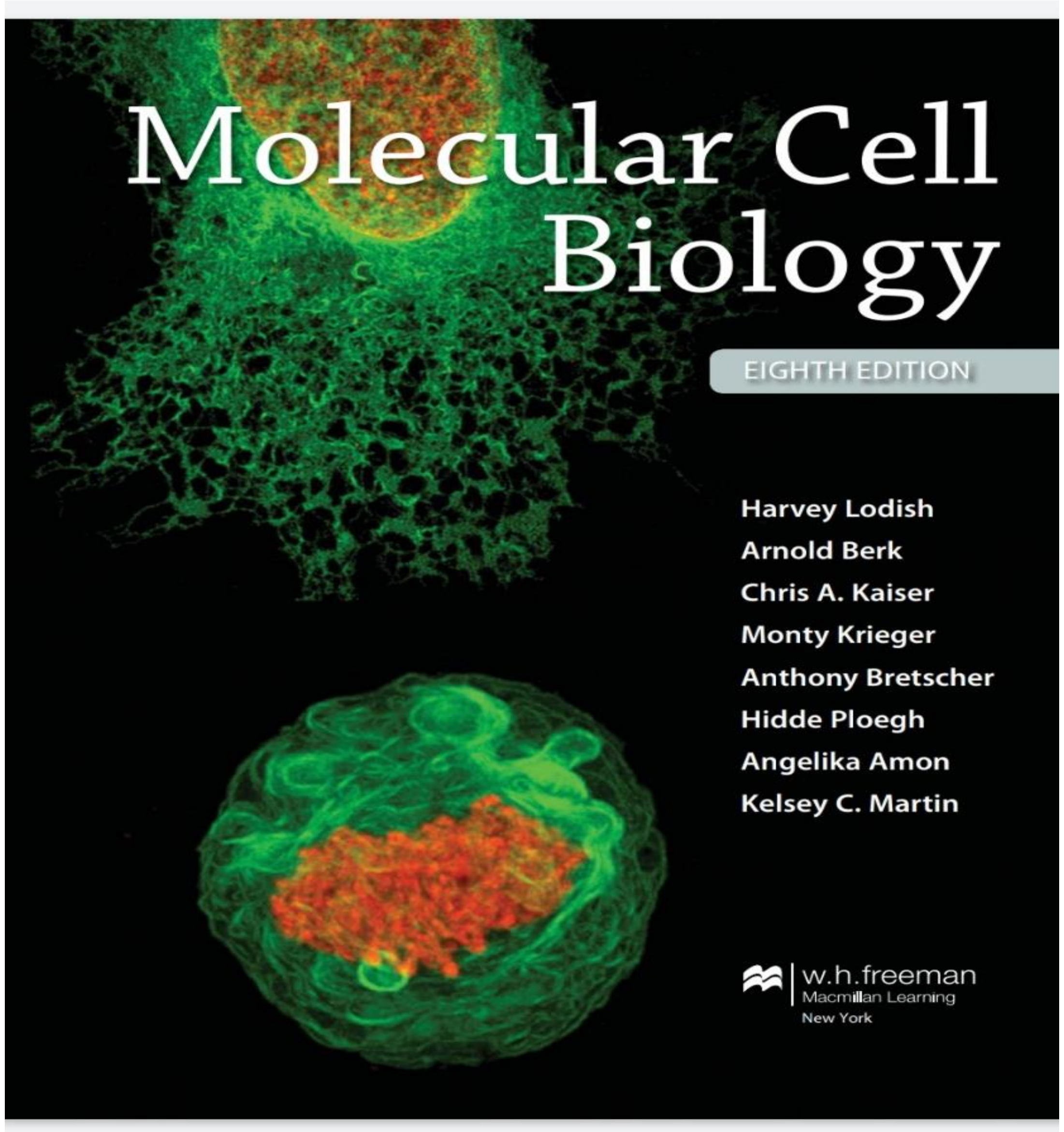
Molecular Cell Biology
EIGHTH EDITION
Harvey Lodish
Arnold Berk
Chris A. Kaiser
Monty Krieger
Anthony Bretscher
Hidde Ploegh
Angelika Amon
Kelsey C. Martin
w.h.freeman
Macmillan Learning
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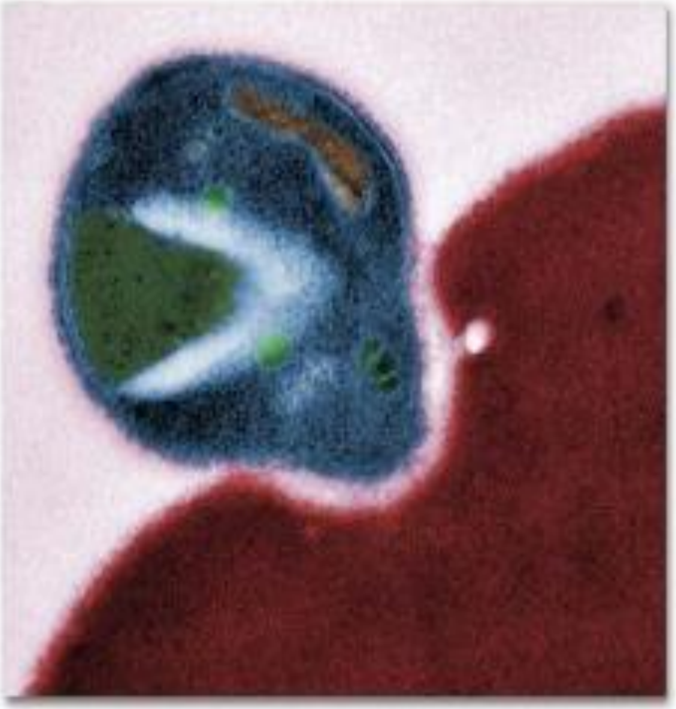
CONTENTS IN BRIEF

CONTENTS



Two cells in mortal combat: a malaria parasite invading a human red blood cell. [Courtesy Dr. Stuart Ralph, University of Melbourne.]

CHAPTER

1

Molecules, Cells, and Model Organisms

OUTLINE

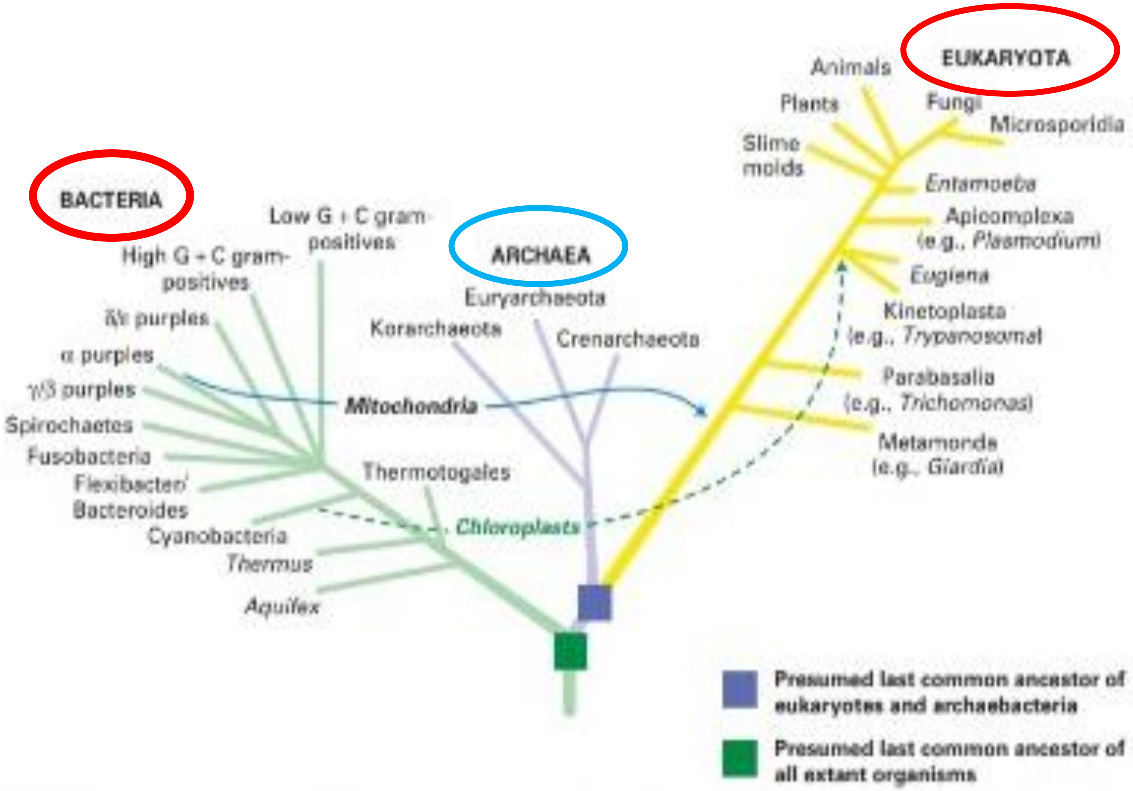


FIGURE 1-1 All living organisms descended from a common ancestral cell. All organisms, from simple bacteria to complex mammals, probably evolved from a common single-celled ancestor. This family tree depicts the evolutionary relationships among the three major lineages of organisms. The structure of the tree was initially ascertained from morphological criteria: creatures that look alike were put close together. More recently, the sequences of DNA and proteins found in organisms have provided more information-rich criteria for assigning relationships. The greater the similarities in these macromolecular sequences, the more closely related organisms are thought to be. The trees based on morphological comparisons and the fossil record generally agree well with those based on molecular data. (Data from J. R. Brown, 2005, "Universal tree of life," in *Encyclopedia of Life Sciences*, Wiley InterScience (online).)

TABLE 1-1 Timeline for Evolution of Life on Earth, as Determined from the Fossil Record

4600 million years ago	The planet Earth forms from material revolving around the young Sun.
~3900–2500 million years ago	Cells resembling prokaryotes appear. These first organisms are chemoautotrophs: they use carbon dioxide as a carbon source and oxidize inorganic materials to extract energy.
3500 million years ago	Lifetime of the last universal ancestor; the split between Eubacteria and Archaea occurs.
3000 million years ago	Photosynthesizing cyanobacteria evolve; they use water as a reducing agent, thereby producing oxygen as a waste product.
1850 million years ago	Unicellular eukaryotes appear.
1200 million years ago	Simple multicellular organisms evolve, mostly consisting of cell colonies of limited complexity.
580–500 million years ago	Most modern phyla of animals begin to appear in the fossil record during the Cambrian explosion.
535 million years ago	Major diversification of living things in the oceans: chordates, arthropods (e.g., trilobites, crustaceans), echinoderms, mollusks, brachiopods, foraminifers, radiolarians, etc.
485 million years ago	First vertebrates with true bones (jawless fishes) evolve.
434 million years ago	First primitive plants arise on land.
225 million years ago	Earliest dinosaurs (prosauropods) and teleost fishes appear.
220 million years ago	Gymnosperm forests dominate the land; herbivores grow to huge sizes.
215 million years ago	First mammals evolve.
65.5 million years ago	The Cretaceous-Tertiary extinction event eradicates about half of all animal species, including all of the dinosaurs.
6.5 million years ago	First hominids evolve.
2 million years ago	First members of the genus *Homo* appear in the fossil record.
350 thousand years ago	Neanderthals appear.
200 thousand years ago	Anatomically modern humans appear in Africa.
30 thousand years ago	Extinction of Neanderthals.

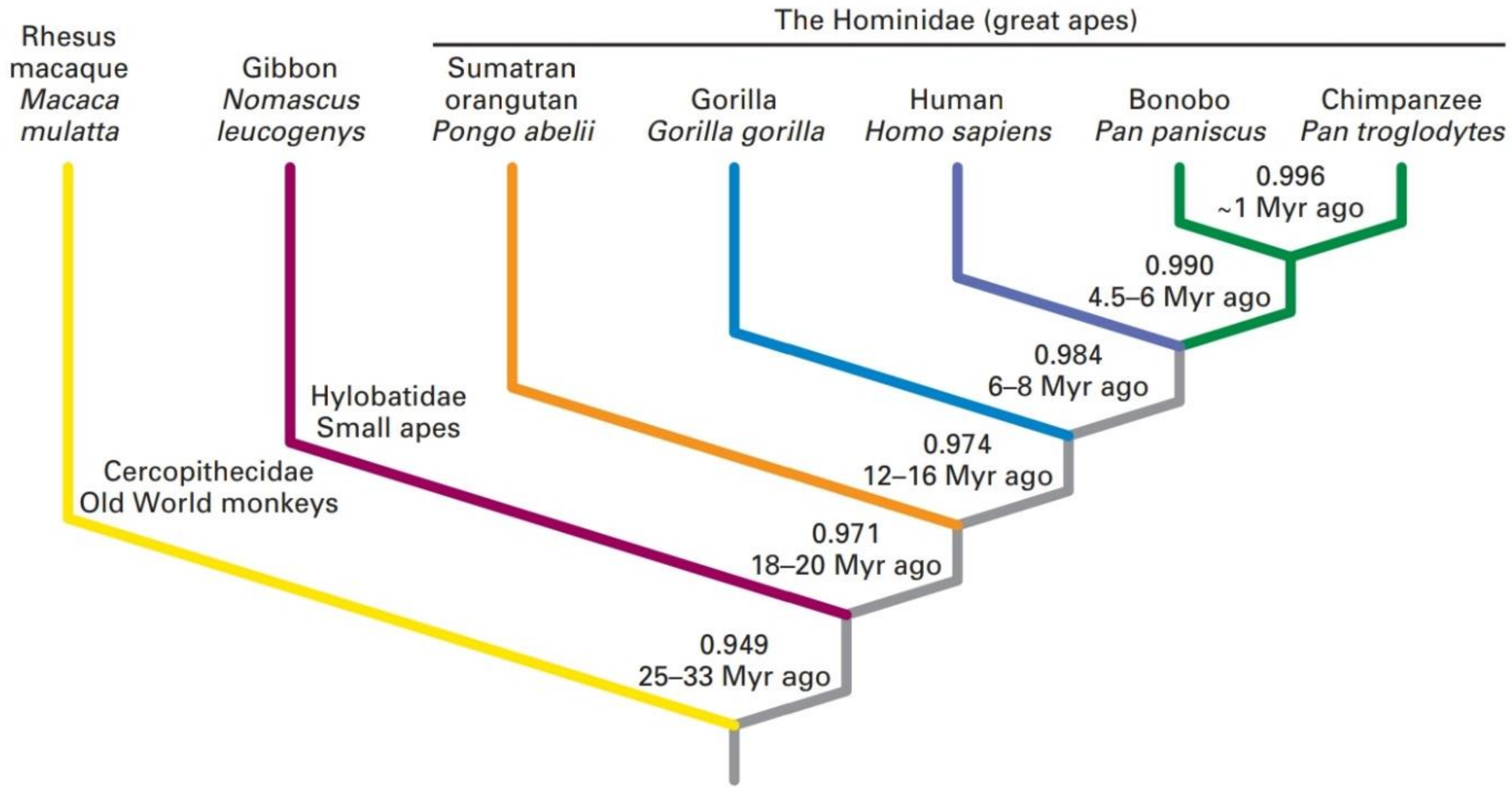


FIGURE 1-26 Evolutionary tree connecting monkeys, apes, and humans. The evolutionary tree of humans, great apes, a small ape, and an Old World monkey was estimated from the divergence among their genomic DNA sequences. Whole-genome DNA sequences were aligned, and the average nucleotide divergence in unique DNA sequences was estimated. Estimates of the times the different species diverged from each other, indicated at each node, were calculated in millions of years (Myr) based on DNA sequence identity; ~1 Myr implies approximately 1 Myr or less. [Data from D. P. Locke et al., 2011, *Nature* **469**:529–533.]

