Universidad de Chile

Programa Académico de Bachillerato

Introducción a la Biología Celular

2011

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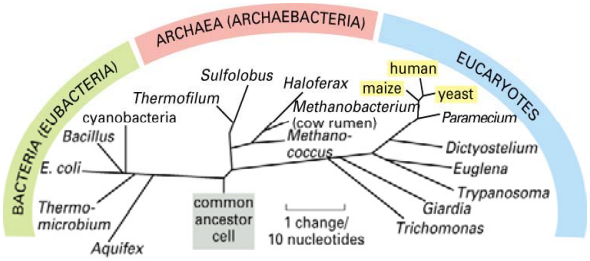
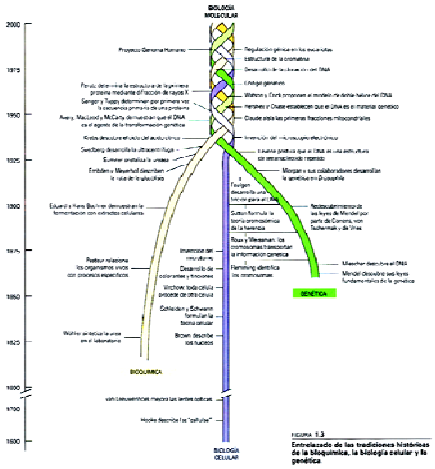
Diversidad de organismos vivos





The microscope used by Robert Hooke (left). and a drawing by Robert Hooke (right), which represents one of the first microscopic descriptions of microorganisms, a blue mold growing on the surface of leather. The round structures contain spores of the mold.

A Timeline of Cell Biology

1600s

1609
Hans Lippershey and Zacharias Janssen independently invent the compound microscope, which later enables scientists to visualize cells.

1665
Robert Hooke publishes Micrographia, in which he describes cells for the first time based on his observations of cork sections.

1675
Marcello Malpighi publishes Anatome Plantarum, the first important work on plant anatomy based on microscopic observation.

1676
Using a simple microscope and pond scum, **Anton van Leeuwenhoek** observes tiny organisms, or what he calls animalcules.

1682
Nehemiah Grew publishes The Anatomy of Plants, in which he shows that plant tissues are composed mostly of small chambers or cells.

Late 17th century
Leeuwenhoek, Malpighi, and Jan Swammerdam describe corpuscles in blood.

A Timeline of Cell Biology

1700s

1766
In a letter, **Abraham Trembley** writes what is probably the first description of binary fission of a cell.

1800s

1805
Lorenz Oken argues that plants and animals are assemblages of "infusoria"-- microbes such as protozoa that scientists had been observing in extracts, or infusions, of plant and animal tissues.

1812
Jöns Berzelius coins the term "catalysis" to describe reactions in which certain substances participate yet are not consumed.

1828
Friedrich Wöhler synthesizes urea in test tubes, thereby disproving the notion that a vital principle is required for the creation of the molecules of living things.

1830s
Jan Purkinje and Gabriel Valentin note that animal tissues, like those of plants, are composed of cells.

A Timeline of Cell Biology

1831
Robert Brown identifies the small body found within plant cells as the "nucleus."

1835
Charles Cagniard-Latour shows that fermentation reactions are associated with living organisms.

1838-39
Theodor Schwann and Matthias Schleiden consolidate many observations to develop what becomes known as the cell theory of biology.

1856
Louis Pasteur reports that fermentation is caused by microorganisms.

1858
Rudolf Virchow publishes Cellularpathologie, in which he states "Omnis cellula e cellula"; that is, all cells come from cells.

1859
Charles Darwin publishes his watershed book on evolution by natural selection, known usually as The Origin of Species.

Early 1860s
Gregor Mendel discovers the laws of heredity.

A Timeline of Cell Biology

1861
Rudolf Kölliker and others begin interpreting embryology in terms of cell theory.

1882
Walther Flemming and Eduard Strasburger describe elongated chromosomal threads forming from the nucleus during the onset of mitosis.

1892
August Weismann proposes that chromosomes are at the heart of heredity.

1897
Eduard and Hans Buchner show that a yeast extract containing a catalytic substance, zymase, promotes fermentation reactions. This evolves into a cornerstone of biochemistry, namely, that protein catalysts, or enzymes, promote life's chemistry.

A Timeline of Cell Biology

1960s
Jacque Monod and François Jacob describe feedback control.

1970
Peter Duesberg and Peter Vogt discover the first oncogene, dubbed src, in a virus. The gene subsequently is implicated in many human cancers.

1971
Albert Knudson discovers the first tumor-suppressor gene.

1971
Yoshio Masui identifies MPF (maturation promoting factor), which advances frog oocytes into M-phase.

1972
Andrew Wyllie and colleagues coin the term apoptosis for the built-in program of cell death, which subsequently is found to be important in development and disease.

1970s
J. Michael Bishop and Harold Varmus link cellular oncogenes with cancer.

1970s
Arnold Levine, Lionel Crawford, and David Lane discover p53, the gene most commonly mutated in human cancer.

A Timeline of Cell Biology

1970s and 80s
Lee Hartwell develops yeast cell cycle mutants and the checkpoint concept; **Paul Nurse** defines cell cycle rate-limiting steps and discovers the cyclin-dependent kinase cdc2 in fission yeast and humans.

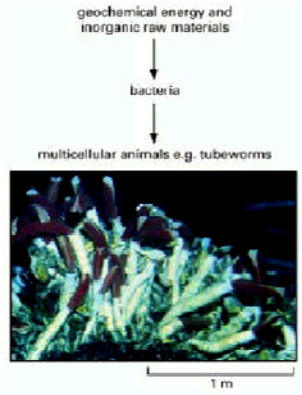
1983
Tim Hunt discovers cyclins.

1984
Marc Kirschner and Tom Mitchison describe the dynamic instability of microtubules.

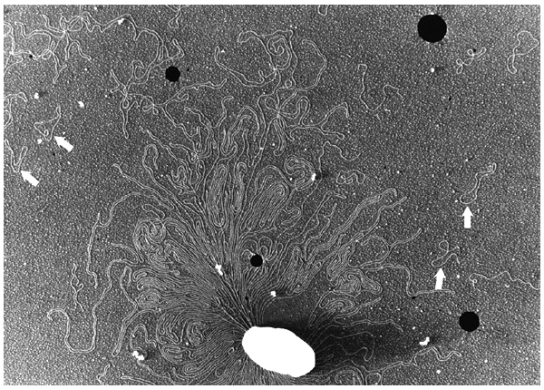
1986
Bob Horvitz proposes programmed cell death during development of the nematode worm.

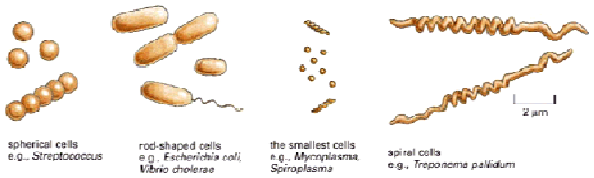
1991
Andrew Hoyt and Andrew Murray discover spindle checkpoints.

