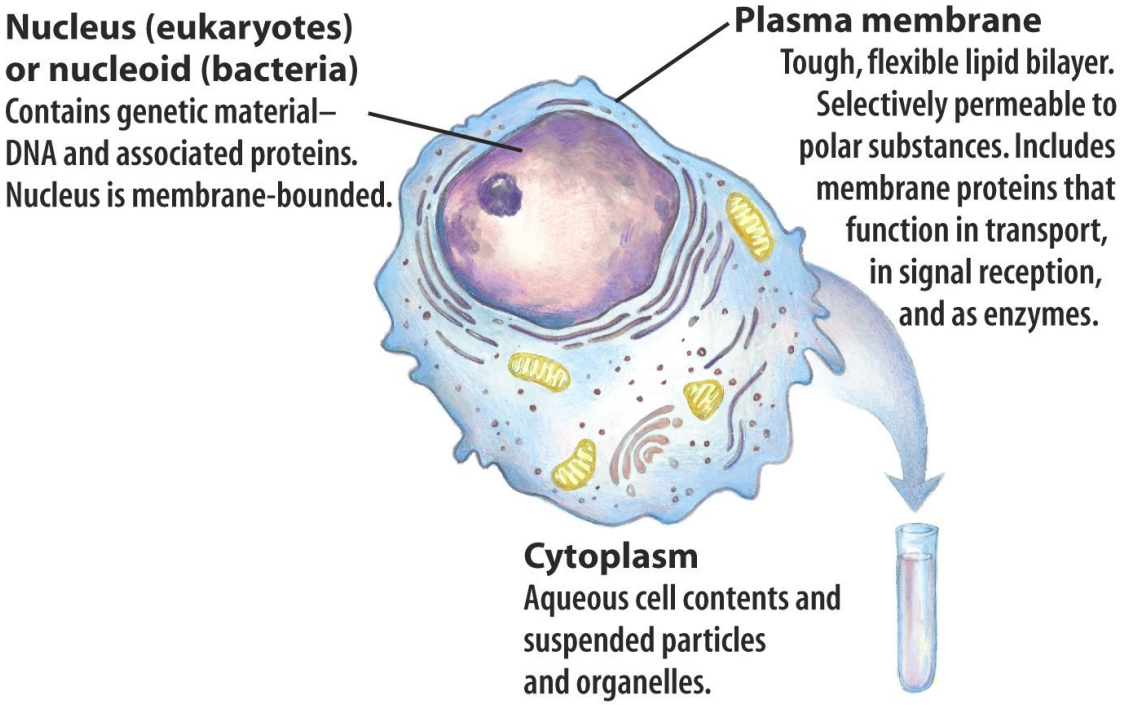


Figure 1-13
Lehninger Principles of Biochemistry, Seventh Edition

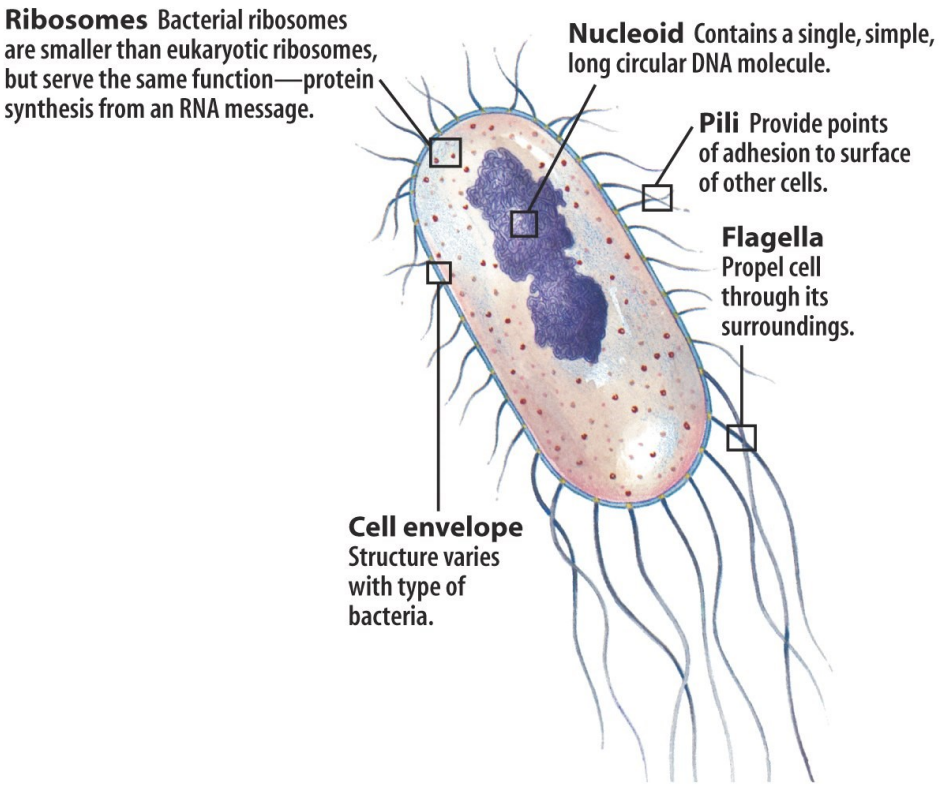
Cells are structural and functional units of all living organisms



Eukaryotic and Prokaryotic Cells

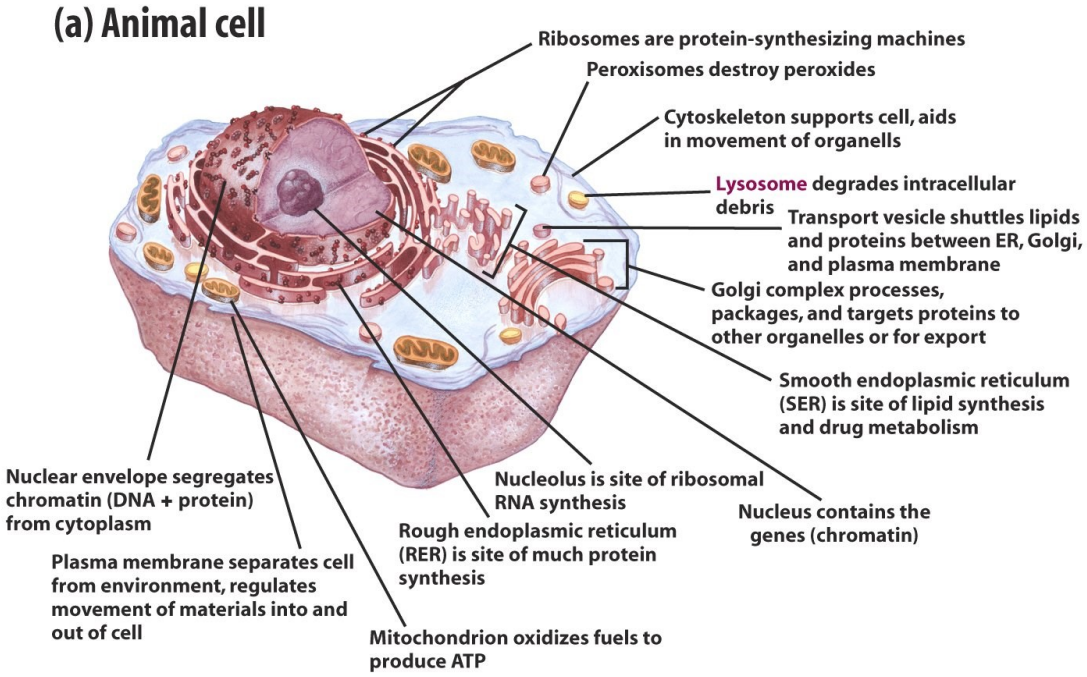
- All the cells can be categorized into two basic types: prokaryotes (*pro-* = before; *-karyon-* = nucleus) and eukaryotes (*eu-* = true; Karyon=nucleus).
- Predominantly, single-celled organisms such as bacteria and archaea are classified as prokaryotes, while the eukaryotes are either single cellular organism (e.g. amoeba etc.) or multi-cellular organisms (e.g. yeast, human etc.).