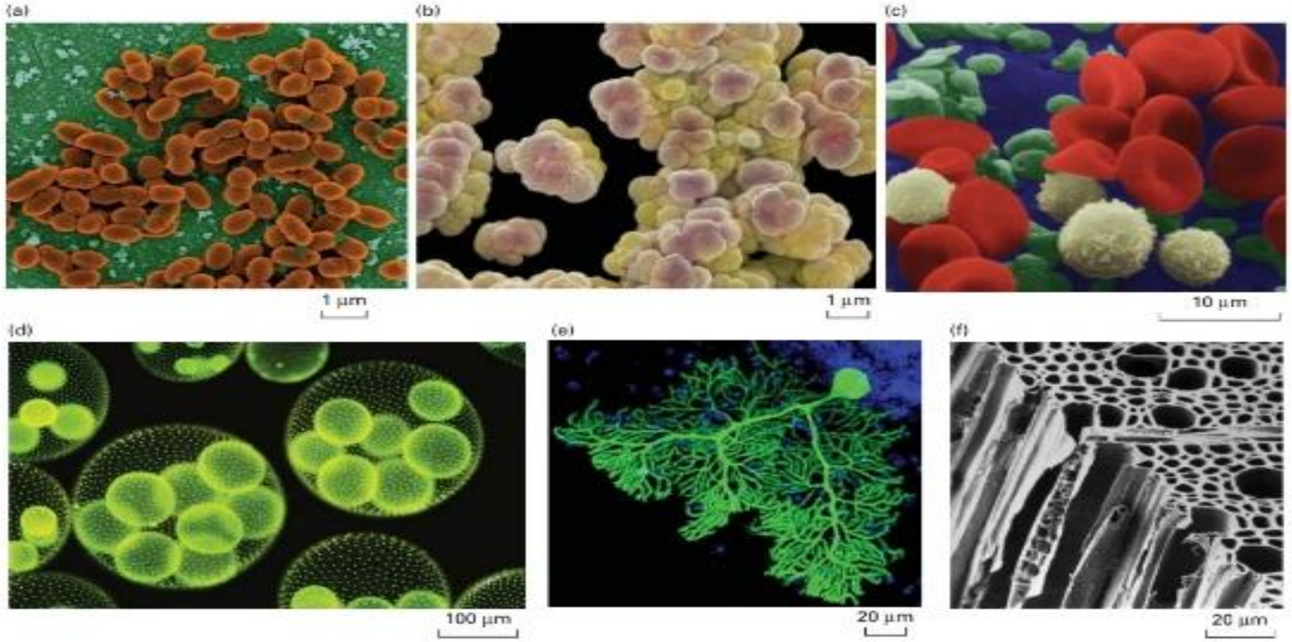
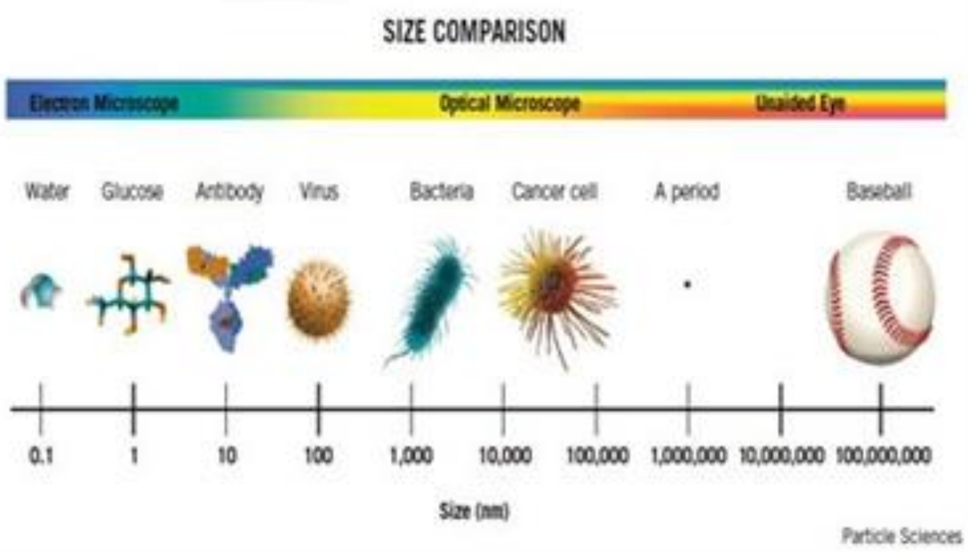


FIGURE 1-3 Cells come in an astounding assortment of shapes and sizes. Some of the morphological variety of cells is illustrated in these photographs. In addition to morphology, cells differ in their ability to move, internal organization (prokaryotic versus eukaryotic cells), and metabolic activities. (a) Eubacteria: *Lactococcus lactis*, which are used to produce cheese such as Roquefort, Brie, and Camembert. Note the dividing cells. (b) A mass of archaeans (*Methanosarcina*) that produce their energy by converting carbon dioxide and hydrogen gas to methane. Some species that live in the rumens of cattle give rise to >150 liters of methane gas each day. (c) Human blood cells, shown in false color. The red cells are oxygen-bearing erythrocytes, the white cells (leukocytes) are part of the immune system and fight infection, and the green cells are platelets that plug wounds and contain substances to initiate blood clotting. (d) A colonial single-celled green alga, *Volvox aureus*. The large spheres are made up of many individual cells, visible as blue or green dots. The yellow masses inside are daughter colonies, each made up of many cells. (e) A single Purkinje neuron of the cerebellum, which can form more than a hundred thousand connections with other cells through its branched network of dendrites. The cell was made visible by introduction of a green fluorescent protein; the cell body is the bulb at the upper right. (f) Plant cells are fixed firmly in place in vascular plants, supported by a rigid cellulose skeleton. Spaces between the cells are joined into tubes for transport of water and food. [Part (a) Gary Gaugler/Science Source. Part (b) Power and Syred/Science Source. Part (c) Science Source. Part (d) micro_photo/iStockphoto/Getty Images. Part (e) Courtesy of Dr. Helen M. Blau (Stanford University School of Medicine) and Dr. Clas B. Johansson (Karolinska Institutet). Part (f) Biophoto Associates/Science Source.]



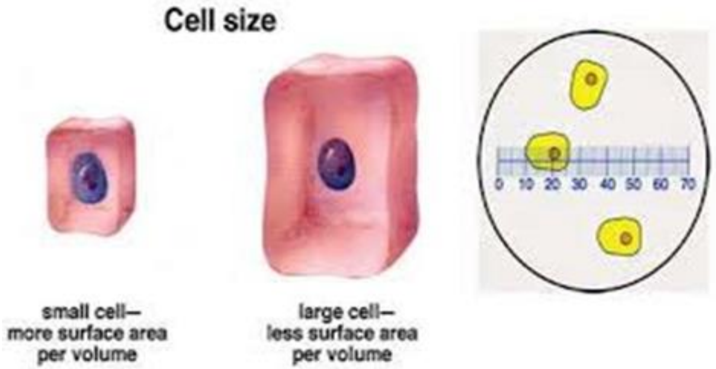


TABLE 1-2 Genome Sizes of Organisms Used in Molecular Cell Biology Research That Have Been Completely Sequenced

	Base Pairs (Millions)	Approximate Number of Encoded Proteins*	Chromosomes**	Reference
Eubacteria				
Mycoplasma genitalum	0.58	500	1	a
Helicobacter pylori	1.67	1,500	1	a
Haemophilus influenza	1.83	1,600	1	a
Escherichia coli	4.64	4,100	1	a
Bacillus subtilis	4.22	4,200	1	a
Archaea				
Methanococcus jannaschii	1.74	1,800	1	a
Sulfolobus solfataricus	2.99	3,000	1	a
Single-Celled Eukaryotes				
Saccharomyces cerevisiae	12.16	6,700	16	b
Chlamydomonas reinhardtii	120.4	14,400	17	b
Plasmodium falciparum	23.26	5,400	14	b
Multicellular Eukaryotes (Metazoans)				
Drosophila melanogaster	168.74	13,900	6	b
Caenorhabditis elegans	100.29	20,500	6	b
Schmidtea mediterranea (planarian)	480	>20,000***	4	c
Danio rerio (zebrafish)	1412.46	26,500	25	b
Gallus gallus (chicken)	1072.54	15,500	33	b
Mus musculus (mouse)	3480.96	23,100	21	b
Homo sapiens (human)	3326.74	20,800	24	b
Arabidopsis thaliana	135.67	27,400	5	b

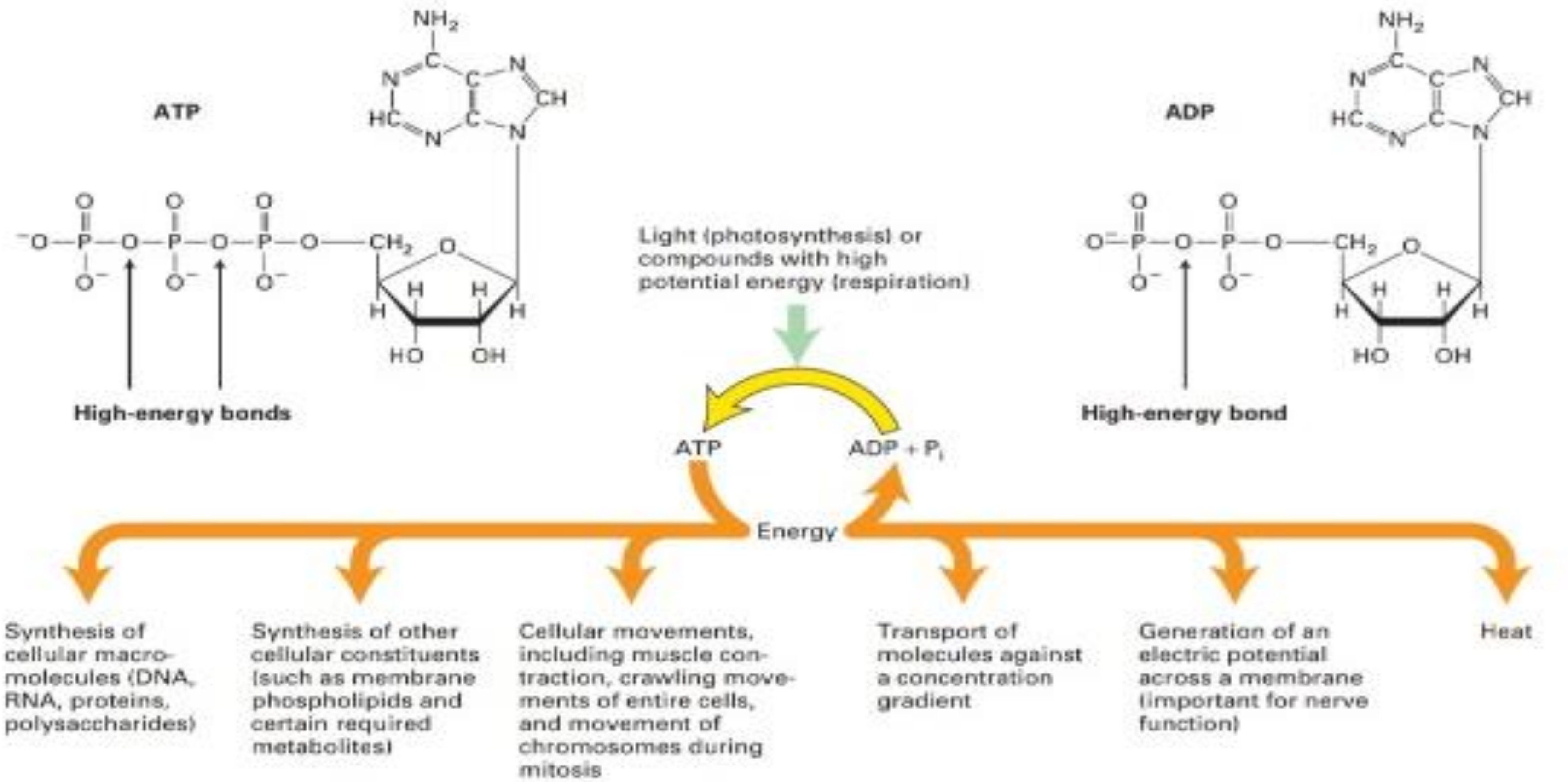
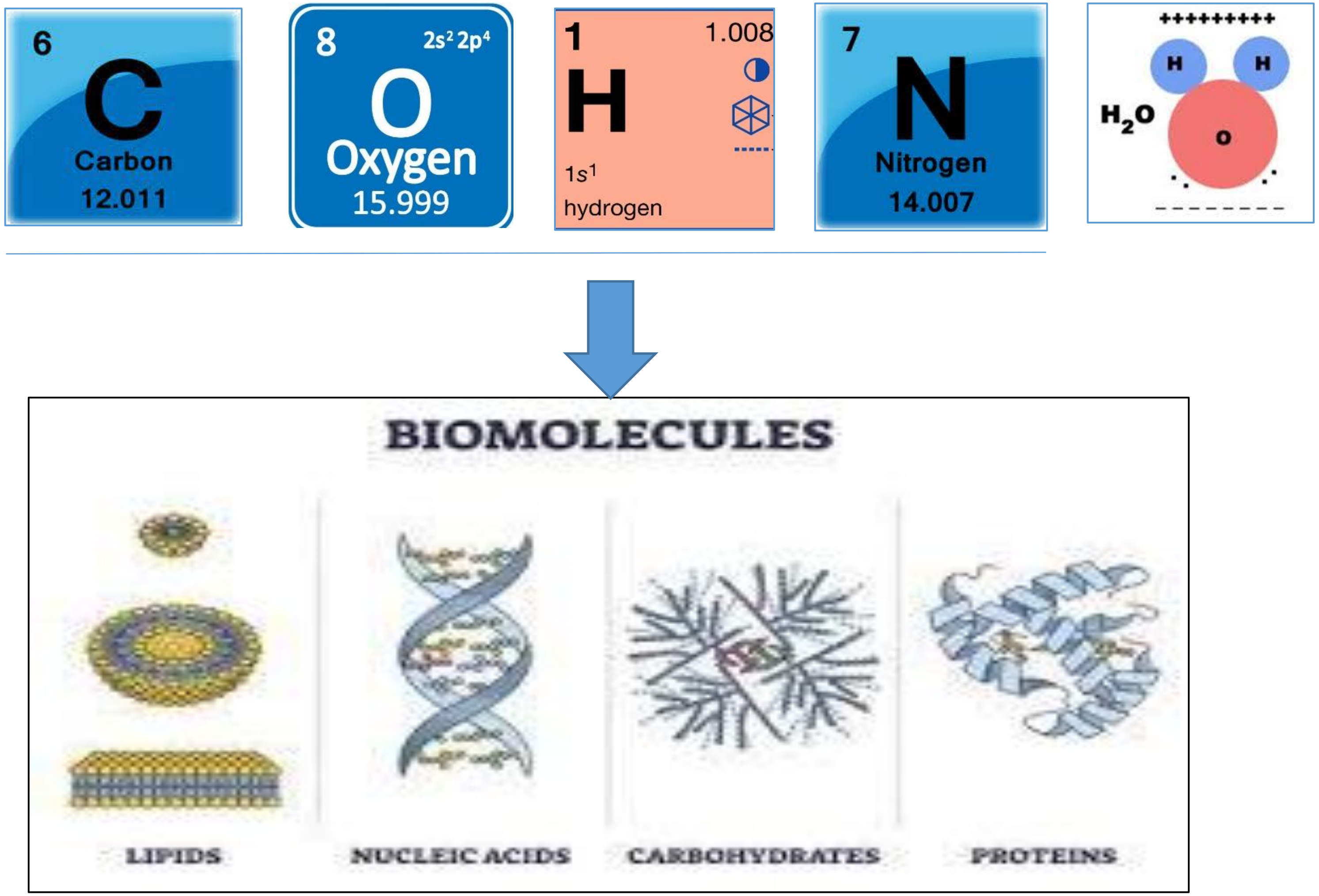


FIGURE 1-6 Adenosine triphosphate (ATP) is the most common molecule used by cells to capture, store, and transfer energy. ATP is formed from adenosine diphosphate (ADP) and inorganic phosphate (P_i) by photosynthesis in plants and by the breakdown of sugars and fats in most cells. The energy released by the splitting (hydrolysis) of P_i from ATP drives many cellular processes.


6
C
Carbon
12.011
8
2s2 2p4
O
Oxygen
15.999
1
1.008
H
1s1
hydrogen
7
N
Nitrogen
14.007
H2O
H
H
O
BIOMOLECULES
LIPIDS
NUCLEIC ACIDS
CARBOHYDRATES
PROTEINS

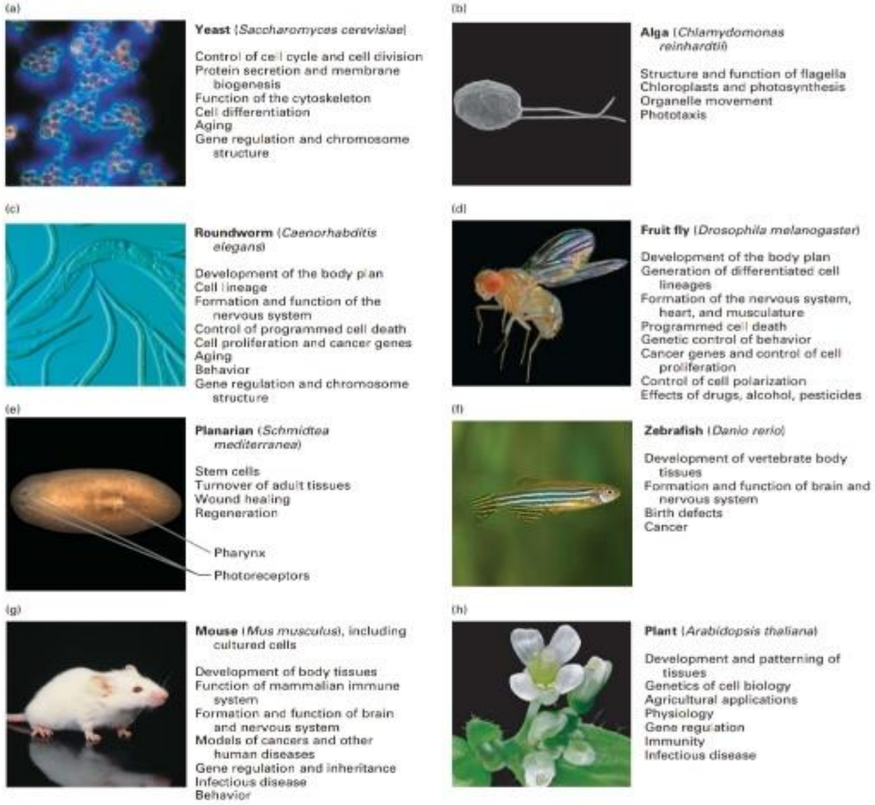
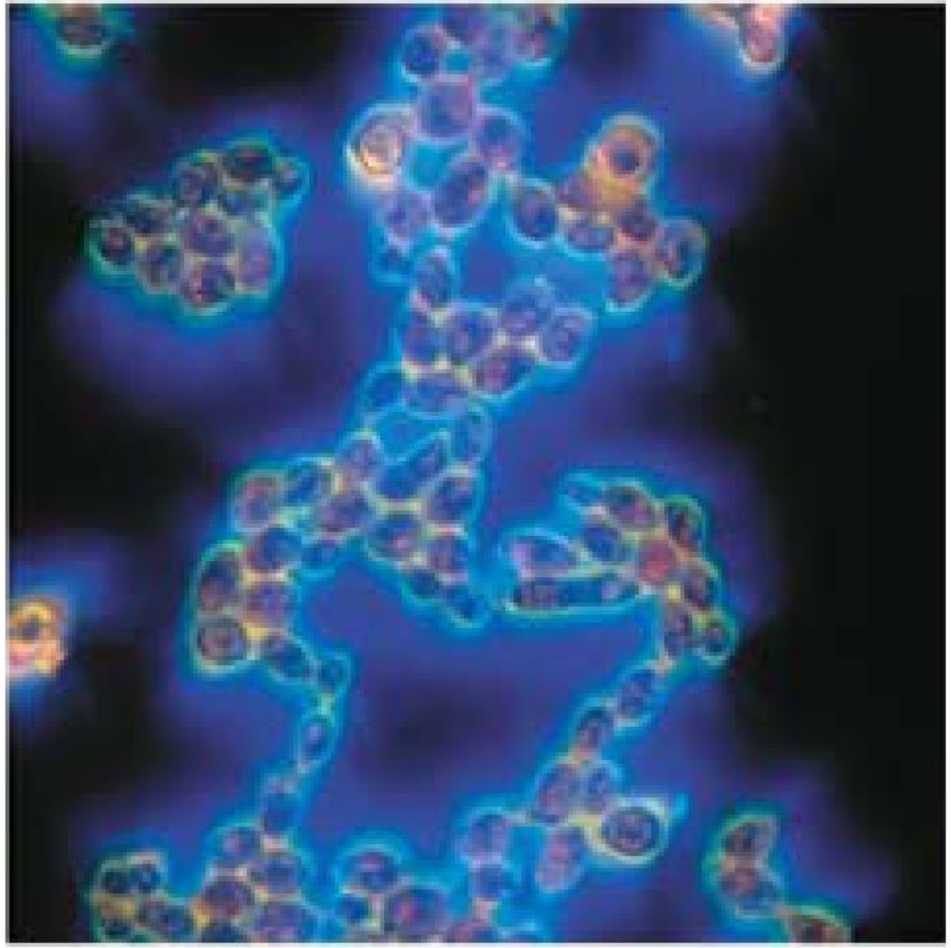


FIGURE 1-22 Each eukaryotic organism used in cell biology has advantages for certain types of studies. The yeast *Saccharomyces cerevisiae* (a) has the cellular organization of a eukaryote but is a relatively simple single-celled organism that is easy to grow and to manipulate genetically. The green alga *Chlamydomonas reinhardtii* (b) is widely used to study photosynthesis and the structure and function of flagella. In the roundworm *Caenorhabditis elegans* (c), which has a small number of cells arranged in a nearly identical way in every worm, the formation of each individual cell can be traced. The fruit fly *Drosophila melanogaster* (d), first used to discover the properties of chromosomes, has been especially valuable in identifying genes that control embryonic development. Many of these genes are evolutionarily conserved in humans. Planaria (e) are flatworms that can regenerate any part of the body that is cut off, including the head and the photoreceptors. The stem cells that give rise to their new cells and tissues are widely studied. The zebrafish *Danio rerio* (f) is used for rapid genetic screens to identify genes that control vertebrate development and organogenesis. Of the experimental animal systems, mice (*Mus musculus*) (g) are evolutionarily the closest to humans and have thus provided models for studying numerous human genetic and infectious diseases. The mustard-family weed *Arabidopsis thaliana* (h) has been used for genetic screens to identify genes involved in nearly every aspect of plant life. [Part (a) Scimat/Photo Researchers, Inc. Part (b) William Dentler University of Kansas. Part (c) Science Source. Part (d) Darwin Dale/Science Source. Part (e) Peter Reddien, MIT Whitehead Institute. Part (f) blickwinkel/Hartl/Alamy. Part (g) J. M. Labat/Jacana/Photo Researchers, Inc. Part (h) Darwin Dale/Science Source.]

