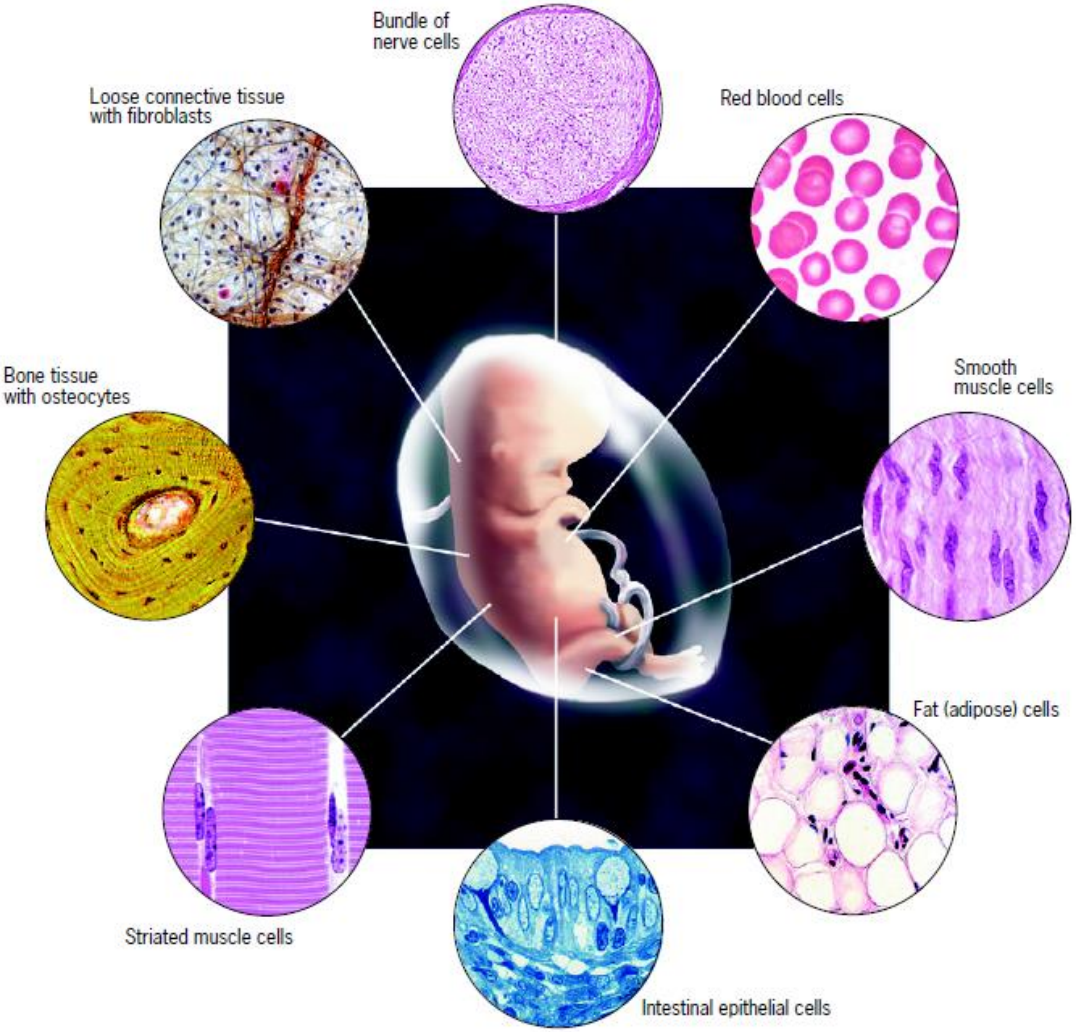
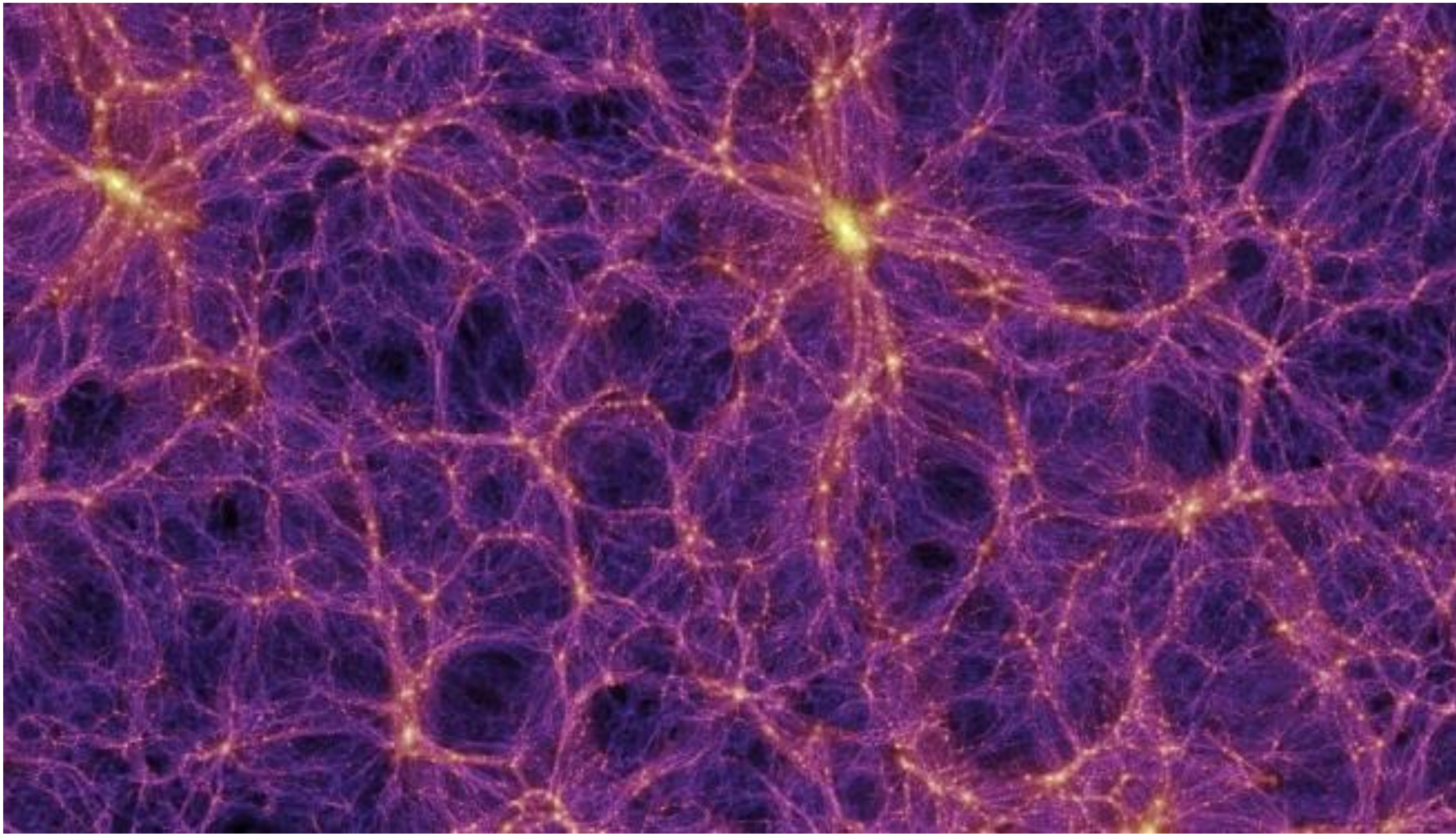
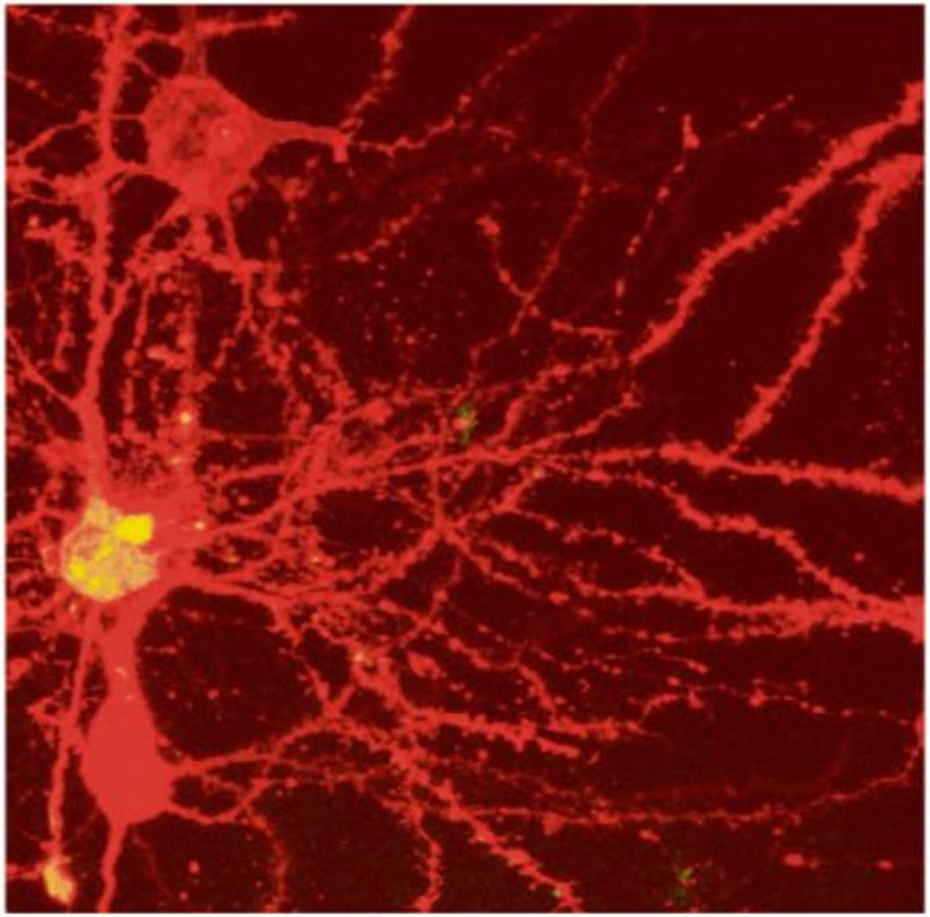
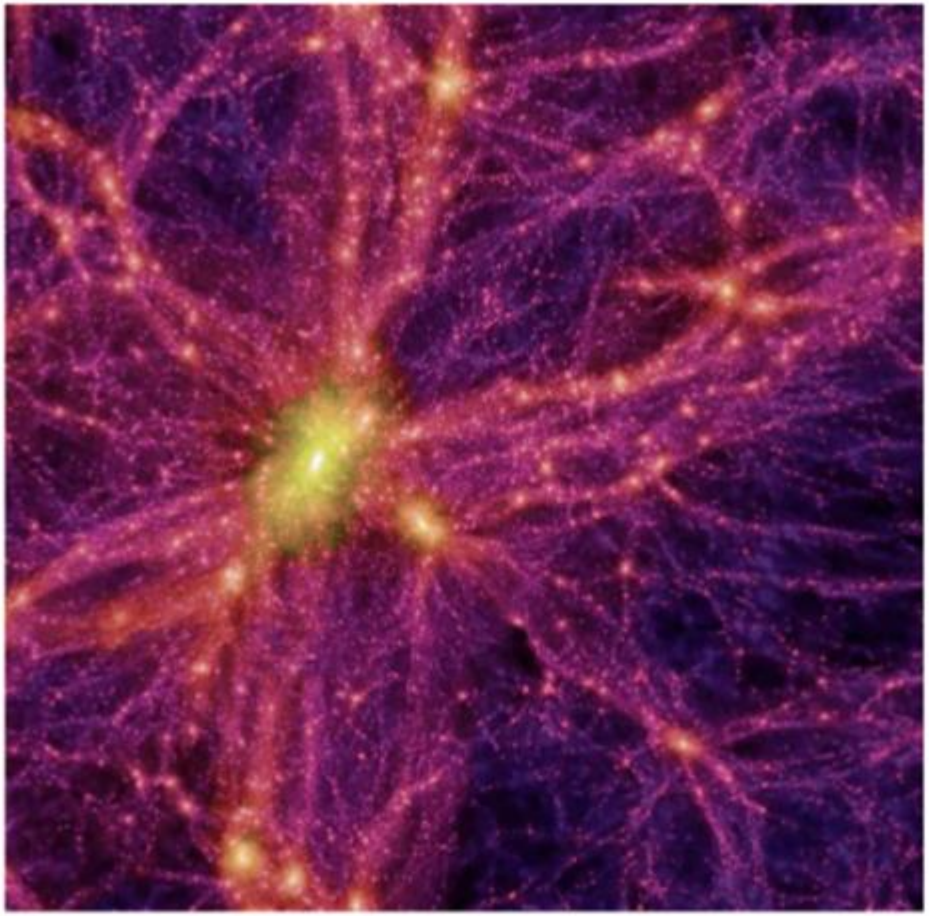
Introduction to the Molecular Biology of the Cell