Prokaryotes Vs. Eukaryotes



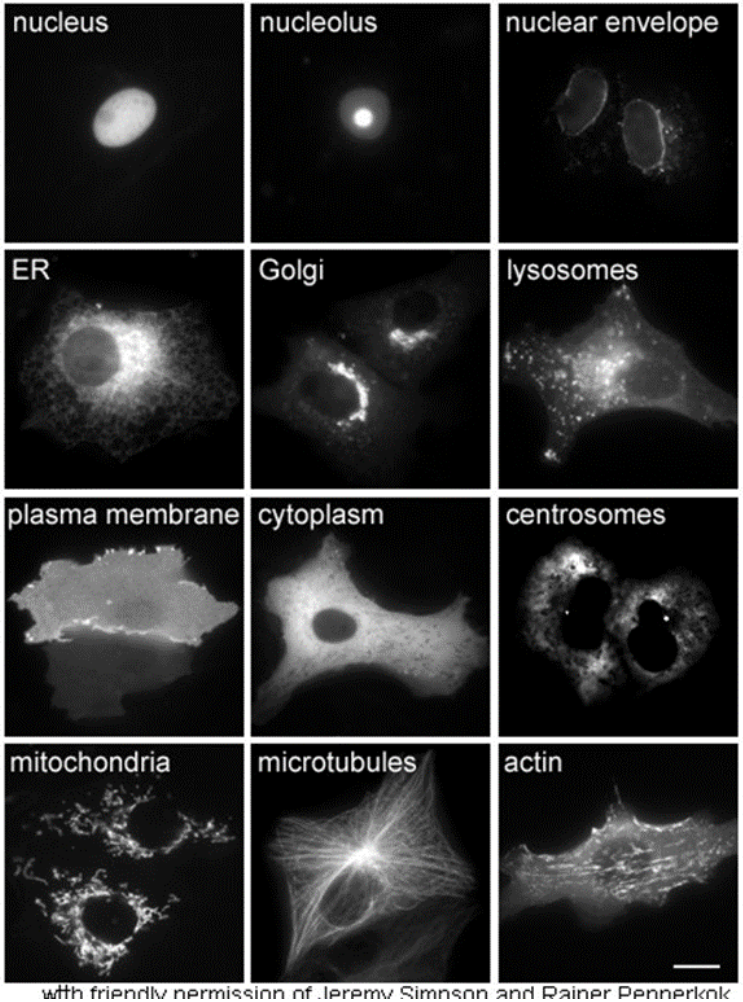
Prokaryotes: (bacteria and archaea)nucleus or nucleoid not separated from the cytoplasm by a membrane

Prokaryotes Vs. Eukaryotes



Eukaryotes: (animal and plant cells)Nuclear materials are separated from cytoplasm and enclosed within a double membrane called the nuclear envelope

Imaging of cell

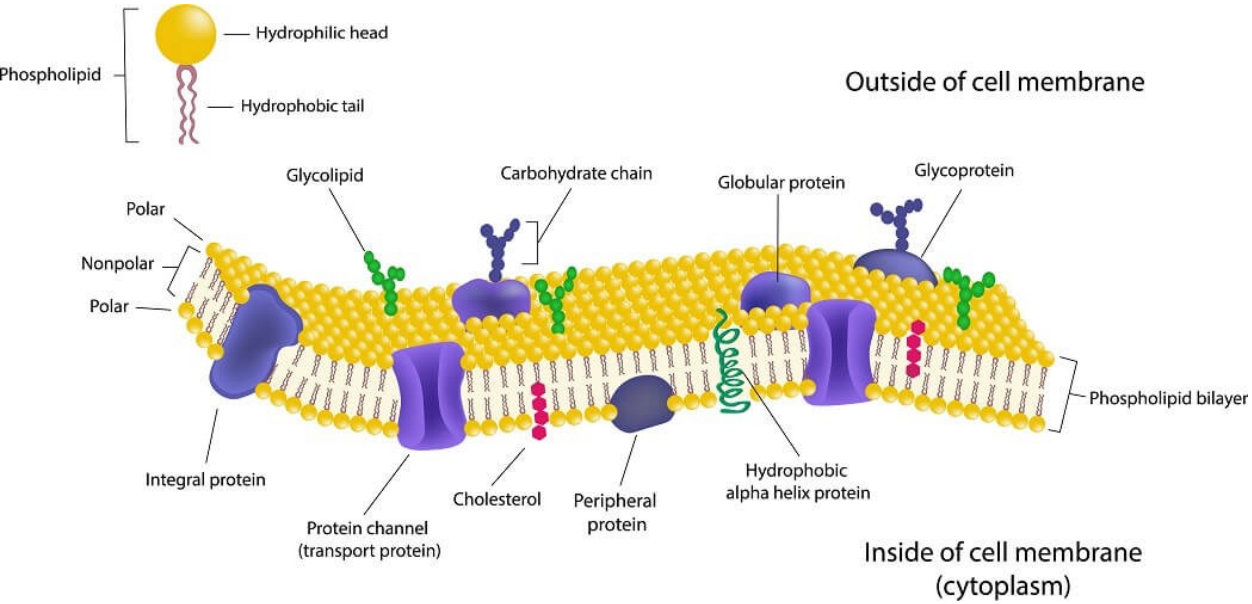


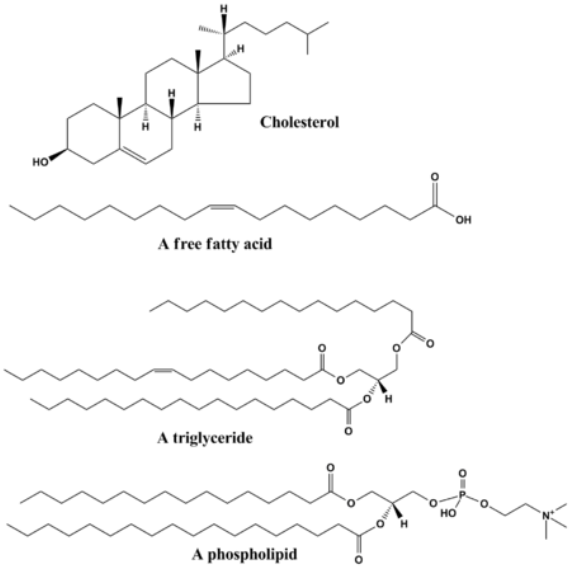
with friendly permission of Jeremy Simpson and Rainer Pepperkok

A typical eukaryotic cell is a dynamic structure which consists of three basic components as observed under the light microscope:

Cell Membrane, Cytoplasm, Nucleus

Cell Membrane

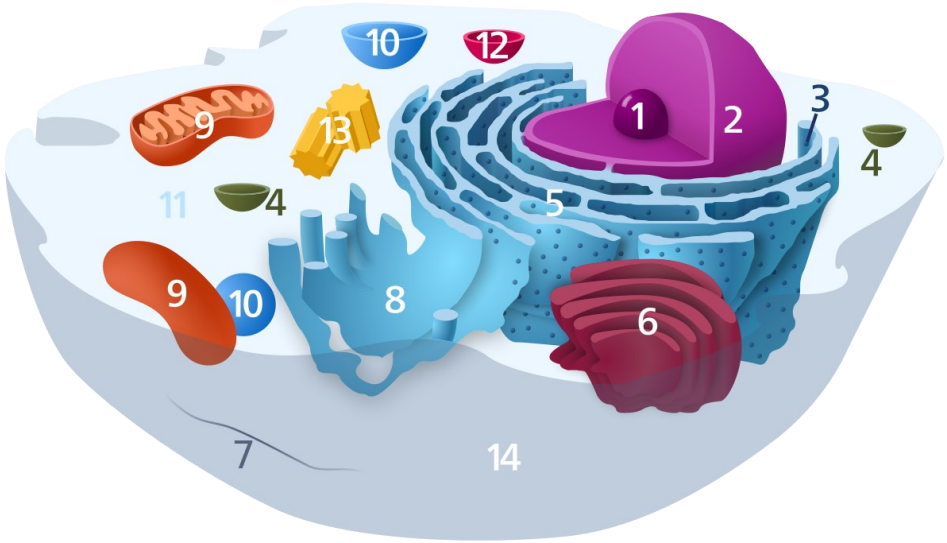


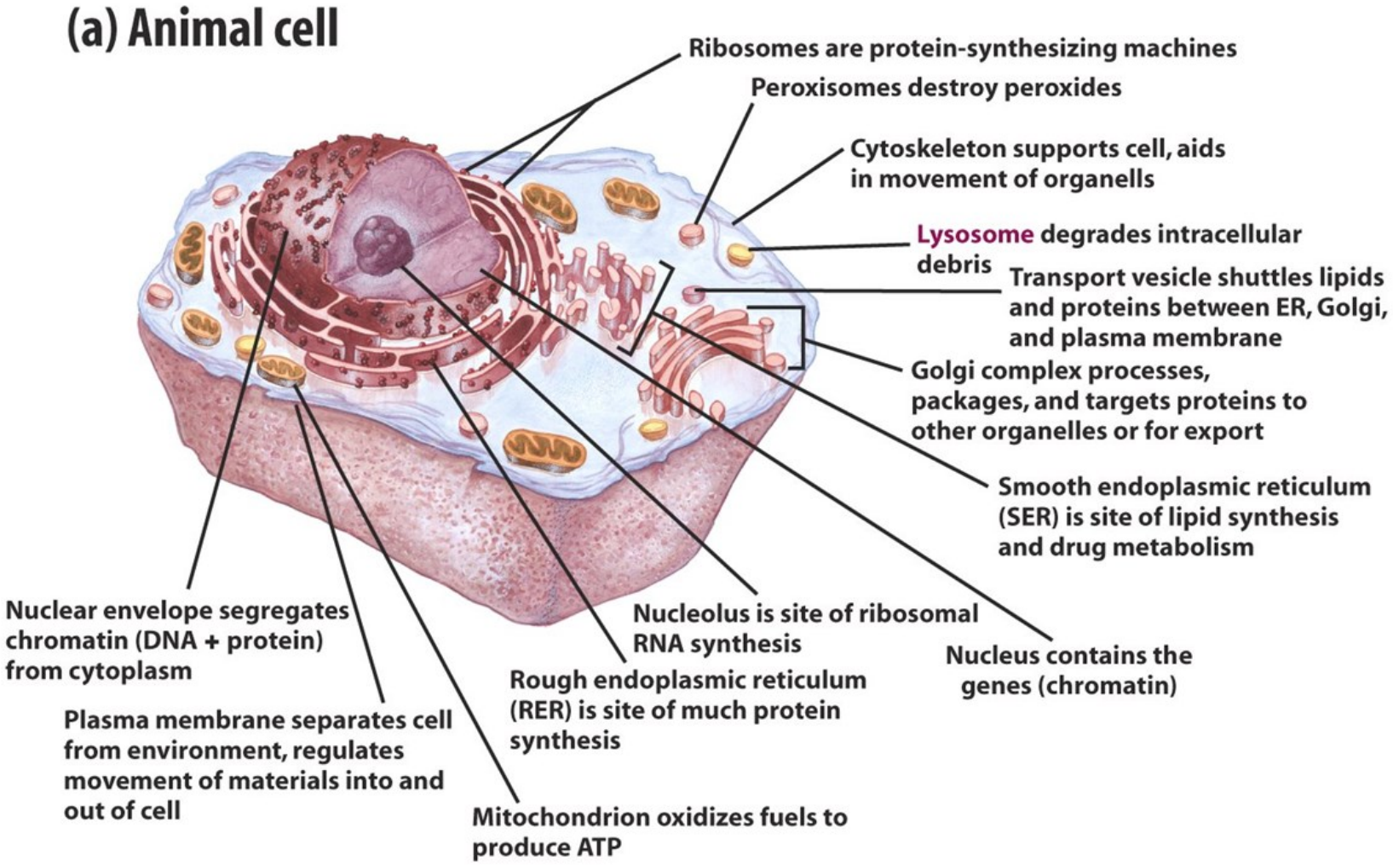


- In addition to phospholipids and proteins, other components, such as cholesterol and carbohydrates, can be found in the membrane. Biochemically, a cell membrane is composed of lipids (40%), proteins (55%) and carbohydrates (5%).
- A phospholipid is a lipid molecule, which primarily consists of two fatty acid chains, a glycerol backbone, and a phosphate group.
- The lipid bilayer of plasma membrane makes it semi-permeable regulating the passage of some substances, such as organic molecules, ions, and water.

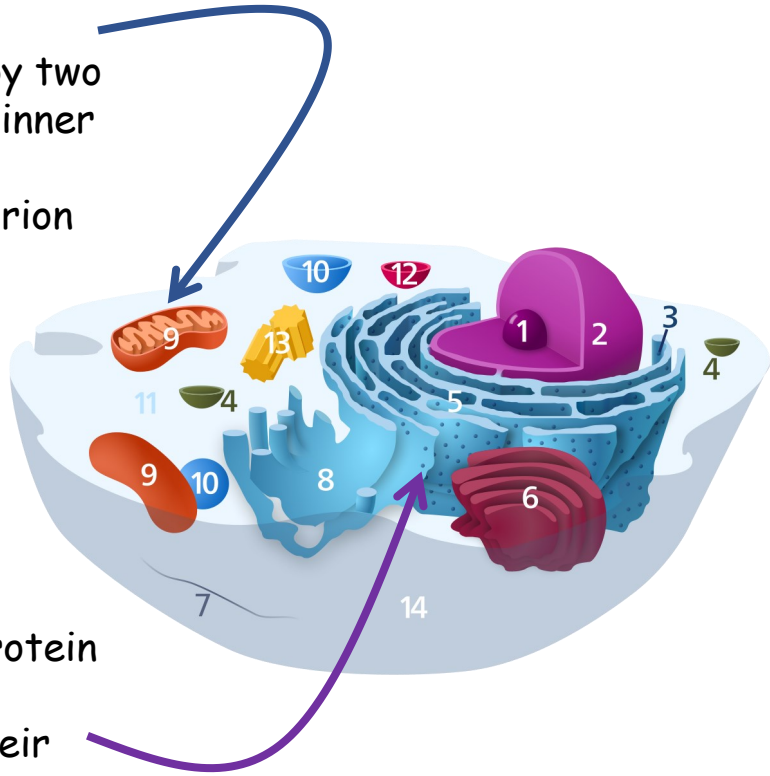
Cytoplasm

Cytoplasm is an aqueous colloidal solution (cytosol) containing numerous functional and structural elements, which exist in the form of molecules/organelles, and can be broadly categorized into three groups: **organelles, inclusion bodies and cytoskeleton**



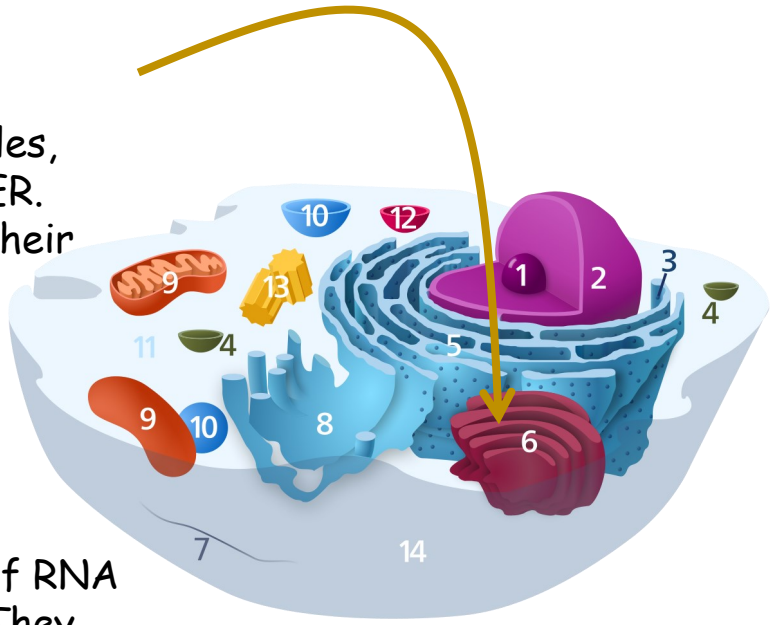

(a) Animal cell
Ribosomes are protein-synthesizing machines
Peroxisomes destroy peroxides
Cytoskeleton supports cell, aids in movement of organelles
Lysosome degrades intracellular debris
Transport vesicle shuttles lipids and proteins between ER, Golgi, and plasma membrane
Golgi complex processes, packages, and targets proteins to other organelles or for export
Smooth endoplasmic reticulum (SER) is site of lipid synthesis and drug metabolism
Nucleolus is site of ribosomal RNA synthesis
Nucleus contains the genes (chromatin)
Nuclear envelope segregates chromatin (DNA + protein) from cytoplasm
Rough endoplasmic reticulum (RER) is site of much protein synthesis
Plasma membrane separates cell from environment, regulates movement of materials into and out of cell
Mitochondrion oxidizes fuels to produce ATP

- **Mitochondria-** They are major sites for adenosine-tri-phosphate (ATP) production (convert foods into usable energy) through aerobic respiration. They are limited by two membranes. The outer membrane is very smooth, while inner membrane forms incomplete septa/projections, called cristae studded with oxysome particles. The mitochondrion carries its own genetic material (DNA).



- **Endoplasmic Reticulum (ER)-** These are a series of interconnected membranous tubules and vesicles called cisternae that collectively play an important role for protein synthesis. There are two types:
  - Rough ER- characterized by having ribosomes on their surfaces and transports proteins made by cisternae.
  - Smooth ER- devoid of having ribosomes and helps in lipid and steroid synthesis.

- **Golgi apparatus-** The Golgi complex or bodies are collections of membrane bound vesicles,s acs and tubules, which are physically independent but continuous with ER. Here, proteins and other molecules are prepared for their transport to other parts of cells or outside the cell.

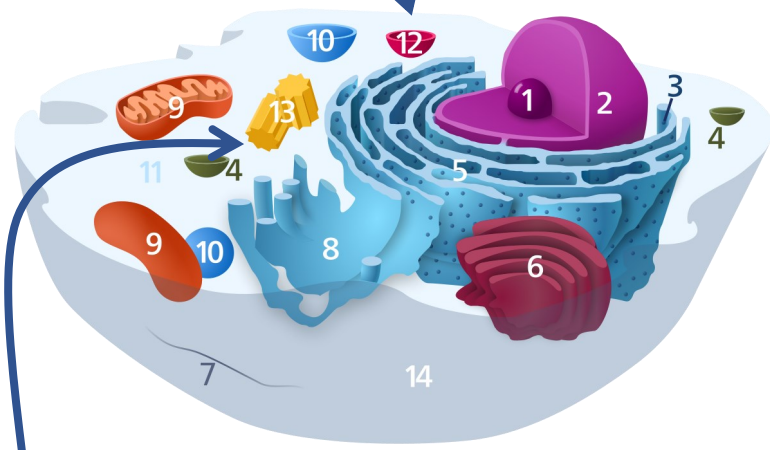


- **Ribosomes-** Cellular structures that contain 80-85% of RNA of the cell and are responsible for protein synthesis. They may be present on the endoplasmic reticulum or in the cytosol as free component, where the RNA goes for translation into proteins. Also, ribosomes help in synthesizing membrane bound proteins.

• **Lysosomes-** Rounded to oval shaped structures, found only in animal cells and are called as the cell's 'garbage disposal.' These organelles are the main point of digestion as they contain various digestive enzymes, which aid in the breakdown of proteins, polysaccharides, lipids, nucleic acids, and even worn-out cell components. Lysosomes also destroy disease-causing organisms with the help of their hydrolytic enzymes.

• **Peroxisomes-** Spherical structures enclosed by single membrane containing enzymes, such as oxidases (use oxygen to carry out catabolic reactions) and catalase (breakdown of hydrogen peroxide into water and oxygen gas).

