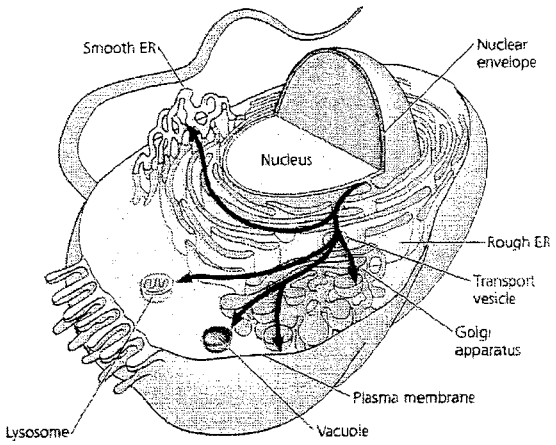
The Endomembrane System: A Review
خلاصة علاقات الغشاء الداخلي



العناصر التي لها علاقة بالطاقة:
الجسيمات الكوندرية (المتقدرات) والصانعات الخضر
Mitochondria and Chloroplasts

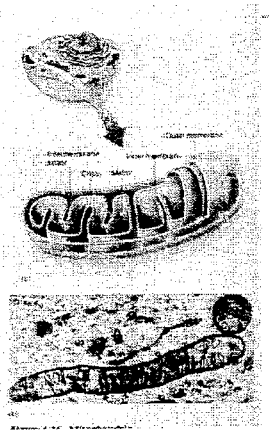
* جسيمات **تغير الطاقة وتحولها من شكل لآخر** .. إذن هي **محولات للطاقة** في خلايا حقيقيات النواة **transformers** of **energy** in eukaryotic cells ,, يميز منها:

- **الجسيمات الكوندرية للتنفس الخلوي** **cellular respiration**
  وعمليات الاستقلاب **metabolic processes**
- **الصانعات الخضر** (في النباتات والطحالب plants and algae) **للتركيب الضوئي**
  Photosynthesis

- ما هي بنيتها ؟

الميتوكوندريا (المتقدرات) : محولات كيميائية للطاقة

Mitochondria: Chemical Energy Converters

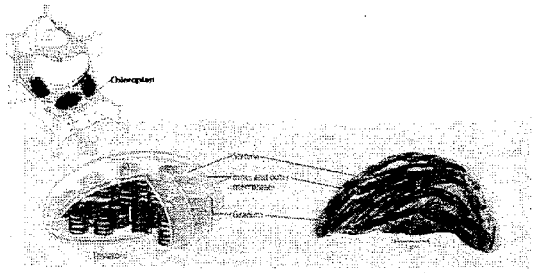


* **حويصلات** .. 1- 10 مكرون
* توجد في جميع حقيقيات النواة .. **نباتات وحيوانات** .. واحدة أو أكثر حسب نشاط الخلية ... مثلاً غزيرة في الخلايا العضلية.
* كل منها محاط **بغلاف مضاعف من الفسفوليبيدات مع بروتينات مندمجة embedded proteins**
* **الغشاء الداخلي** أملس و منطوي إلى الداخل مشكلاً أعراف cristae مما يزيد السطح الداخلي.
* فراغ بين الغشائين intermembrane space
* **محتوى الكوندريوم** ... مادة أساس (**متطرس**) **matrix** داخل الجدار الداخلي.. تحوي **إنزيمات** و **دنا كوندري** و **ريبوزومات** تساهم في الفعاليات التي تحدث في المتقدرة.

الصانعات الخضر: لاقطات الطاقة الضوئية

Chloroplasts: Capturer of Light Energy

* صانعات متخصصة بشكل العدسات . 3- 6 ميكرون يميز منها .....
  - **صانعات خضر chloroplasts**
  - **صانعات نشاء amyloplasts**
  - **صانعات ملونة chromoplasts**
* **الصانعات الخضر:chloroplastes.....**



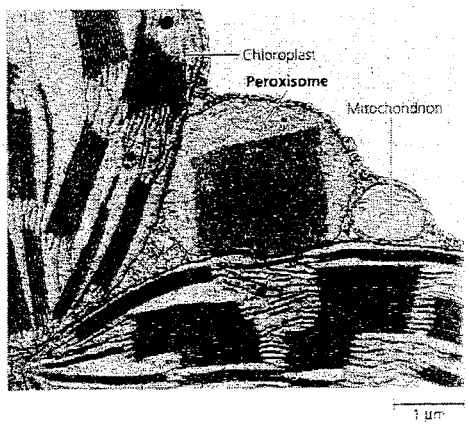
* **الصانعات الخضر: chloroplastes**
  - غشاء مضاعف
  - **فراغ يملؤه سائل .. سترومـا stroma ..** يحتوي على **دنا** و **ريبوزومات** إضافة لبعض **الإنزيمات** .. محاط بغشاءين: داخلي وخارجي
  - الفراغ يحوي **أكياساً** (**جيوياً**) .. **thylacoids** فيها اليخضور ... تتراكم ... فوق بعضها لتشكل **حبيبات يخضورية grana** (مفردها granum)
* **صانعات نشاء amyloplastes** توجد في النباتات وتحمل حبيبات النشاء
* **الصانعات الملونة chromoplasts** تحوي أصبغة ملونة خصوصاً في الأزهار

البيروكسيزومات peroxysomes للأكسدة oxidation

* **مكونات مختصة بالأكسدة ذات غشاء بطبقة واحدة**

Specialized metabolic components, with single layered membrane

* تحتوي على **إنزيمات تُحَوِّل الأكسيجن إلى جزيء ماء مُؤكسِد .... مكونة بِروكسيد الهيدروجين** (H_2O_2) hydrogen peroxide السام الذي يفككه إنزيم **الكاتالاز** catalase إلى ماء و أكسيجين. لذا تقوم البِروكسيزومات بتفكيك الحموض الدسمة في النباتات وتحويلها إلى مواد يمكن أن تتحول إلى سكريات تتحرر منها الطاقة في تفاعلات التنفس الخلوي
* في الكبد تقوم البِروكسيزومات بإزالة السمية من الكحول والمواد السامة الأخرى مثل الحموض الصفراوية bile acids التي يشكلها الكولِسترول.

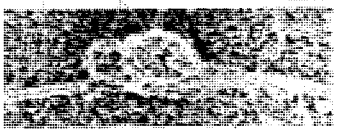


الهيكل الخلوي Cytoskeleton

* شبكة من الألياف تنتشر في السيتوزول تنظم بنية الخلية وشكلها ووظائفها، تمتد بين النواة وغشاء الخلية. تم اكتشافها بعد تحسين المجاهر بعد السبعينات 1970.
* دورها **دعم support وتنظيم شكل الخلية form و حركية motility عناصرها.**

تنظيم الحركة داخل الخلية يتم ببروتينات محركة motor proteins تحرك حويصلات على طول نبيب من الهيكل

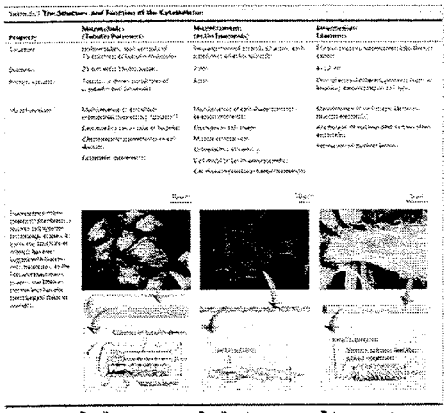
تَحَرُّك حويصلات على طول نَبِيب من الهيكل
بروتينات محركة بطاقة من أتب



صورة بالمجهر الإلكتروني لانتقال مفرزات منبهة على طول النبيب الدقيق)

مُكَوِّنات الهيكل الخلوي Components of the Cytoskeleton

- يتألف من ثلاثة أنماط من العناصر: **نبيبات دقيقة microtubules**،
- **خيوط دقيقة microfilaments و خيوط متوسطة intermediate filaments**



نبيبات دقيقة خيوط دقيقة خيوط متوسطة

النبيبات الدقيقة ***Microtubules***

* أسطوانات مجوفة بقطر نحو 25 نانو متر طولها بين 0.2-25 ميكرومتر.
* تتألف من **مثنويات dimers** (نوعين) من البروتينات تختلف بترتيب حمضيهما الأمينيين: التوبيولين ألفا tubulin α و التوبيولين بيتا tubulin β
* تعطي الخلية شكلها و مساراً لتحرك العضيات المختلفة للخلية ...