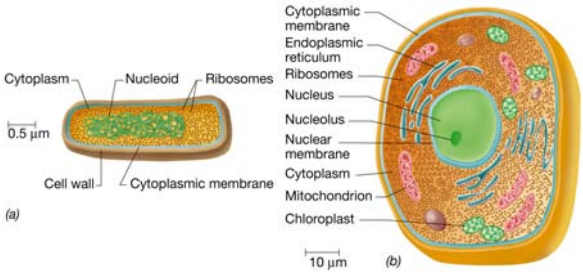
1990s
Mechanisms of initiation of eukaryotic DNA replication begin to be elucidated.



Living organisms at a hot hydrothermal vent. Close to the vent, at temperatures up to about 150°C, various lithotrophic species of bacteria and archaea (archaebacteria) live, directly fuelled by geochemical energy. A little further away, where the temperature is lower, various invertebrate animals live by feeding on these microorganisms. Most remarkable are the giant (2-meter) tube worms, which, rather than feed on the lithotrophic cells, live in symbiosis with them: specialized organs in the worms harbor huge numbers of symbiotic sulfur-oxidizing bacteria. These bacteria harness geochemical energy and supply nourishment to their hosts, which have no mouth, gut, or anus. The dependence of the tube worms on the bacteria for the harnessing of geothermal energy is analogous to the dependence of plants on chloroplasts for the harnessing of solar energy. The tube worms, however, are thought to have evolved from more conventional animals, and to have become secondarily adapted to life at hydrothermal vents







Why eukaryotic are so complex?

Which may be turned out to

Why prokaryotic are so simple?

"Eukaryotic" traits found in prokaryotes

Lane and Martin 2010 *Nature* **467**:929-934

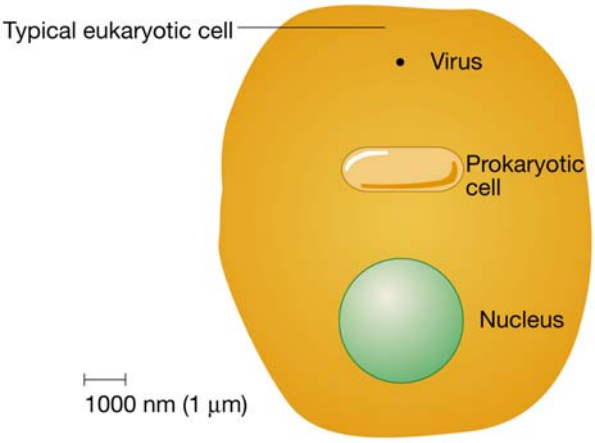
Energy budget in a bacterial cell

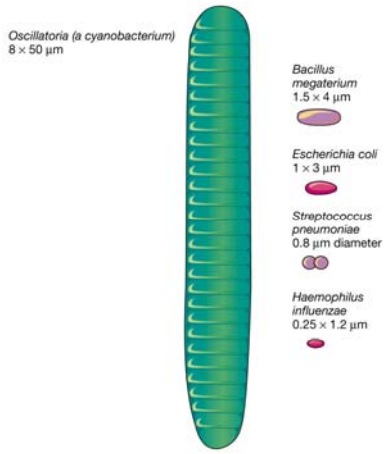
Proccess	Devoted energy (%)
DNA replicación	2*
Protein synthesis	75
4400 different proteins	0.017**

* during growth
** per protein (caution is needed about considering different copy number for different proteins)

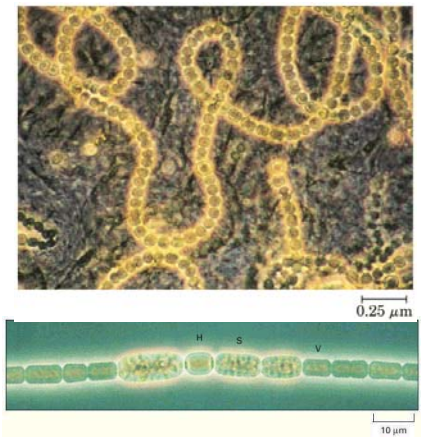
Cell type	Number of ribosomes
Escherichia coli	1,3 x 10^4
Human liver*	1,3 x 10^7

* ER bounded ribosomes

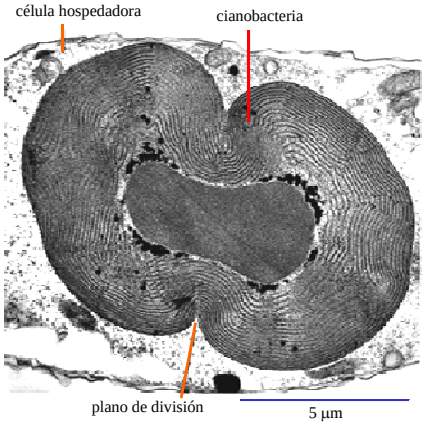


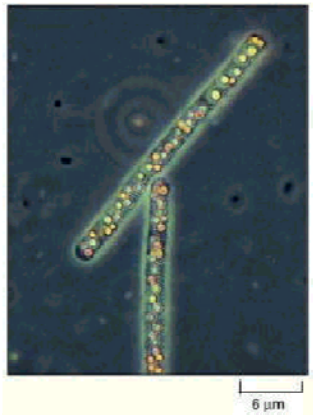


Photomicrograph of a photosynthetic microorganism called cyanobacteria. Cyanobacteria were the first O_2-evolving organisms on Earth and were responsible for oxygenating the atmosphere.

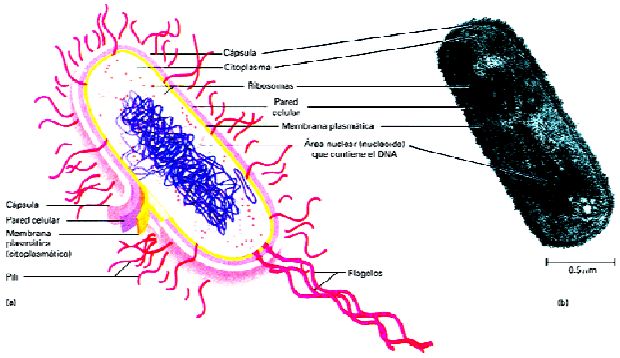


The phototrophic bacterium *Anabaena cylindrica* viewed in the light microscope. The cells of this species form long, multicellular filaments. Most of the cells (labeled *V)* perform photosynthesis, while others become specialized for nitrogen fixation (labeled *H)*, or develop into resistant spores (labeled *S*)





A lithotrophic bacterium. *Beggiatoa*, which lives in sulfurous environments, gets its energy by oxidizing H_2S and can fix carbon even in the dark. Note the yellow deposits of sulfur inside the cells.