The Discovery of Cells

- Cells, and the structures they comprise, are too small to be directly seen, heard, or touched.

- Because of their small size, cells can only be observed with the aid of a microscope.

- By the mid-1600s, a handful of pioneering scientists had used their handmade microscopes to uncover a world that would never have been revealed to the naked eye and the discovery of cells is generally credited to Robert Hooke

- Anton van Leeuwenhoek, a Dutchman, was the first to examine a drop of pond water under the microscope and describe various forms of bacteria.

- In 1838, Matthias Schleiden, a German lawyer turned botanist, concluded that, despite differences in the structure of various tissues, plants were made of cells.

- In 1839, Theodor Schwann, a German zoologist published a comprehensive report on the cellular basis of animal life and proposed the cell theory:

    - All organisms are composed of one or more cells.

    - The cell is the structural unit of life.

- By 1855, Rudolf Virchow, a German pathologist, had made the third tenet of the cell theory:

  - Cells can arise only by division from a preexisting cell.

- **Life, is the most basic property of cells**, and cells are the smallest units to exhibit this property.

- Unlike the parts of a cell, which simply deteriorate if isolated, whole cells can be removed from a plant or animal and cultured in a laboratory.

- Death can also be considered one of the most basic properties of life.

- Cells within the body generally die "by their own hand" according to an internal program.

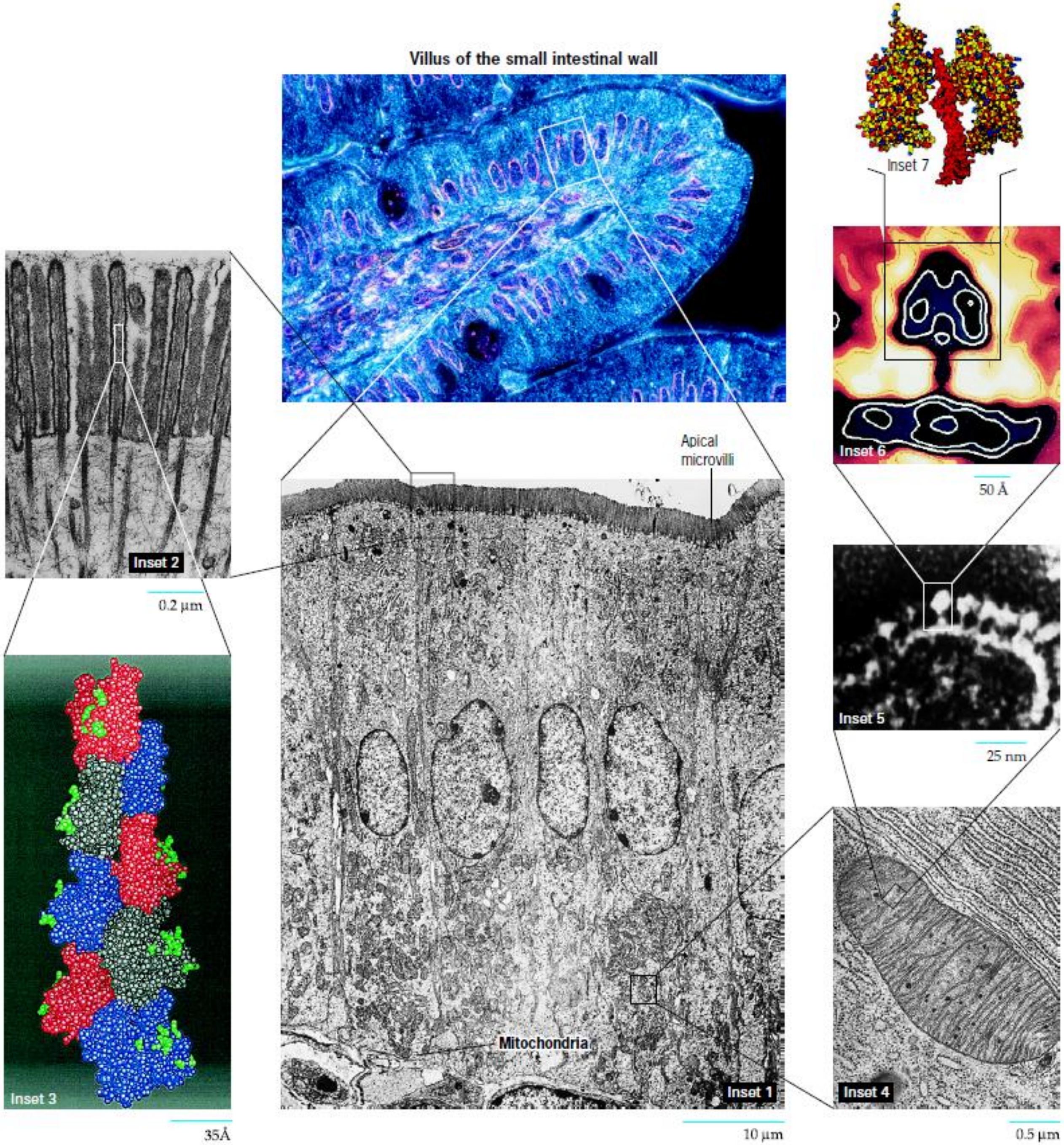
- The first culture of human cells was begun by George and Martha Gey in 1951.