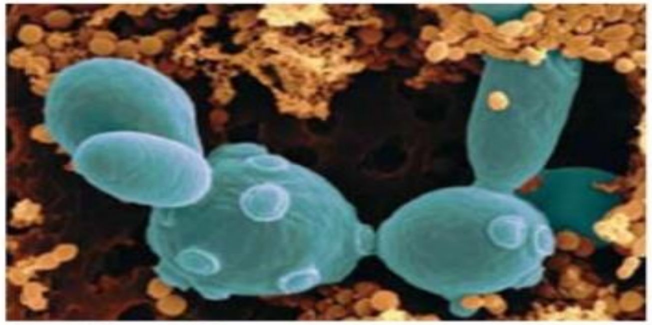
(a)



Yeast (*Saccharomyces cerevisiae*)

Control of cell cycle and cell division
Protein secretion and membrane biogenesis
Function of the cytoskeleton
Cell differentiation
Aging
Gene regulation and chromosome structure

(a)



Budding (*S. cerevisiae*)

(b)

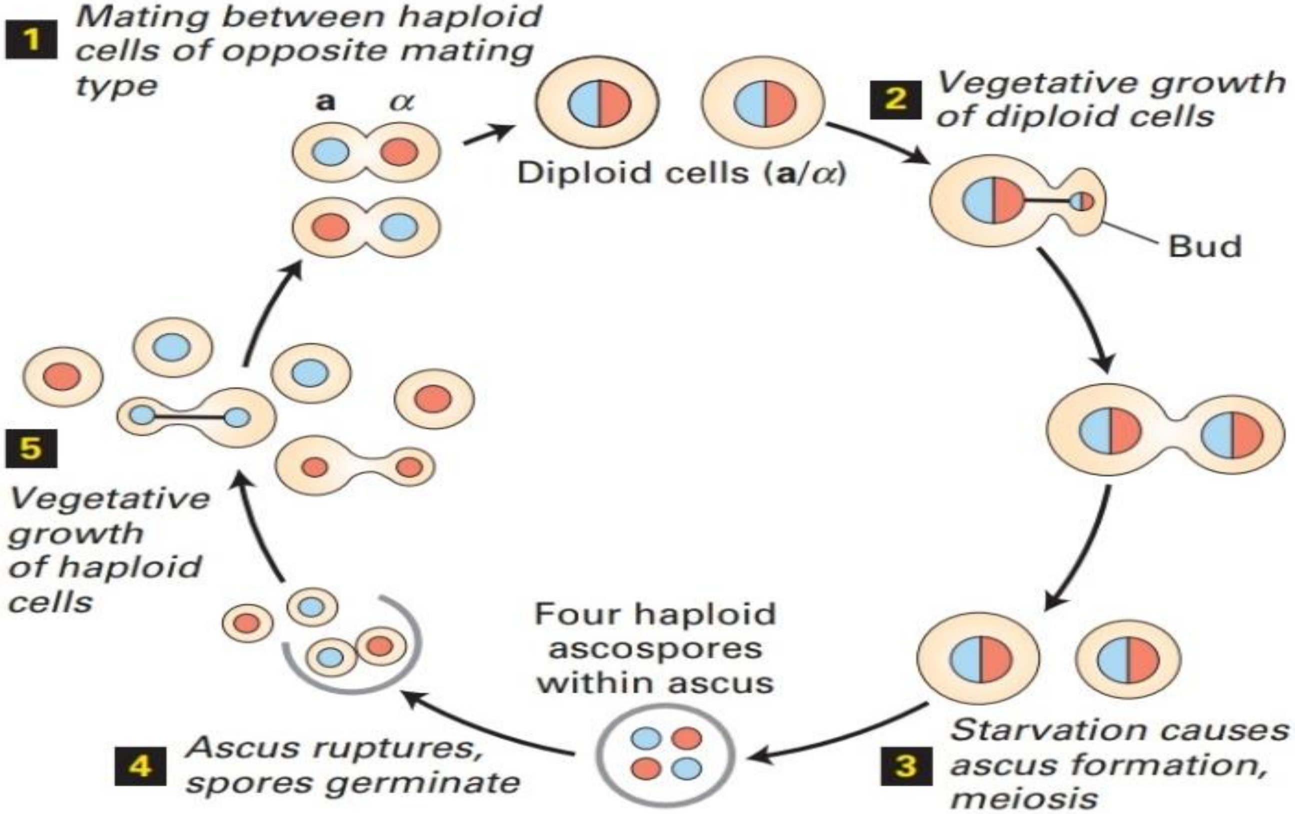
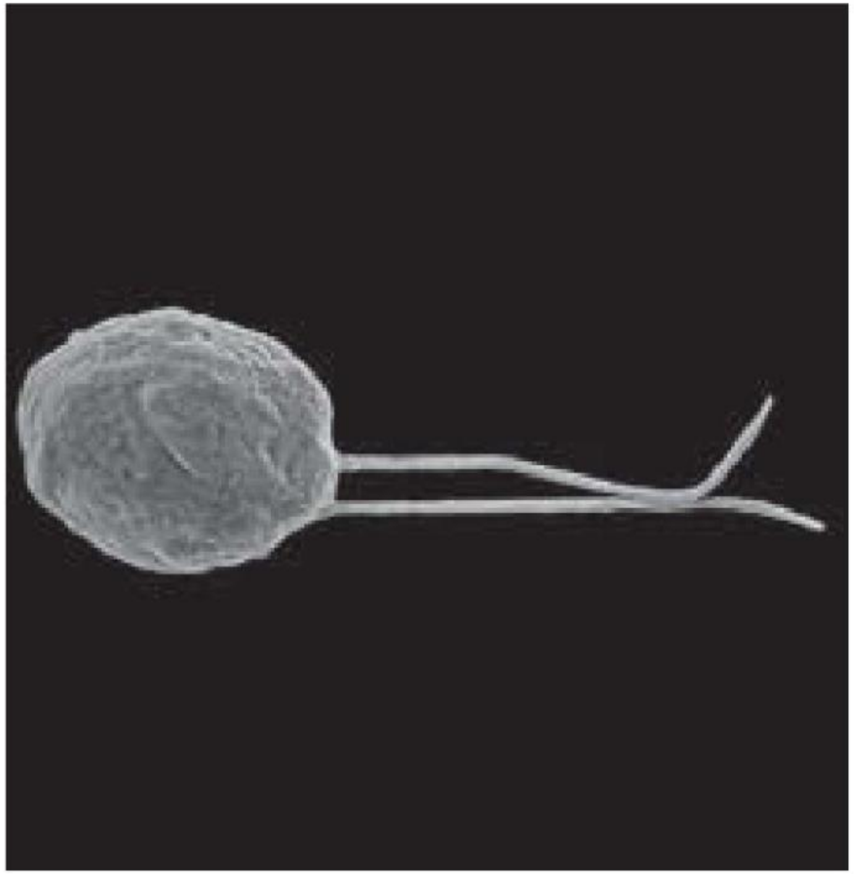


FIGURE 1-23 The yeast *Saccharomyces cerevisiae* can be haploid or diploid and can reproduce sexually or asexually. (a) Scanning

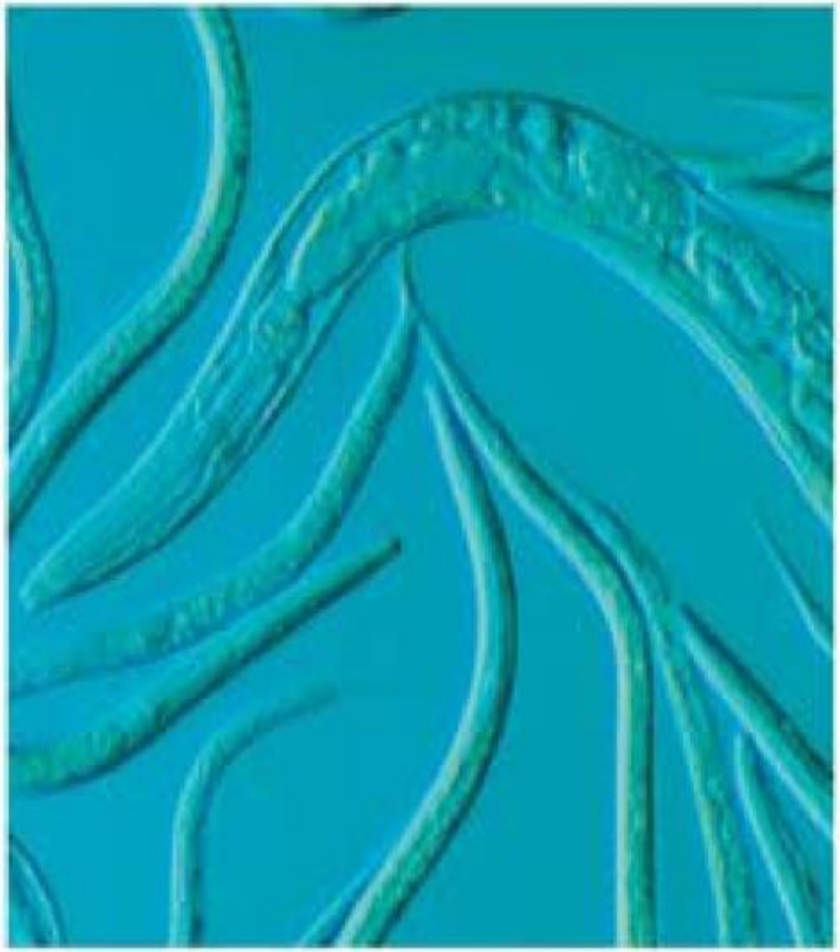
(b)



Alga (*Chlamydomonas reinhardtii*)

Structure and function of flagella
Chloroplasts and photosynthesis
Organelle movement
Phototaxis

(c)



Roundworm (*Caenorhabditis elegans*)

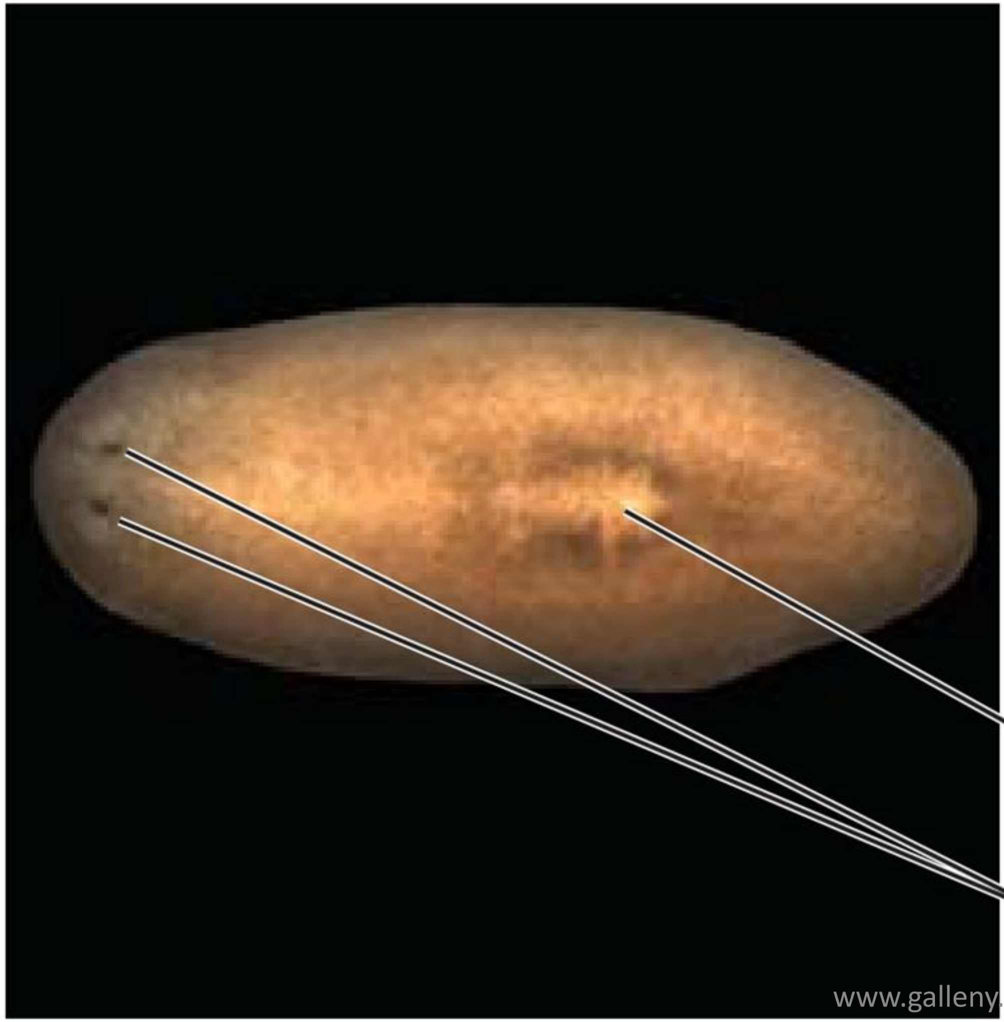
Development of the body plan
Cell lineage
Formation and function of the nervous system
Control of programmed cell death
Cell proliferation and cancer genes
Aging
Behavior
Gene regulation and chromosome structure

(d)

Fruit fly (*Drosophila melanogaster*)

Development of the body plan
Generation of differentiated cell lineages
Formation of the nervous system, heart, and musculature
Programmed cell death
Genetic control of behavior
Cancer genes and control of cell proliferation
Control of cell polarization
Effects of drugs, alcohol, pesticides

(e)



Planarian (*Schmidtea mediterranea*)

Stem cells
Turnover of adult tissues
Wound healing
Regeneration

(f)

Zebrafish (*Danio rerio*)

Development of vertebrate body tissues
Formation and function of brain and nervous system
Birth defects
Cancer

(g)

Mouse (*Mus musculus*), including cultured cells

Development of body tissues
Function of mammalian immune system
Formation and function of brain and nervous system
Models of cancers and other human diseases
Gene regulation and inheritance
Infectious disease
Behavior