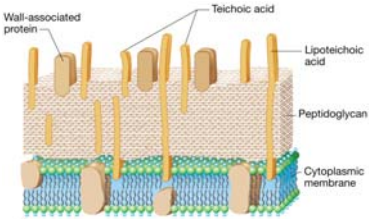


Diagram of the gram-positive cell wall

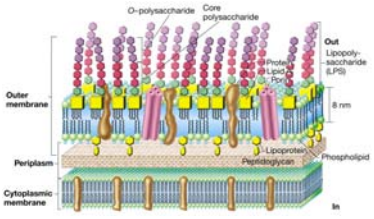
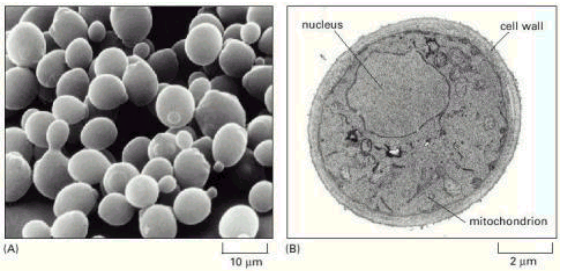
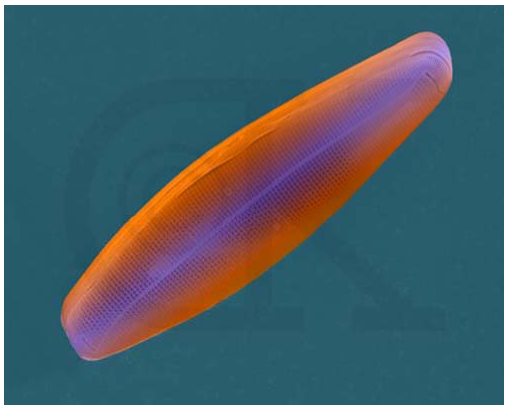
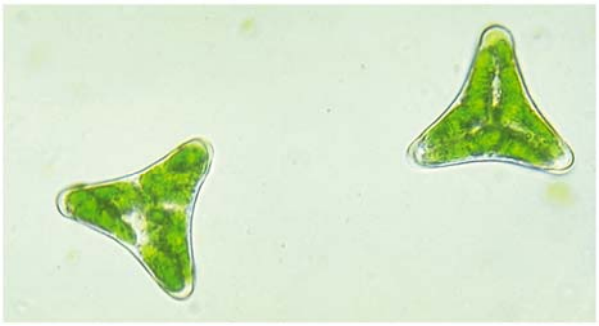


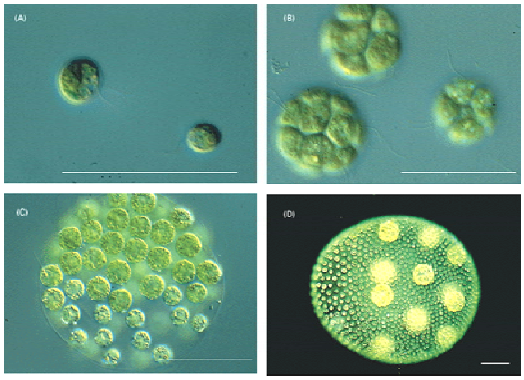
Diagram of the gram-negative cell wall



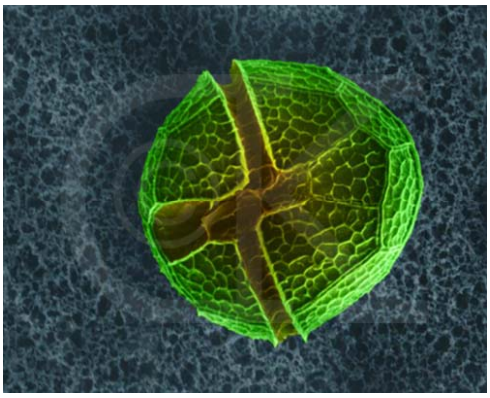
The yeast *Saccharomyces cerevisiae*. (A) A scanning electron micrograph of a cluster of the cells. This species is also known as budding yeast; it proliferates by forming a protrusion or bud that enlarges and then separates from the rest of the original cell. Many cells with buds are visible in this micrograph. (B) A transmission electron micrograph of a cross section of a yeast cell, showing its nucleus, mitochondrion, and thick cell wall.

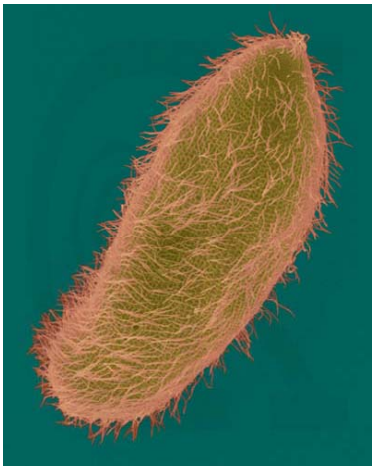


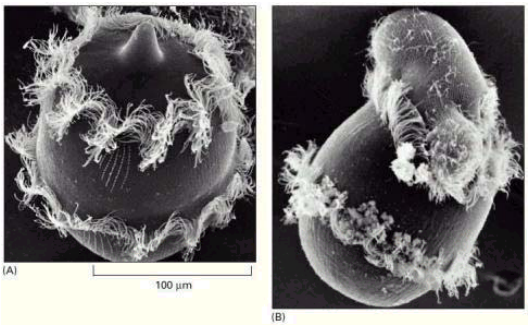




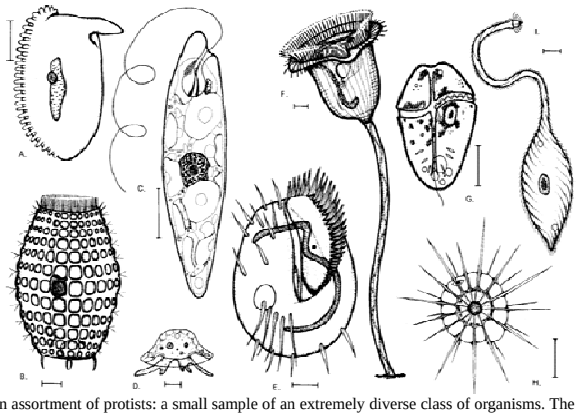
(la barra representa 50 µm en cada caso)



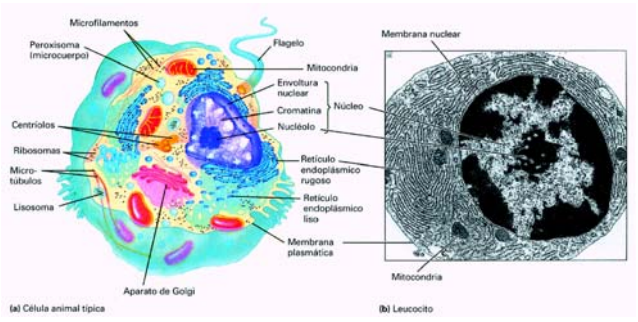


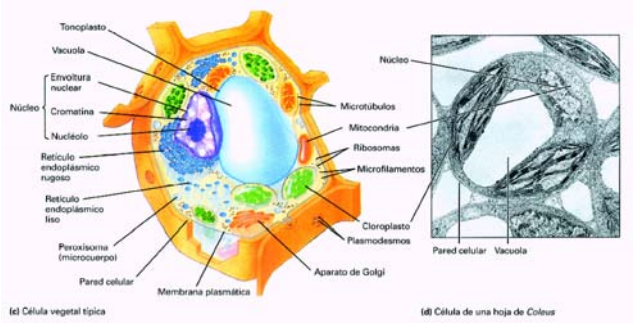


A single-celled eucaryote that eats other cells. (A) *Didinium* is a carnivorous protozoan, belonging to the group known as *ciliates*. It has a globular body, about 150 µm in diameter, encircled by two fringes of ciliasinuous, whiplike appendages that beat continually; its front end is flattened except for a single protrusion, rather like a snout. (B) *Didinium* normally swims around in the water at high speed by means of the synchronous beating of its cilia. When it encounters a suitable prey, usually another type of protozoan, it releases numerous small paralyzing darts from its snout region. Then, the *Didinium* attaches to and devours the other cell by phagocytosis, inverting like a hollow ball to engulf its victim, which is almost as large as itself.