- The cells were obtained from a malignant tumor and named HeLa cells after the donor, Henrietta Lacks.

- HeLa cells—descended by cell division from this first cell sample—are still being grown in laboratories around the world today.

- Because they are so much simpler to study than cells situated within the body, cells grown *in vitro* have become an essential tool of cell and molecular biologists.

- **Cells are highly complex and organized structures.**
- A molecular biologist should consider the complexity of life at several different levels;
  - organization of atoms into small-sized molecules;
  - the organization of these molecules into giant polymers;
  - the organization of different types of polymeric molecules into complexes,
  - and organization of subcellular organelles and finally into cells.
- There is a great deal of consistency at every level. Each type of cell has a consistent appearance when viewed under a high-powered electron microscope.


Villus of the small intestinal wall
Inset 7
Inset 6
50 Å
Inset 2
0.2 µm
Apical
microvilli
Inset 5
25 nm
Inset 3
35Å
Mitochondria
Inset 1
10 µm
Inset 4
0.5 µm

- On the other hand evolution has moved slowly at the levels of biological organization.

- Whereas a human and a cat, for example, have very different anatomical features, the cells that make up their tissues, and the organelles that make up their cells, are very similar.

- The actin filament portrayed in Inset 3, and the ATP-synthesizing enzyme of Inset 6 are virtually identical to similar structures found in such diverse organisms as humans, snails, yeast, and redwood trees.

- Many of the most basic processes, such as the synthesis of proteins, the conservation of chemical energy, or the construction of a membrane, are remarkably similar in all living organisms.

- **Cells possess a genetic program and capable of reproducing.**
- Organisms are built according to information encoded in a collection of genes, which are constructed of DNA.
- Genes are more than storage lockers for information: they constitute the blueprints for constructing cellular structures, the directions for running cellular activities, and the program for making more of themselves.
- Cells reproduce by division, a process in which the contents of a “mother” cell are distributed into two “daughter” cells.
- Prior to division, the genetic material is faithfully duplicated, and each daughter cell receives a complete and equal share of genetic information.

- **Since all biological processes requires the input of energy, cells need to aquire and utilize it**.

- Virtually all of the energy utilized by life on the Earth's surface arrives in the form of electromagnetic radiation from the sun.

- The energy of light is trapped by light-absorbing pigments present in the membranes of photosynthetic cells.

- Light energy is converted by photosynthesis into chemical energy that is stored in energy-rich carbohydrates, such as sucrose or starch.

- For most animal cells, energy arrives prepackaged, often in the form of the sugar glucose.

- Once in a cell, the glucose is disassembled in such a way that its energy content can be stored in a readily available form (usually as ATP).

- **Cells function like miniaturized chemical plants. Even the simplest bacterial cell is capable of hundreds of different chemical transformations.**

- Virtually all chemical changes that take place in cells require enzymes—molecules that greatly increase the rate at which a chemical reaction occurs.

- The sum total of the chemical reactions in a cell represents that cell's metabolism.

- **Cells also engage mechanical activities.**

- Materials are transported from place to place, structures are assembled and then rapidly disassembled, and, in many cases, the entire cell moves itself from one site to another.

- **Cells are able to respond to stimuli.** Most cells are covered with receptors that interact with substances (ligands) in highly specific ways.

- Cells possess receptors to hormones, growth factors, and extracellular materials, as well as to substances on the surfaces of other cells.

- A cell's receptors provide pathways through which external stimuli can evoke specific responses in target cells.

- Cells may respond to specific stimuli by altering their metabolic activities, moving from one place to another, or even committing suicide.

- **Cells are capable of self regulation.**
- Cells are robust, that is, durable, because they are protected from dangerous fluctuations in composition and behavior.
- Should such fluctuations occur, specific feedback circuits are activated that serve to return the cell to the appropriate state.
- In addition to requiring energy, maintaining a complex, ordered state requires constant regulation.
- The importance of a cell's regulatory mechanisms becomes most evident when they break down. For example, failure of a cell to correct a mistake when it duplicates its DNA may result destroying the entire organism.

- **One important aspect of cells are they are evolve.**

- Of all the major questions posed by biologists, this question may be the least likely ever to be answered.

- Whereas the origin of cells is shrouded in near-total mystery, the evolution of cells can be studied by examining organisms that are alive today.

- Different species share many features, including a common genetic code, a plasma membrane, and ribosomes.

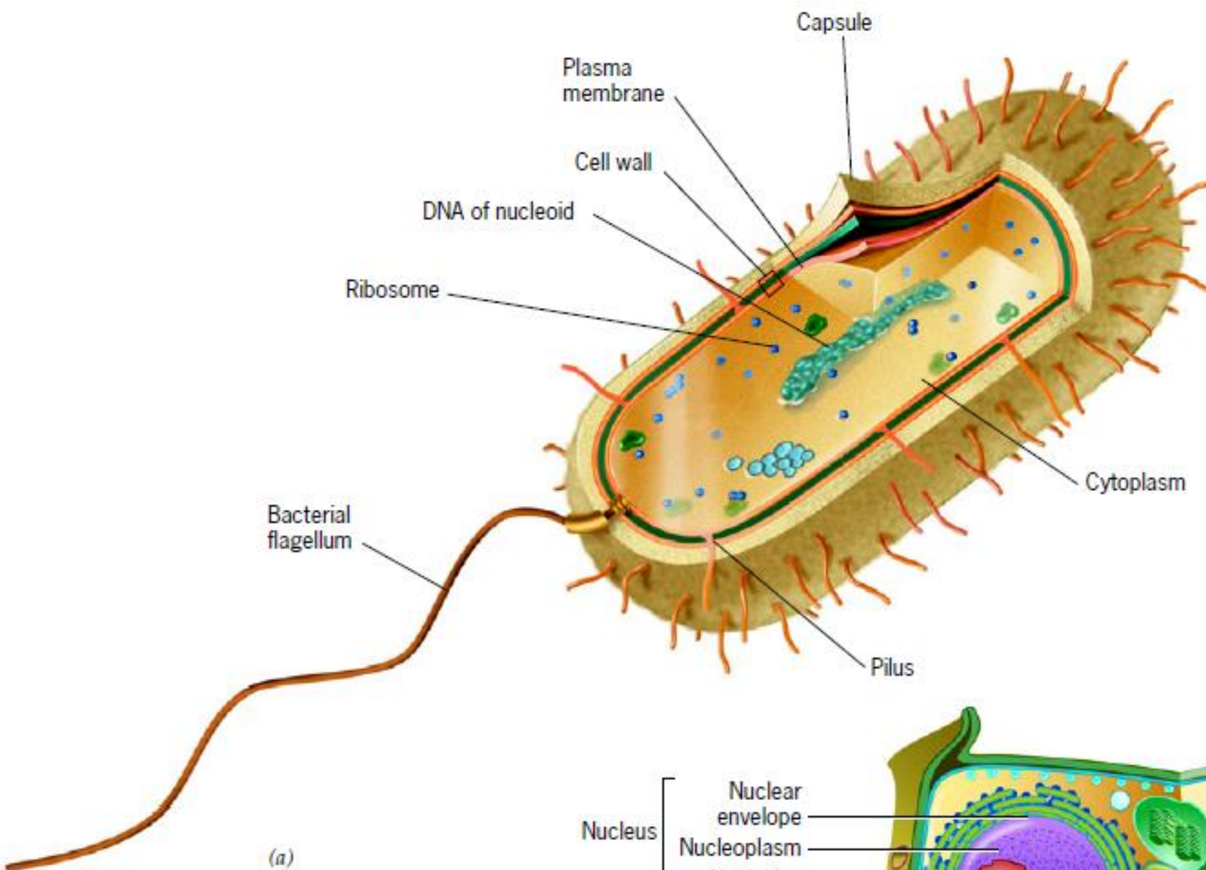
- According to one of the tenets of modern biology, all living organisms have evolved from a single, common ancestral cell that lived more than three billion years ago.

Classes of Cells

- There were two basic classes of cells distinguished by their size and the types of internal structures, or organelles, they contain.

- The existence of two distinct classes of cells, without any known intermediates, represents one of the most fundamental evolutionary divisions in the biological world.

- The structurally simpler prokaryotic cells include bacteria, whereas the structurally more complex eukaryotic cells include protists, fungi, plants, and animals.