تقوم جزيئات الميوزين myosin المرتبطة بالجزيئات المحركة kinesin والداينيئين dinein بنقل الحويصلات المختلفة التي تحمل المفرزات في الخلية، وعلى السطح الداخلي للخملات microvilli في الأمعاء، **وتنقل الكروموزومات** أثناء انقسام الخلية بعد تشكيلها مغزل الانقسام spindle واصطفاف الكروموزومات على طولها.... **محركة**

الخيوط الدقيقة microfilaments

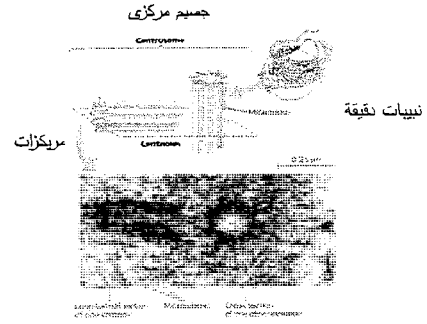
* تسمى أيضاً خيوط الأكتين actin filaments.... **دعم وحركة**
* ليفات دقيقة مرنة طولها نحو 7 نانو متر، من سلسلتين ملتفتين على بعضهما حلزونياً من مونوميرات كروية globular monomere (أكتينات كروية globular actins).
* **تنتشر تحت غشاء الخلية مباشرة لدعم الغشاء، لتساهم في تكوين الأرجل الكاذبة pseudopodia التي تساهم في تحرك وحيدات الخلية.**
* **تكثر أيضاً في الخملات الدقيقة microvilli التي تبرز عن السطح الداخلي للأمعاء الدقيقة.**
* **تساهم في انزلاق خيوط الأكتين والميوزين في العضلات ومن ثم تقلصها.**

الخيوط المتوسطة intermediate filaments ... مرونة و توتر

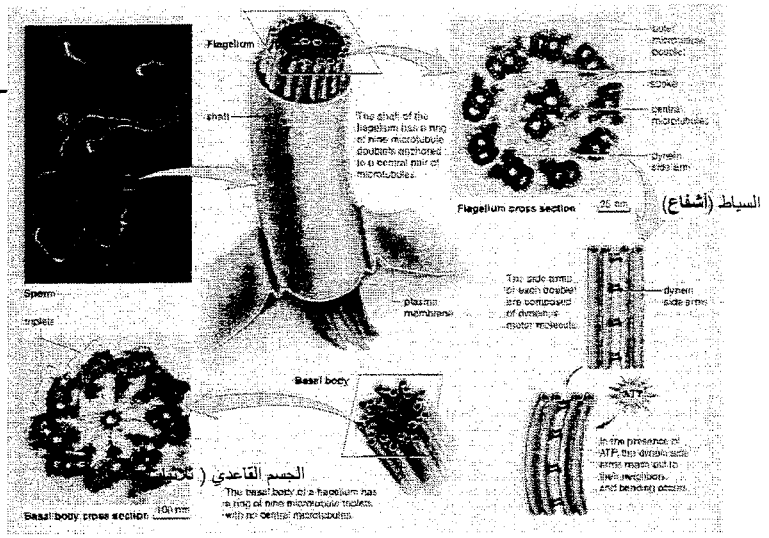
* وسط من حيث الحجم بين النوعين السابقين (8-11 نانومتر) بشكل الحبال المجدولة، يختلف دورها حسب النسج التي توجد فيها، **بعضها يدعم غشاء النواة، وما يوجد منها تحت الجلد وبما تحويه من القرنين keratin يمنح الجلد التوتر المعروف tension-bearing elements.**

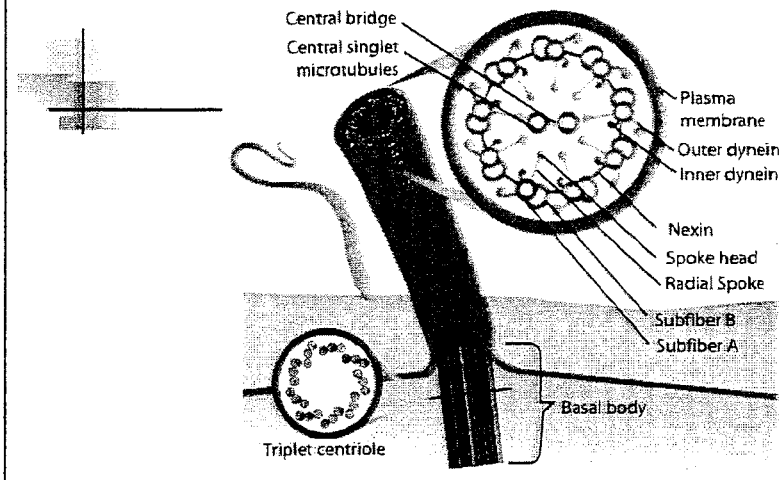
الجسيم المركزي centrosome والمُرَيْكِز centrioles

* جسيم في سيتوبلاسما جميع الخلايا حقيقية النواة عدا خلايا الفطريات، قرب النواة، تتشكل منه النبيبات الدقيقة، يتألف كل منها من مريكزين centrioles متعامدين .. كل منهما من **تسع ثلاثيات من النُبَيْبات مرتبة على هيئة أسطوانة فارغة لايحوي مركزها نُبَيْبات (ترتيب 9+0)**. لهذا الجسيم أهميته في انقسام الخلية، وذلك بتنظيم نُبَيْبات المغزل أثناء انقسام الخلية.



Cilia and flagella الأهداب والسياط





الأهداب والسياط Cilia and flagella

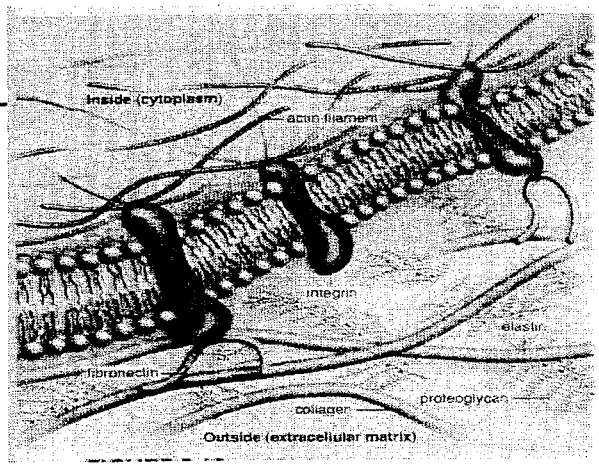
* عناصر محركة في الخلية (السطح الداخلي للقصبة الهوائية والنطاف وقناة البيوض "البوق" oviduct في الجهاز التناسلي الأنثوي وغيرها)، والمتعضيات صغيرة الحجم.
* **أشفاع** من النبيبات الدقيقة microtubules مرتبة بشكل أسطوانات بترتيب 9 + 2 (9 محيطية و 2 مركزية)، ترتبط ببروتينات محركة (داينئين) motor proteins (dinein) (باللون الأحمر) يغلفها غشاء بلاسمي (باللون الأزرق).
* ترتبط بالأسفل بجسيم قاعدي basal body ... أسطوانة من ثُلاثيات من النبيبات الدقيقة بترتيب 9 + 0 (دون نبيبات مركزية)، تتثني بسبب الطاقة المتحررة من الأتب، ما يسبب انثناء الهدب و من ثم تحرك العضية.