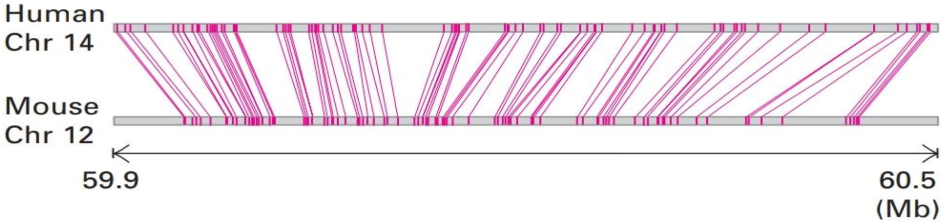


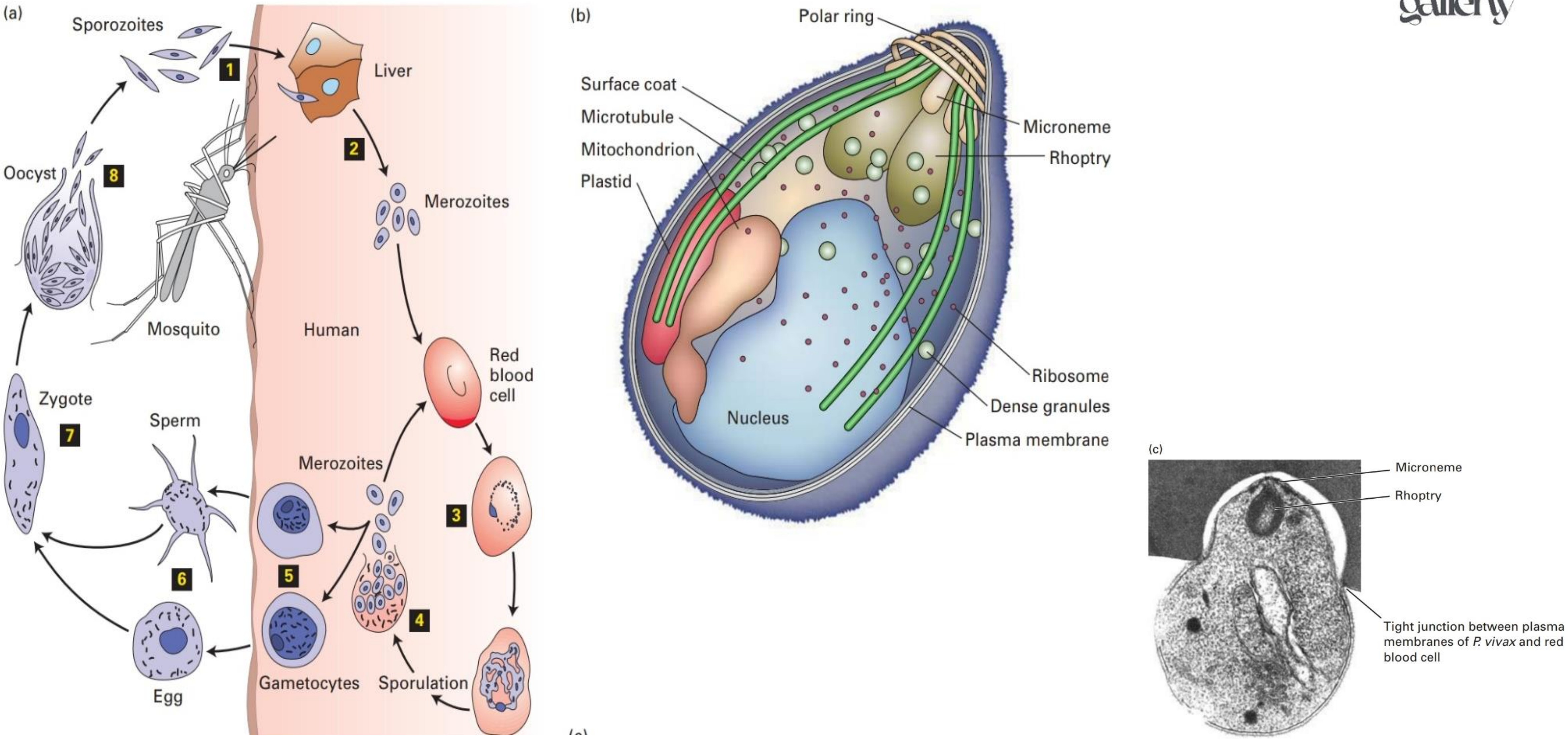
FIGURE 1-27 Conservation of synteny between human and mouse. Shown is a 510,000-base-pair (bp) segment of mouse chromosome 12 that shares common ancestry with a 600,000-bp section of human chromosome 14. Pink lines connect the reciprocal unique DNA sequences in the two genomes. Mb, 1 million base pairs. [Data from Mouse Genome Sequencing Consortium, 2002, *Nature* **420**:520.]

(h)

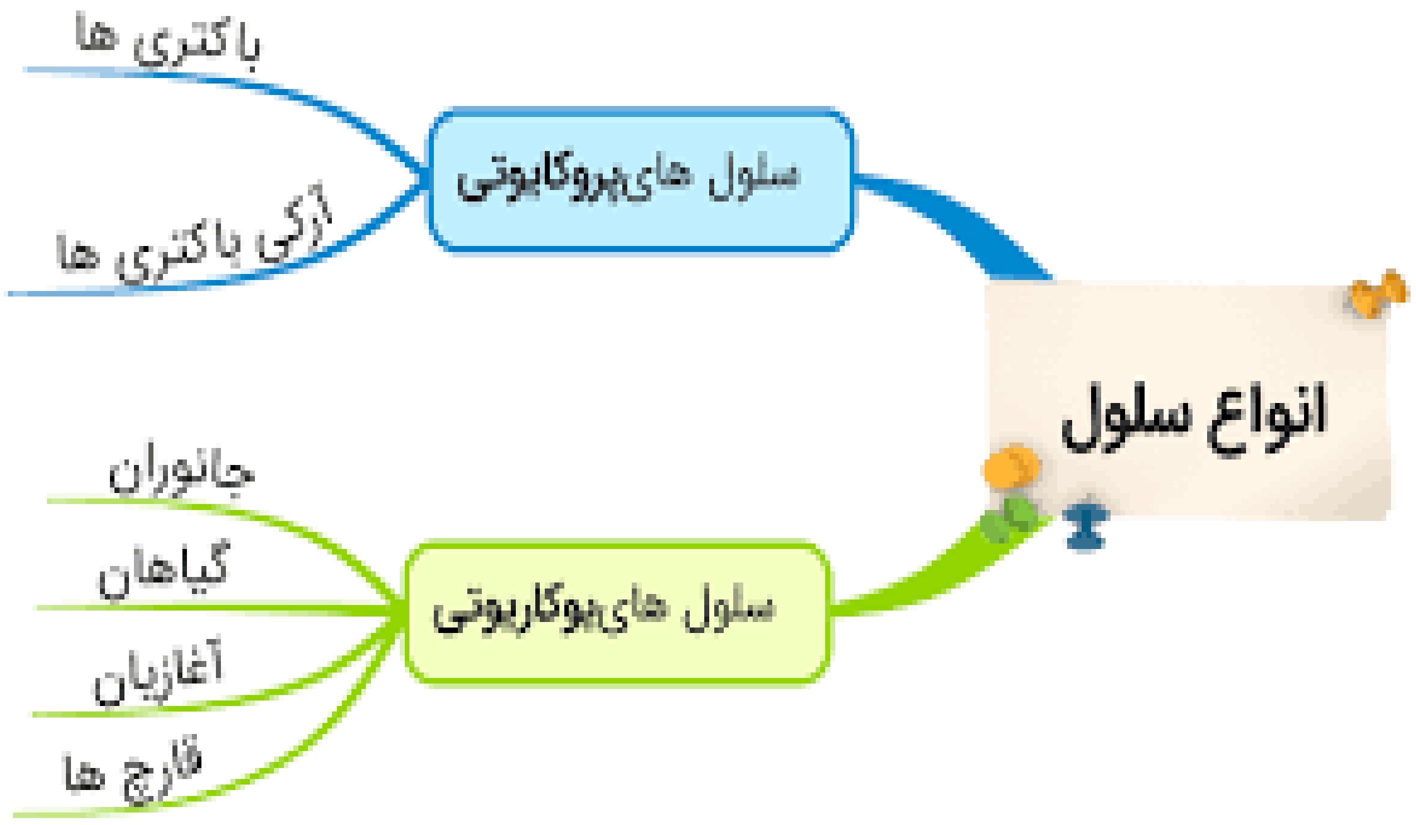
Plant (*Arabidopsis thaliana*)

Development and patterning of tissues
Genetics of cell biology
Agricultural applications
Physiology
Gene regulation
Immunity
Infectious disease

Malaria

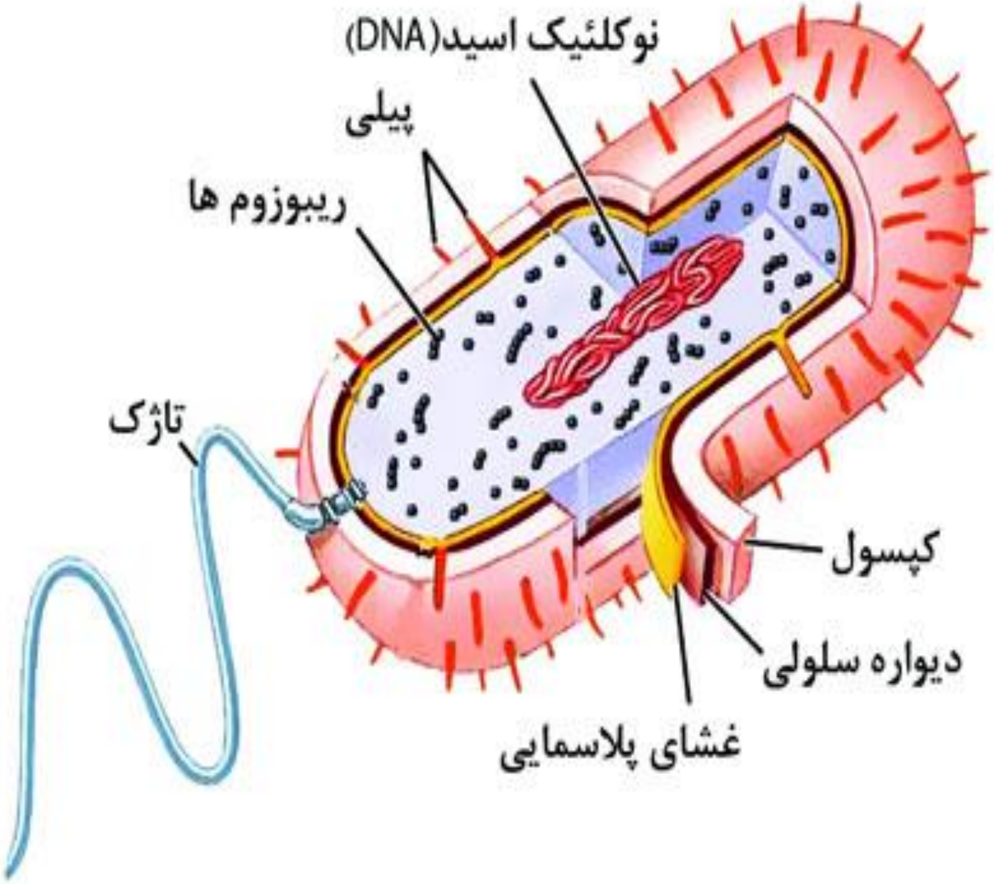


(a)
Sporozoites
1
Liver
2
Merozoites
Oocyst
8
Mosquito
Human
Red blood cell
Zygote
7
Sperm
Merozoites
3
5
6
4
Egg
Gametocytes
Sporulation
(b)
Polar ring
Surface coat
Microtubule
Mitochondrion
Plastid
Microneme
Rhoptry
Ribosome
Dense granules
Nucleus
Plasma membrane
(c)
Microneme
Rhoptry
Tight junction between plasma membranes of P. vivax and red blood cell

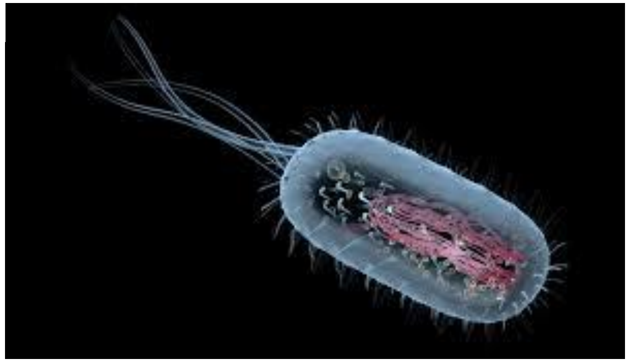


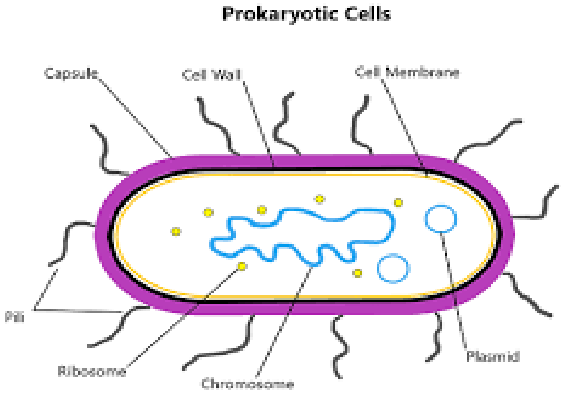
انواع سلول
سلول های پروکاریوتی
باکتری ها
آرکی باکتری ها
سلول های یوکاریوتی
جانوران
گیاهان
آغازیان
قارچ ها

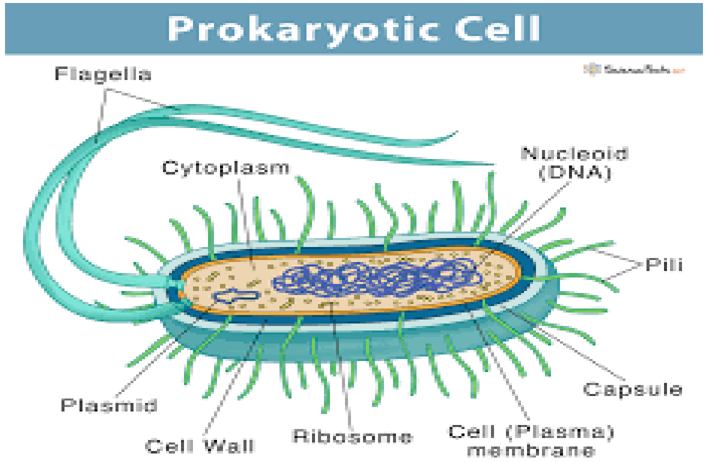
پروکاریوت

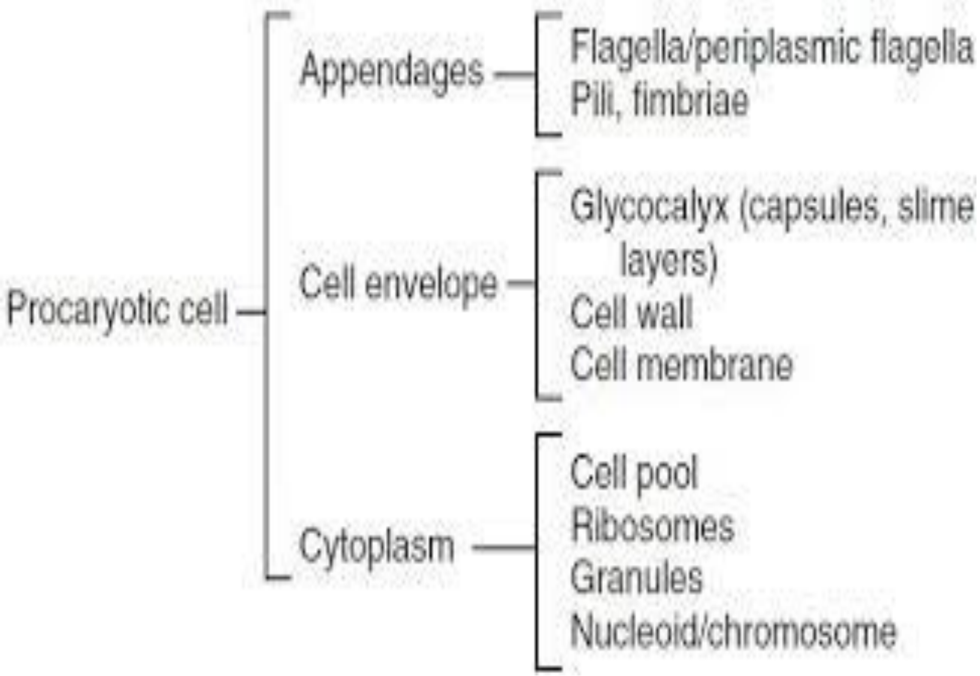


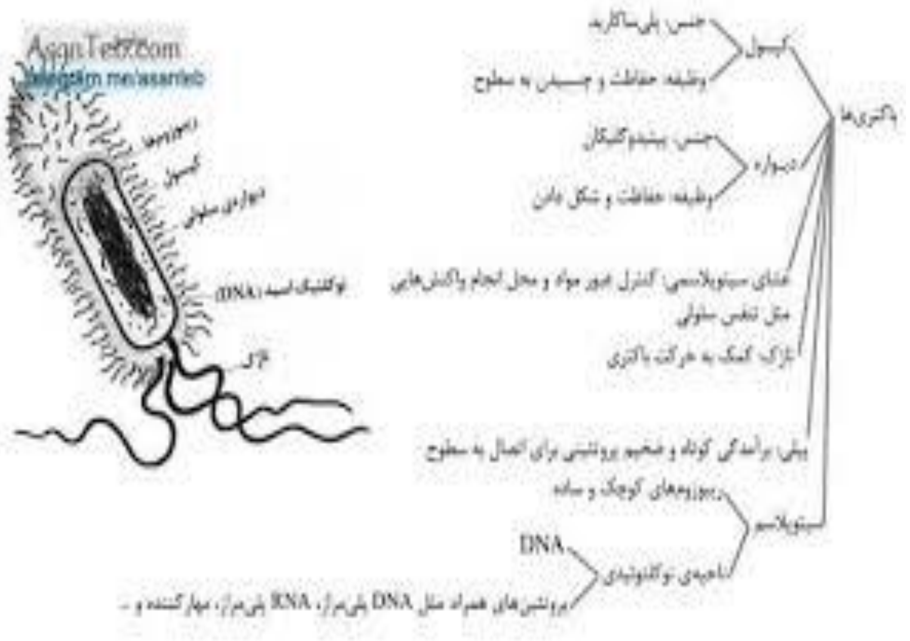
نوکلئیک اسید(DNA)
پیلی
ریبوزوم ها
تاژک
کپسول
دیواره سلولی
غشای پلاسمایی




Prokaryotic Cells
Capsule
Cell Wall
Cell Membrane
Pili
Ribosome
Chromosome
Plasmid


Prokaryotic Cell
Flagella
Cytoplasm
Nucleoid (DNA)
Pili
Capsule
Plasmid
Cell Wall
Ribosome
Cell (Plasma) membrane