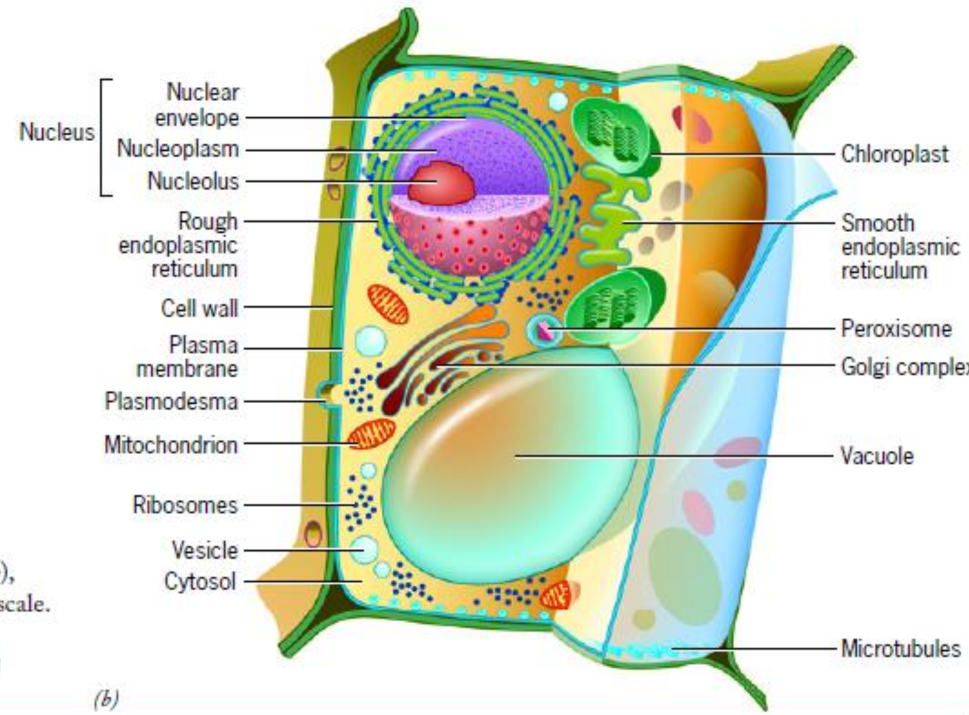


Figure 1.8 **The structure of cells.** Schematic diagrams of a "generalized" bacterial (*a*), plant (*b*), and animal (*c*) cell. Note: Organelles are not drawn to scale. (FROM D. J. DES MARAIS, SCIENCE 289:1704, 2001. COPYRIGHT © 2000. REPRINTED WITH PERMISSION FROM AAAS.)

- We are not sure when prokaryotic cells first appeared on Earth.

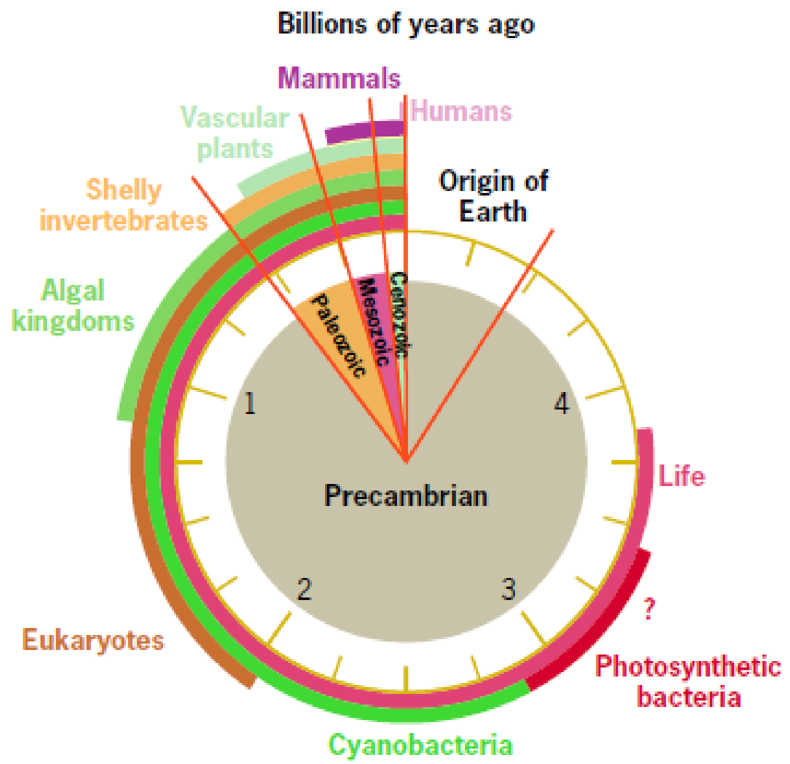
- Evidence of prokaryotic life has been obtained from rocks approximately 2.7 billion years of age.

- These rocks contain what appears to be fossilized microbes, also they contain complex organic molecules that are characteristic of particular types of prokaryotic organisms, including cyanobacteria.

- Cyanobacteria almost certainly appeared by 2.4 billion years ago, because that is when the atmosphere become infused with molecular oxygen (O_2), which is a byproduct of the photosynthetic activity of these prokaryotes.

- The dawn of the age of eukaryotic cells is also shrouded in uncertainty.

- Complex multicellular animals appear rather suddenly in the fossil record approximately 600 million years ago, but there is considerable evidence that simpler eukaryotic organisms were present on Earth more than one billion years earlier.



- The shared properties of eukaryotic and prokaryotic cells reflect the fact that eukaryotic cells almost certainly evolved from prokaryotic ancestors.

- Because of their common ancestry, both types of cells share an identical genetic language, a common set of metabolic pathways, and many common structural features.

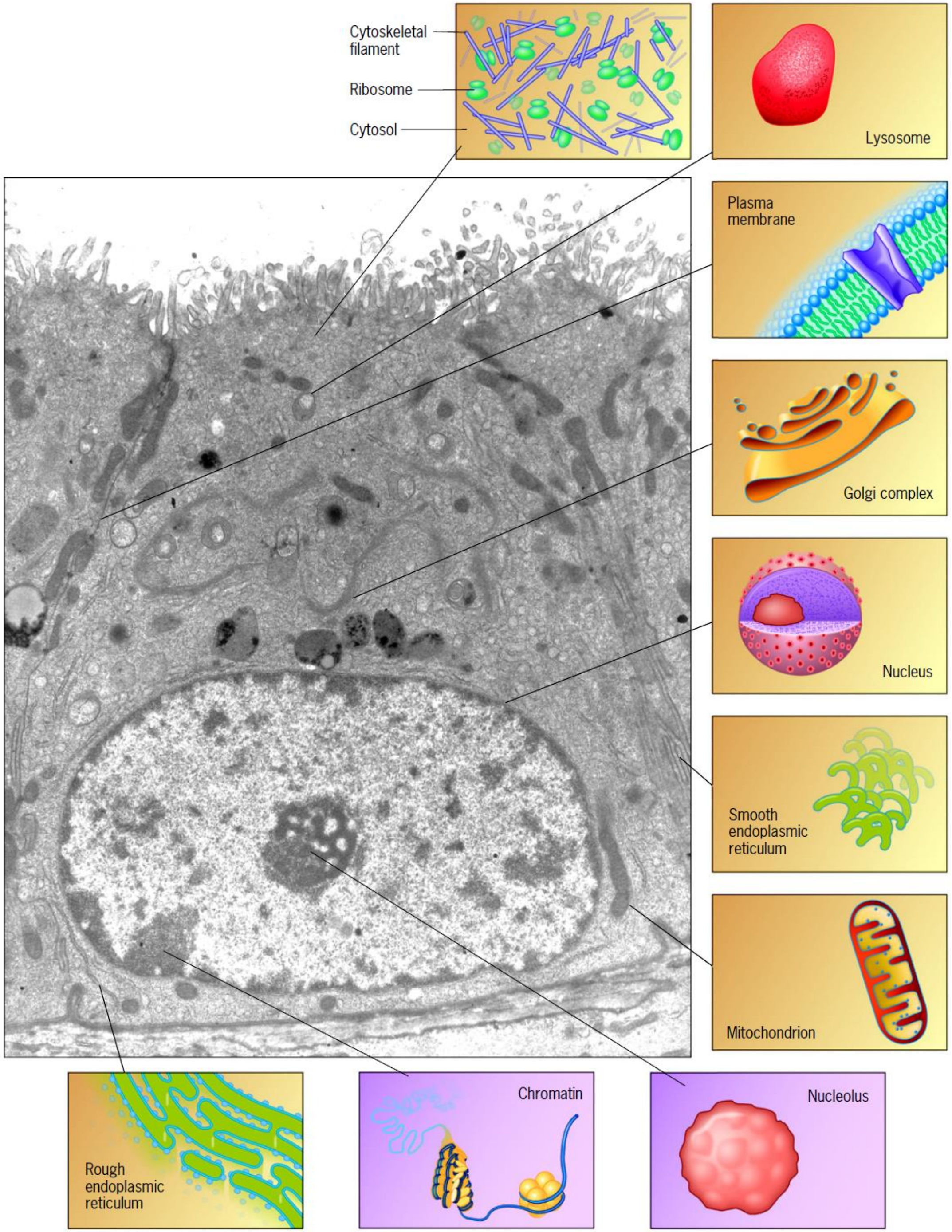
- Both contain a nuclear region, which houses the cell's genetic material, surrounded by cytoplasm.