• **Centrosome-** These are cellular organelles that consist of two short cylindrical shaped structures, known as centrioles. These are situated close to the nucleus near the centre of the cell. They are responsible for the movement during cell division.



Cytoplasmic Inclusions

These are the temporary structures of certain cells, which may or may not be bounded by cell membrane. The examples of cytoplasmic inclusions are lipid droplets (adipose tissue), glycogen (liver and skeletal muscles) and melanin pigment (epidermis and retina), etc.

Cytoskeletons

Cytoskeletons are certain protein fibres present in the cytoplasm. Their presence helps to execute from different functions:

a) maintaining the shape of the cells,

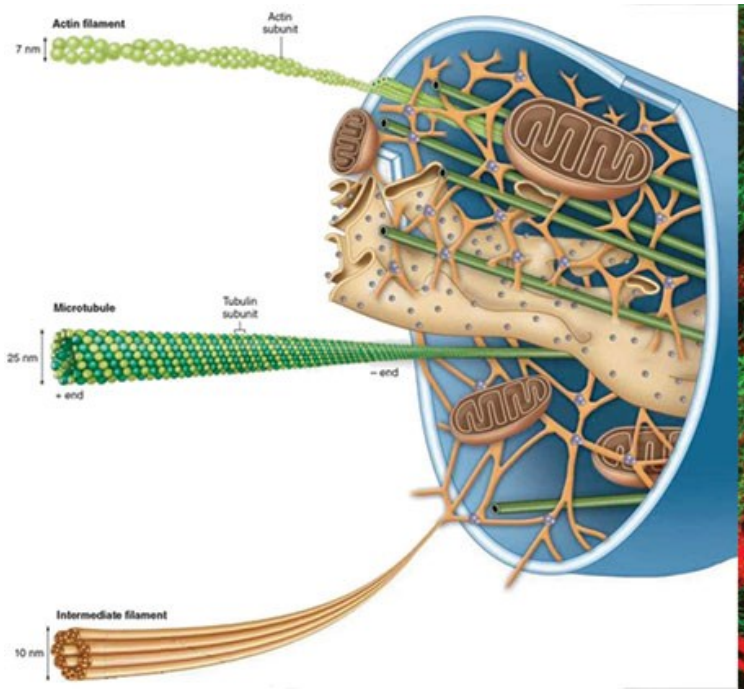
b) securing certain organelles in specific positions,

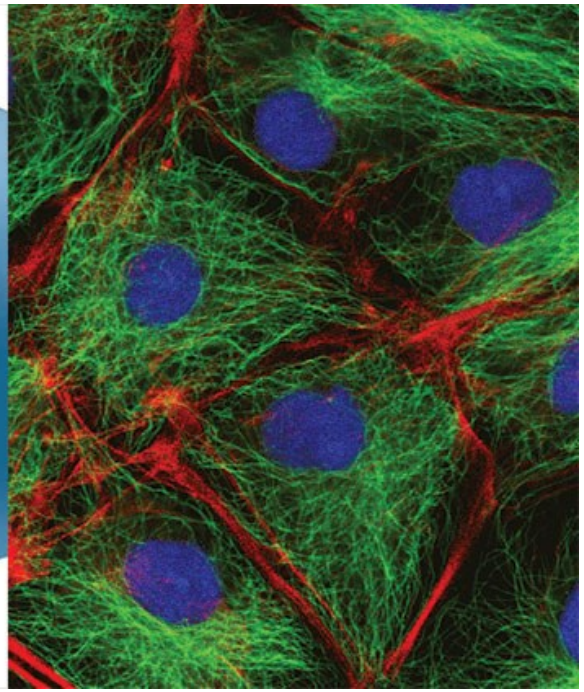
c) allowing cytoplasm and vesicles to move within the cell

d) Enabling unicellular organisms to move independently.

Cytoskeletons

There are three types of cytoskeletal fibres which include actin filaments, intermediate filaments, and microtubule





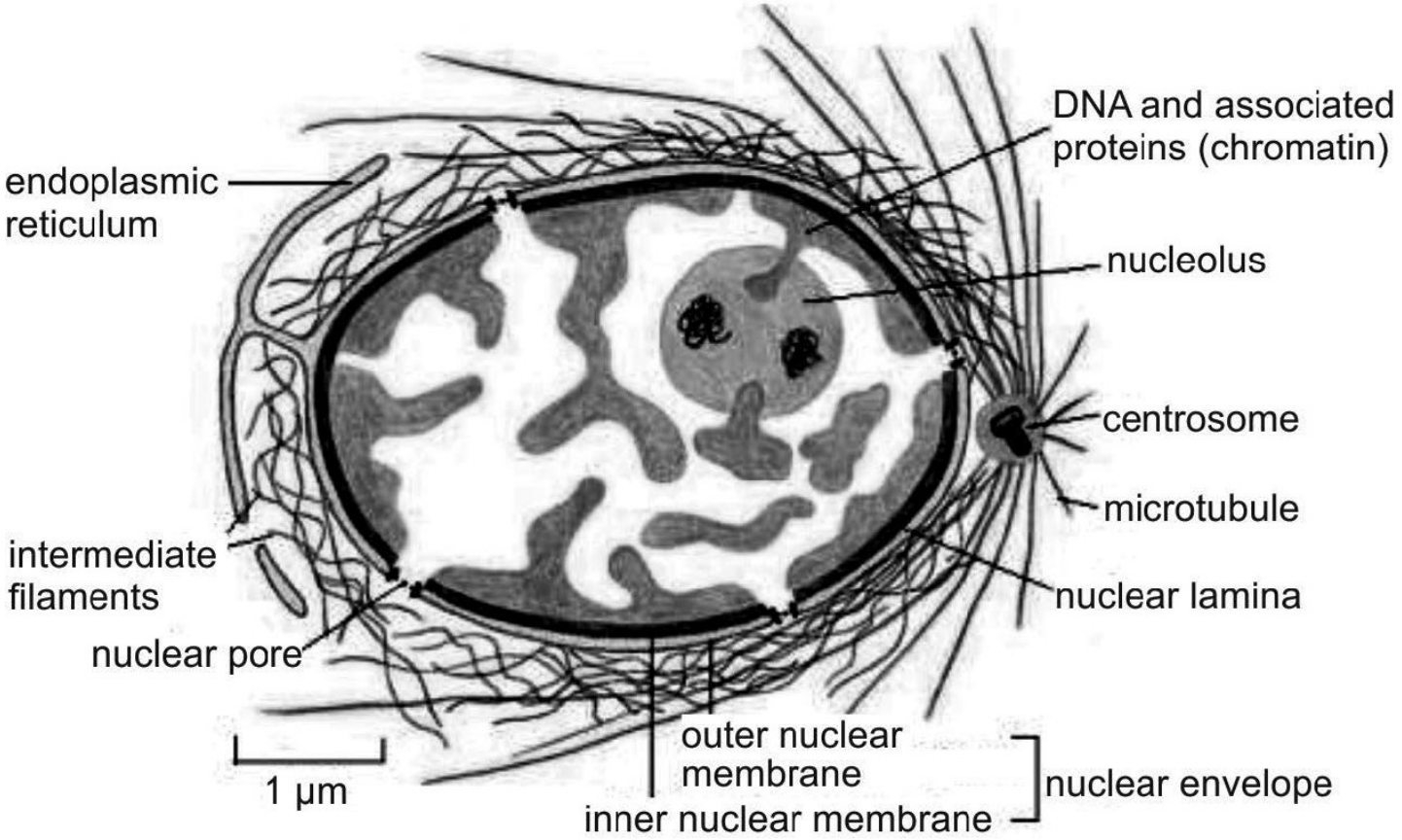
The eukaryotic cytoskeleton. Actin filaments are shown in red, and microtubules composed of beta tubulin are in green.

05/01/2024

A typical eukaryotic cell is a dynamic structure which consists of three basic components as observed under the light microscope:

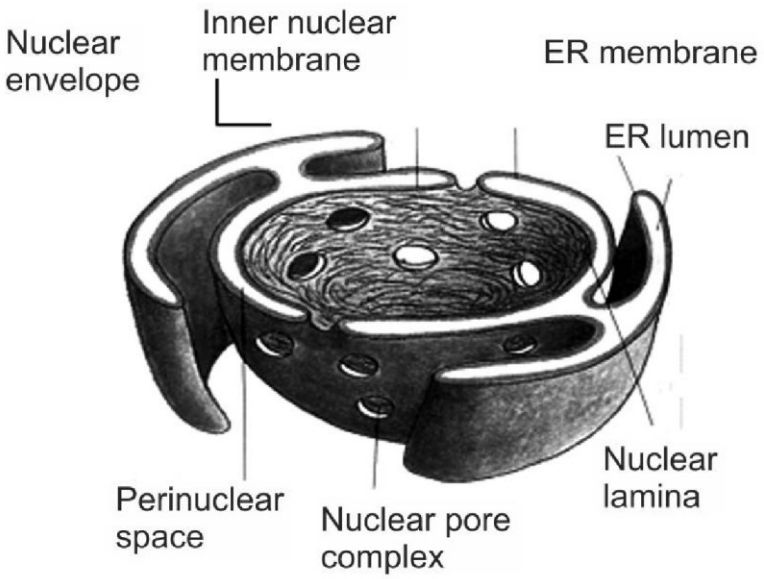
Cell Membrane, Cytoplasm, Nucleus

Nucleus



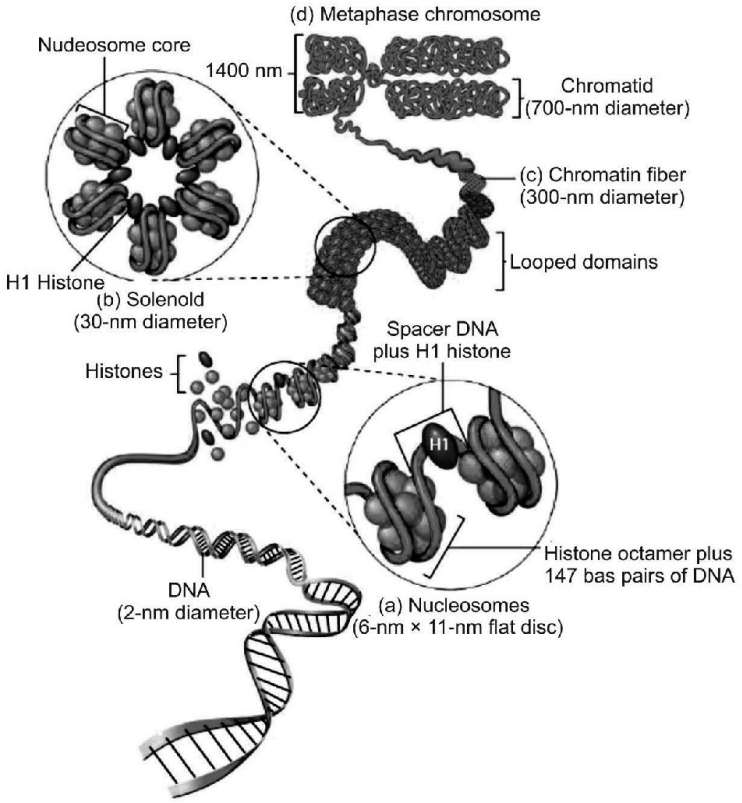
- The nucleus is the most prominent membrane bound organelle as it accounts for most of (10 percent) the cell's volume as compared to other cellular organelles.
- It is separated from the rest of the cell components by nuclear membrane.
- The nucleus (plural = nuclei) houses the cell's DNA in the form of chromatin and directs the synthesis of ribosomes and proteins.
- Typically, the nucleus of a eukaryotic cell consists of a **nuclear membrane** (nuclear envelope), **nucleoplasm or karyoplasms** (matrix present inside the nucleus), **nucleolus and chromosomes**.

Nuclear Membrane



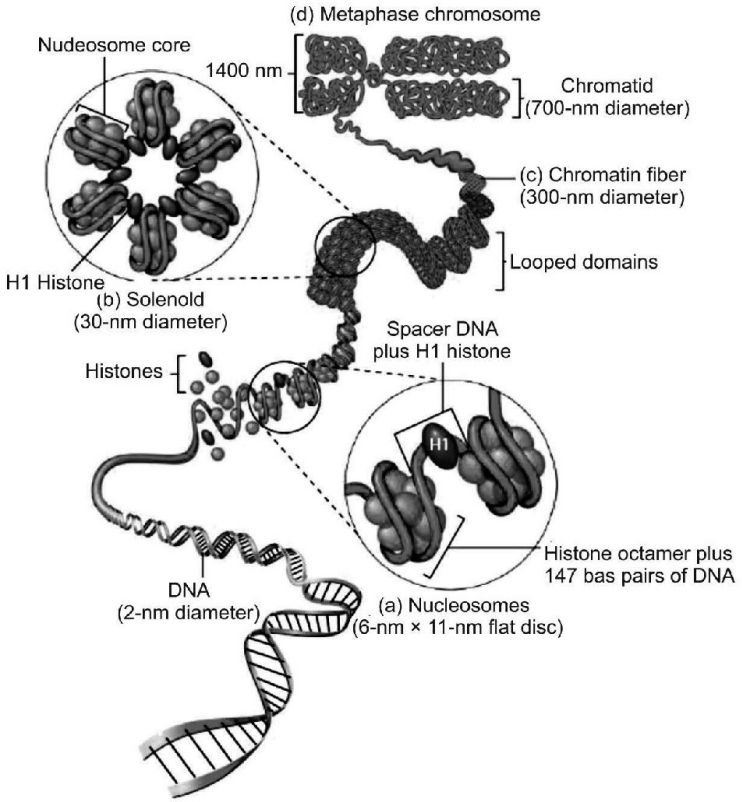
- The nuclear membrane, also called as nuclear envelope is a double-membrane structure that encloses all the contents of nucleus.
- The outer membrane of nucleus is connected to the endoplasmic reticulum. A perinuclear space filled with fluid is present between the two layers of a nuclear membrane.
- Nuclear membrane is punctuated with several openings, known as nuclear pores that control exchange of large molecules (ions, molecules, proteins and RNA) between the nucleoplasm and cytoplasm, permitting some to pass through the membrane, but not others.
- All these pores form nuclear pore complex. At the nuclear pores, the outer membrane is continuous with the inner membrane and thus renders a bi-membrane nuclear envelope.

Chromosomes



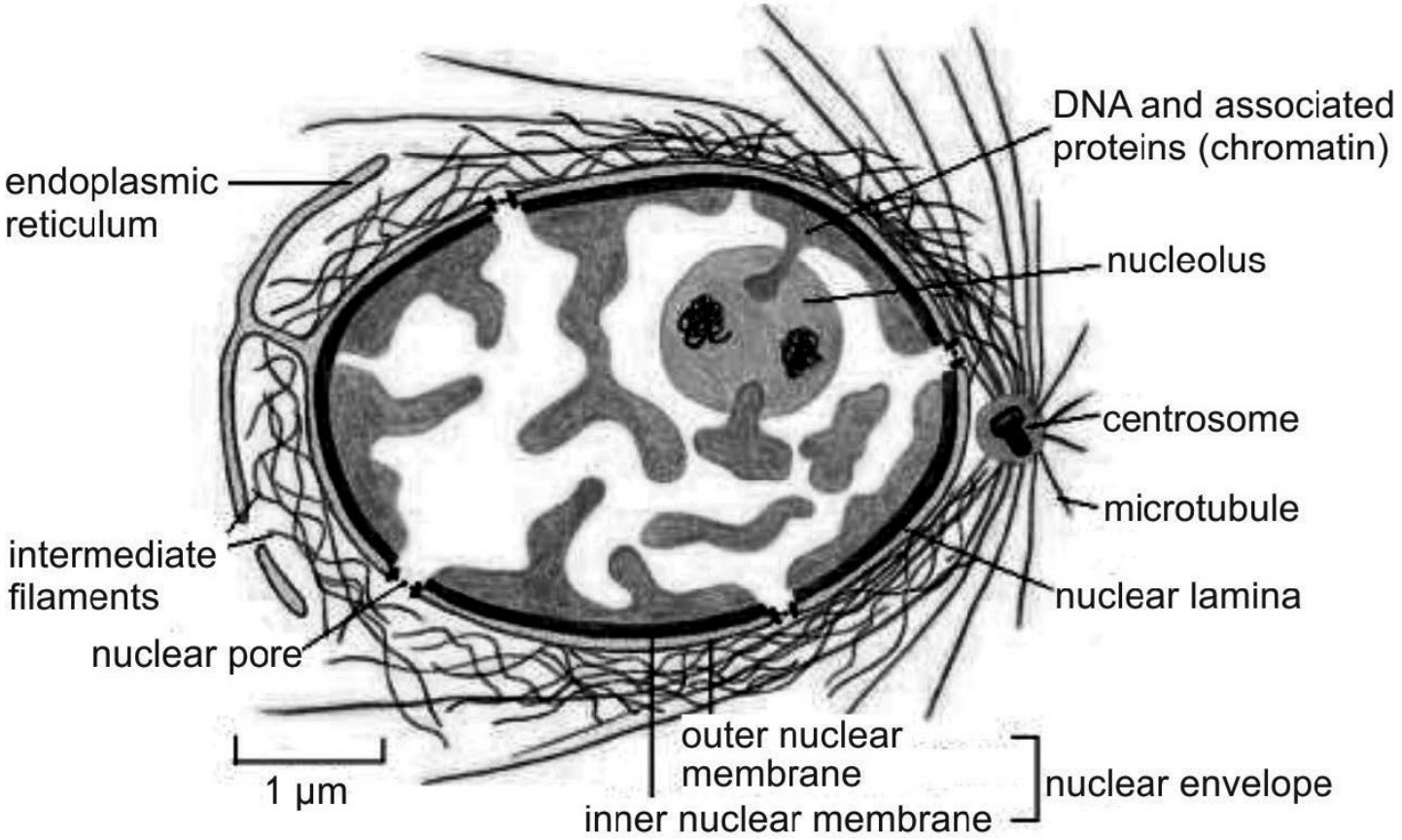
- Chromosomes are packed inside the nucleus of every cell and DNA is the hereditary material with proteins ultimately forming a complex structure, called as chromosome.
- DNA and proteins are packaged inside chromatin, which is further classified as heterochromatin and euchromatin, based on their functions.
- The **heterochromatin** is present adjacent to the nuclear membrane and is a highly condensed and transcriptionally inactive form.

Chromosomes



- In contrast, **euchromatin** is less condensed and is a delicate form of chromatin found abundantly in a transcribing cell.
- Chromosomes are clearly distinguished, when cell is about to divide. For example, when a cell is in the growth/maintenance phase of its cell cycle, the chromosomes appear like an unwound, jumbled bunch of threads.
- During cell division process, in particular, these chromosomes are duplicated as DNA is replicated.