المكونات خارج الخلوية والوصلات بين الخلايا تنسق نشاطات الخلايا

Extracellular components and connections between cells help coordinate cellular activities.

المطرس خارج الخلوي extracellular matrix (ECM): (ميدر ص 98)

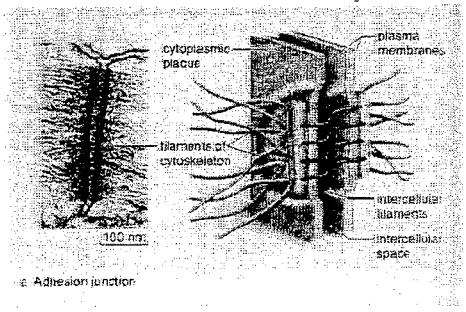
- **بروتينات سكرية glycoproteins** في الخلايا الحيوانية تحيط بالخلايا الحيوانية ... تضم أليافاً كولاجينية collagen (تقاوم الشد resist stretching) وَ إلاستين elastin (مخمدة resilencing).
- **فيبرونكتين fibronectin** يربط ألياف الكولاجين في المطرس خارج الخلوي بالبروتين المنغرس integral protein (integrin) في جدار الخلية.
- **بروتيوغليكان proteoglycan** (نوع آخر من البروتينات السكرية) أيضاً تساهم في نقل الرسائل في داخل الخلية ... كأن تساهم في التمييز recognition.
- المطرس خارج الخلوي في العظام extracellular matrix in bone صلب بسبب ترسب أملاح الكالسيوم فيه.



الموصِلات (الوصلات) بين الخلايا Junctions Between Cells

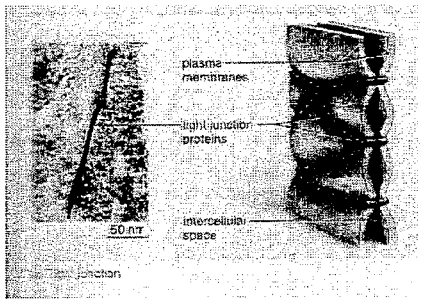
- المواقع التي يتم فيها ارتباط الخلايا بعضها مع بعض.
- يميز منها 3 أنواع:

. **موصلات (وصلات) التصاق adhesion junctions:** ترتبط فيها جسيمات موصلة desmosomes (هي صفيحات سيتوبلاسمية cytoplasmic plaques) مع بعضها و بالهيكل الخلوي بصورة جيدة، مثل ما يوجد في القلب والمعدة والمثانة و ما بين خلايا الجلد.

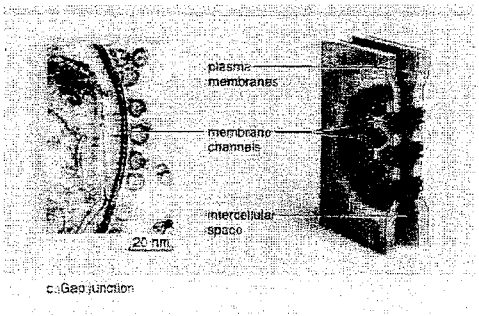


c Adhesion junction

. **موصلات (وصلات) وثيقة tight junctions:** ترتبط فيها الأغشية البلاسمية بشدة مع بعضها بالتصاق البروتينات الغشائية ببعضها على هيئة " السَحَاب"، مثلما في النسج التي تفصل بين العناصر النسيجية .. المعدة والأمعاء والمثانة للفصل بين هذه الأعضاء ومحتوياتها.

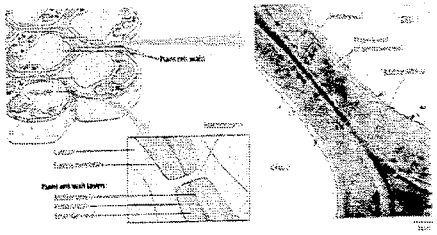


. **موصلات (وصلات) فضوية gap junctions:** وهي التي تسمح بوجود قنيوات بين الخلايا يبطن كل منها ست طبقات من البروتينات الغشائية تسمح بمرور المواد والإيونات بين الخلايا. مثل عضلة القلب والعضلات الملساء لتسمح بمرور الإيونات من أجل تنبيه العضلة.



جدار الخلايا النباتية Cell Walls of Plants

- يحيط بالغشاء البلاسمي يميزها عن الخلية النباتية.
- قاسٍ rigid خارج الخلية يحمي الخلية ويمنح الخلية شكلها.
- يختلف بين الخلايا النباتية لكن بشكل عام يتألف من ليفات من السلولوز مع سكريات أخرى وبعض البروتينات.
- **جدار أولي primary wall** رقيق ومرن، ثم بعد النضج توجد عدة طبقات من **الجدار الثانوي** secondary wall ، بينها **صفيحة وسط** middle lamella غنية بالبكتين pectin (عديد سكريد polysaccharides) تصل الجدارين ببعضهما.
- تتصل الخلايا ببعضها **بثقوب plasmodesmata (مفردها) plasmodesma**



الدارة الخلوية و انقسام الخلايا
The Cell Cycle and Cellular Division
(Mader P. 151 - 152 & 155 - 158)

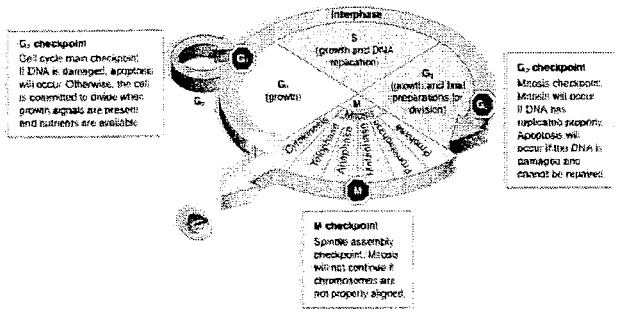
* الدارة الخلوية cell cycle هي مجموعة الحوادث التي تتم بين بدء انقسام الخلية وبدء انقسام الخلية البنت.
* تؤدي هذه الحوادث إلى:
  - زيادة حجم المتعضية
  - تجدد النسج tissues renewal
  - نسخ الدنا replication of DNA
  - زيادة عدد الخلايا بانقسام خيطي mitosis
  - التحضير للتكاثر reproduction الذي يفضي إلى تشكُّل خلايا بنات بانقسام اختزالي (مُنصّف) meiosis، وتوزع الصبغيات distribution of the chromosomes وتشكل الأعراس
* كل ذلك يتم في مراحل .... الدارة الخلوية cell cycle
* **مراحل الدارة الخلوية** ←

9.1 – الدارة الخلوية The cell cycle :