Procaryotic cell
Appendages
Flagella/periplasmic flagella
Pili, fimbriae
Cell envelope
Glycocalyx (capsules, slime layers)
Cell wall
Cell membrane
Cytoplasm
Cell pool
Ribosomes
Granules
Nucleoid/chromosome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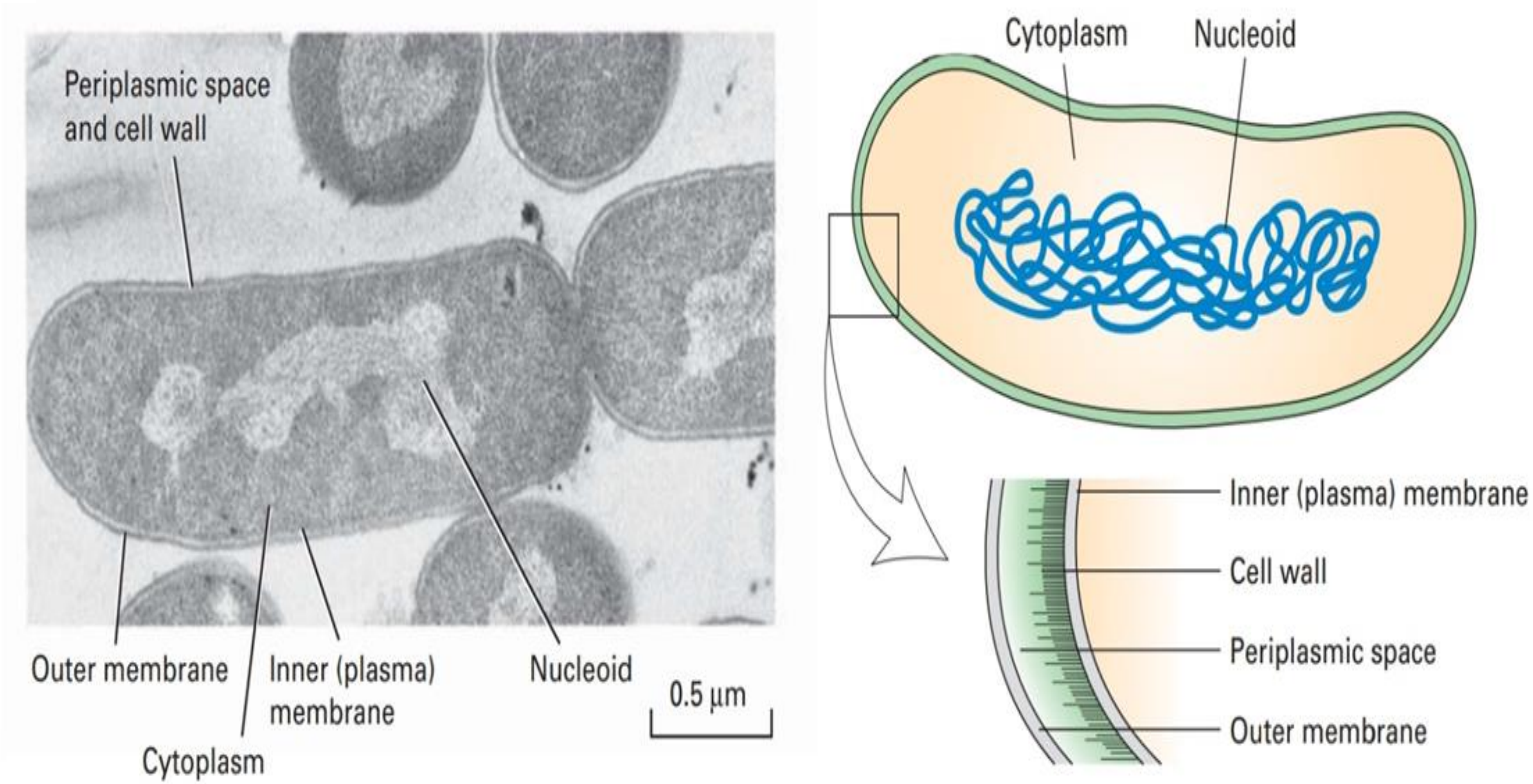
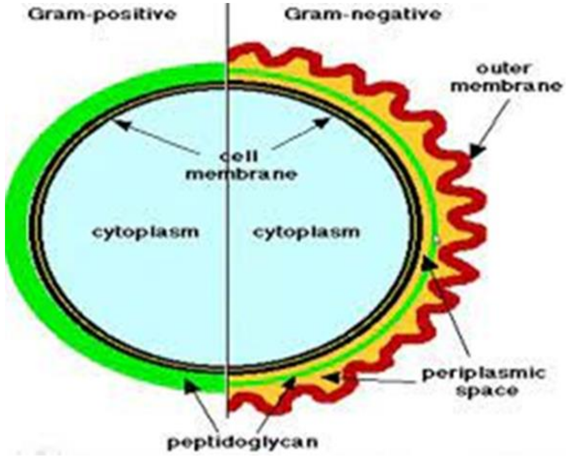
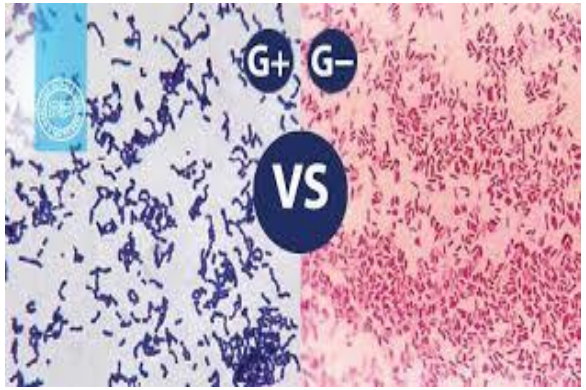
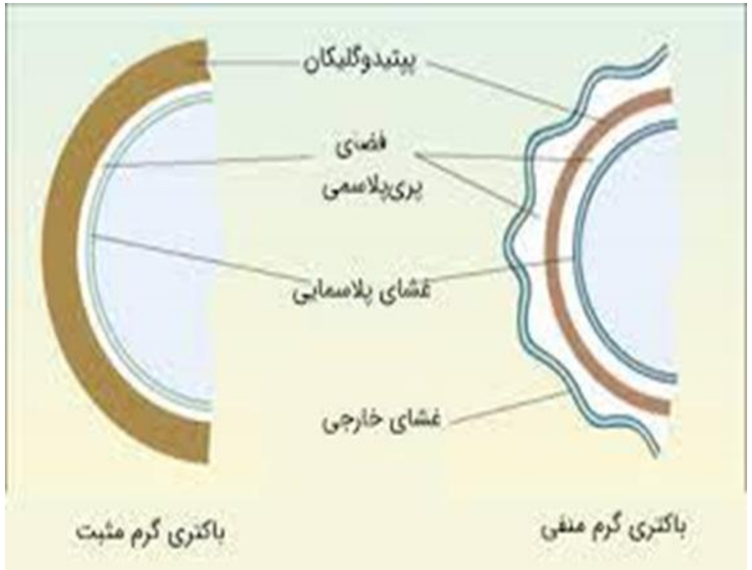
کپسول
جنس: پلی‌ساکارید
وظیفه: حفاظت و چسبیدن به سطوح
دیواره
جنس: پپتیدوگلیکان
وظیفه: حفاظت و شکل دادن
غشای سیتوپلاسمی: کنترل عبور مواد و محل انجام واکنش‌هایی مثل تنفس سلولی
تاژک: کمک به حرکت باکتری
پیلی: برآمدگی کوتاه و ضخیم پروتئینی برای اتصال به سطوح
سیتوپلاسم
ریبوزوم‌های کوچک و ساده
ناحیه‌ی نوکلئوتیدی
DNA
پروتئین‌های همراه مثل DNA پلی‌مراز، RNA پلی‌مراز، مهارکننده و ...


Periplasmic space
and cell wall
Outer membrane
Inner (plasma)
membrane
Nucleoid
0.5 μm
Cytoplasm
Cytoplasm
Nucleoid
Inner (plasma) membrane
Cell wall
Periplasmic space
Outer membrane


Gram-positive
Gram-negative
outer membrane
cell membrane
cytoplasm
cytoplasm
periplasmic space
peptidoglycan


G+
G−
VS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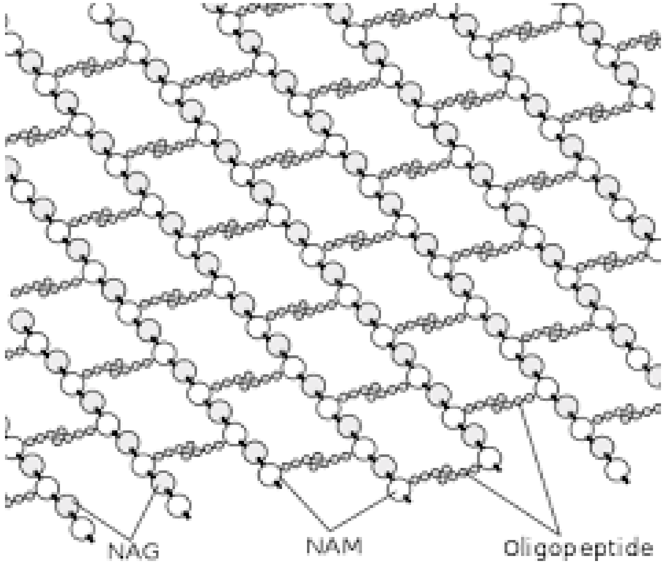
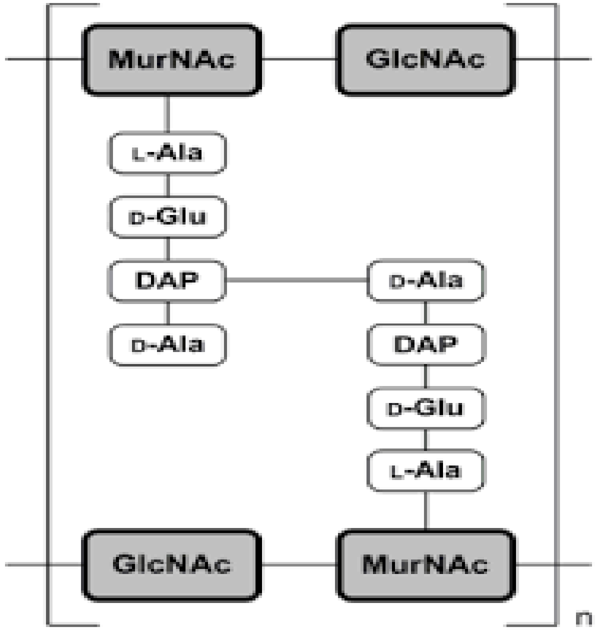
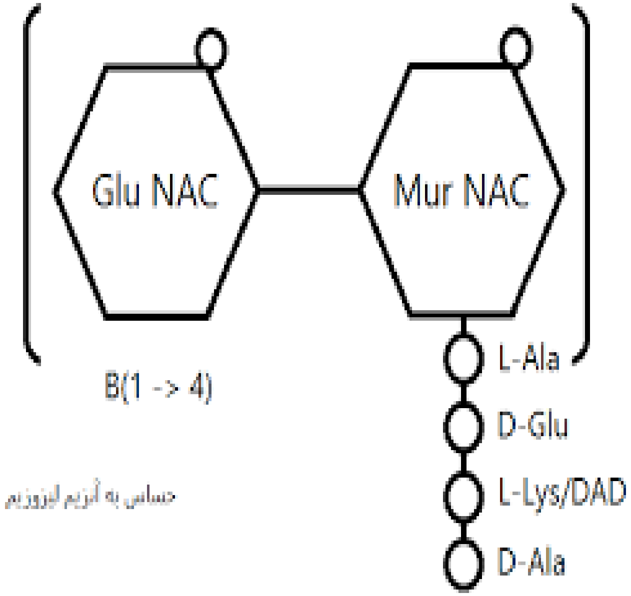
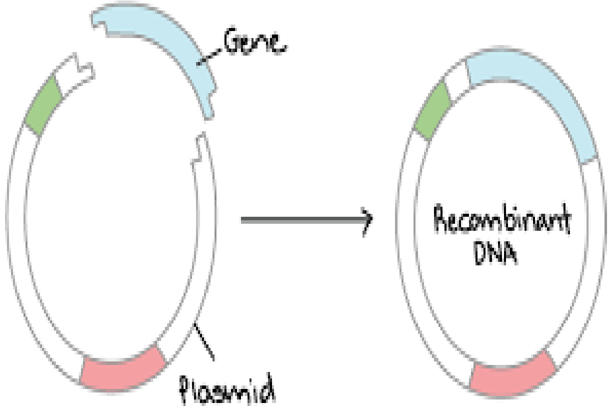
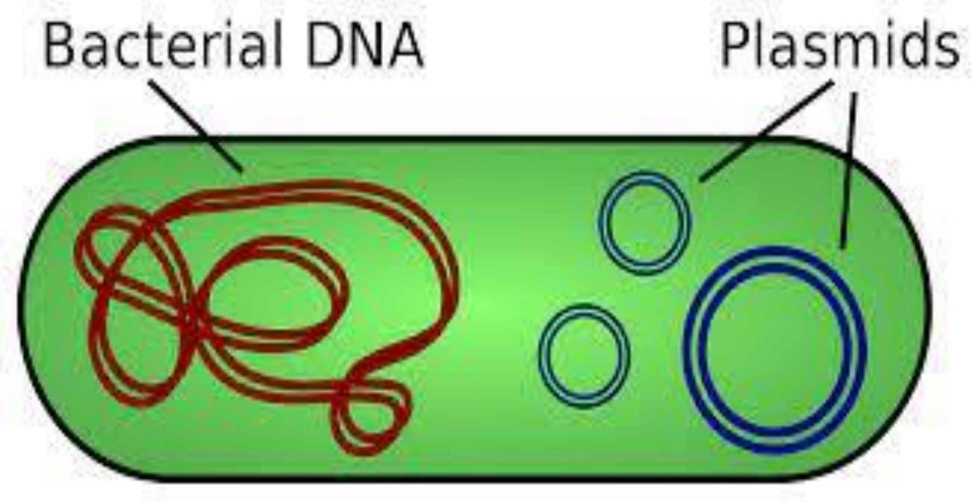
فضای پری‌پلاسمی
غشای پلاسمایی
غشای خارجی
باکتری گرم مثبت
باکتری گرم منفی


NAG
NAM
Oligopeptide


MurNAc
GlcNAc
L-Ala
D-Glu
DAP
D-Ala
D-Ala
DAP
D-Glu
L-Ala
GlcNAc
MurNAc
n

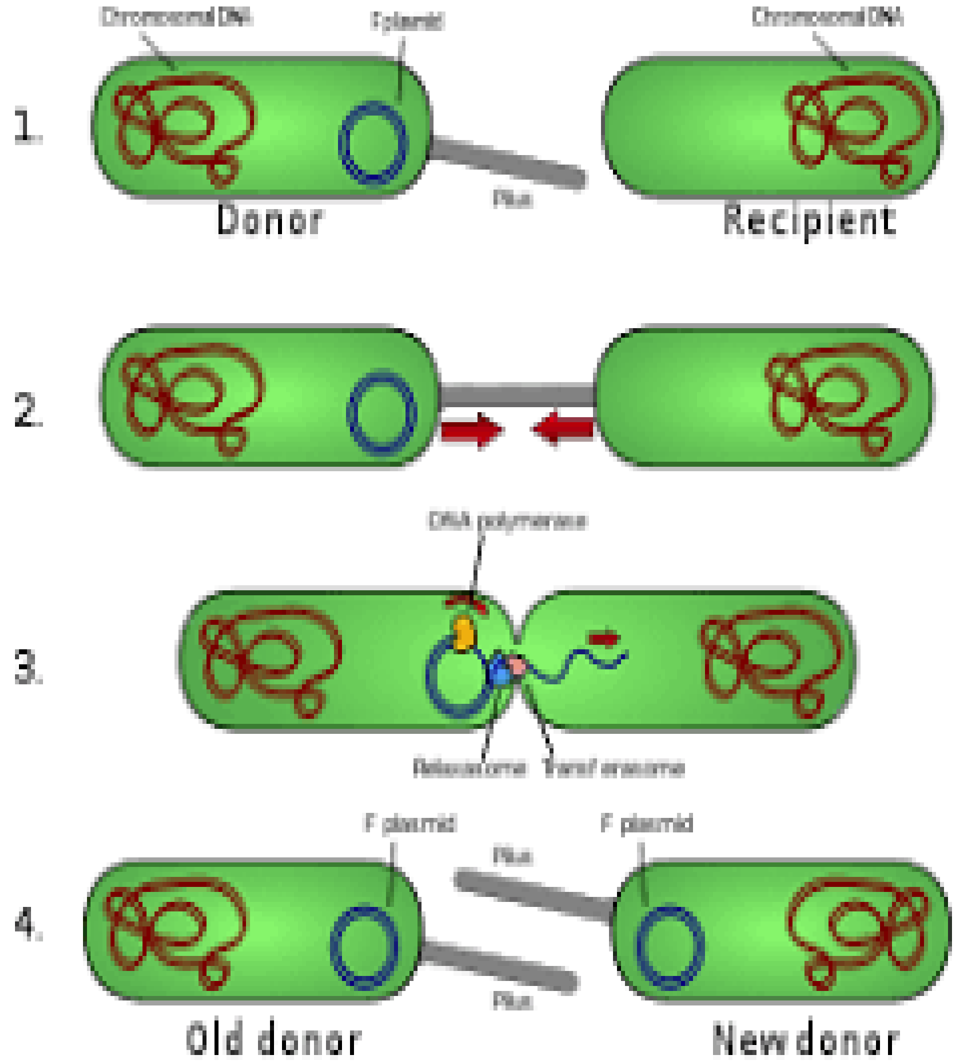

Glu NAC
Mur NAC
B(1 -> 4)
L-Ala
D-Glu
L-Lys/DAD
D-Ala
حساس به آنزیم لیزوزیم


Gene
Plasmid
Recombinant DNA

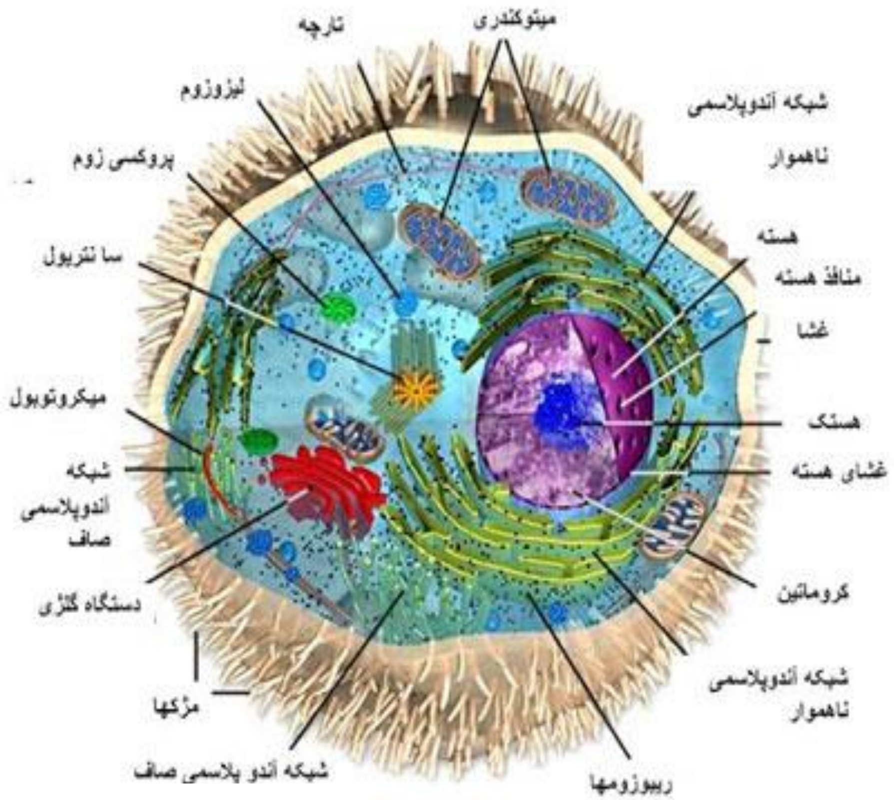

Bacterial DNA
Plasmids


تولید مثل باکتری ها (دو نیم شدن)