An assortment of protists: a small sample of an extremely diverse class of organisms. The drawings are done to different scales, but in each case the scale bar represents 10 µm. The organisms in (A), (B), (E), (F), and (I) are ciliates; (C) is a euglenoid; (D) is an amoeba; (G) is a dinoflagellate; (H) is a heliozoan.





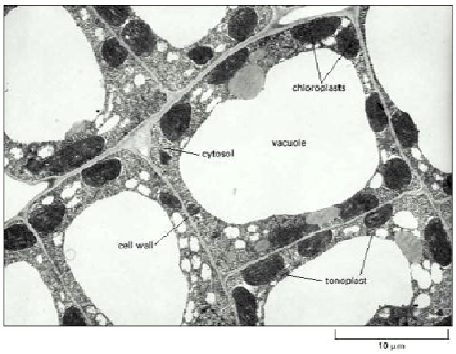
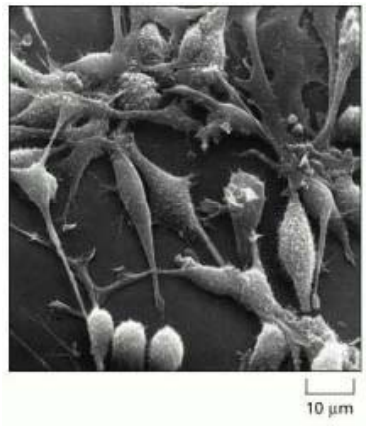
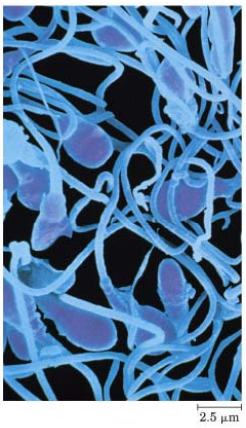
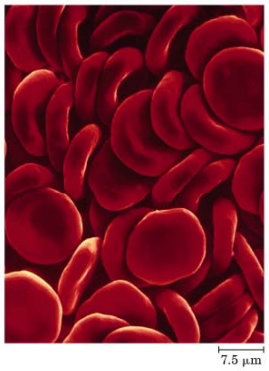
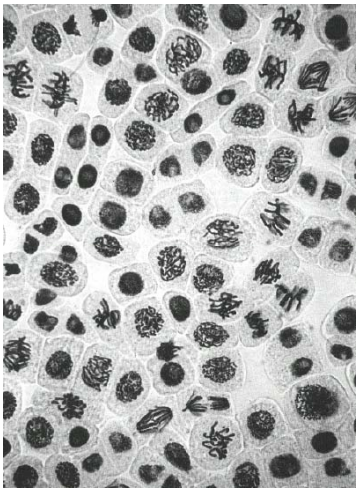


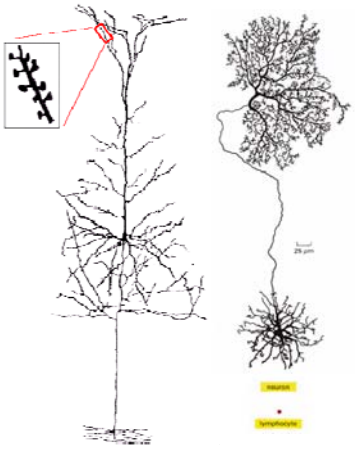
Figure 13-33. The plant cell vacuole. This electron micrograph of cells in a young tobacco leaf shows the cytosol as a thin layer, containing chloroplasts, pressed against the cell wall by the enormous vacuole. The membrane of the vacuole is called the tonoplast. (Courtesy of J. Burgess.)

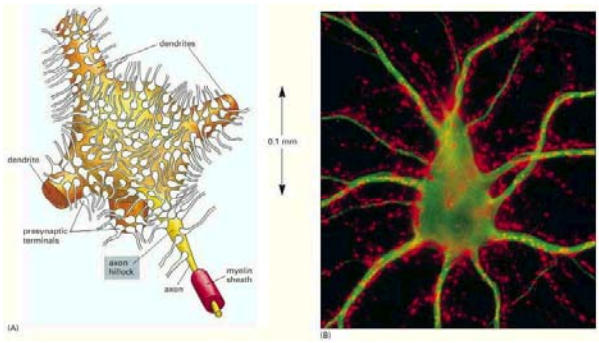


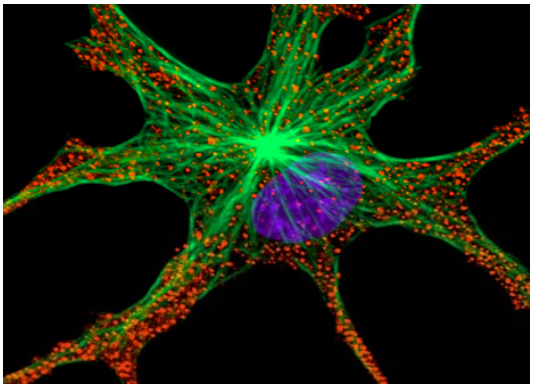


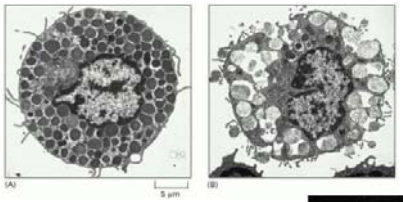

7.5 µm



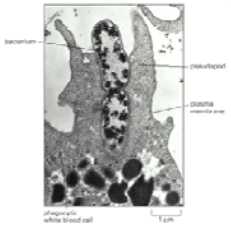



dendrites
dendrite
0.1 mm
presynaptic terminals
axon hillock
myelin sheath
axon
(A)
(B)

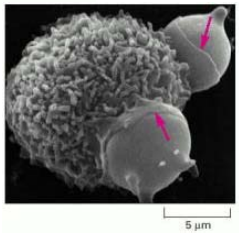




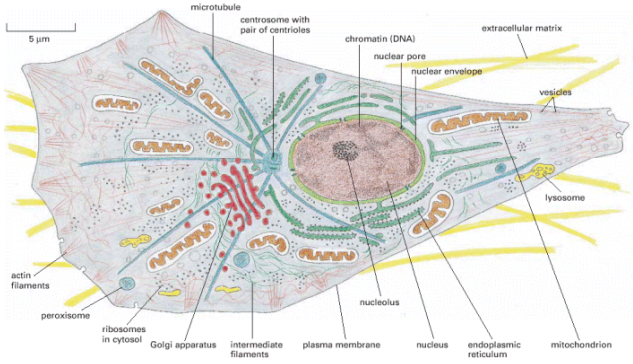
Exocytosis in rat mast cells

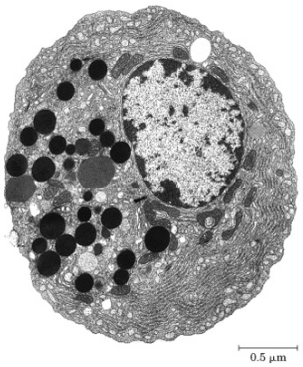


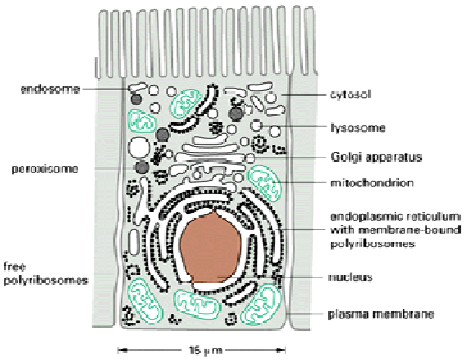
Phagocytosis by a neutrophil.