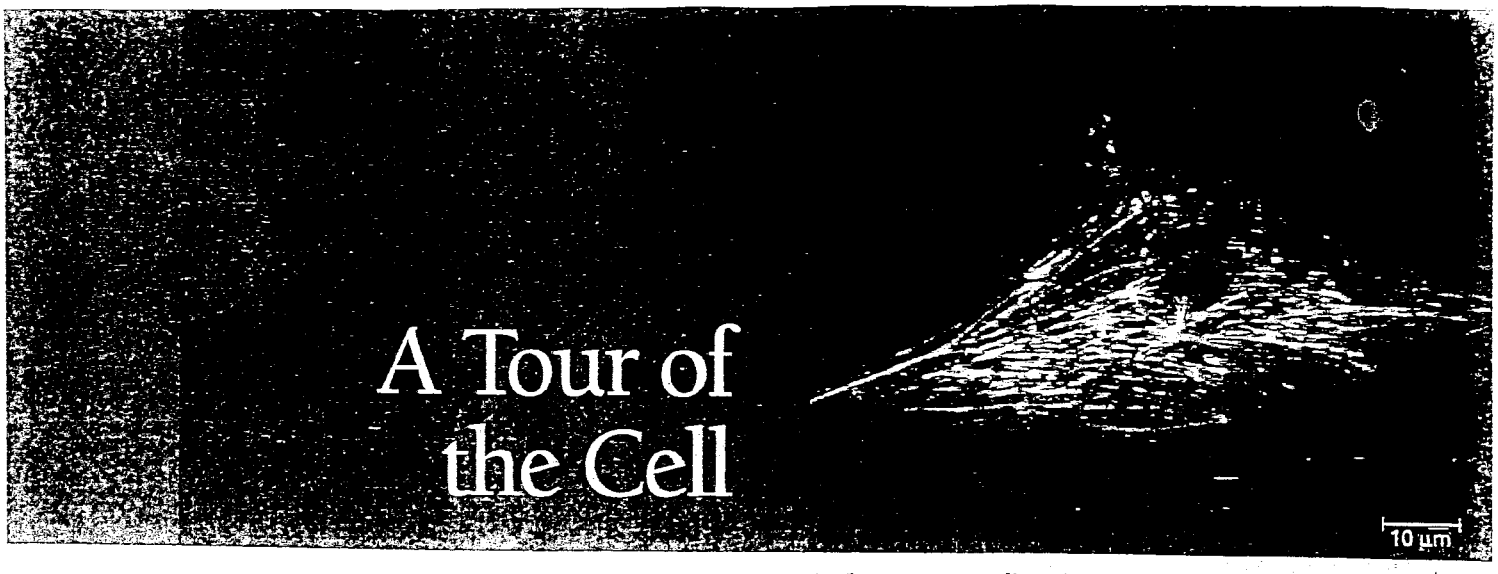
– تتم الدارة الخلوية خلال 24 ساعة تقريباً ..... في مرحلتين :

1- الطور البيني **interphase** ..... تهيئة الخلية وتحضيرها للانقسام، ثم

2- **طور الانقسام الخيطي (M) mitotic phase** للخلايا.



A Tour of the Cell



▲ Figure 5.1 A cell and its skeleton viewed by fluorescence microscopy.

Key Concepts

- 5.1 To study cells, biologists use microscopes and the tools of biochemistry
- 5.2 Eukaryotic cells have internal membranes that compartmentalize their functions
- 5.3 The eukaryotic cell's genetic instructions are housed in the nucleus and carried out by the ribosomes
- 5.4 The endomembrane system regulates protein traffic and performs metabolic functions in the cell
- 5.5 Mitochondria and chloroplasts change energy from one form to another
- 5.6 The cytoskeleton is a network of fibers that organizes structures and activities in the cell
- 5.7 Extracellular components and connections between cells help coordinate cellular activities

Overview

The Importance of Cells

The cell is as fundamental to biology as the atom is to chemistry: All organisms are made of cells. In the hierarchy of biological organization, the cell is the simplest collection of matter that can live. Indeed, there are diverse forms of life existing as single-celled organisms. More complex organisms, including plants and animals, are multicellular; their bodies are cooperatives of many kinds of specialized cells that could not survive for long on their own. However, even when they are arranged into higher levels of organization, such as tissues and organs, cells can be singled out as the organism's basic units of structure and function. The contraction of muscle cells moves your eyes as you read this sentence; when you decide to turn the next page, nerve cells will transmit that decision from your brain to the muscle cells of your hand. Everything an organism does occurs fundamentally at the cellular level.

The cell is a microcosm that demonstrates most of the themes introduced in Chapter 1. Life at the cellular level arises from structural order, reinforcing the themes of emergent properties and the correlation between structure and function. For example, the movement of an animal cell depends on an intricate interplay of the structures that make up a cellular skeleton (green and red in the micrograph in Figure 5.1). Another recurring theme in biology is the interaction of organisms with their environment. Cells sense and respond to environmental fluctuations. And keep in mind the one biological theme that unifies all others: evolution. All cells are related by their descent from earlier cells. However, they have been modified in many different ways during the long evolutionary history of life on Earth.

Although cells can differ substantially from each other, they share certain common characteristics. In this chapter, we'll first learn about the tools and experimental approaches that have allowed us to understand subcellular details; then we'll tour the cell and become acquainted with its components.

Concept

To study cells, biologists use microscopes and the tools of biochemistry

It can be difficult to understand how a cell, usually too small to be seen by the unaided eye, can be so complex. How can cell biologists possibly investigate the inner workings of such tiny entities? Before we actually tour the cell, it will be helpful to learn how cells are studied.

Microscopy

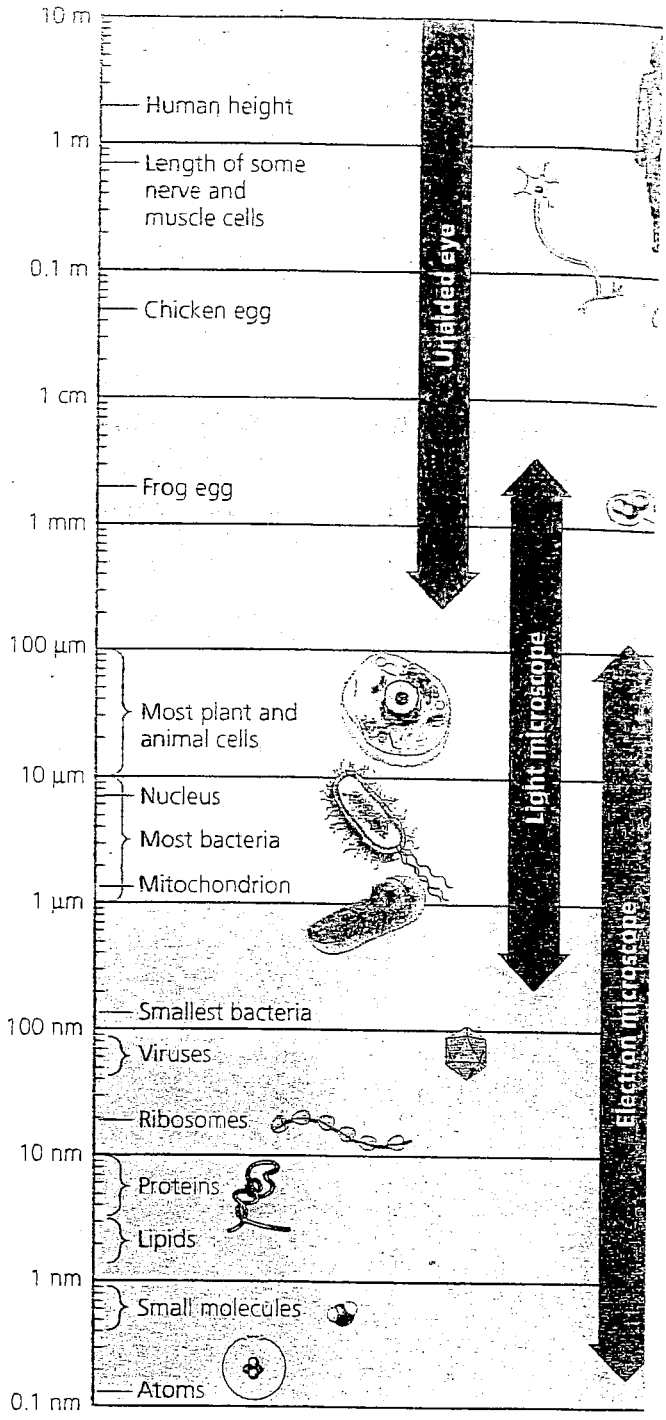
The advance of a scientific field often parallels the invention of instruments that extend human senses to new limits. The discovery and early study of cells progressed with the invention of microscopes in 1590 and their improvement in the 17th century. Microscopes of various types are still indispensable tools for the study of cells.