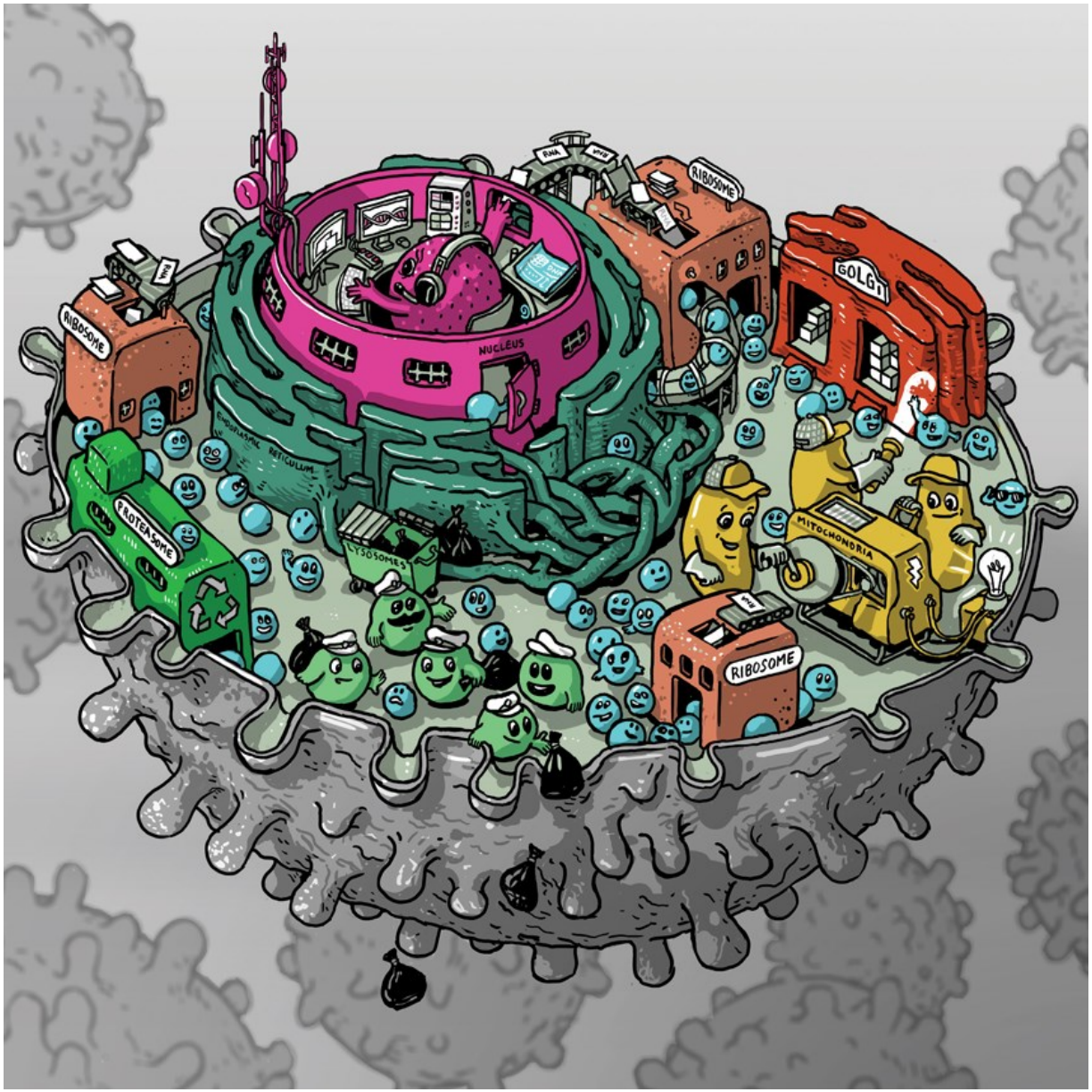
Nucleolus



- Nucleolus (plural nucleoli) is a dense, spherical membrane-less organelle also known as cell's protein-producing structures within the nucleus.
- Nucleolus also plays an indirect role in protein synthesis by producing ribosomes.

Quality control in the cell

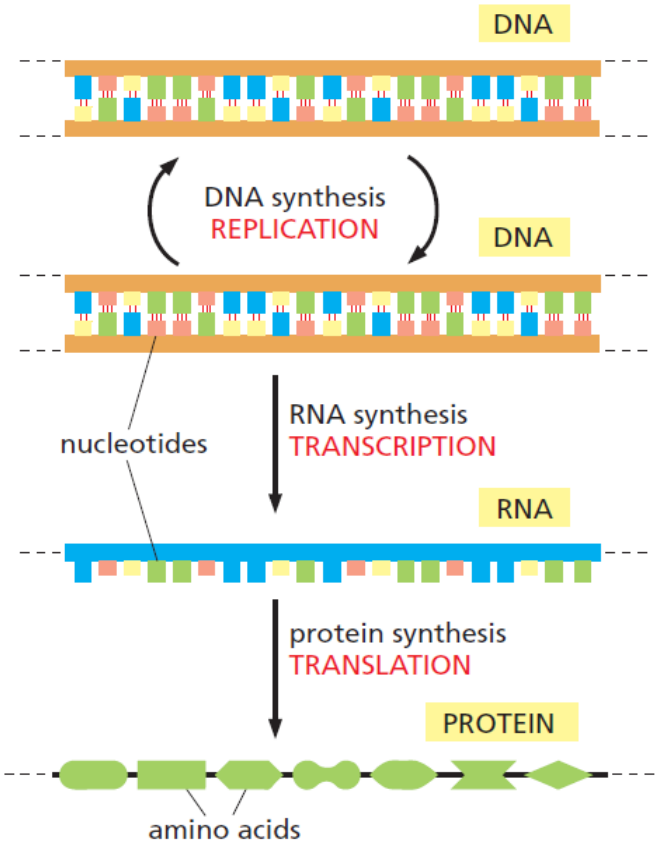
NIGEL SUSSMAN



Tour of Organelles

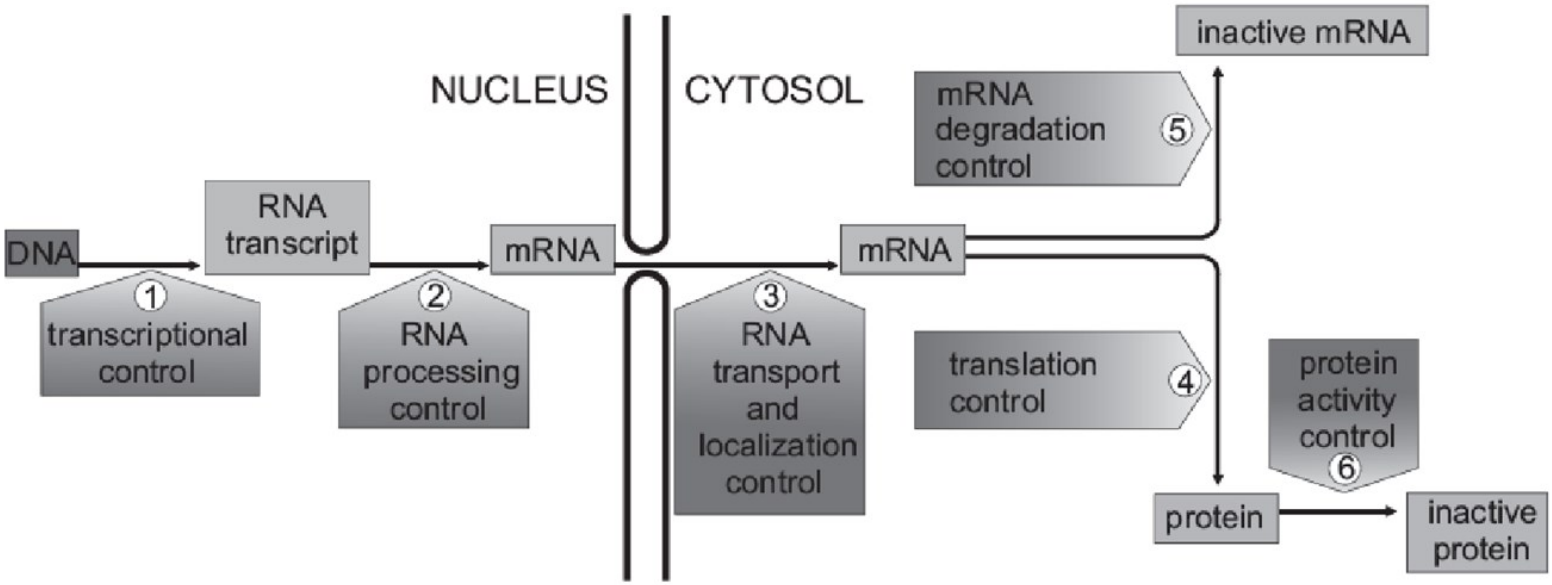
https://www.youtube.com/watch?v=1Z9pqST72is

Central dogma of molecular biology



Central Dogma of Chemical Biology
Transcription and Translation

https://www.youtube.com/watch?v=whV_CkKT7F0



Overview: A Chemical Connection to Biology

- Biology is a multidisciplinary science
- Living organisms are subject to basic laws of physics and chemistry