Conjugation



یوکاریوت



(b)

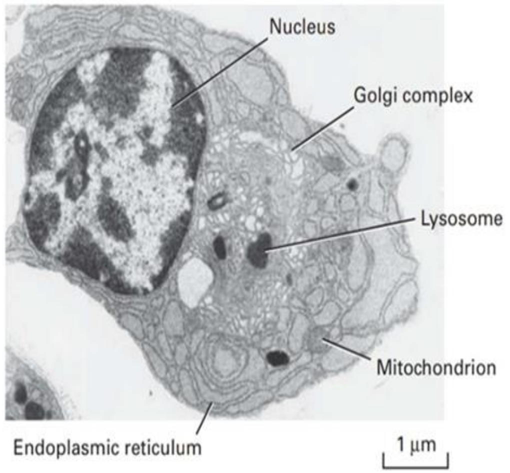
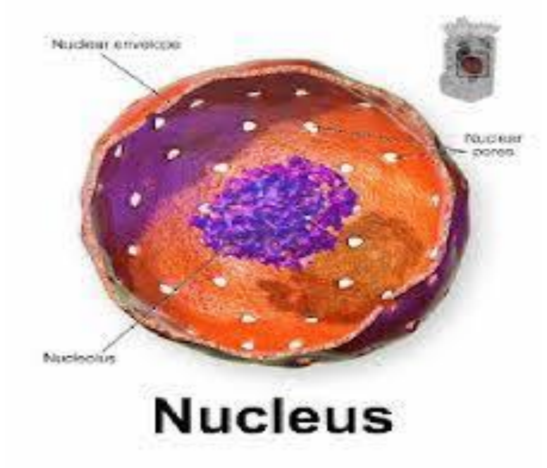


FIGURE 1-12 Subcellular organization of eukaryotic cells. (a) Schematic overview of a "typical" animal cell (*top*) and plant cell (*bottom*) and their major substructures. Not every cell type will contain all the organelles, granules, and fibrous structures shown here, and other substructures can be present in some cell types. Cells also differ considerably in shape and in the prominence of various organelles and substructures. (b) Electron micrograph of a plasma cell, a type of white blood cell that secretes antibodies, showing some of the larger organelles. [Part (b) courtesy of I. D. J. Burdett and R. G. E. Murray.]



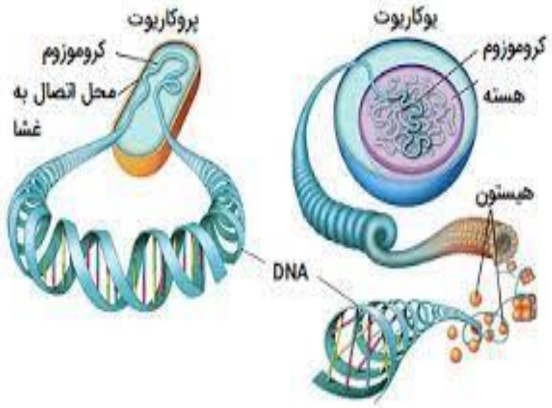
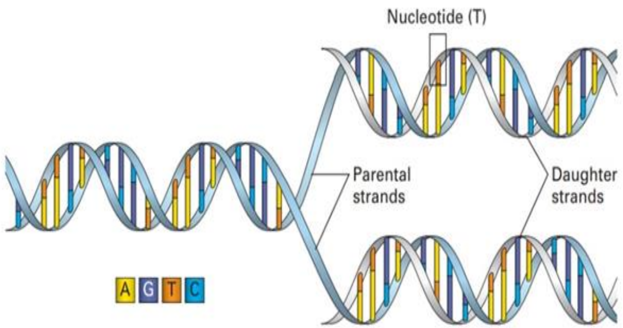
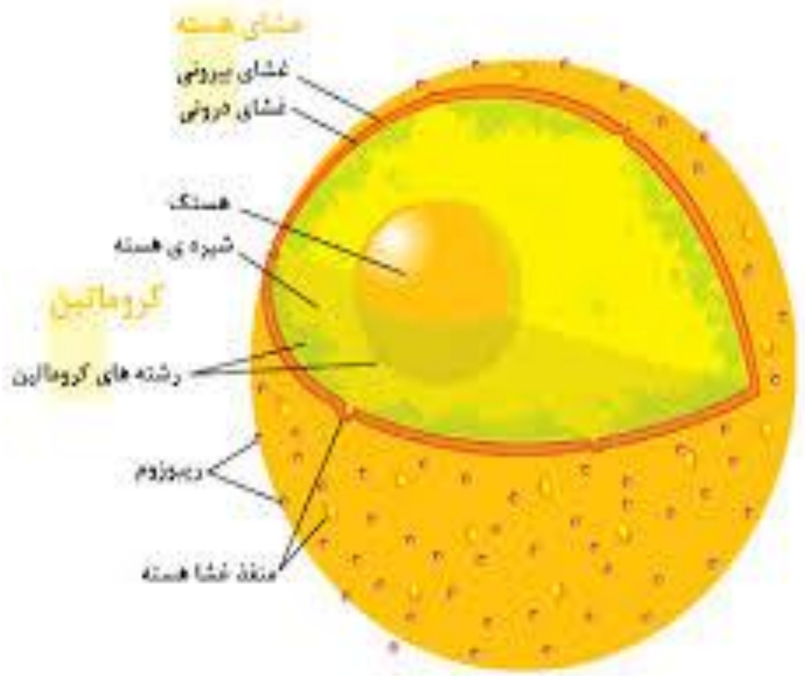


FIGURE 1-8 DNA consists of two complementary strands wound around each other to form a double helix. The double helix is stabilized by weak hydrogen bonds between the A and T bases and between the C and G bases. During replication, the two strands are unwound and used as templates to produce complementary strands. The outcome is two identical copies of the original double helix, each containing one of the original strands and one new daughter (complementary) strand.





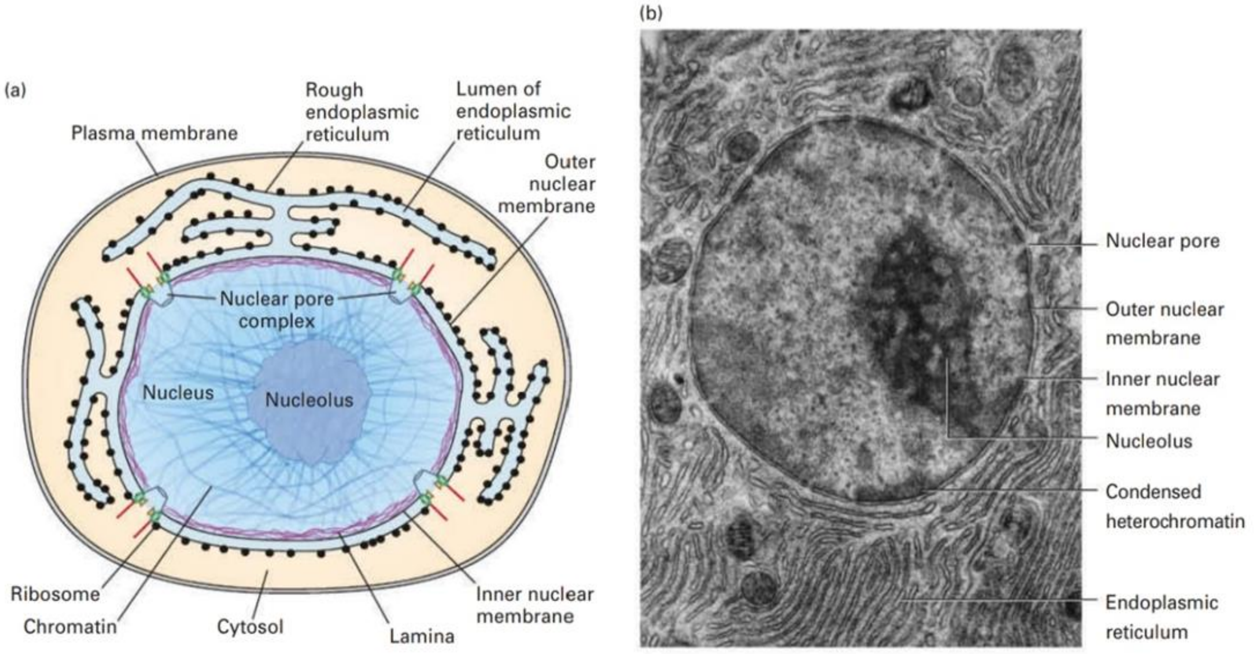


FIGURE 1-15 Structure of the nucleus. (a) Schematic diagram

proteins. (b) Electron micrograph of a pancreatic acinar cell from the bat

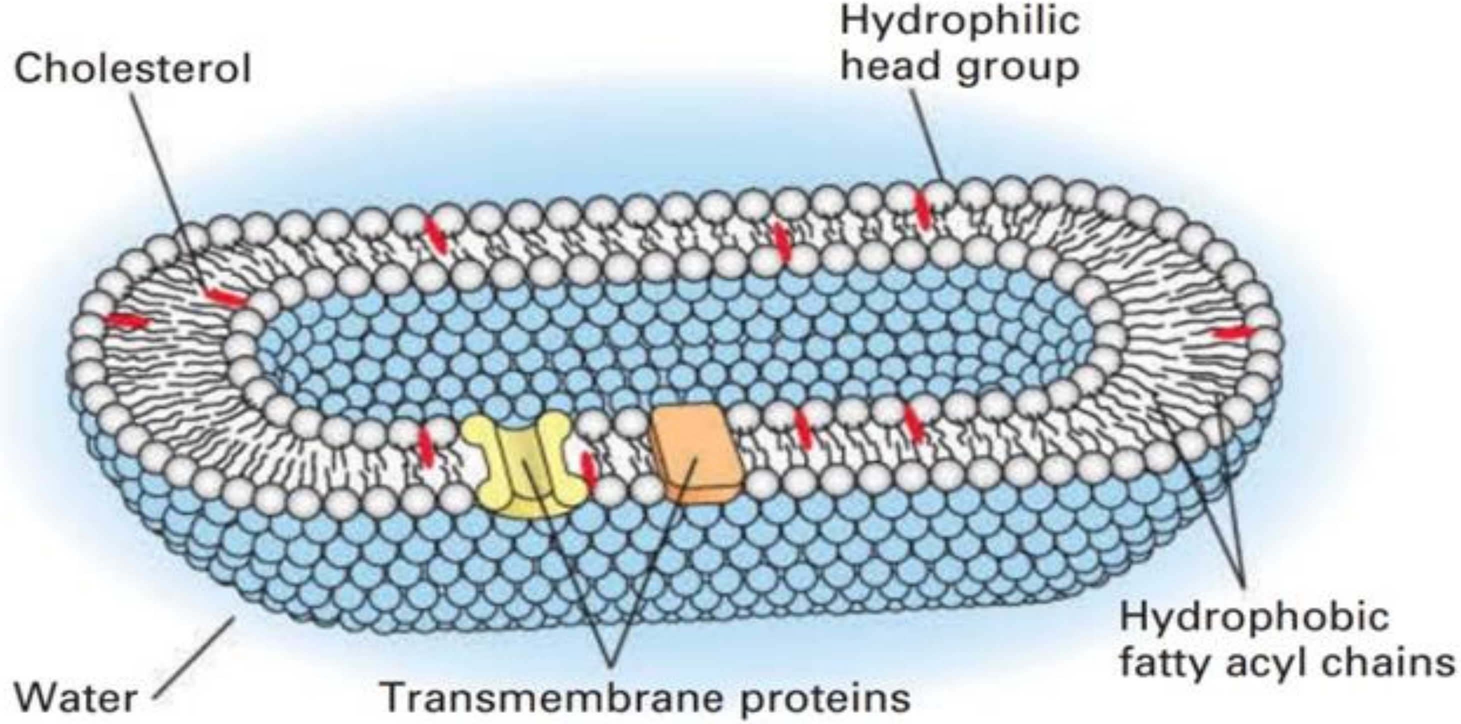
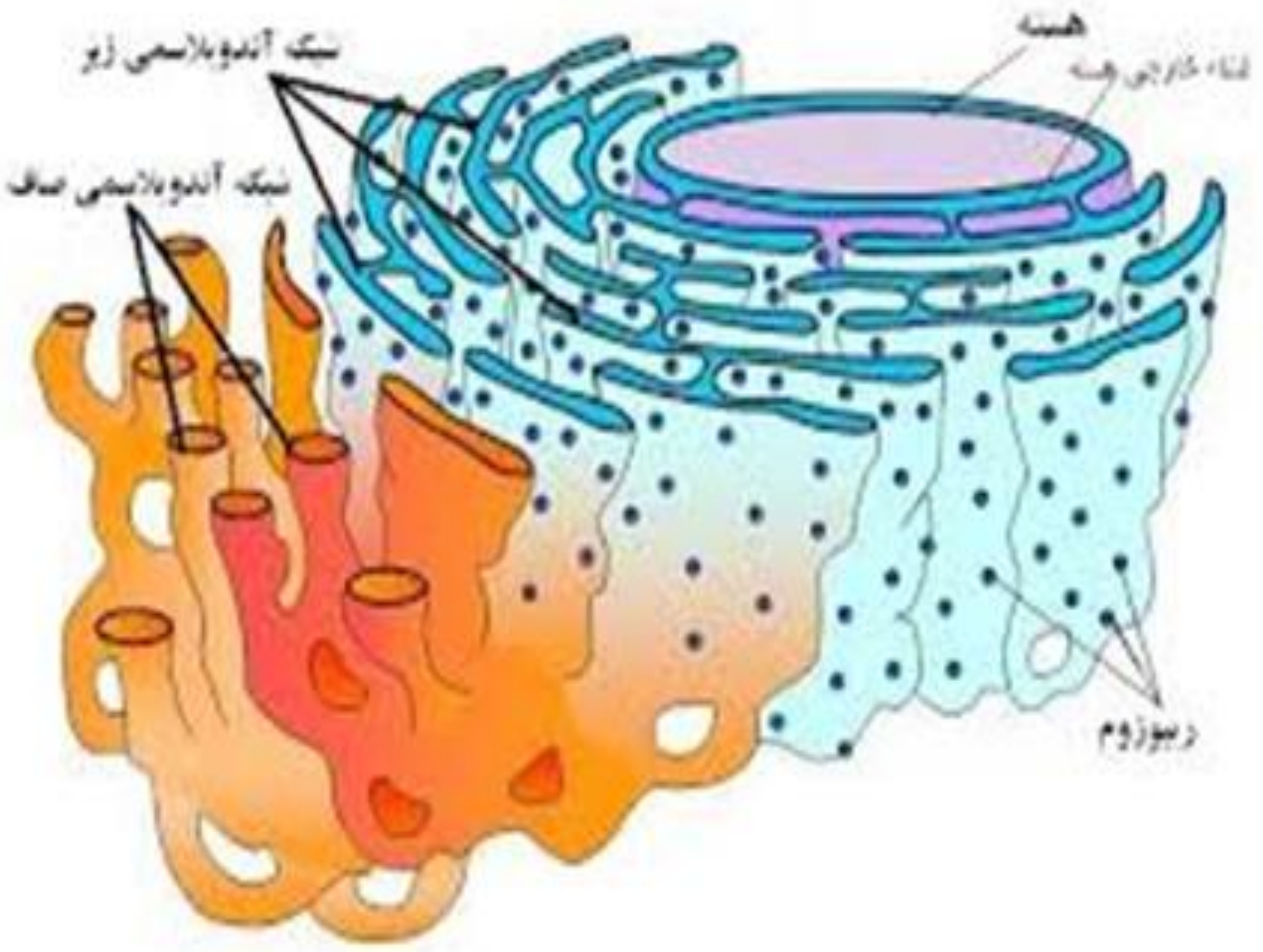


FIGURE 1-10 The watery interior of cells is surrounded by the plasma membrane, a two-layered shell of phospholipids. The