The microscopes first used by Renaissance scientists, as well as the microscopes you are likely to use in the laboratory, are all **light microscopes (LMs)**. Visible light is passed through the specimen and then through glass lenses. The lenses refract (bend) the light in such a way that the image of the specimen is magnified as it is projected into the eye, onto photographic film or a digital sensor, or onto a video screen. (See the diagram of microscope structure in Appendix C.)

Two important parameters in microscopy are magnification and resolving power, or resolution. *Magnification* in microscopy is the ratio of an object's image size to its real size. *Resolution* is a measure of the clarity of the image; it is the minimum distance two points can be separated and still be distinguished as two points. For example, what appears to the unaided eye as one star in the sky may be resolved as twin stars with a telescope.

Just as the resolving power of the human eye is limited, the resolution of telescopes and microscopes is limited. Microscopes can be designed to magnify objects as much as desired, but the light microscope cannot resolve detail finer than about 0.2 micrometer (μm), or 200 nanometers (nm), the size of a small bacterium (**Figure 6.2**). This resolution is limited by the shortest wavelength of light used to illuminate the specimen. Light microscopes can magnify effectively to about 1,000 times the size of the actual specimen; at greater magnifications, the image becomes increasingly blurry. Most of the improvements in light microscopy since the beginning of the 20th century have involved new methods for enhancing contrast, which clarifies the details that can be resolved (**Figure 6.3**, next page). In addition, scientists have developed methods for staining or labeling particular cell components so that they stand out visually.

Although cells were discovered by Robert Hooke in 1665, the geography of the cell was largely uncharted until the 1950s. Most subcellular structures, or **organelles**, are too small to be resolved by the light microscope. Cell biology advanced rapidly in the 1950s with the introduction of the electron microscope. Instead of using light, the **electron microscope (EM)** focuses a beam of electrons through the specimen or onto its surface (see Appendix C). Resolution is inversely related to the wavelength of the radiation a microscope uses for imaging, and electron beams have wavelengths much shorter than the wavelengths of visible light. Modern electron microscopes can theoretically achieve a resolution of about 0.002 nm, but the practical limit for biological structures is generally only about 2 nm—still a hundredfold improvement over the light microscope. Biologists use the term *cell ultrastructure* to refer to a cell's anatomy as revealed by an electron microscope.



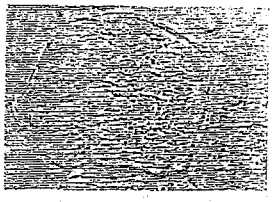
Measurements
1 centimeter (cm) = 10^{-2} meter (m) = 0.4 inch
1 millimeter (mm) = 10^{-3} m
1 micrometer (μm) = 10^{-3} mm = 10^{-6} m
1 nanometer (nm) = 10^{-3} μm = 10^{-9} m

▲ Figure 6.2 The size range of cells. Most cells are betw 1 and 100 μm in diameter (yellow region of chart) and are then visible only under a microscope. Notice that the scale along the is logarithmic to accommodate the range of sizes shown. Starti the top of the scale with 10 m and going down, each reference measurement marks a tenfold decrease in diameter or length. F complete table of the metric system, see Appendix B.

Figure 6.3 Light Microscopy

TECHNIQUE | RESULTS

a) **Brightfield (unstained specimen).** Passes light directly through specimen. Unless cell is naturally pigmented or artificially stained, image has little contrast. [Parts (a)–(d) show a human cheek epithelial cell.]

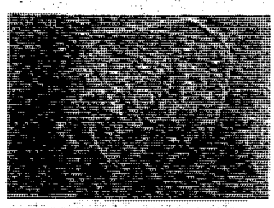


50 µm

b) **Brightfield (stained specimen).** Staining with various dyes enhances contrast, but most staining procedures require that cells be fixed (preserved).

c) **Phase-contrast.** Enhances contrast in unstained cells by amplifying variations in density within specimen; especially useful for examining living, unpigmented cells.

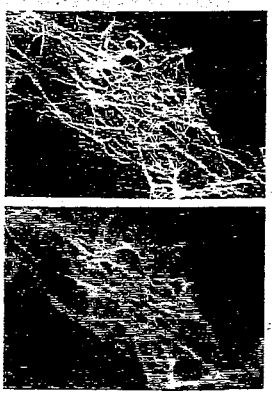
d) **Differential-interference-contrast (Nomarski).** Like phase-contrast microscopy, it uses optical modifications to exaggerate differences in density, making the image appear almost 3D.



e) **Fluorescence.** Shows the locations of specific molecules in the cell by tagging the molecules with fluorescent dyes or antibodies. These fluorescent substances absorb ultraviolet radiation and emit visible light, as shown here in a cell from an artery.

50 µm

f) **Confocal.** Uses lasers and special optics for "optical sectioning" of fluorescently-stained specimens. Only a single plane of focus is illuminated; out-of-focus fluorescence above and below the plane is subtracted by a computer. A sharp image results, as seen in stained nervous tissue (top), where nerve cells are green, support cells are red, and regions of overlap are yellow. A standard fluorescence micrograph (bottom) of this relatively thick tissue is blurry.

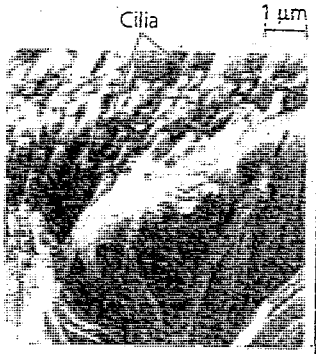


50 µm

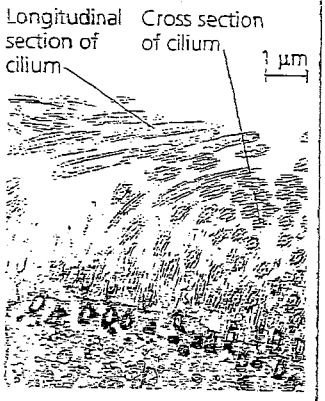
Figure 6.4 Electron Microscopy

TECHNIQUE | RESULTS

(a) **Scanning electron microscopy (SEM).** Micrographs taken with a scanning electron microscope show a 3D image of the surface of a specimen. This SEM shows the surface of a cell from a rabbit trachea (windpipe) covered with motile organelles called cilia. Beating of the cilia helps move inhaled debris upward toward the throat.



(b) **Transmission electron microscopy (TEM).** A transmission electron microscope profiles a thin section of a specimen. Here we see a section through a tracheal cell, revealing its ultrastructure. In preparing the TEM, some cilia were cut along their lengths, creating longitudinal sections, while other cilia were cut straight across, creating cross sections.



There are two basic types of electron microscopes: the **scanning electron microscope (SEM)** and the **transmission electron microscope (TEM)**. The SEM is especially useful for detailed study of the surface of a specimen (Figure 6.4a). The electron beam scans the surface of the sample, which is usually coated with a thin film of gold. The beam excites electrons on the sample's surface, and these secondary electrons are detected by a device that translates the pattern of electrons into an electronic signal to a video screen. The result is an image of the topography of the specimen. The SEM has great depth of field, which results in an image that appears three-dimensional.