- The genetic material of a prokaryotic cell is present in a nucleoid: a poorly demarcated region of the cell that lacks a boundary membrane to separate it from the surrounding cytoplasm.

- In contrast, eukaryotic cells possess a nucleus: a region bounded by a complex membranous structure.

- Prokaryotic cells contain relatively small amounts of DNA.
- Both prokaryotic and eukaryotic cells have DNA-containing chromosomes.
- Eukaryotic cells possess a number of separate chromosomes, each containing a single linear molecule of DNA.
- In contrast, nearly all prokaryotes that have been studied contain a single, circular chromosome.
- More importantly, the chromosomal DNA of eukaryotes, unlike that of prokaryotes, is tightly associated with proteins to form a complex nucleoprotein material known as chromatin.

- Eukaryotic cells contain an array of membrane-bound organelles.
- In contrast, the cytoplasm of prokaryotic cells is essentially devoid of membranous structures.
- The complex photosynthetic membranes of the cyanobacteria are a major exception to this generalization.
- The cytoplasmic membranes of eukaryotic cells form a system of interconnecting channels and vesicles that function in the transport of substances from one part of a cell to another, as well as between the inside of the cell and its environment.
- The necessary movement of materials in prokaryotic cells can be accomplished by simple diffusion.

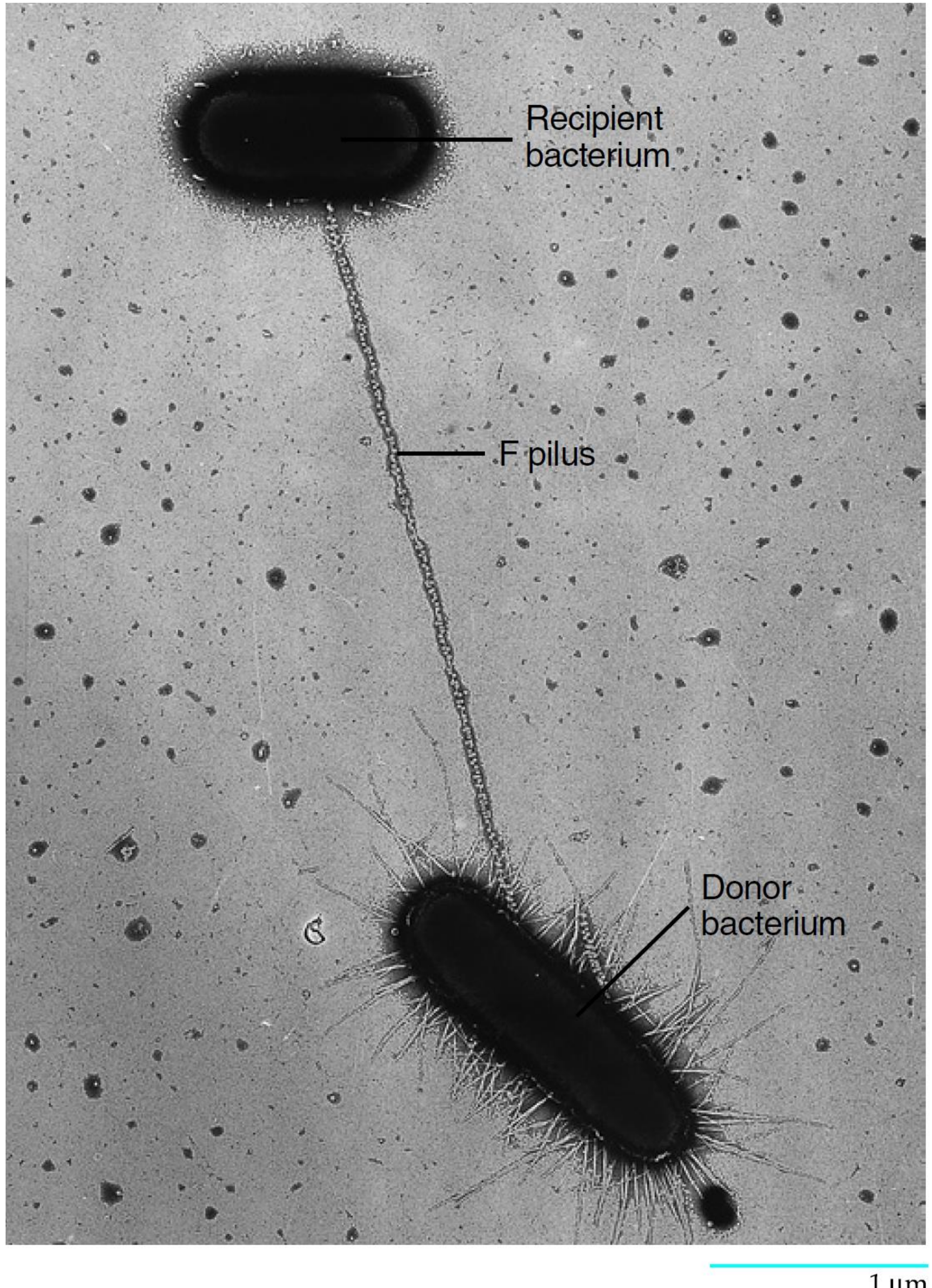


Cytoskeletal filament
Ribosome
Cytosol
Lysosome
Plasma membrane
Golgi complex
Nucleus
Smooth endoplasmic reticulum
Mitochondrion
Rough endoplasmic reticulum
Chromatin
Nucleolus

- For the most part, prokaryotes are nonsexual organisms. They contain only one copy of their single chromosome and have no processes comparable to meiosis, gamete formation, or true fertilization.

- Even though true sexual reproduction is lacking among prokaryotes, some are capable of conjugation, in which a piece of DNA is passed from one cell to another.

- Although prokaryotes may not be as efficient as eukaryotes in exchanging DNA with other members of their own species, they are more adept than eukaryotes at picking up and incorporating foreign DNA from their environment.


Recipient bacterium
F pilus
Donor bacterium
1 μm

- Eukaryotic cells possess a variety of complex locomotor mechanisms, whereas those of prokaryotes are relatively simple.
- The movement of a prokaryotic cell may be accomplished by a thin protein filament, called a flagellum