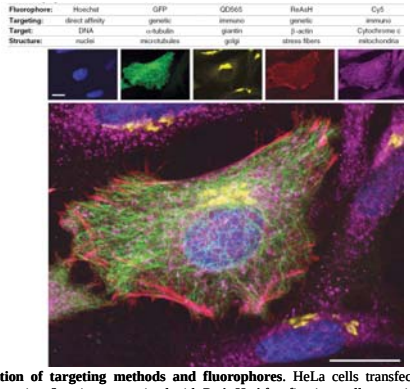
Phagocytosis of red cells by a macrophage



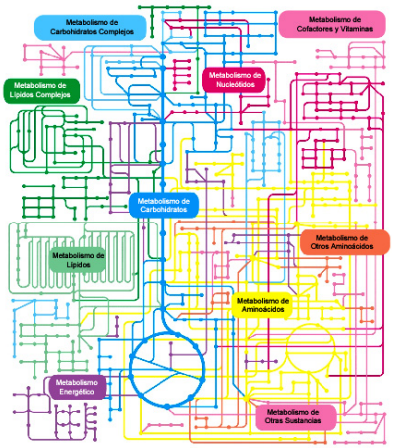


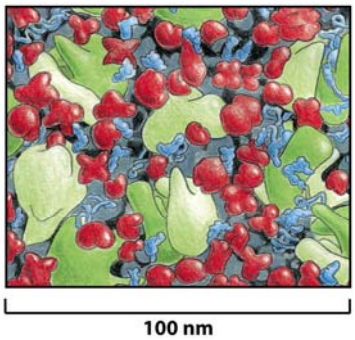


The major intracellular compartments of an animal cell. The cytosol (*gray*), endoplasmic reticulum, Golgi apparatus, nucleus, mitochondrion, endosome, lysosome, and peroxisome are distinct compartments isolated from the rest of the cell by at least one selectively permeable membrane.



Parallel application of targeting methods and fluorophores. HeLa cells transfected with GFP–a-tubulin and tetracysteine–β-actin were stained with ReAsH. After fixation, cells were immunolabeled for the Golgi matrix protein giantin with QDs and for the mitochondrial enzyme cytochrome c with Cy5 as indicated. DNA was stained with Hoechst 33342. Images were acquired from Z planes that best represent each structure using excitation and emission wavelengths as indicated. Individual channels are false-colored (middle) and merged (bottom). Scale bars, 20 μm. (Giepmans *et al*. 2006 *Science* 312: 217-224)

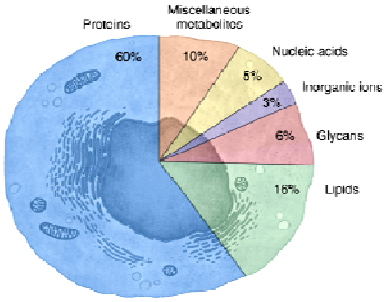




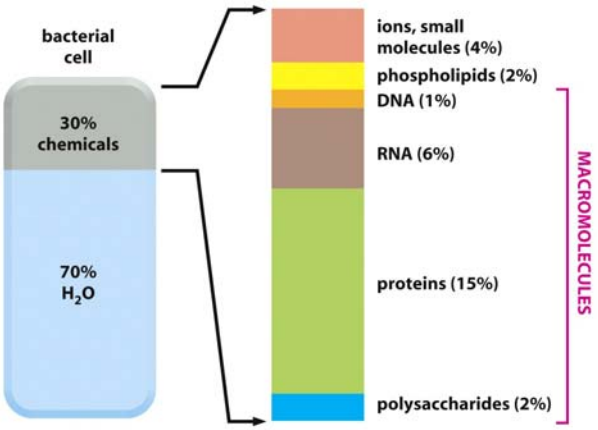
La estructura del citoplasma. El esquema (aproximadamente a escala) resalta el enorme volumen ocupado por las macromoléculas. **Los RNAs se muestran en *azul*, los ribosomas en *verde* y las proteínas en *rojo***. Las enzimas y otras macromoléculas difunden lentamente en el citoplasma lo que se debe, en parte, a sus interacciones con otras macromoléculas; los metabolitos pequeños en cambio difunden a una velocidad cercana a su velocidad de difusión en agua

Composición química aproximada de una bacteria y una célula de mamífero típicas

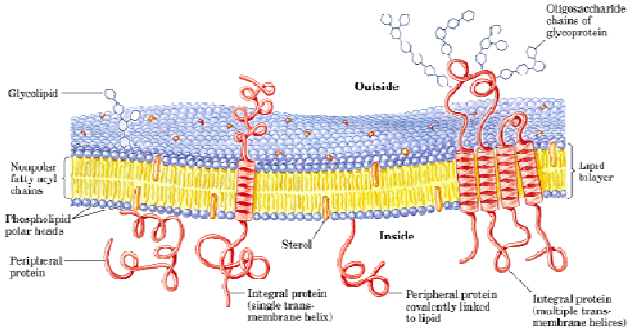
Componente	% del peso total celular	
	E. coli	Célula de mamífero
H_2O	70	70
Iones inorgánicos (Na^+, K^+, $Mg2^+$, Ca^{2+}, Cl^-, etc.	1	1
Metabolitos pequeños varios	3	3
Proteínas	15	18
RNA	6	1,1
DNA	1	0,25
Fosfolípidos	2	3
Otros lípidos	-	2
Polisacáridos	2	2
Volumen celular (ml)	2×10^{-12}	4×10^{-4}
Volumen celular relativo	1	2000

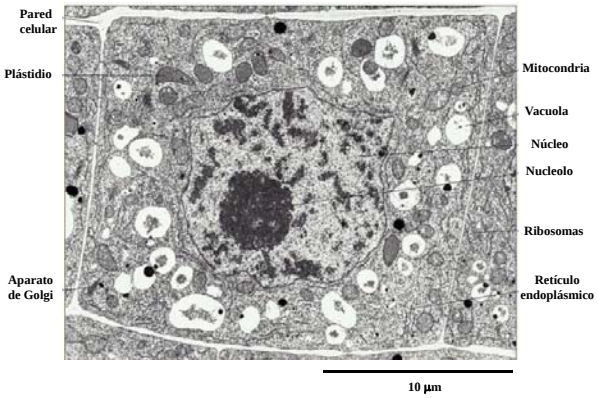


Composición de una célula de mámifero típica. Aunque las proteínas representan la fracción más importante del peso seco de una célula, se estima que más de la mitad se encuentra modificada con oligosacáridos, lípidos y otros metabolitos. (*Prescher J. A. & C.R. Bertozzi 2005 Nature Chem. Biol (1): 14-21.2005*)



Todas las células tienen el mismo conjunto básico de organelos conformados por membranas





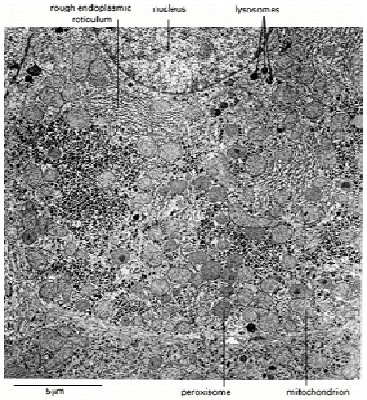


Figure 12-2. Electron micrograph of part of a liver cell seen in cross-section. Examples of most of the major intracellular compartments are indicated. (Courtesy of Daniel S. Friend.)