Cell biologists use the TEM mainly to study the internal ultrastructure of cells (Figure 6.4b). The TEM aims an electron beam through a very thin section of the specimen, similar to the way a light microscope transmits light through a slide. The specimen has been stained with atoms of heavy metals, which attach to certain cellular structures, thus enhancing the electron density of some parts of the cell more than others. The electrons passing through the specimen are scattered more in the denser regions, so fewer electrons are transmitted. The image is created by the pattern of transmitted electrons. Instead of using glass lenses, the TEM uses electromagnets as lenses to bend the paths of the electrons, ultimately focusing the image onto a screen for viewing or onto photographic film. Some microscopes are

.pped with a digital camera to photograph the image on screen; others are equipped with a digital detector in place oth screen and camera.

lectron microscopes reveal many organelles that are im- ible to resolve with the light microscope. But the light mi- cope offers advantages, especially for the study of living . A disadvantage of electron microscopy is that the meth- used to prepare the specimen kill the cells. Also, specimen paration can introduce artifacts, structural features seen in rographs that do not exist in the living cell (as is true for nicroscopy techniques). From this point on in the book, rographs are identified by the type of microscopy: LM for ht micrograph, SEM for a scanning electron micrograph, TEM for a transmission electron micrograph.

Microscopes are the most important tools of *cytology*, the y of cell structure. But simply describing the diverse or- elles within the cell reveals little about their function. Mod- cell biology developed from an integration of cytology with *hemistry*, the study of the molecules and chemical processes tabolism) of cells. A biochemical approach called cell tionation has been particularly important in cell biology.

lating Organelles by Cell Fractionation

goal of cell fractionation is to take cells apart and sepa- the major organelles from one another (Figure 6.5). The rument used to fractionate cells is the centrifuge, which spin test tubes holding mixtures of disrupted cells at var- speeds. The resulting force separates the cell components size and density. The most powerful machines, called acentrifuges, can spin as fast as 130,000 revolutions per ute (rpm) and apply forces on particles of more than illion times the force of gravity (1,000,000 *g*).

Cell fractionation enables the researcher to prepare specific nponents of cells in bulk quantity to study their composition functions. By following this approach, biologists have been to assign various functions of the cell to the different or- elles, a task that would be far more difficult with intact cells. example, one cellular fraction collected by centrifugation enzymes that function in the metabolic process known as ular respiration. The electron microscope reveals this fraction e very rich in the organelles called mitochondria. This evi- ce helped cell biologists determine that mitochondria are the of cellular respiration. Cytology and biochemistry comple- it each other in correlating cellular structure and function.

oncept Check

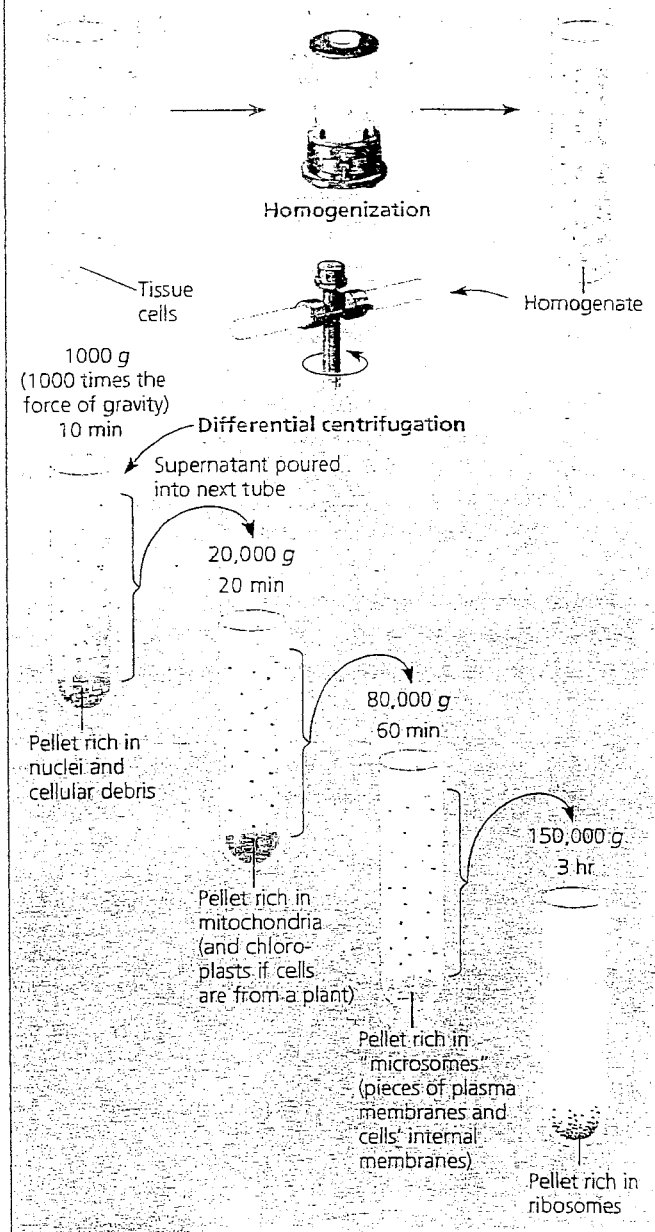
.. Which type of microscope would you use to study (a) the changes in shape of a living white blood cell, (b) the details of surface texture of a hair, and (c) the detailed structure of an organelle?

For suggested answers, see Appendix A.

Figure 6.5 **Cell Fractionation**

APPLICATION Cell fractionation is used to isolate (fractionate) cell components, based on size and density.

TECHNIQUE First, cells are homogenized in a blender to break them up. The resulting mixture (cell homogenate) is then centrifuged at various speeds and durations to fractionate the cell components, forming a series of pellets.



RESULTS In the original experiments, the researchers used microscopy to identify the organelles in each pellet, establishing a baseline for further experiments. In the next series of experiments, researchers used biochemical methods to determine the metabolic functions associated with each type of organelle. Researchers currently use cell fractionation to isolate particular organelles in order to study further details of their function.

Concept

Eukaryotic cells have internal membranes that compartmentalize their functions

The basic structural and functional unit of every organism is one of two types of cells—prokaryotic or eukaryotic. Only organisms of the domains Bacteria and Archaea consist of prokaryotic cells. Protists, fungi, animals, and plants all consist of eukaryotic cells. This chapter focuses on generalized animal and plant cells, after first comparing them with prokaryotic cells.