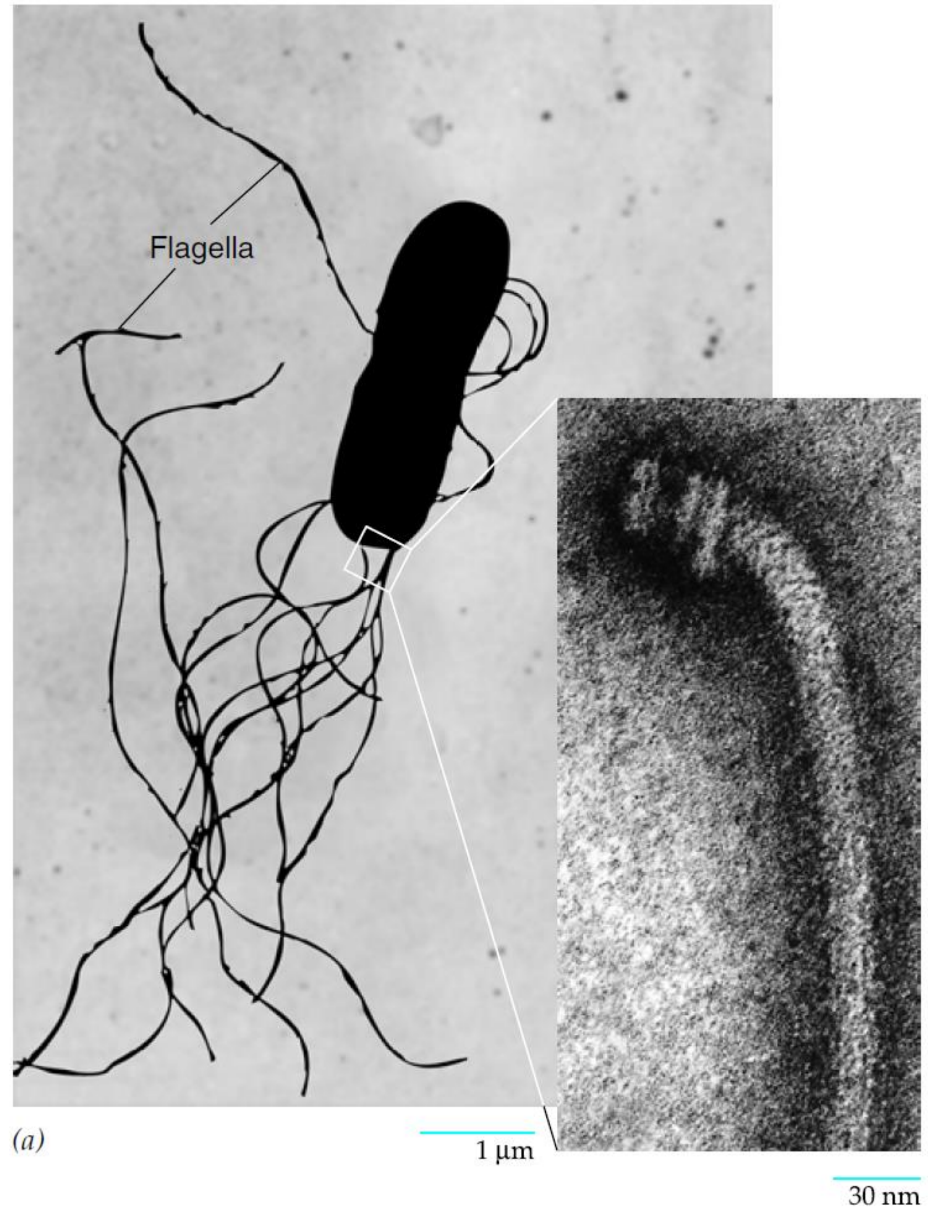


Table 1.1 A Comparison of Prokaryotic and Eukaryotic Cells

Features held in common by the two types of cells:

- Plasma membrane of similar construction
- Genetic information encoded in DNA using identical genetic code
- Similar mechanisms for transcription and translation of genetic information, including similar ribosomes
- Shared metabolic pathways (e.g., glycolysis and TCA cycle)
- Similar apparatus for conservation of chemical energy as ATP (located in the plasma membrane of prokaryotes and the mitochondrial membrane of eukaryotes)
- Similar mechanism of photosynthesis (between cyanobacteria and green plants)
- Similar mechanism for synthesizing and inserting membrane proteins
- Proteasomes (protein digesting structures) of similar construction (between archaebacteria and eukaryotes)

Features of eukaryotic cells not found in prokaryotes:

- Division of cells into nucleus and cytoplasm, separated by a nuclear envelope containing complex pore structures
- Complex chromosomes composed of DNA and associated proteins that are capable of compacting into mitotic structures
- Complex membranous cytoplasmic organelles (includes endoplasmic reticulum, Golgi complex, lysosomes, endosomes, peroxisomes, and glyoxisomes)
- Specialized cytoplasmic organelles for aerobic respiration (mitochondria) and photosynthesis (chloroplasts)
- Complex cytoskeletal system (including microfilaments, intermediate filaments, and microtubules) and associated motor proteins
- Complex flagella and cilia
- Ability to ingest particulate material by enclosure within plasma membrane vesicles (phagocytosis)
- Cellulose-containing cell walls (in plants)
- Cell division using a microtubule-containing mitotic spindle that separates chromosomes
- Presence of two copies of genes per cell (diploidy), one from each parent
- Presence of three different RNA synthesizing enzymes (RNA polymerases)
- Sexual reproduction requiring meiosis and fertilization

Type of Prokaryotic Cells

- Prokaryotes are divided into two major taxonomic groups, or domains: the Archaea (or archaebacteria) and the Bacteria (or eubacteria).

- Members of the Archaea are more closely related to eukaryotes than they are to the other group of prokaryotes (the Bacteria).

- The best known Archaea are species that live in extremely inhospitable environments; they are often referred to as "extremophiles."

- Included among the Archaea are the methanogens, the halophiles, acidophiles and thermophiles.

- Recent analyses of soil and ocean microbes indicate that many members of the Archaea are also at home in habitats of normal temperature, pH, and salinity.

- All other prokaryotes are classified in the domain Bacteria.

- This domain includes the smallest known cells, the mycoplasma (0.2 μm diameter).

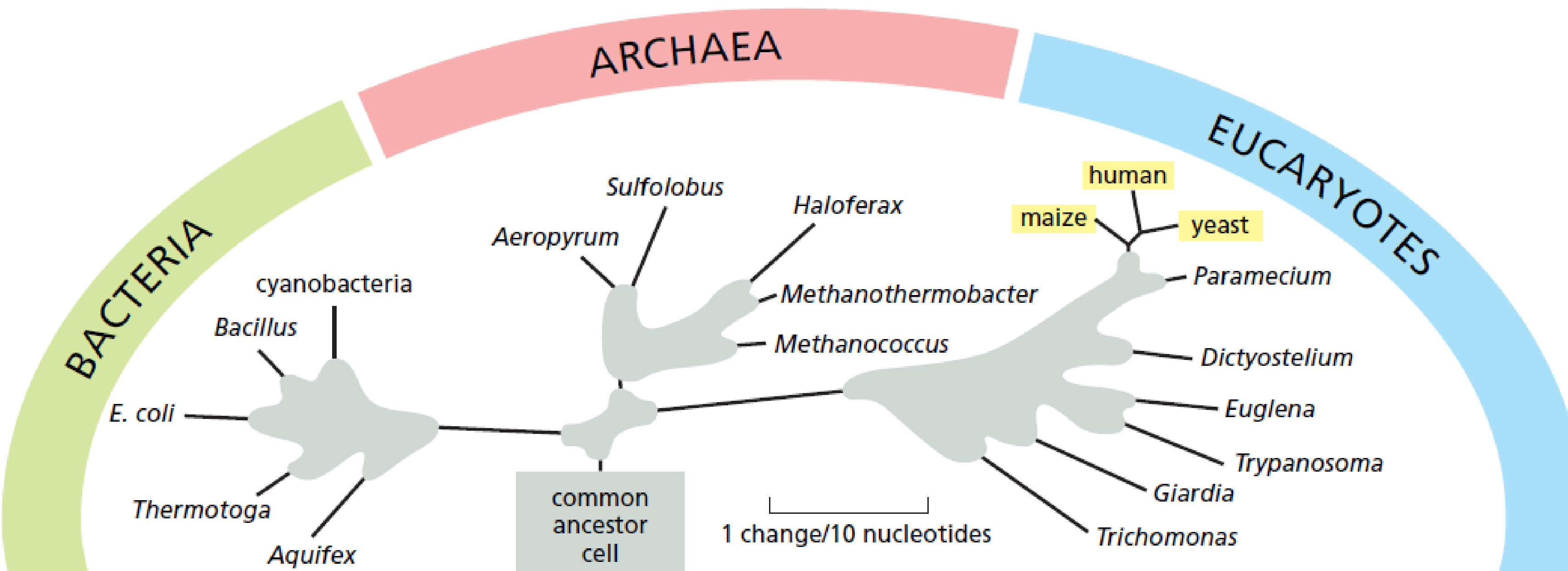
- Bacteria are present in every conceivable habitat on Earth, from the permanent ice shelf of the Antarctic to the driest African deserts, to the internal confines of plants and animals.

- The most complex prokaryotes are the cyanobacteria. Cyanobacteria contain elaborate arrays of cytoplasmic membranes, which serve as sites of photosynthesis.

- As in eukaryotic plants, photosynthesis in cyanobacteria is accomplished by splitting water molecules, which releases molecular oxygen.

- Many cyanobacteria are capable not only of photosynthesis, but also of nitrogen fixation, the conversion of nitrogen (N_2) gas into reduced forms of nitrogen (such as ammonia, NH_3)

- Those species capable of both photosynthesis and nitrogen fixation can survive on the barest of resources—light, N_2, CO_2, and H_2O.



Types of Eukaryotic Cells: Cell Specialization

- In many regards, the most complex eukaryotic cells are not found inside of plants or animals, but rather among the singlecelled (unicellular) protists.

- All of the machinery required for the complex activities in which this organism engages—sensing the environment, trapping food, expelling excess fluid, evading predators—is housed within the confines of a single cell.

- Complex unicellular organisms represent one evolutionary pathway.

- An alternate pathway has led to the evolution of multicellular organisms in which different activities are conducted by different types of specialized cells.