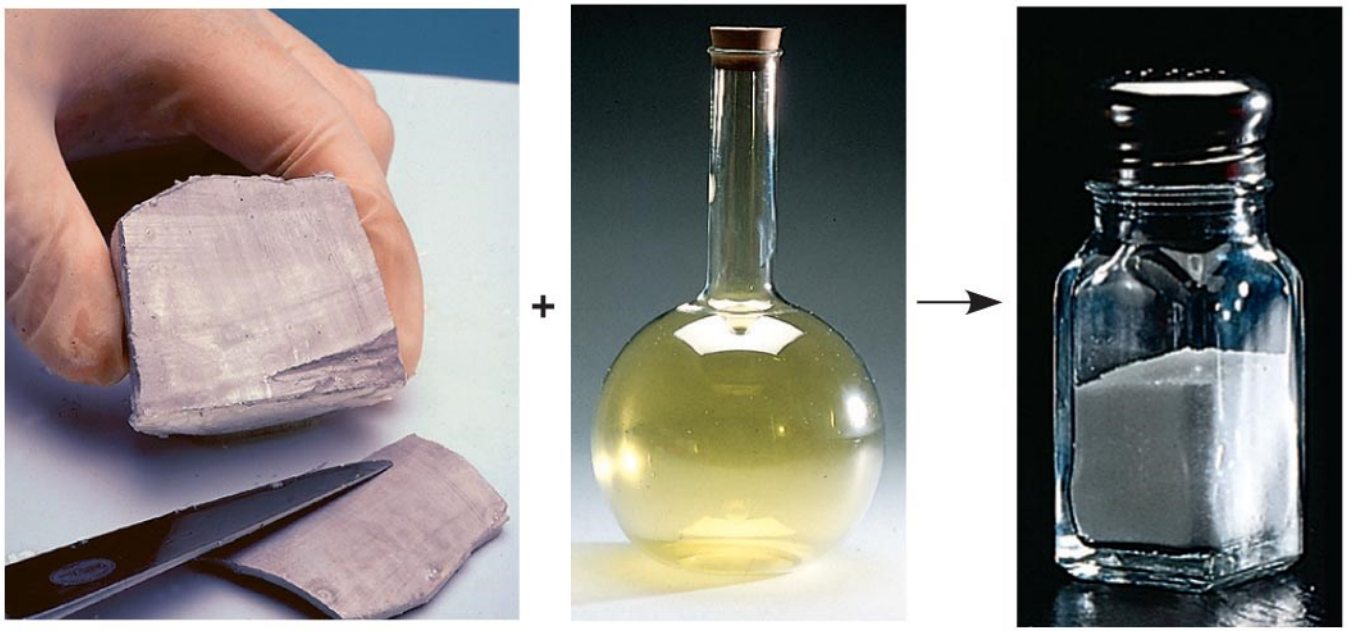
Matter consists of chemical elements in pure form and in combinations called compounds

- Organisms are composed of **matter**
- Matter is anything that takes up space and has mass

Elements and Compounds

- Matter is made up of elements
- An **element** is a substance that cannot be broken down to other substances by chemical reactions
- A **compound** is a substance consisting of two or more elements in a fixed ratio
- A compound has characteristics different from those of its elements

Fig. 2-3

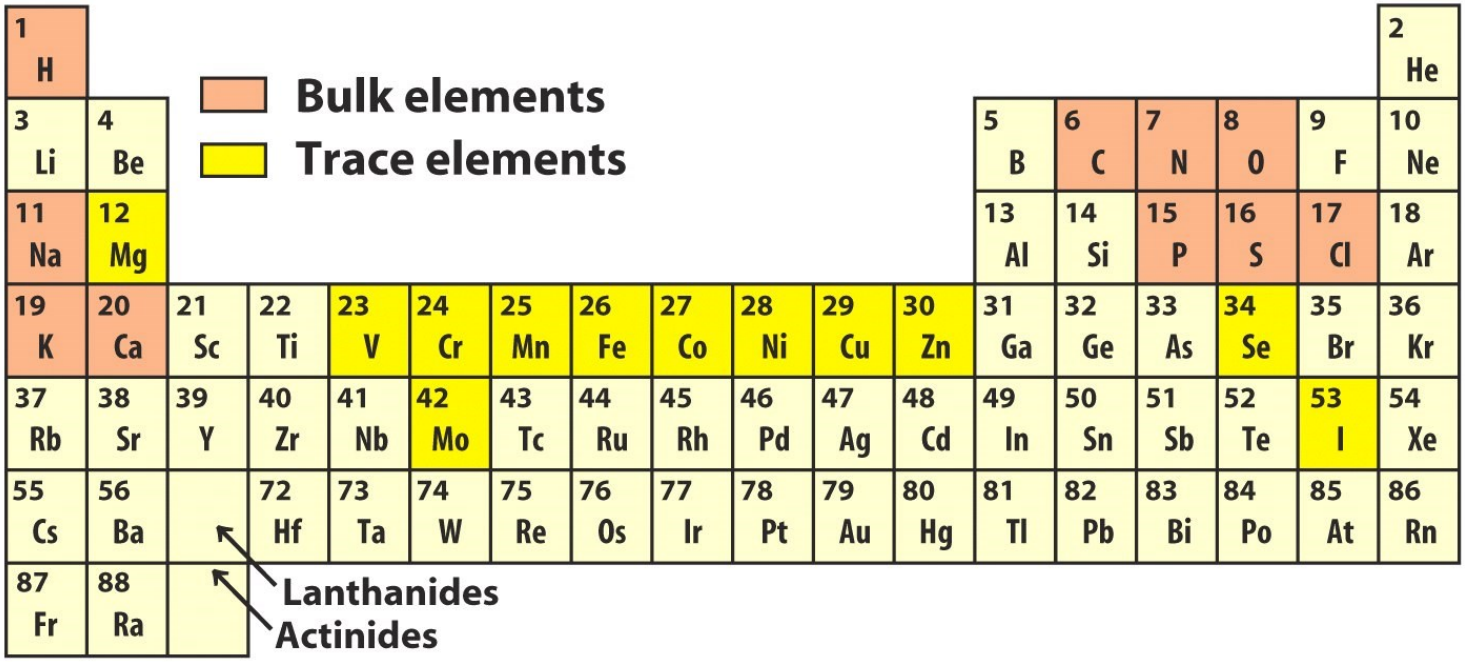


Sodium **Chlorine** **Sodium chloride**

Essential Elements of Life

- About 25 of the 92 elements are essential to life
- Carbon, hydrogen, oxygen, and nitrogen make up 96% of living matter
- Most of the remaining 4% consists of calcium, phosphorus, potassium, and sulfur
- **Trace elements** are those required by an organism in minute quantities

Biochemist's periodic table



- Four most abundant elements in living organisms: H, O, N, C, 99% of the mass of most cells.
- The trace elements are essential to the function of specific proteins.

Table 2-1

Table 2.1 Naturally Occurring Elements in the Human Body

Symbol	Element	Atomic Number (see p. 33)	Percentage of Human Body Weight
Elements making up about 96% of human body weight			
O	Oxygen	8	65.0
C	Carbon	6	18.5
H	Hydrogen	1	9.5
N	Nitrogen	7	3.3
Elements making up about 4% of human body weight			
Ca	Calcium	20	1.5
P	Phosphorus	15	1.0
K	Potassium	19	0.4
S	Sulfur	16	0.3
Na	Sodium	11	0.2
Cl	Chlorine	17	0.2
Mg	Magnesium	12	0.1
Elements making up less than 0.01% of human body weight (trace elements)			
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)			