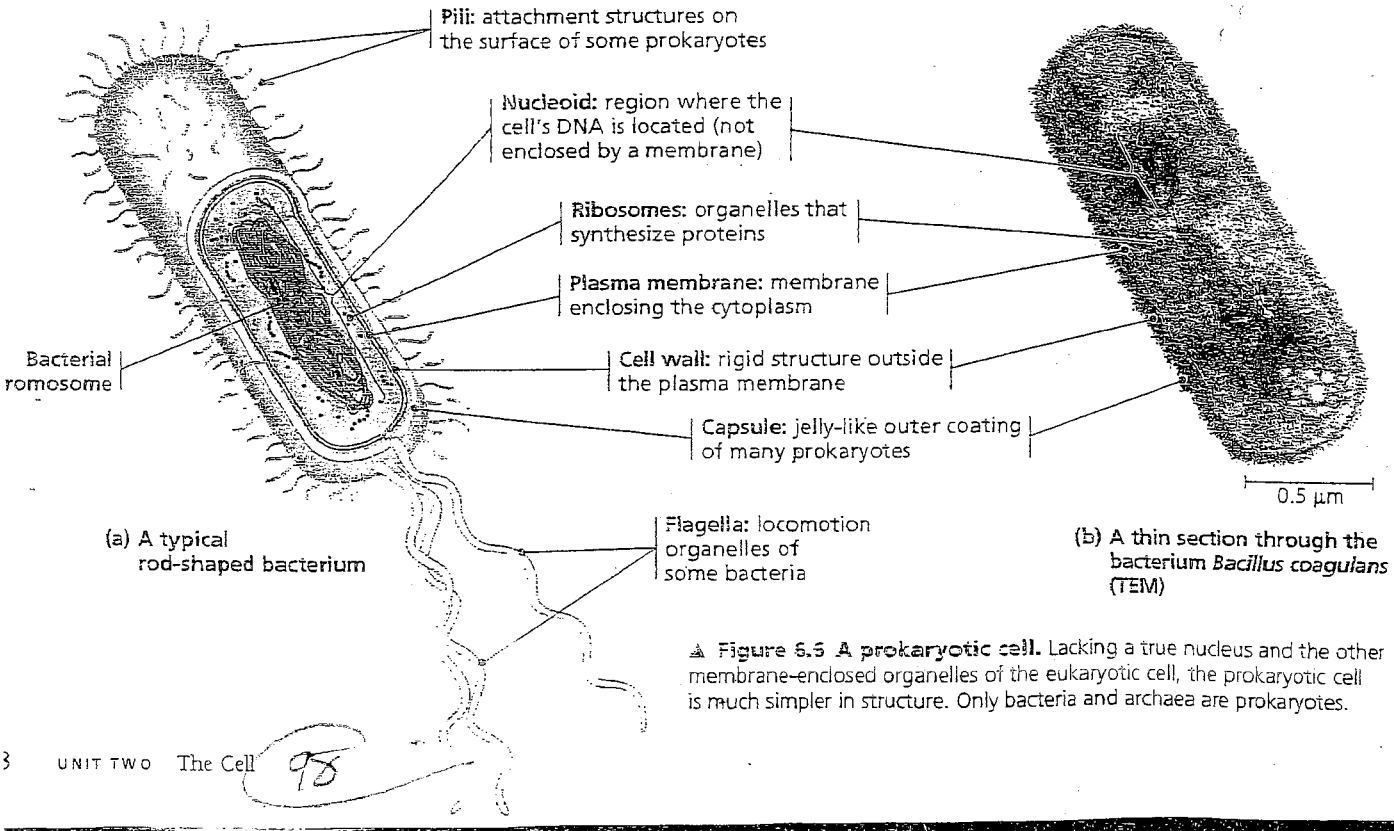
Comparing Prokaryotic and Eukaryotic Cells

All cells have several basic features in common: They are all bounded by a membrane, called a *plasma membrane*. Within the membrane is a semifluid substance, **cytosol**, in which organelles are found. All cells contain *chromosomes*, carrying genes in the form of DNA. And all cells have *ribosomes*, tiny organelles that make proteins according to instructions from the genes.

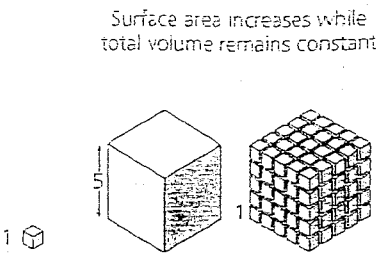
A major difference between prokaryotic and eukaryotic cells, indicated by their names, is that the chromosomes of a prokaryotic cell are located in a membrane-enclosed organelle called the *nucleus*. The word *prokaryotic* is from the Greek *pro*, meaning "before," and *karyon*, meaning "kernel," referring here to the nucleus. In a **prokaryotic cell** (Figure 6.5), the DNA is concentrated in a region called the **nucleoid**, but no membrane separates this region from the rest of the cell. In contrast, the **eukaryotic cell** (Greek *eu*, true, and *karyon*) has a true nucleus, bounded by a membranous nuclear envelope (see Figure 6.9, pp. 100–101). The entire region between the nucleus and the plasma membrane is called the **cytoplasm**, a term also used for the interior of a prokaryotic cell. Within the cytoplasm of a eukaryotic cell, suspended in cytosol, are a variety of membrane-bounded organelles of specialized form and function. These are absent in prokaryotic cells. Thus, the presence or absence of a true nucleus is just one example of the disparity in structural complexity between the two types of cells.

Eukaryotic cells are generally quite a bit bigger than prokaryotic cells (see Figure 6.2). Size is a general aspect of cell structure that relates to function. The logistics of carrying out cellular metabolism sets limits on cell size. At the lower limit, the smallest cells known are bacteria called mycoplasmas, which have diameters between 0.1 and 1.0 μm. These are perhaps the smallest packages with enough DNA to program metabolism and enough enzymes and other cellular equipment to carry out the activities necessary for a cell to sustain itself and reproduce. Most bacteria are 1–10 μm in diameter, a dimension about ten times greater than that of mycoplasmas. Eukaryotic cells are typically 10–100 μm in diameter.

Metabolic requirements also impose theoretical upper limits on the size that is practical for a single cell. As an object of a particular shape increases in size, its volume grows proportionately more than its surface area. (Area is proportional to a linear dimension squared, whereas volume is proportional to the linear dimension cubed.) Thus, the smaller the object, the greater its ratio of surface area to volume (Figure 6.7).



▲ **Figure 6.5 A prokaryotic cell.** Lacking a true nucleus and the other membrane-enclosed organelles of the eukaryotic cell, the prokaryotic cell is much simpler in structure. Only bacteria and archaea are prokaryotes.



	1	150	750
Total surface area (height × width × number of sides × number of boxes)	6	150	750
Total volume (height × width × length × number of boxes)	1	125	125
Surface-to-volume ratio (surface area ÷ volume)	6	1.2	6

Figure 6.7 Geometric relationships between surface area and volume. In this diagram, cells are represented as boxes. Using arbitrary units of length, we can calculate the cell's surface area (in square units), volume (in cubic units), and ratio of surface area to volume. The smaller the cell, the higher the surface-to-volume ratio. A high surface-to-volume ratio facilitates the exchange of materials between a cell and its environment.

At the boundary of every cell, the **plasma membrane** functions as a selective barrier that allows sufficient passage of oxygen, nutrients, and wastes to service the entire volume of the cell (Figure 6.8). For each square micrometer of membrane, only so much of a particular substance can cross per second. Rates of chemical exchange with the extracellular environment might be inadequate to maintain a cell with a very large cytoplasm. The need for a surface area sufficiently large to accommodate the volume helps explain the microscopic size of most cells. Larger organisms do not generally have *larger* cells than smaller organisms—simply *more* cells. A sufficiently high ratio of surface area to volume is especially important in cells that exchange a lot of material with their surroundings, such as intestinal cells. Such cells may have many long, thin projections from their surface called microvilli, which increase surface area without an appreciable increase in volume.

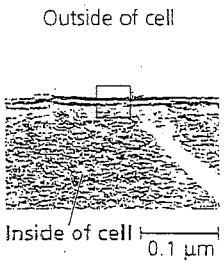
Prokaryotic cells will be described in detail in Chapters 18 and 27 (see Table 27.2 for a comparison of prokaryotes and eukaryotes), and the possible evolutionary relationships between prokaryotic and eukaryotic cells will be discussed in Chapter 26. Most of the discussion of cell structure that follows in this chapter applies to eukaryotic cells.