شبکه آندوپلاسمی زبر
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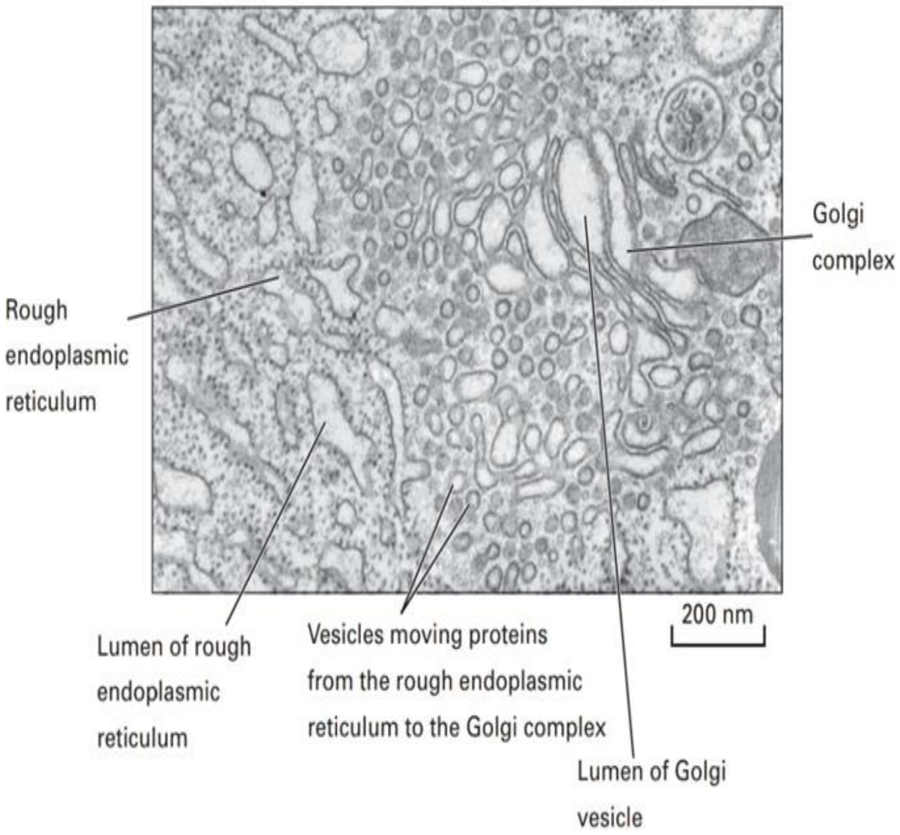
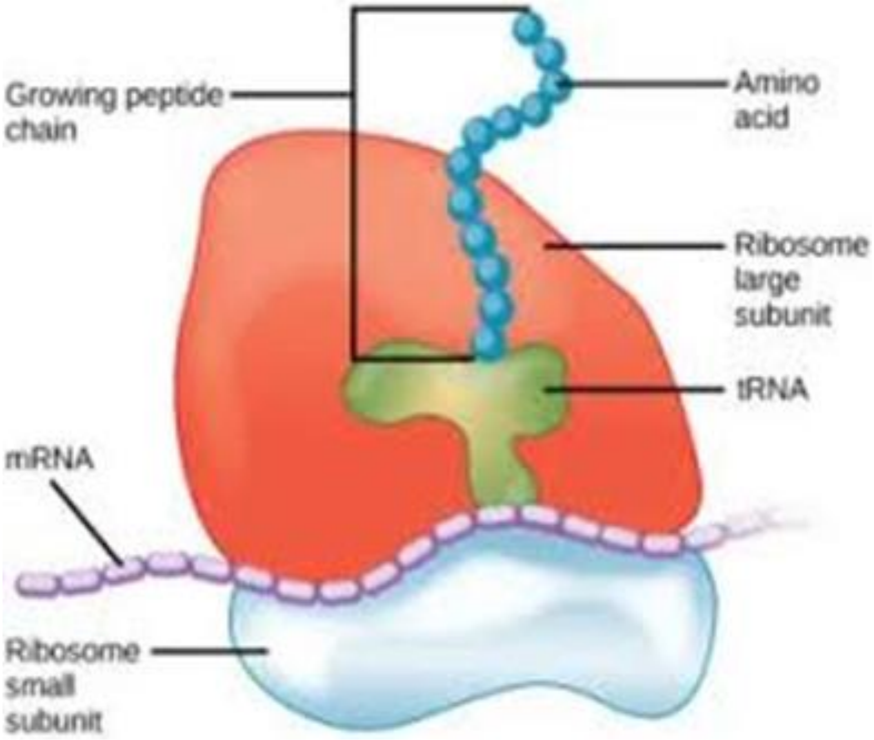
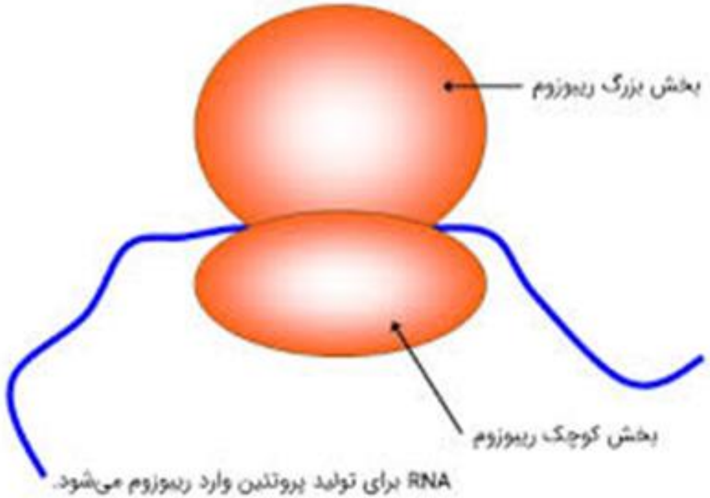


FIGURE 1-17 The Golgi complex and rough endoplasmic reticulum. An electron micrograph of a section of a human liver cell shows the abundant ribosome-studded rough endoplasmic reticulum and the Golgi complex, as well as many ribosomes free in the cytosol. [Courtesy George E. Palade EM Slide Collection, University of California, San Diego.]


Growing peptide chain
Amino acid
Ribosome large subunit
tRNA
mRNA
Ribosome small subunit


بخش بزرگ ریبوزوم
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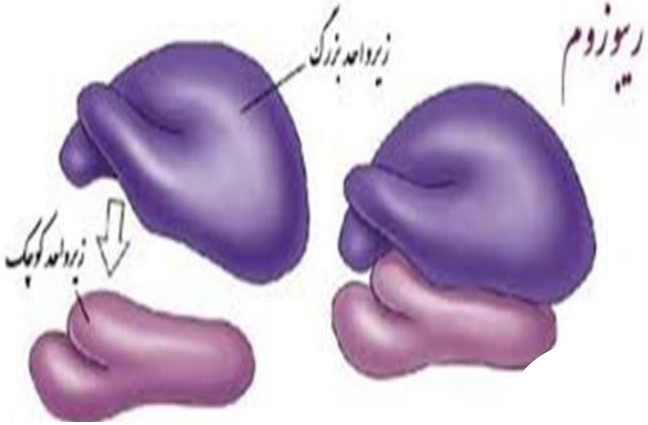
RNA برای تولید پروتئین وارد ریبوزوم می‌شود.


ریبوزوم
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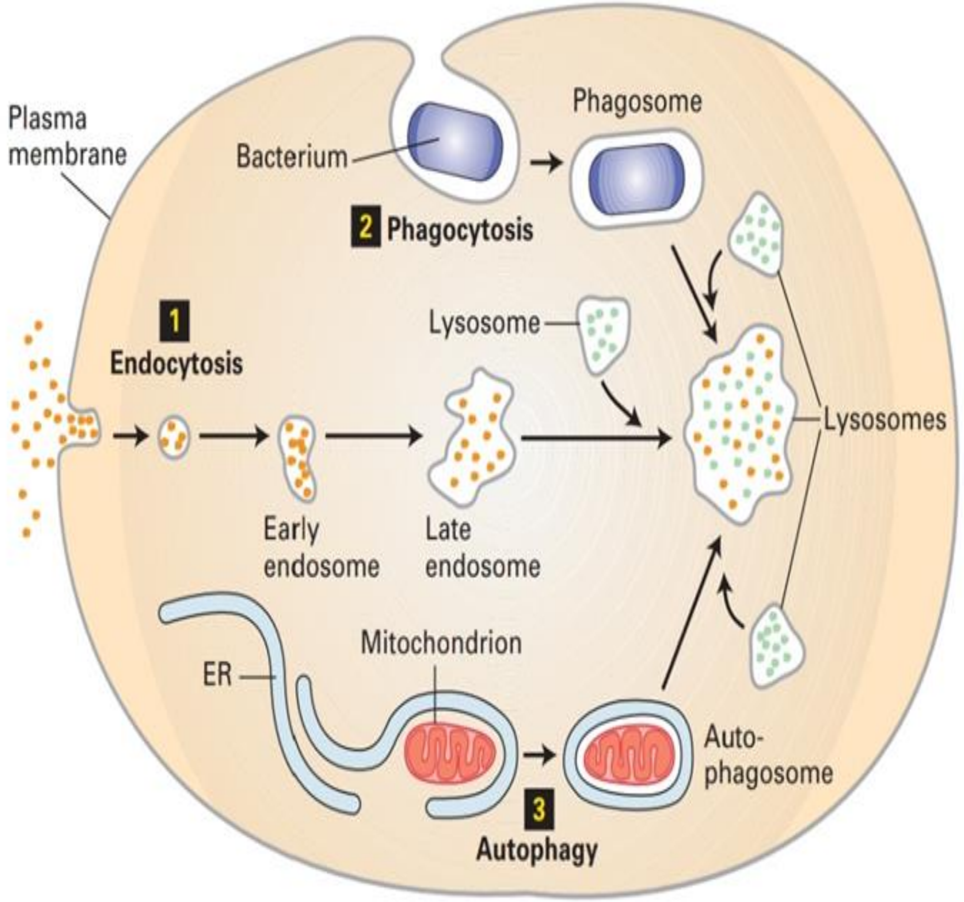
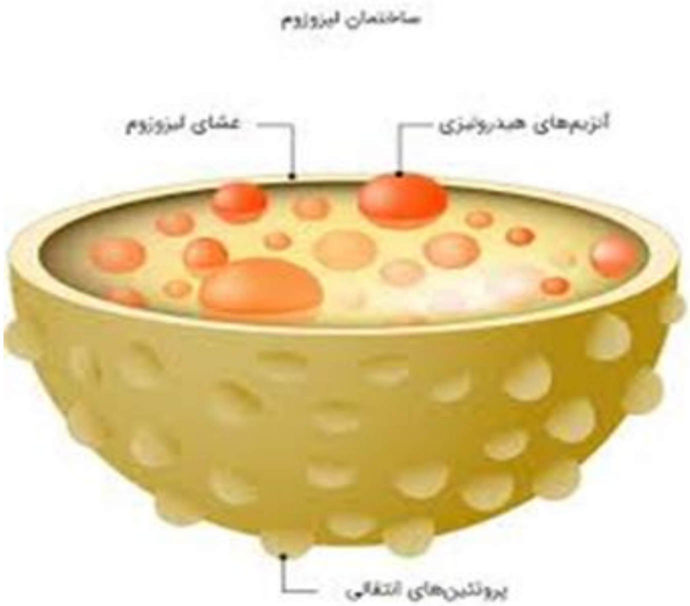
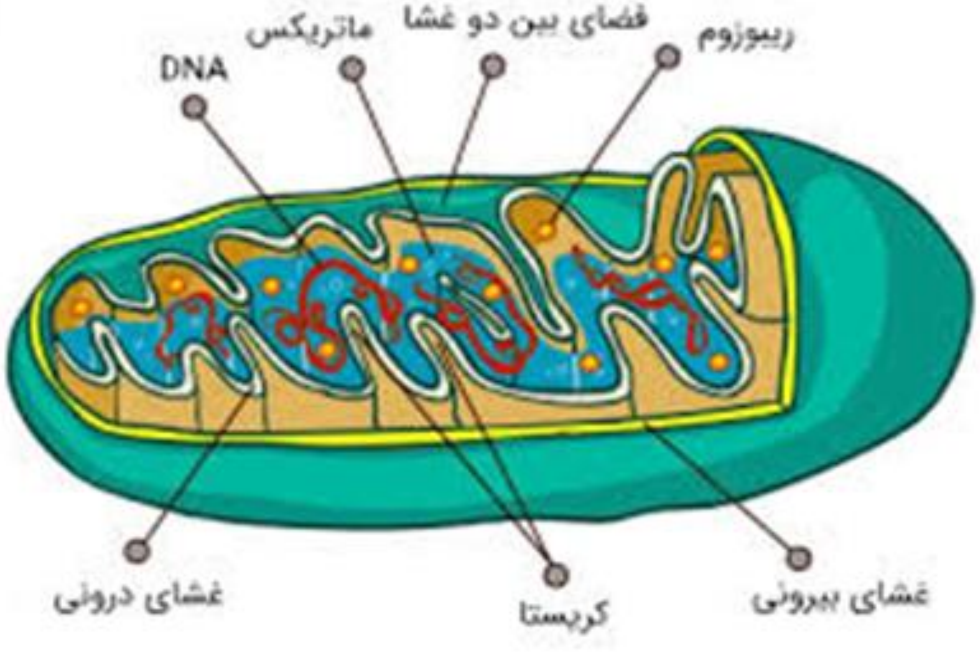
زیرواحد کوچک

FIGURE 1-18 Endosomes and other cellular structures deliver materials to lysosomes. Schematic overview of three pathways by which materials are moved to lysosomes. Soluble macromolecules and molecules bound to proteins on the cell surface are taken into the cell by invagination of segments of the plasma membrane and delivered to lysosomes through the endocytic pathway **1**. Whole cells and other large, insoluble particles move from the cell surface to lysosomes through the phagocytic pathway **2**. Worn-out organelles and bulk cytoplasm are delivered to lysosomes through the autophagic pathway **3**. Within the acidic lumen of a lysosome, hydrolytic enzymes degrade proteins, nucleic acids, lipids, and other large molecules.







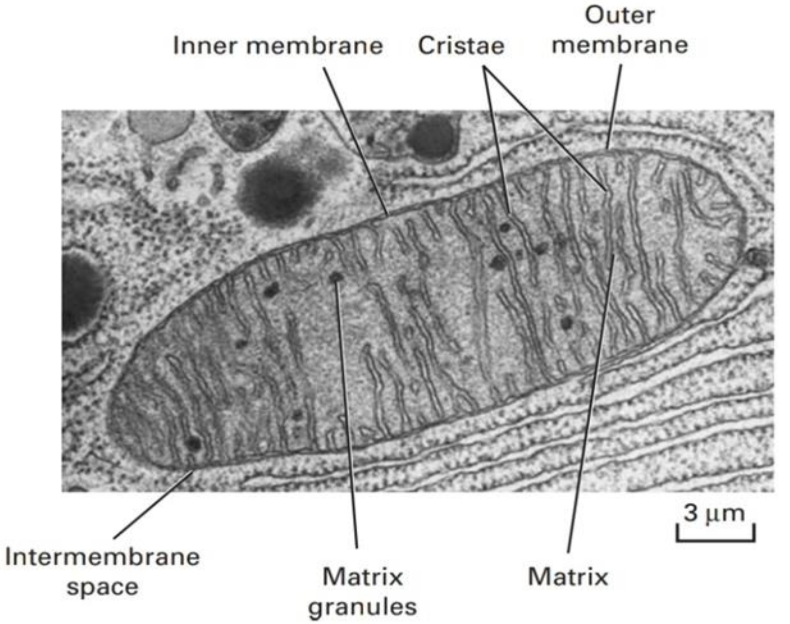


FIGURE 1-20 Electron micrograph of a mitochondrion in a pancreas cell. The smooth outer membrane forms the outside boundary of the mitochondrion. The inner membrane is distinct from the outer membrane and is highly invaginated to form sheets and tubes called cristae; ATP is produced by proteins embedded in the membranes of the cristae. The aqueous space between the inner and outer membranes (the intermembrane space) and the space inside the inner