Fig. 2-4

(a) Nitrogen deficiency

(b) Iodine deficiency

goitre

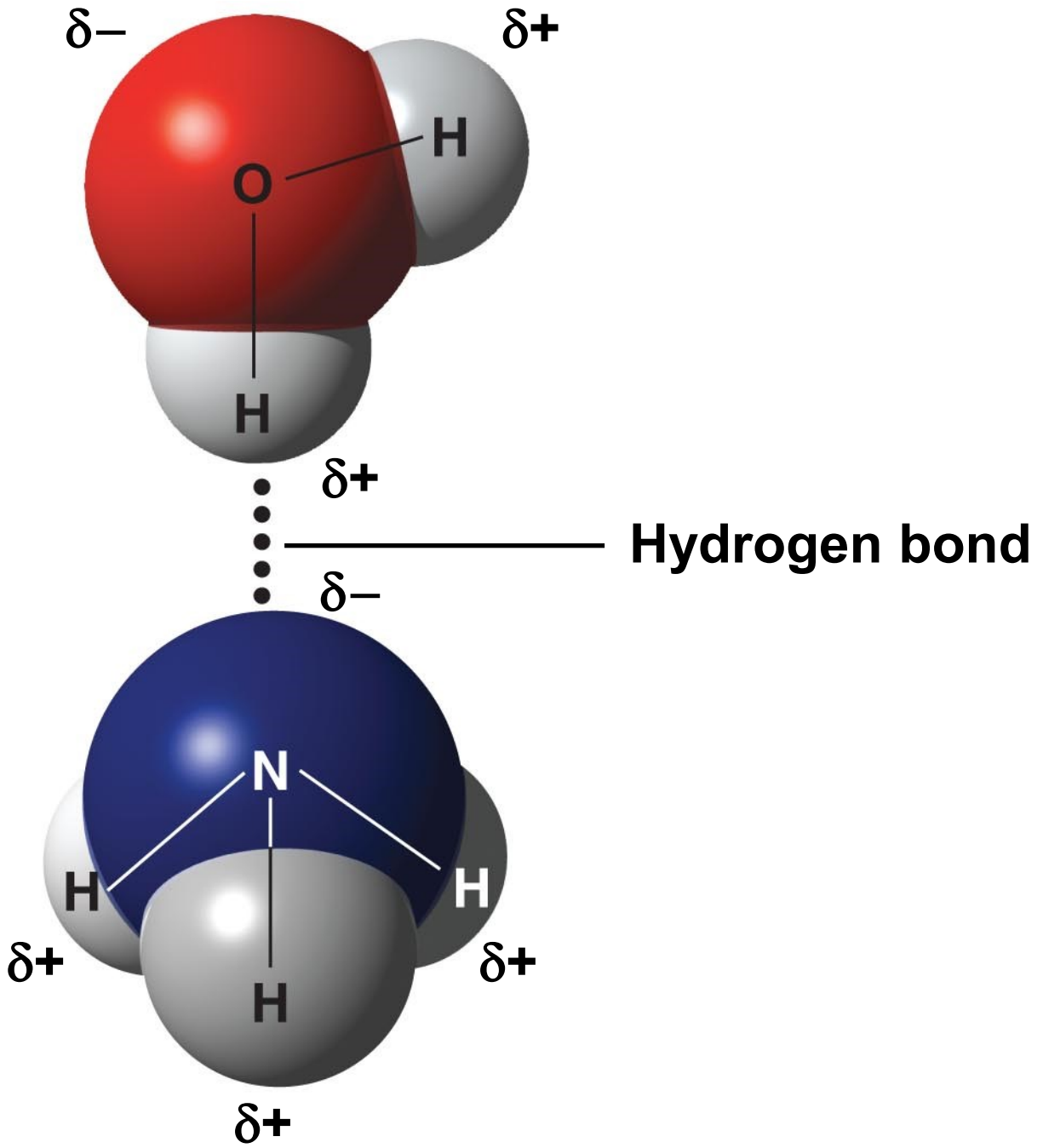
Weak Chemical Bonds

- Most of the strongest bonds in organisms are covalent bonds that form a cell's molecules
- Weak chemical bonds, such as ionic bonds and hydrogen bonds, are also important
- Weak chemical bonds reinforce shapes of large molecules and help molecules adhere to each other

Hydrogen Bonds

- A **hydrogen bond** forms when a hydrogen atom covalently bonded to one electronegative atom is also attracted to another electronegative atom
- In living cells, the electronegative partners are usually oxygen or nitrogen atoms

Fig. 2-16

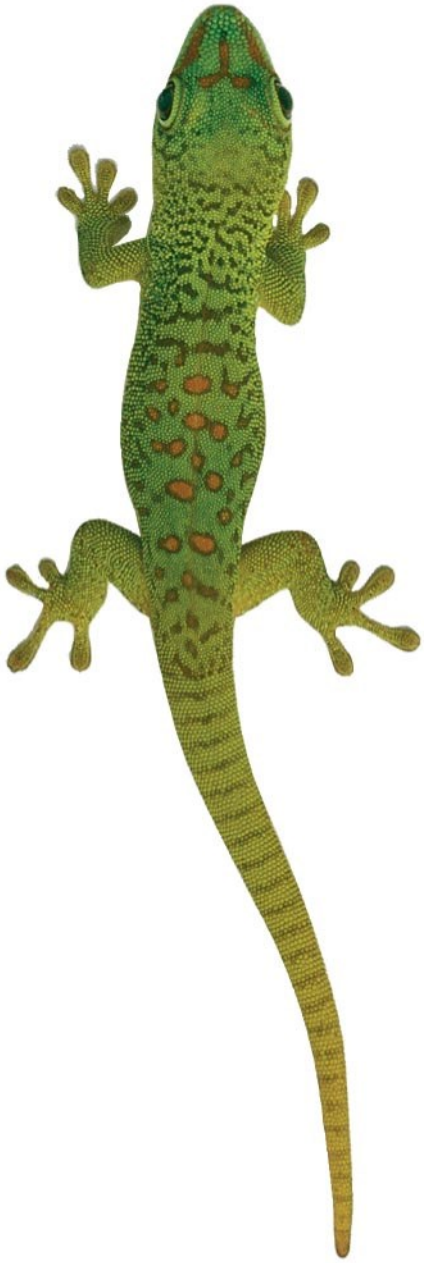


Van der Waals Interactions

- If electrons are distributed asymmetrically in molecules or atoms, they can result in “hot spots” of positive or negative charge
- **Van der Waals interactions** are attractions between molecules that are close together as a result of these charges

- Collectively, such interactions can be strong, as between molecules of a gecko's toe hairs and a wall surface

Fig. 2-UN1

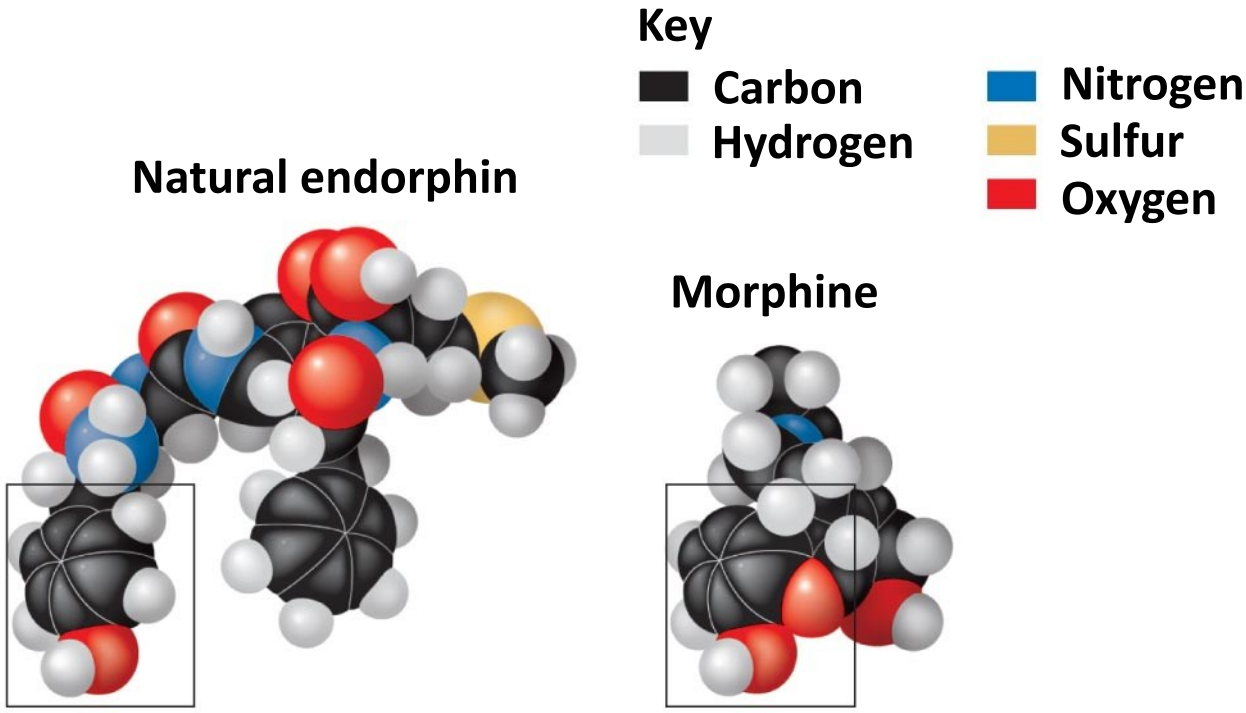


Molecular Shape and Function

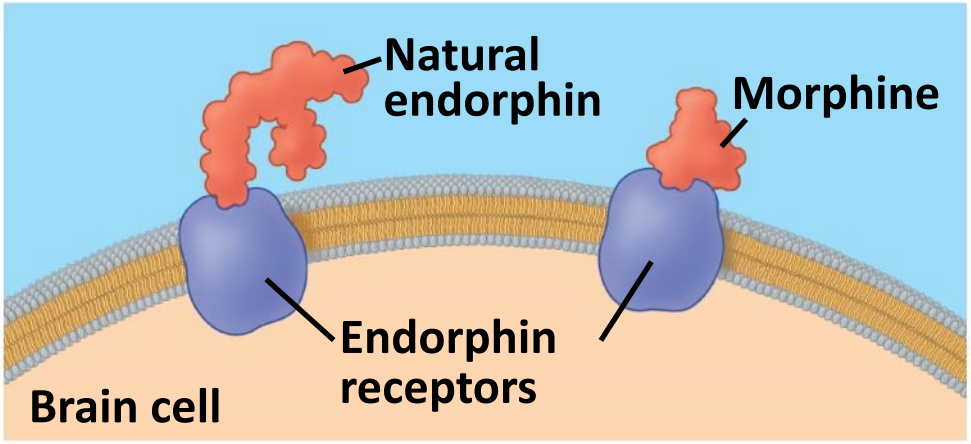
- A molecule's shape is usually very important to its function
- A molecule's shape is determined by the positions of its atoms' valence orbitals
- In a covalent bond, the *s* and *p* orbitals may hybridize, creating specific molecular shapes

- Biological molecules recognize and interact with each other with a specificity based on molecular shape
- Molecules with similar shapes can have similar biological effects

Fig. 2-18



(a) Structures of endorphin and morphine



(b) Binding to endorphin receptors