A Panoramic View of the Eukaryotic Cell

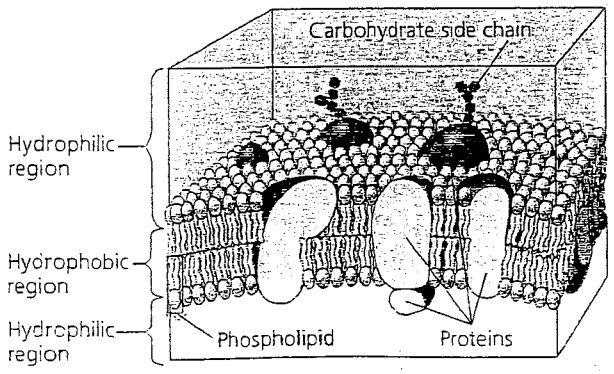
In addition to the plasma membrane at its outer surface, a eukaryotic cell has extensive and elaborately arranged internal membranes, which partition the cell into compartments—the membranous organelles mentioned earlier. These membranes also participate directly in the cell's metabolism, because many enzymes are built right into the membranes. Furthermore, the cell's compartments provide different local environments that facilitate specific metabolic functions, so incompatible processes can go on simultaneously inside the same cell.

Membranes of various kinds are fundamental to the organization of the cell. In general, biological membranes consist of a double layer of phospholipids and other lipids. Embedded in this lipid bilayer or attached to its surfaces are diverse proteins (see Figure 6.8). However, each type of membrane has a unique composition of lipids and proteins suited to that membrane's specific functions. For example, enzymes embedded in the membranes of the organelles called mitochondria function in cellular respiration.

Before continuing with this chapter, examine the overviews of eukaryotic cells in **Figure 6.9** on the next two pages. These generalized cell diagrams introduce the various organelles and provide a map of the cell for the detailed tour upon which we will now embark. Figure 6.9 also contrasts animal and plant cells. As eukaryotic cells, they have much more in common than either has with any prokaryotic cell. As you will see, however, there are important differences between animal and plant cells.



(a) TEM of a plasma membrane. The plasma membrane, here in a red blood cell, appears as a pair of dark bands separated by a light band.



(b) Structure of the plasma membrane

Figure 6.8 The plasma membrane. The plasma membrane and the membranes of organelles consist of a double layer (bilayer) of phospholipids with various proteins attached to or embedded in it. The phospholipid tails in the interior of a membrane are hydrophobic; the interior portions of membrane proteins are also hydrophobic. The phospholipid heads, exterior proteins, exterior parts of proteins, and carbohydrate side chains are hydrophilic and in contact with the aqueous solution on either side of the membrane. Carbohydrate side chains are found only on the outer surface of the plasma membrane. The specific functions of a membrane depend on the kinds of phospholipids and proteins present.

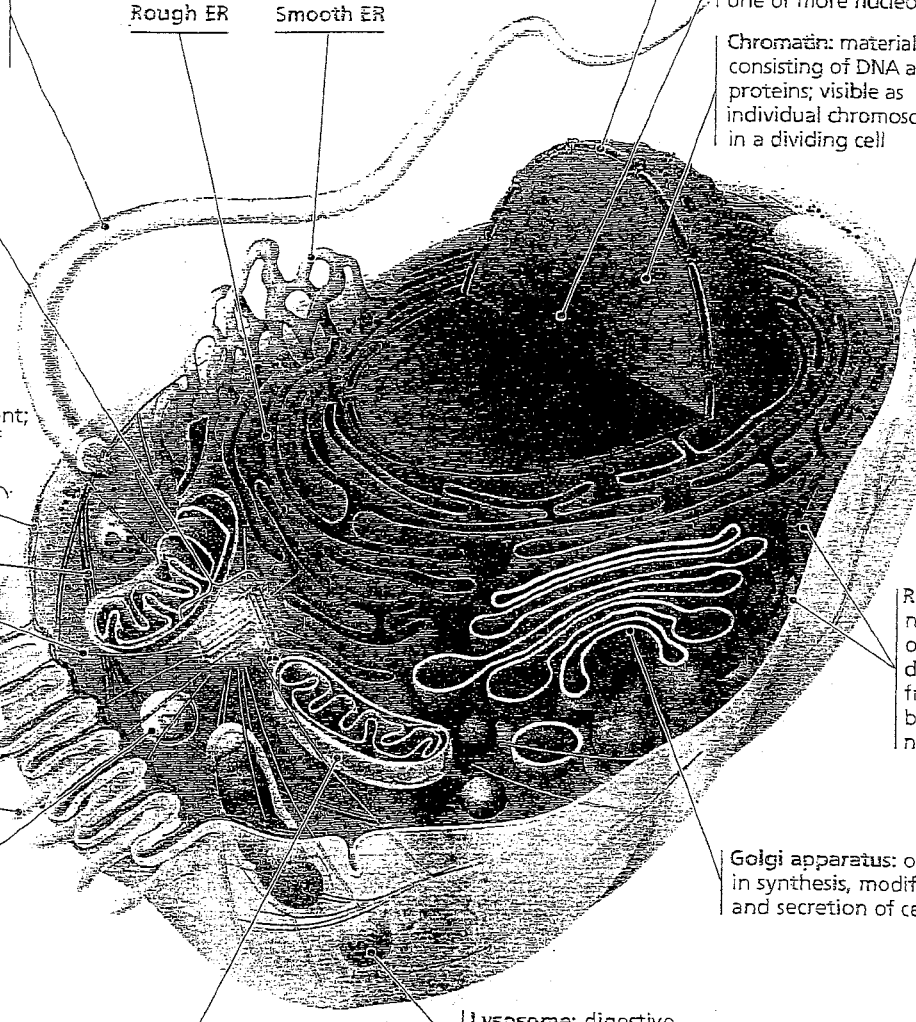
Figure 6.9

Animal and Plant Cells

ANIMAL CELL

This drawing of a generalized animal cell incorporates the most common structures of animal cells (no cell actually looks just like this). As shown by this cutaway view, the cell has a variety of organelles ("little organs"), many of which are bounded by membranes. The most prominent organelle in an animal cell is usually the nucleus.

Most of the cell's metabolic activities occur in the cytoplasm, the entire region between the nucleus and the plasma membrane. The cytoplasm contains many organelles suspended in a semifluid medium, the cytosol. Pervading much of the cytoplasm is a labyrinth of membranes called the endoplasmic reticulum (ER).



Nuclear envelope: double membrane enclosing the nucleus; perforated by pores; continuous with ER

Nucleolus: nonmembranous organelle involved in production of ribosomes; a nucleus has one or more nucleoli

Chromatin: material consisting of DNA and proteins; visible as individual chromosomes in a dividing cell

NUCLEUS

ENDOPLASMIC RETICULUM (ER): network of membranous sacs and tubes; active in membrane synthesis and other synthetic and metabolic processes; has rough (ribosome-studded) and smooth regions

Rough ER

Smooth ER

Flagellum: locomotion organelle present in some animal cells; composed of membrane-enclosed microtubules

Centrosome: region where the cell's microtubules are initiated; in an animal cell, contains a pair of centrioles (function unknown)

CYTOSKELETON: reinforces cell's shape, functions in cell movement; components are made of protein

Microfilaments

Intermediate filaments

Microtubules

Microvilli: projections that increase the cell's surface area

Peroxisome: organelle with various specialized metabolic functions; produces hydrogen peroxide

Mitochondrion: organelle where cellular respiration occurs and most ATP is generated

Lysosome: digestive organelle where macromolecules are hydrolyzed

Plasma membrane: membrane enclosing the cell

Ribosomes: nonmembranous organelles (small brown dots) that make proteins; free in cytoplasm or bound to rough ER or nuclear envelope

Golgi apparatus: organelle active in synthesis, modification, sorting, and secretion of cell products

In animal cells but not plant cells:
Lysosomes
Centrioles
Flagella (in some plant sperm)