Table 12-1. Relative Volumes Occupied by the Major Intracellular Compartments in a Liver Cell (Hepatocyte)

INTRACELLULAR COMPARTMENT	PERCENTAGE OF TOTAL CELL VOLUME
Cytosol	54
Mitochondria	22
Rough ER cisternae	9
Smooth ER cisternae plus Golgi cisternae	6
Nucleus	6
Peroxisomes	1
Lysosomes	1
Endosomes	1

Table 12-2. Relative Amounts of Membrane Types in Two Kinds of Eucaryotic Cells

MEMBRANE TYPE	PERCENTAGE OF TOTAL CELL MEMBRANE	
	LIVER HEPATOCYTE*	PANCREATIC EXOCRINE CELL*
Plasma membrane	2	5
Rough ER membrane	35	60
Smooth ER membrane	16	<1
Golgi apparatus membrane	7	10
Mitochondria		
Outer membrane	7	4
Inner membrane	32	17
Nucleus		
Inner membrane	0.2	0.7
Secretory vesicle membrane	not determined	3
Lysosome membrane	0.4	not determined
Peroxisome membrane	0.4	not determined
Endosome membrane	0.4	not determined

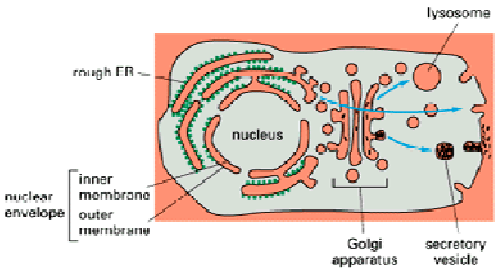


Figure 12-4. Topological relationships between compartments in a eucaryotic cell. Topologically equivalent spaces are shown in *red*. In principle, cycles of vesicle budding and fusion permit any lumen to communicate with any other and with the cell exterior. The *blue arrows* indicate the outward direction of vesicle traffic from the ER to Golgi apparatus to plasma membrane (or lysosomes), and the *black dots* represent protein molecules that are secreted by the cell. Some organelles, most notably mitochondria and (in plant cells) chloroplasts, however, do not take part in this vesicular communication and so are isolated from the traffic between organelles shown here.

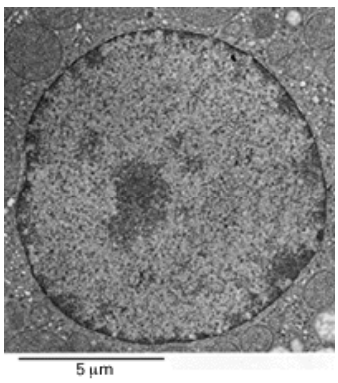


Figure 1-18. The cell nucleus. The nucleus contains most of the DNA of the eucaryotic cell. It is seen here in a thin section of a mammalian cell examined in the electron microscope. (Courtesy of Daniel S. Friend.)

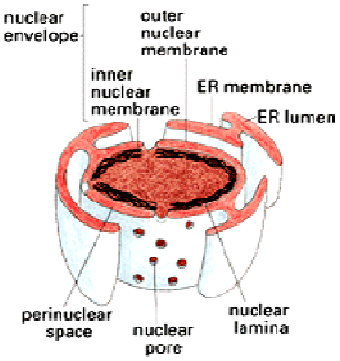


Figure 12-9. The nuclear envelope. The double-membrane envelope is penetrated by nuclear pores and is continuous with the endoplasmic reticulum. The ribosomes that are bound to the cytosolic surface of the ER membrane and outer nuclear membrane are not shown.

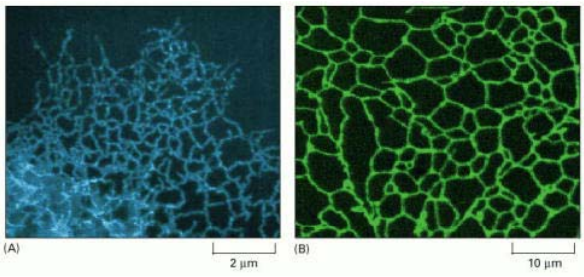


Figure 12-35. Fluorescent micrographs of the endoplasmic reticulum. (A) Part of the ER network in a cultured mammalian cell, stained with an antibody that binds to a protein retained in the ER. The ER extends as a network throughout the entire cytosol, so that all regions of the cytosol are close to some portion of the ER membrane. (B) Part of an ER network in a living plant cell that was genetically engineered to express a fluorescent protein in the ER. (A, courtesy of Hugh Pelham; B, courtesy of Petra Boevink and Chris Hawes.)

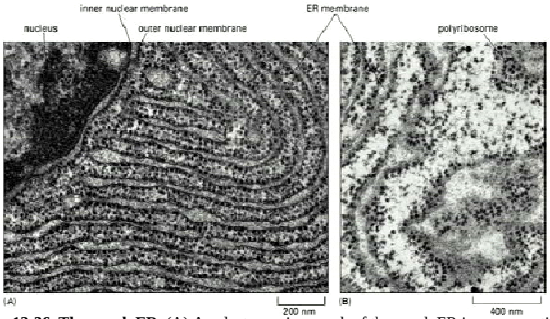


Figure 12-36. The rough ER. (A) An electron micrograph of the rough ER in a pancreatic exocrine cell that makes and secretes large amounts of digestive enzymes every day. The cytosol is filled with closely packed sheets of ER membrane studded with ribosomes. At the top left is a portion of the nucleus and its nuclear envelope; note that the outer nuclear membrane, which is continuous with the ER, is also studded with ribosomes. (B) A thin section electron micrograph of polyribosomes attached to the ER membrane. The plane of section in some places cuts through the ER roughly parallel to the membrane, giving a face-on view of the rosettelike pattern of the polyribosomes. (A, courtesy of Lelio Orci; B, courtesy of George Palade.)

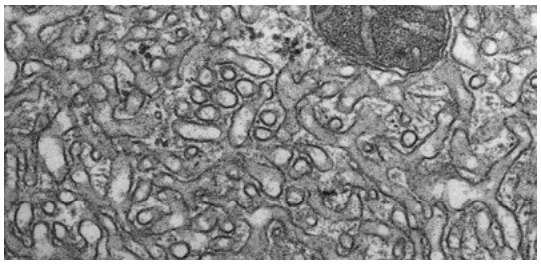


Figure 12-34. Abundant smooth ER in a steroid-hormone-secreting cell. This electron micrograph is of a testosterone-secreting Leydig cell in the human testis.