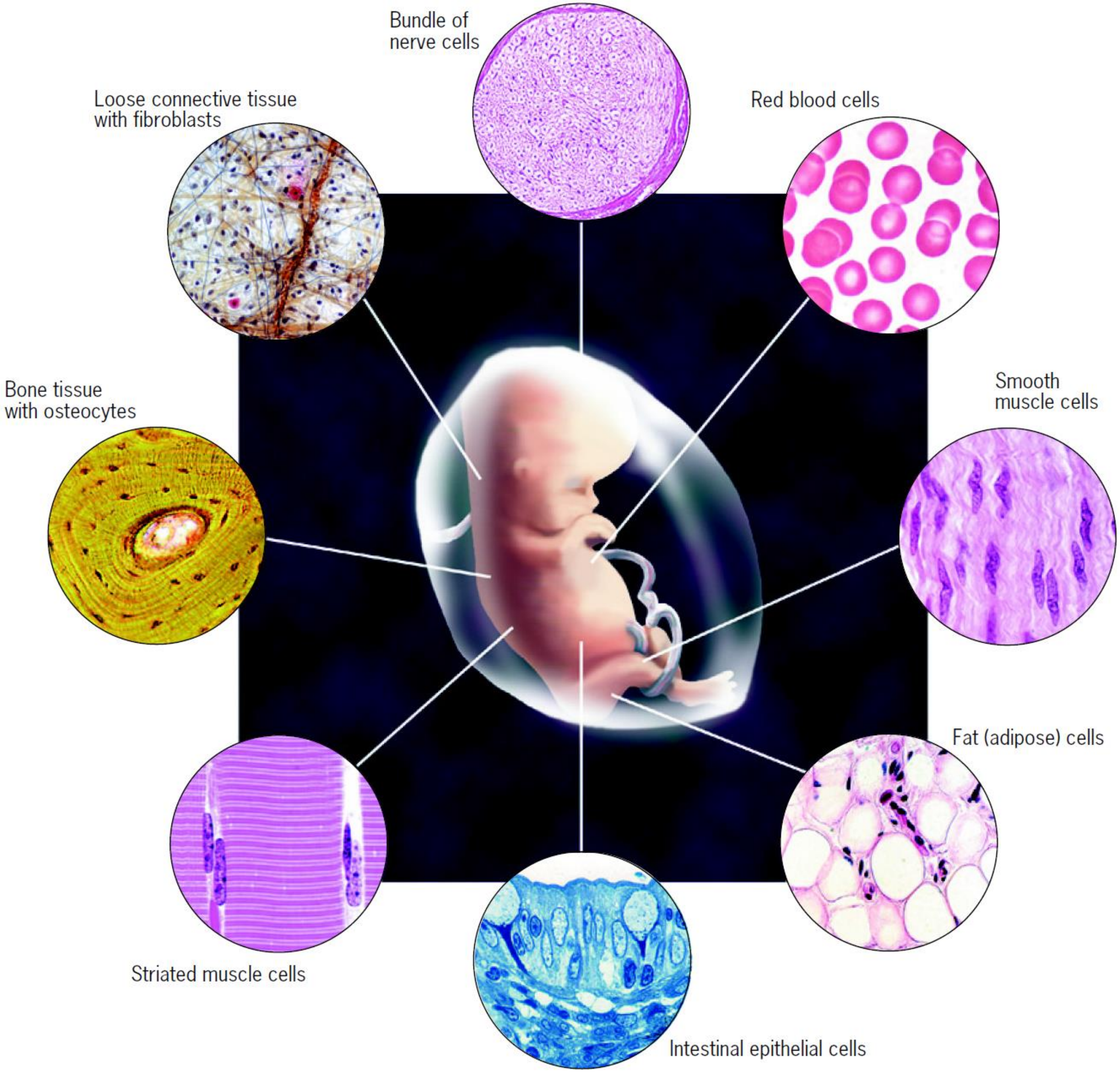
- Specialized cells are formed by a process called differentiation.

- A fertilized human egg, for example, will progress through a course of embryonic development that leads to the formation of approximately 250 distinct types of differentiated cells.

- Some cells become part of a particular digestive gland, others part of a large skeletal muscle, others part of a bone, and so forth.

- The pathway of differentiation followed by each embryonic cell depends primarily on the signals it receives from the surrounding environment; these signals in turn depend on the position of that cell within the embryo.

- Researchers are learning how to control the process of differentiation in the culture dish and applying this knowledge to the treatment of complex human diseases.


Bundle of nerve cells
Loose connective tissue with fibroblasts
Red blood cells
Bone tissue with osteocytes
Smooth muscle cells
Fat (adipose) cells
Striated muscle cells
Intestinal epithelial cells

- Living organisms are highly diverse, and the results obtained from a particular experimental analysis may depend on the particular organism being studied.

- As a result, cell and molecular biologists have focused considerable research activities on a small number of “representative” or model organisms.

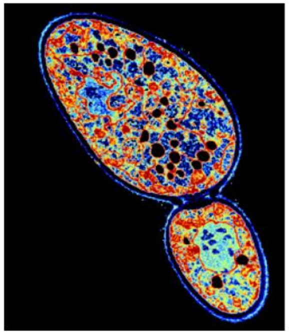
- Six model organisms—one prokaryote and five eukaryotes—have captured much of the attention: a bacterium, *E. coli*; a budding yeast, *Saccharomyces cerevisiae*; a flowering plant, *Arabidopsis thaliana*; a nematode, *Caenorhabditis elegans*; a fruit fly, *Drosophila melanogaster*; and a mouse, *Mus musculus*.

(*a*) *Escherichia coli* is a rod-shaped bacterium that lives in the digestive tract of humans and other mammals. Much of what we will discuss about the basic molecular biology of the cell, including the mechanisms of replication, transcription, and translation, was originally worked out on this one prokaryotic organism.

(*b*) *Saccharomyces cerevisiae*, more commonly known as baker's yeast or brewer's yeast. It is the least complex of the eukaryotes commonly studied, yet it contains a surprising number of proteins that are homologous to proteins in human cells. Such proteins typically have a conserved function in the two organisms. The species has a small genome encoding about 6200 proteins; it can be grown in a haploid state (one copy of each gene per cell rather than two as in most eukaryotic cells); and it can be grown under either aerobic (O_2-containing) or anaerobic (O_2-lacking) conditions.

(*c*) *Arabidopsis thaliana*, a weed that is related to mustard and cabbage, which has an unusually small genome (120 million base pairs) for a flowering plant, a rapid generation time, and large seed production, and it grows to a height of only a few inches.

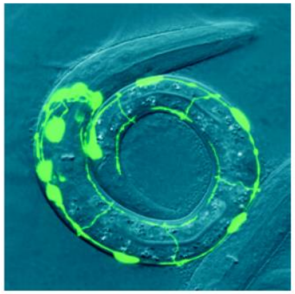
(*a*)



(*b*)

(*c*)

(*d*) *Caenorhabditis elegans*, a microscopic-sized nematode, consists of a defined number of cells (roughly 1000), each of which develops according to a precise pattern of cell divisions. The animal is easily cultured, can be kept alive in a frozen state, has a transparent body wall, a short generation time, and facility for genetic analysis. This micrograph shows the larval nervous system, which has been labeled with the green fluorescent protein (GFP). The 2002 Nobel Prize was awarded to the researchers who pioneered its study.



(*d*)

(*e*)

(*f*)

(*e*) *Drosophila melanogaster*, the fruit fly, is a small but complex eukaryote that is readily cultured in the lab, where it grows from an egg to an adult in a matter of days. *Drosophila* has been a favored animal for the study of genetics, the molecular biology of development, and the neurological basis of simple behavior. Certain larval cells have giant chromosomes, whose individual genes can be identified for studies of evolution and gene expression.

(*f*) *Mus musculus*, the common house mouse, is easily kept and bred in the laboratory. Thousands of different genetic strains have been developed, many of which are stored simply as frozen embryos due to lack of space to house the adult animals. The "nude mouse" pictured here develops without a thymus gland and, therefore, is able to accept human tissue grafts that are not rejected.

Viruses

- By the end of the nineteenth century, the work of Louis Pasteur and others had convinced the scientific world that infectious diseases of plants and animals were due to bacteria.

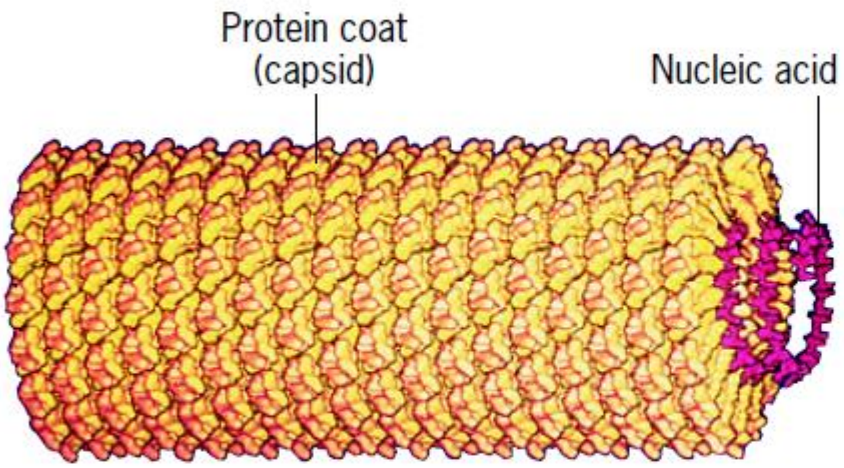
- Studies of tobacco mosaic disease in tobacco plants pointed to the existence of another type of infectious agent.