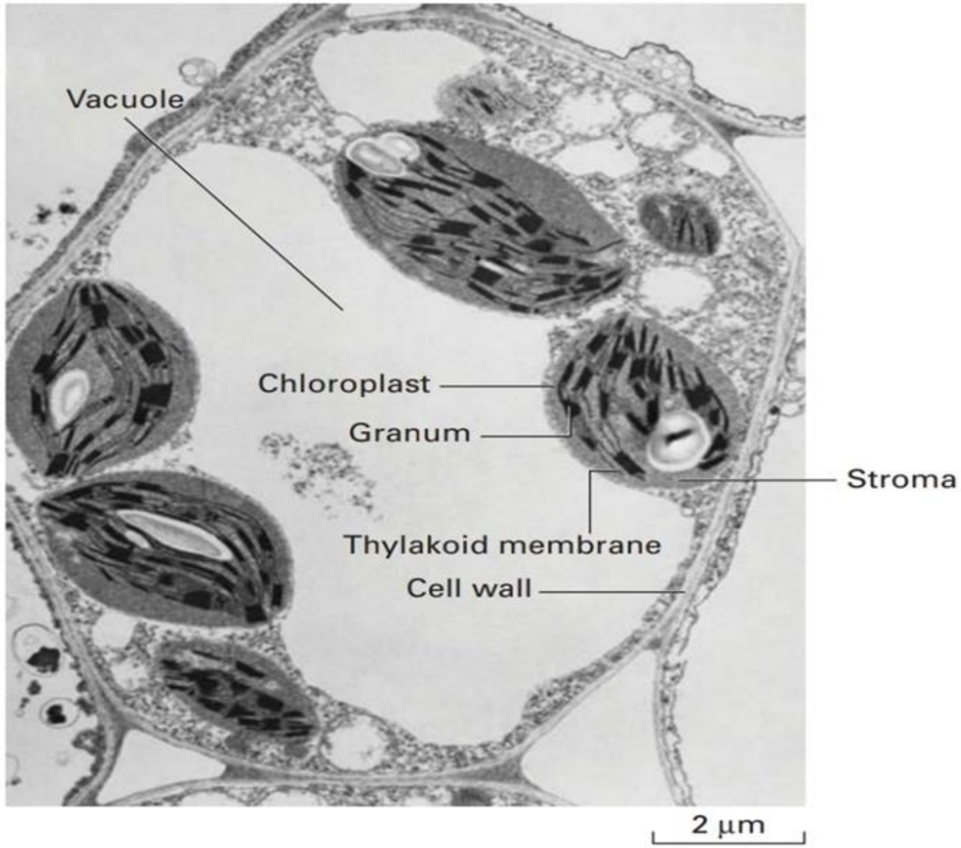
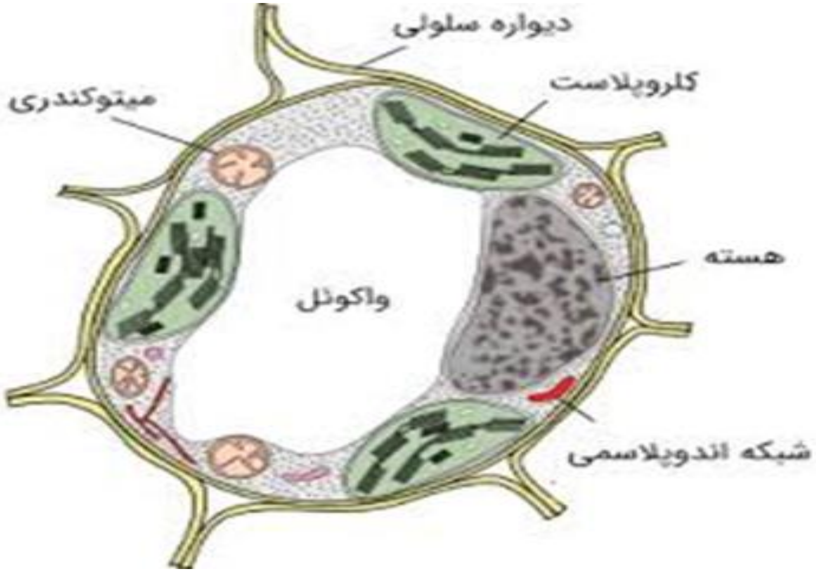
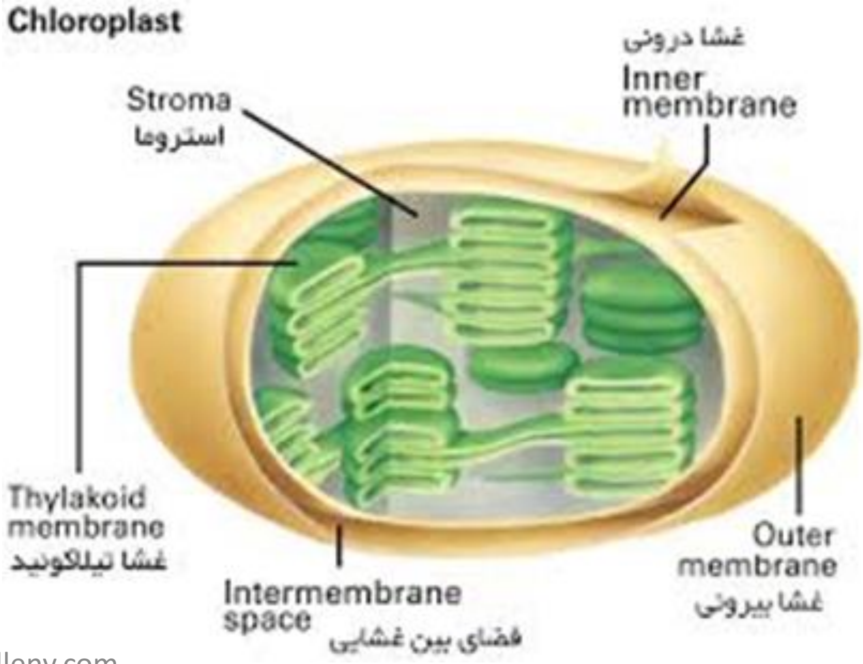
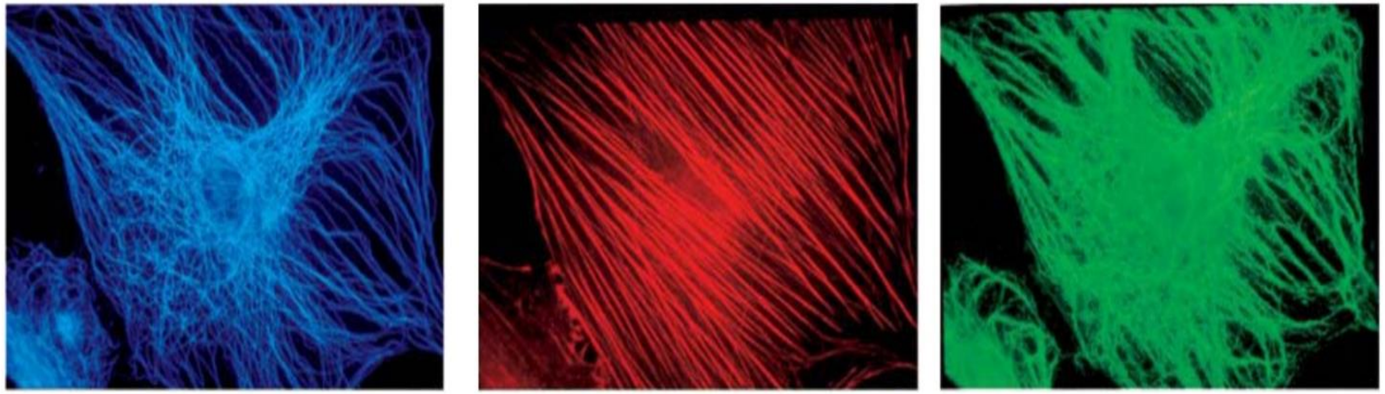


FIGURE 1-19 Electron micrograph of a thin section of a leaf cell.





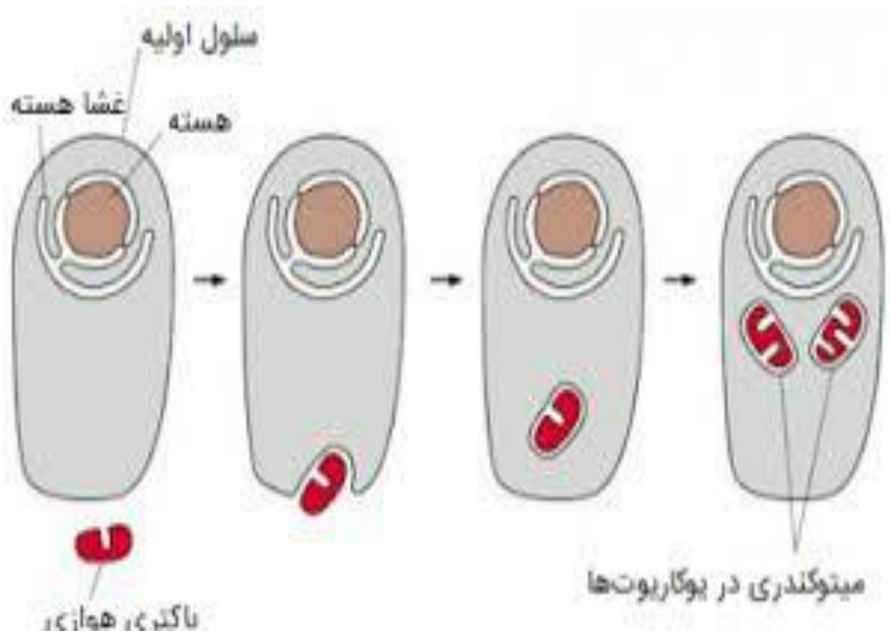


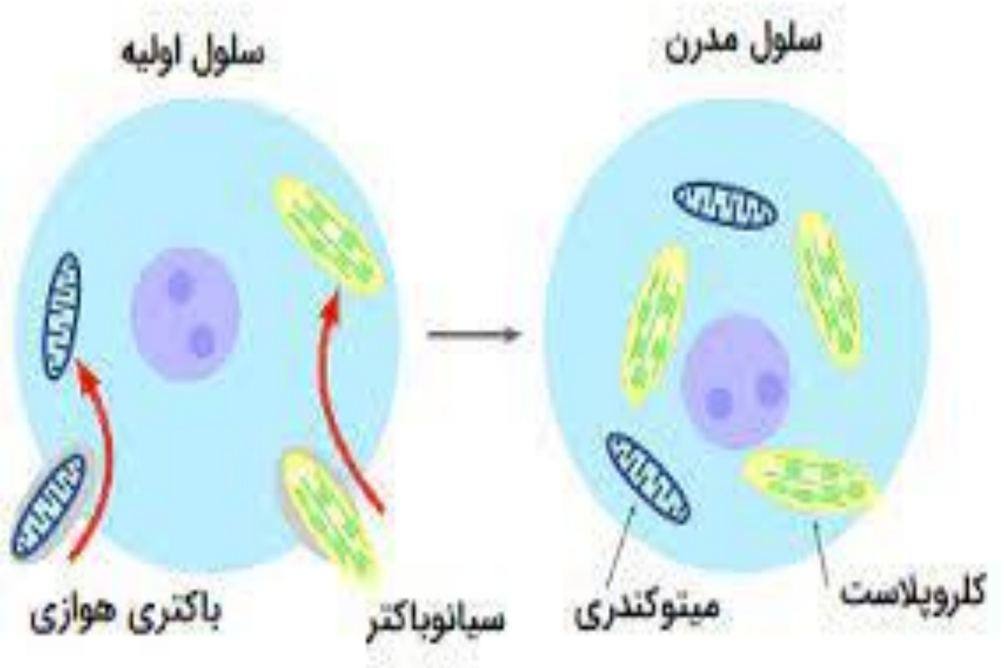
Microtubules | Microfilaments | Intermediate filaments

FIGURE 1-13 The three types of cytoskeletal filaments have characteristic distributions within mammalian cells. Three views of the same cell. A cultured fibroblast was permeabilized and then treated with three different antibody preparations. Each antibody binds specifically to the protein monomers forming one type of filament and is chemically linked to a differently colored fluorescent dye (green, blue, or red). Visualization of the stained cell in a fluorescence microscope reveals the locations of filaments bound to a particular dye-antibody preparation. In this case, microtubules are stained blue; microfilaments, red; and intermediate filaments, green. All three fiber systems contribute to the shape and movements of cells. [Courtesy of V. Small.]

ساختار سانتریول

Endosymbiosis Theory





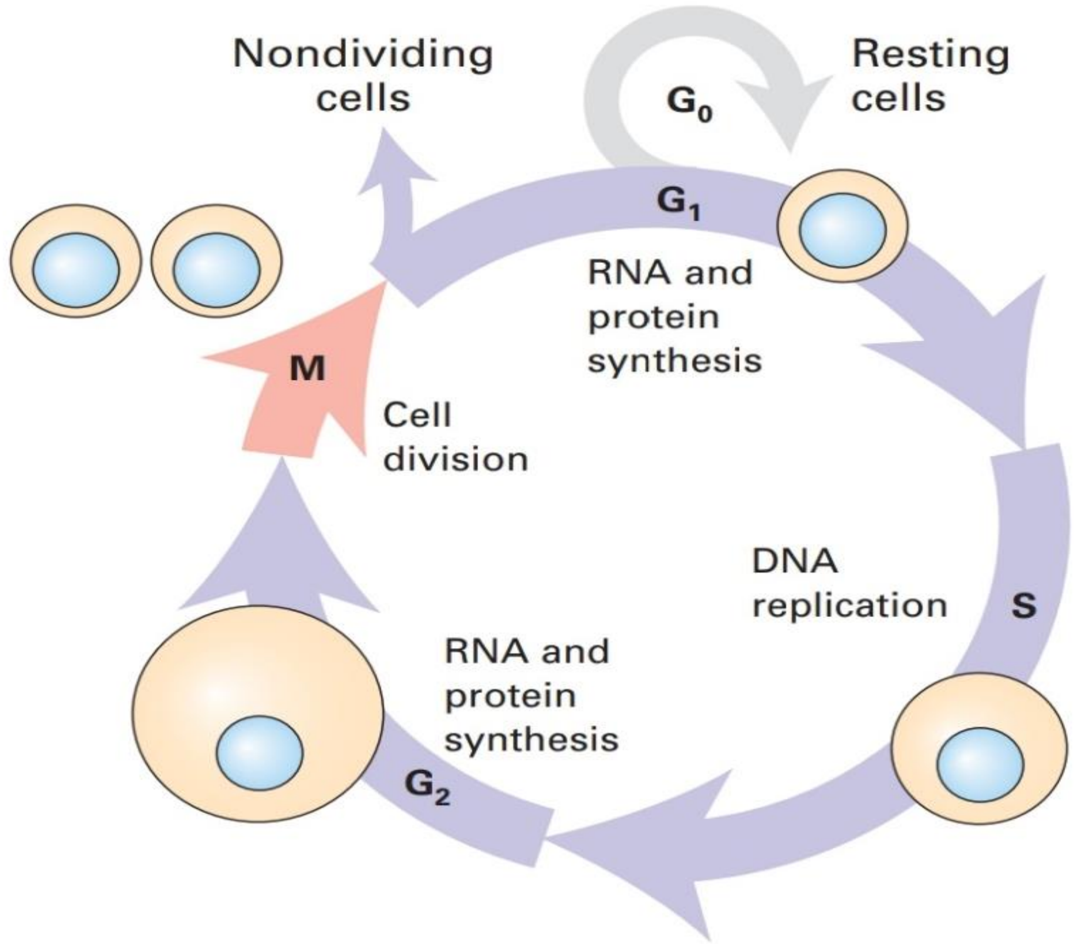


FIGURE 1-21 During growth, all eukaryotic cells continually progress through the four phases of the cell cycle. In proliferating

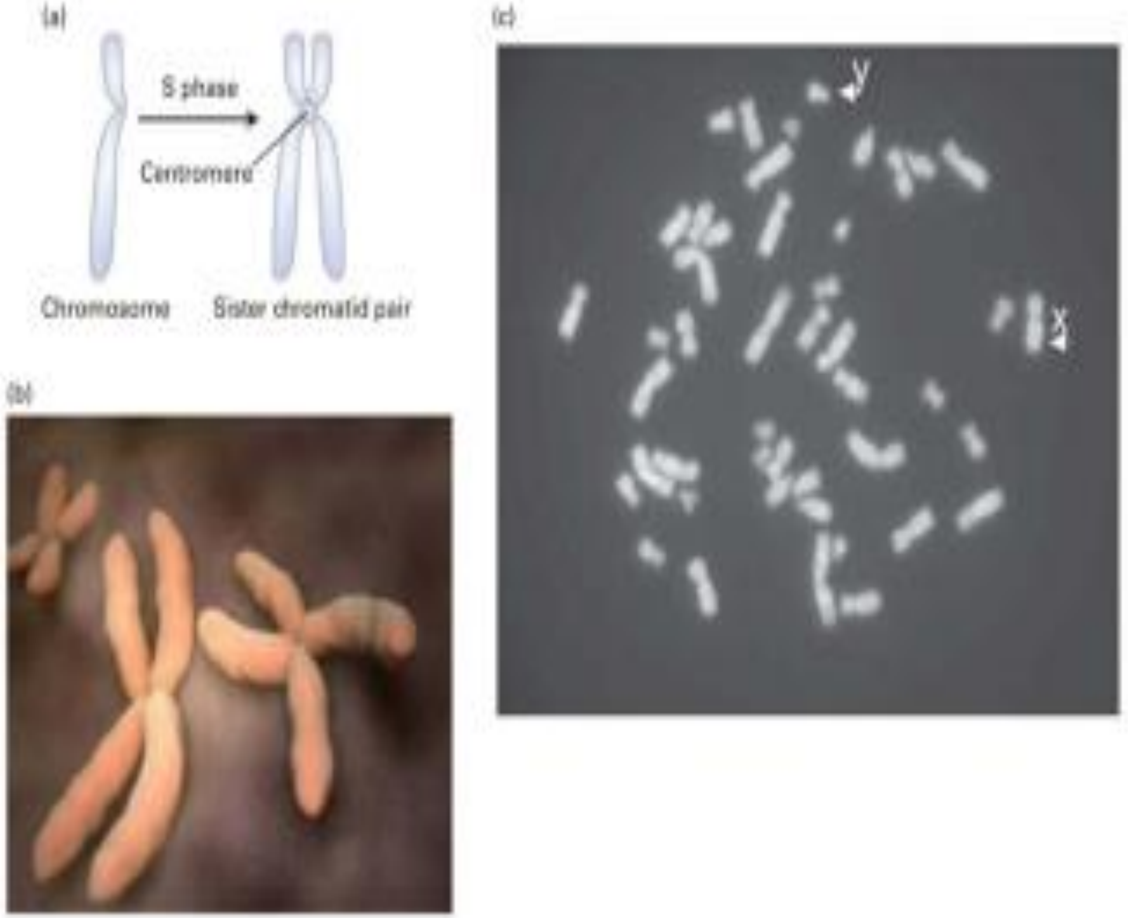


FIGURE 1-16 Individual chromosomes can be seen in cells during cell division (mitosis). (a) During the S phase of the cell cycle (see Figure 1-21) chromosomes are duplicated, and the daughter "sister chromatids," each with a complete copy of the chromosomal DNA, remain attached at the centromere. (b) During the actual cell division process (mitosis), the chromosomal DNA becomes highly compacted, scope, as depicted here. (c) Light-microscope image of a chromosomal spread from a cultured human male lymphoid cell arrested in the metaphase stage of mitosis by treatment with the microtubule-depolymerizing drug colcemid. There is a single copy of the duplicated X and Y chromosomes and two copies of each of the others. [Part (b) Medical RF/The Medical File/Peter Arnold Inc. Part (c) courtesy of Tatyana Pyntikova.]

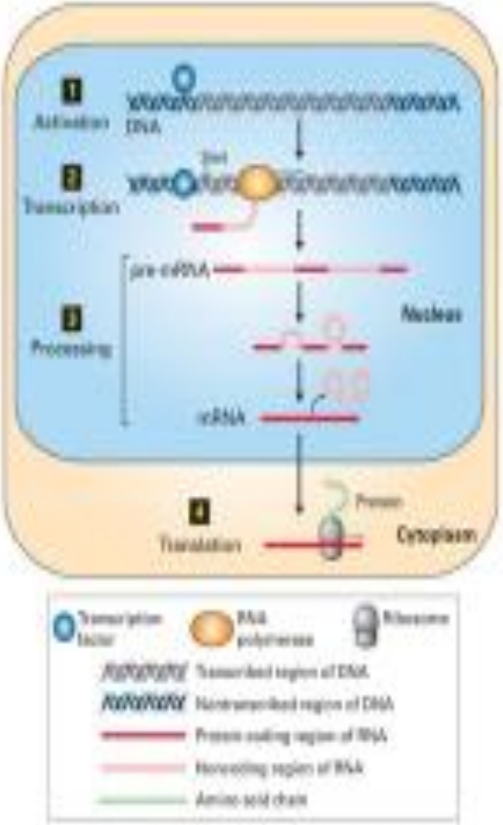


FIGURE 1-9 The information encoded in DNA is converted into the amino acid sequences of proteins by a multistep process.