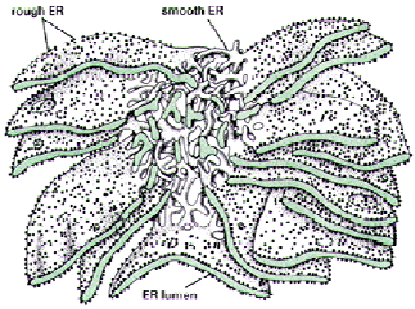


Figure 12-35. Three-dimensional reconstruction of a region of the smooth and rough ER in a liver cell. The rough ER forms oriented stacks of flattened cisternae, each having a luminal space 20 to 30 nm wide. The smooth ER membrane is connected to these cisternae and forms a fine network of tubules 30 to 60 nm in diameter. (After R.V. Krsti Ultrastructure of the Mammalian Cell. New York: Springer-Verlag, 1979.)

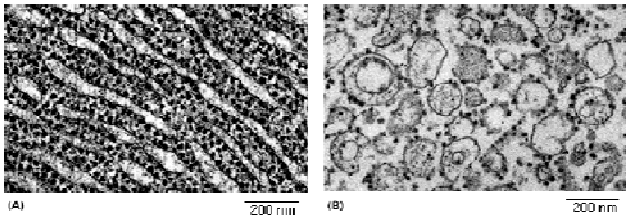


Figure 12-36. Electron micrographs of microsomes. When cells are disrupted by homogenization, the cisternae of rough ER (A) break up into small closed vesicles called *rough microsomes* (B). Similarly, the smooth ER breaks up into small vesicles that lack ribosomes and are called *smooth microsomes.* (A, courtesy of Daniel S. Friend; B, courtesy of George Palade.)

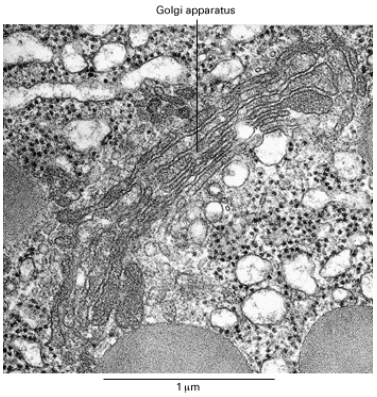
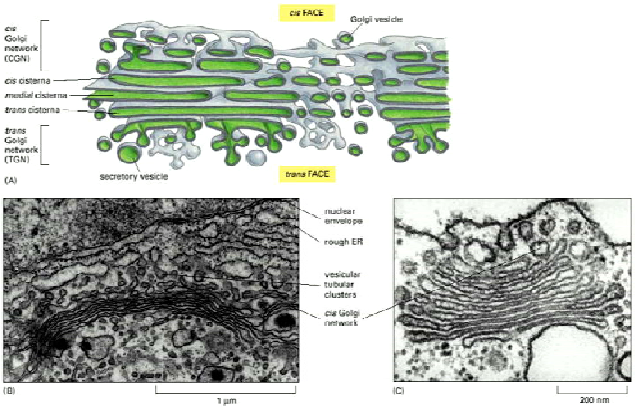
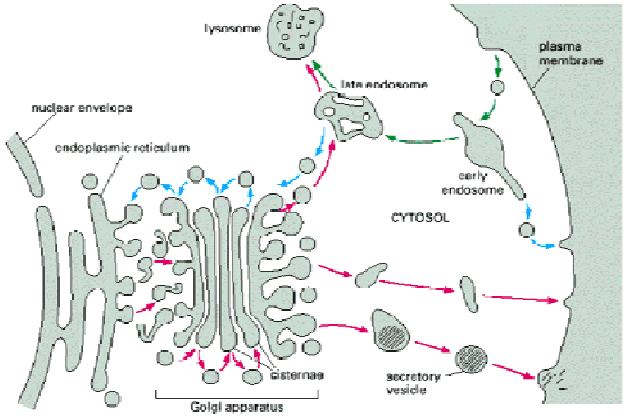


Figure 1-25. The Golgi apparatus. Electron micrograph of a thin section of a mammalian cell showing the Golgi apparatus, which is composed of flattened sacs of membrane arranged in multiple layers. The Golgi apparatus is involved in the synthesis and packaging of molecules destined to be secreted from the cell, as well as in the routing of newly synthesized proteins to the correct cellular compartments. (Courtesy of Daniel S. Friend.)





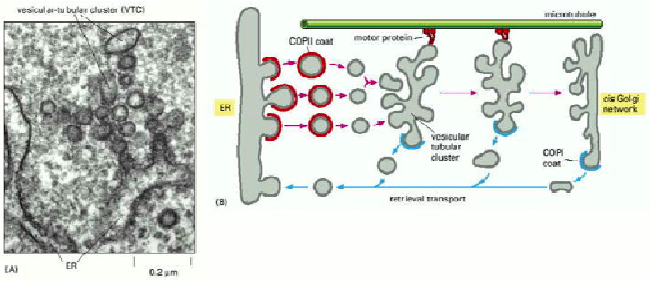


Figure 13-20. Vesicular tubular clusters. (A) An electron micrograph section of vesicular tubular clusters forming from the ER membrane. Many of the vesicle-like structures seen in the micrograph are cross sections of tubules that extend above and below the plane of this thin section and are interconnected. (B) Vesicular tubular clusters move along microtubules to carry proteins from the ER to the Golgi apparatus. COPI coats mediate the budding of vesicles that return to the ER from these clusters. As indicated, the coats quickly disassemble after the vesicles have formed. (A, courtesy of William Balch.)

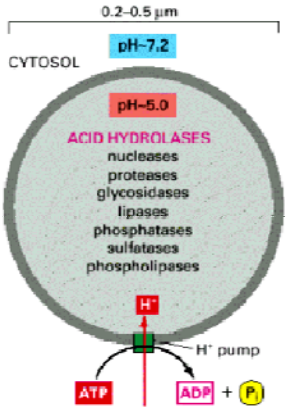
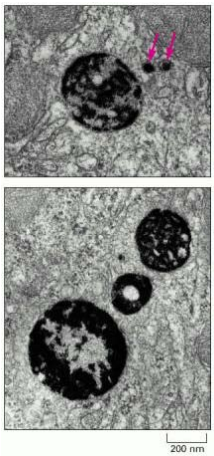
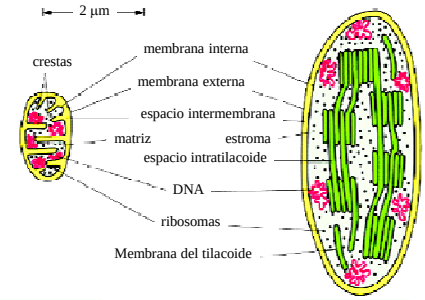


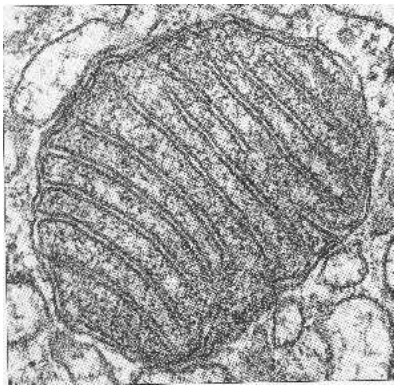
Figure 13-31. Lysosomes. The acid hydrolases are hydrolytic enzymes that are active under acidic conditions. The lumen is maintained at an acidic pH by an H^+ ATPase in the membrane that pumps H^+ into the lysosome.

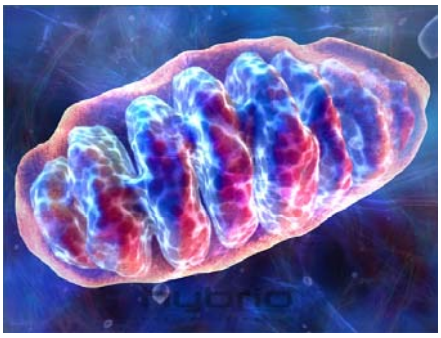


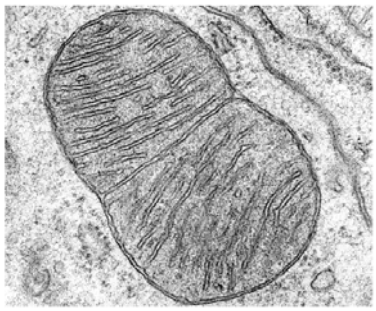
Histochemical visualization of lysosomes. These electron micrographs show two sections of a cell stained to reveal the location of acid phosphatase, a marker enzyme for lysosomes. The larger membrane-enclosed organelles, containing dense precipitates of lead phosphate, are lysosomes. Their diverse morphology reflects variations in the amount and nature of the material they are digesting. The precipitates are produced when tissue fixed with glutaraldehyde (to fix the enzyme in place) is incubated with a phosphatase substrate in the presence of lead ions. Two small vesicles thought to be carrying acid hydrolases from the Golgi apparatus are indicated by *red arrows* in the top panel. (Courtesy of Daniel S. Friend.)

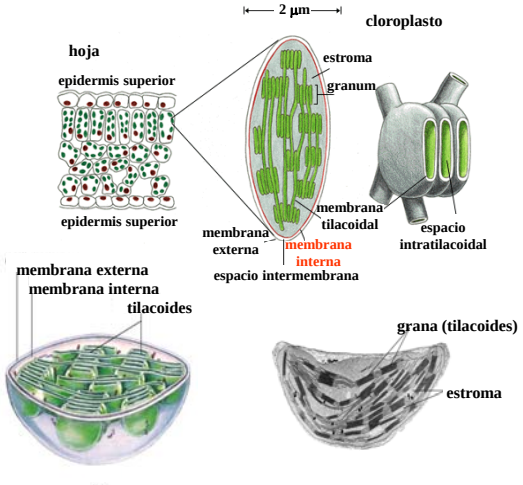


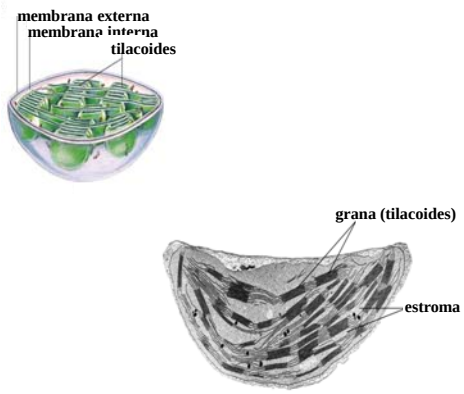
Mitocondria Cloroplasto

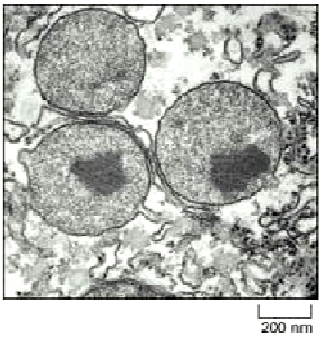







2 µm
cloroplasto
hoja
epidermis superior
estroma
granum
epidermis superior
membrana tilacoidal
espacio intratilacoidal
membrana externa
membrana interna
espacio intermembrana
membrana externa
membrana interna
tilacoides
grana (tilacoides)
estroma





An electron micrograph of three peroxisomes in a rat liver cell. The paracrystalline electron-dense inclusions are composed of the enzyme urate oxidase. (Courtesy of Daniel S. Friend.) Peroxisomes are unusually diverse organelles containing different set of enzymes

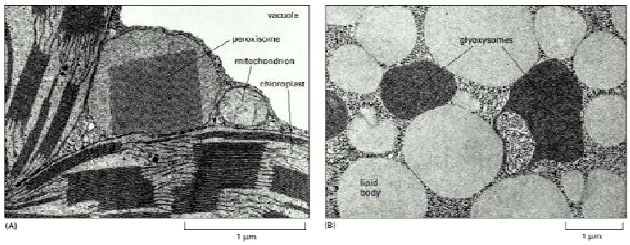


Figure 12-33. Electron micrographs of two types of peroxisomes found in plant cells. (A) A peroxisome with a paracrystalline core in a tobacco leaf mesophyll cell. Its close association with chloroplasts is thought to facilitate the exchange of materials between these organelles during photorespiration. (B) Peroxisomes in a fat-storing cotyledon cell of a tomato seed 4 days after germination. Here, the peroxisomes (glyoxysomes) are associated with the lipid bodies where fat is stored, reflecting their central role in fat mobilization and gluconeogenesis during seed germination.

Características comunes de las células

- **Todas las células "guardan" su información en el mismo código químico lineal (DNA)**
- **Todas las células "copian" su información hereditaria por medio de una polimerización "dirigida" por un molde**
- **Todas las células transcriben porciones de su información hereditaria en una misma forma de intermediario (RNA)**
- **Todas las células utilizan proteínas como catalizadores**
- **Todas las células traducen el RNA en proteínas de la misma manera**
- **El fragmento de información génica que corresponde a una proteína es un gen**
- **Los organismos vivos requieren de energía libre**
- **Todas las células funcionan con el mismo conjunto de moléculas básicas**
- **Todas las células están delimitadas por una membrana a través de la cual deben pasar los nutrientes y los productos de desecho**
- **Una célula puede existir con un poco menos de 500 genes**

Las células y el microscopio

- La invención **del microsocopio óptico** condujo al descubrimiento de las células
- Hoy, células, organelos e incluso moléculas pueden verse con un microscopio apropiado

La célula eucarionte

- El núcleo es el "almacén de información" de la célula
- Las mitocondrias "generan" energía, a partir de los alimentos, necesaria para efectuar las actividades celulares
- Los cloroplastos "capturan" energía luminosa "producida" en el sol
- Membranas internas definen **compartimientos** con diferentes funciones
- El citosol es un gel acuoso concentrado, altamente organizado, en el que existen macromoléculas y moléculas pequeñas
- El citoesqueleto es responsable de los **movimientos** celulares

Unidad y diversidad celular

- Las células varían enormemente tanto en aspecto (forma) como en función
- Todas las células comparten una química básica que es común
- Todas las células actuales parecen haber evolucionado a partir del mismo ancestro
- Las bacterias son organismos "simples" y pequeños; los virus son los organismos más pequeños conocidos en la actualidad
- Los biólogos moleculares han usado como modelo de estudio de bacterias a *Escherichia coli*
- *Giardia* parece representar un estado intermedio en la evolución de las células eucariontes
- La levadura de cerveza (*Saccharomyces cerevisiae*) es una célula eucarionte "simple"
- Los organismos unicelulares (protozoos) pueden ser grandes, complejos y "fieros"
- De entre 300.000 especies, *Arabidopsis thaliana* ha sido elegida como modelo en plantas
- El mundo de los animales está representado por una mosca (*Drosophila melanogaster*) un gusano (*Caenorhabditis elegans*), un ratón (*Mus musculus*) y el humano (*Homo sapiens*)
- Las células que conforman un organismo multicelular pueden ser espectacularmente diferentes