- To gain further insight into the size and nature of the infectious agent, Dmitri Ivanovsky, a Russian biologist, forced the sap from a diseased plant through filters whose pores were so small that they retarded the passage of the smallest known bacterium.

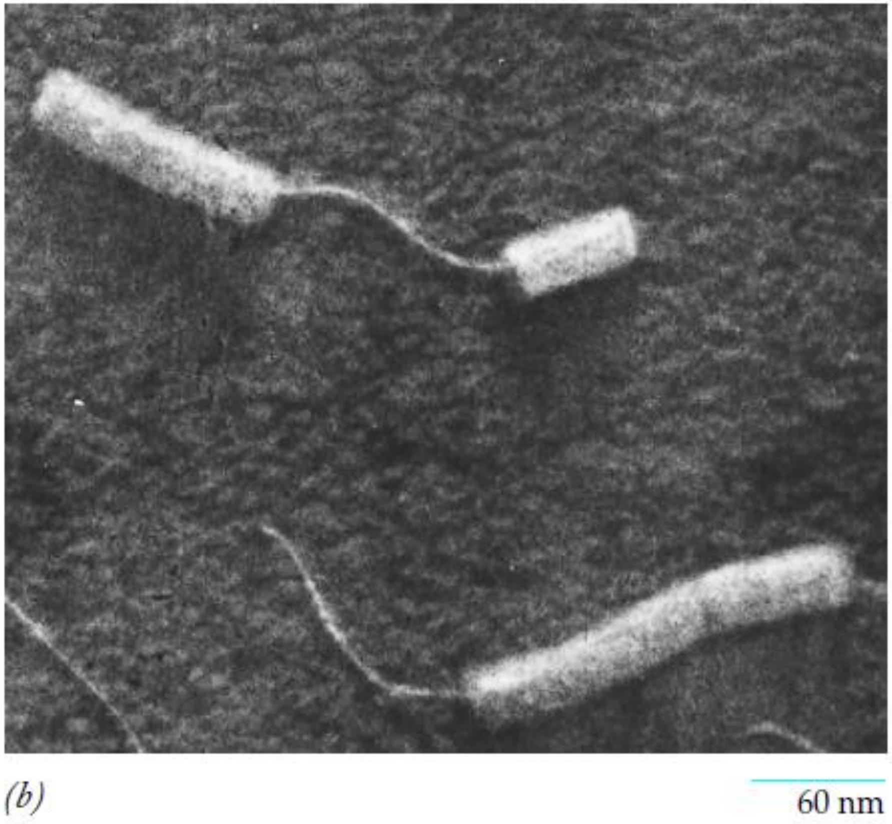
- The filtrate was still infective, causing Ivanovsky to conclude in 1892 that certain diseases were caused by pathogens that were even smaller, and presumably simpler, than the smallest known bacteria. These pathogens became known as viruses.

- The virus responsible for tobacco mosaic disease could be crystallized and that the crystals were infective.

- Tobacco mosaic virus (TMV) is a rod-shaped particle consisting of a single molecule of RNA surrounded by a helical shell composed of protein subunits



(a)



(b)

- Viruses are responsible for dozens of human diseases, including AIDS, polio, influenza, cold sores, measles, and a few types of cancer.

- Viruses occur in a wide variety of very different shapes, sizes, and constructions, but all of them share certain common properties.

- All viruses are obligatory intracellular parasites; that is, they cannot reproduce unless present within a host cell.

- Outside of a living cell, the virus exists as a particle, or virion, which is little more than a macromolecular package.

- The virion contains a small amount of genetic material that, depending on the virus, can be single-stranded or double-stranded,RNA or DNA.

- The genetic material of the virion is surrounded by a protein capsule, or capsid.

- Virions are macromolecular aggregates, inanimate particles that by themselves are unable to reproduce, metabolize, or carry on any of the other activities associated with life.

- For this reason, viruses are not considered to be organisms and are not described as being alive.

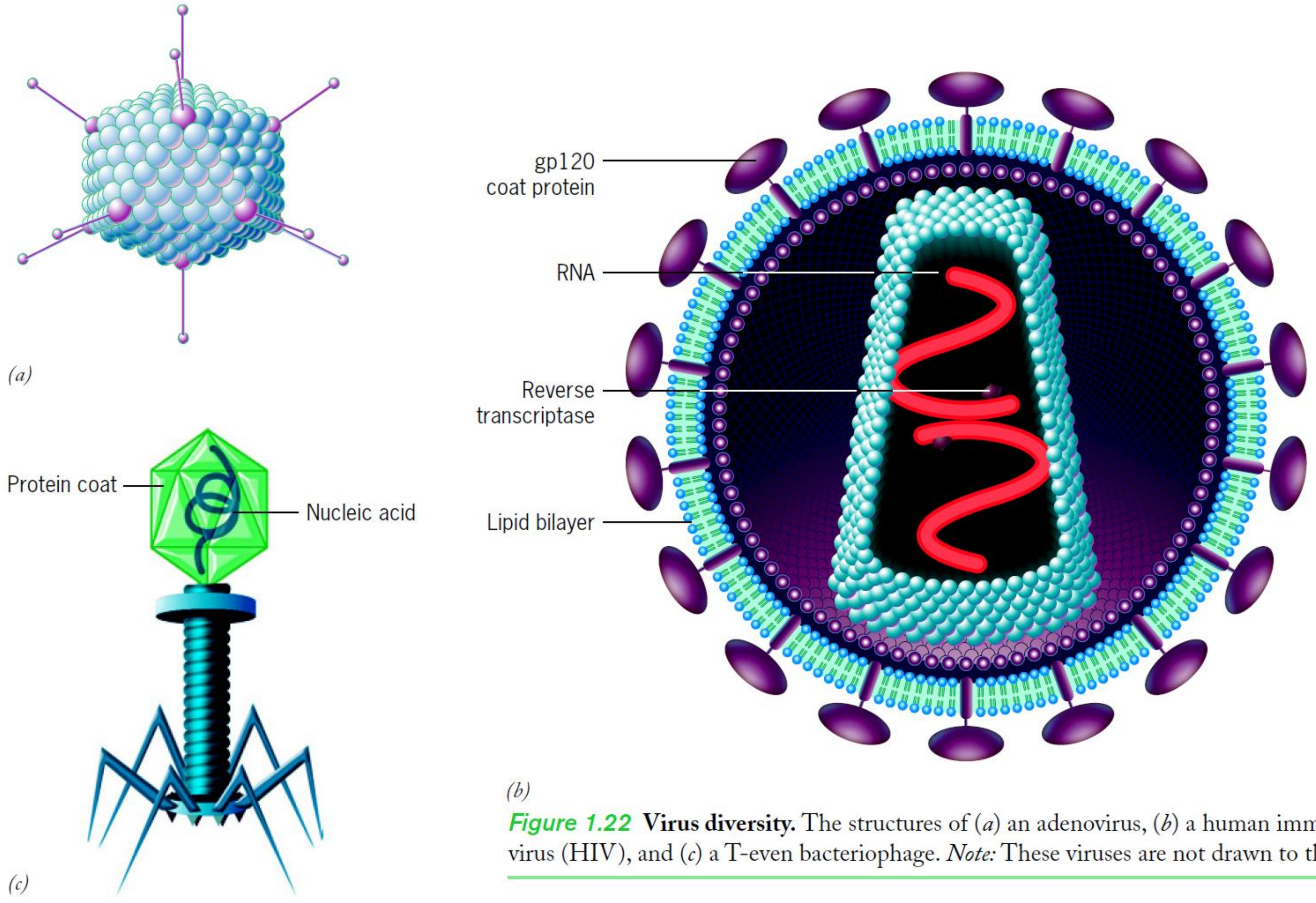


Figure 1.22 **Virus diversity.** The structures of (*a*) an adenovirus, (*b*) a human immunodeficiency virus (HIV), and (*c*) a T-even bacteriophage. *Note:* These viruses are not drawn to the same scale.

- Some viruses have a wide host range, being able to infect cells from a variety of different organs or host species.

- The virus that causes rabies, for example, is able to infect many different types of mammalian hosts, including dogs, bats, and humans.

- Most viruses, however, have a relatively narrow host range. This is true, for example, of human cold and influenza viruses, which are generally able to infect only the respiratory epithelial cells of human hosts.

- There are two basic types of viral infection. (1) In most cases, the virus arrests the normal synthetic activities of the host and redirects the cell to use its available materials to manufacture viral nucleic acids and proteins, which assemble into new virions.

- Ultimately, the infected cell ruptures (lyses) and releases a new generation of viral particles capable of infecting neighboring cells.

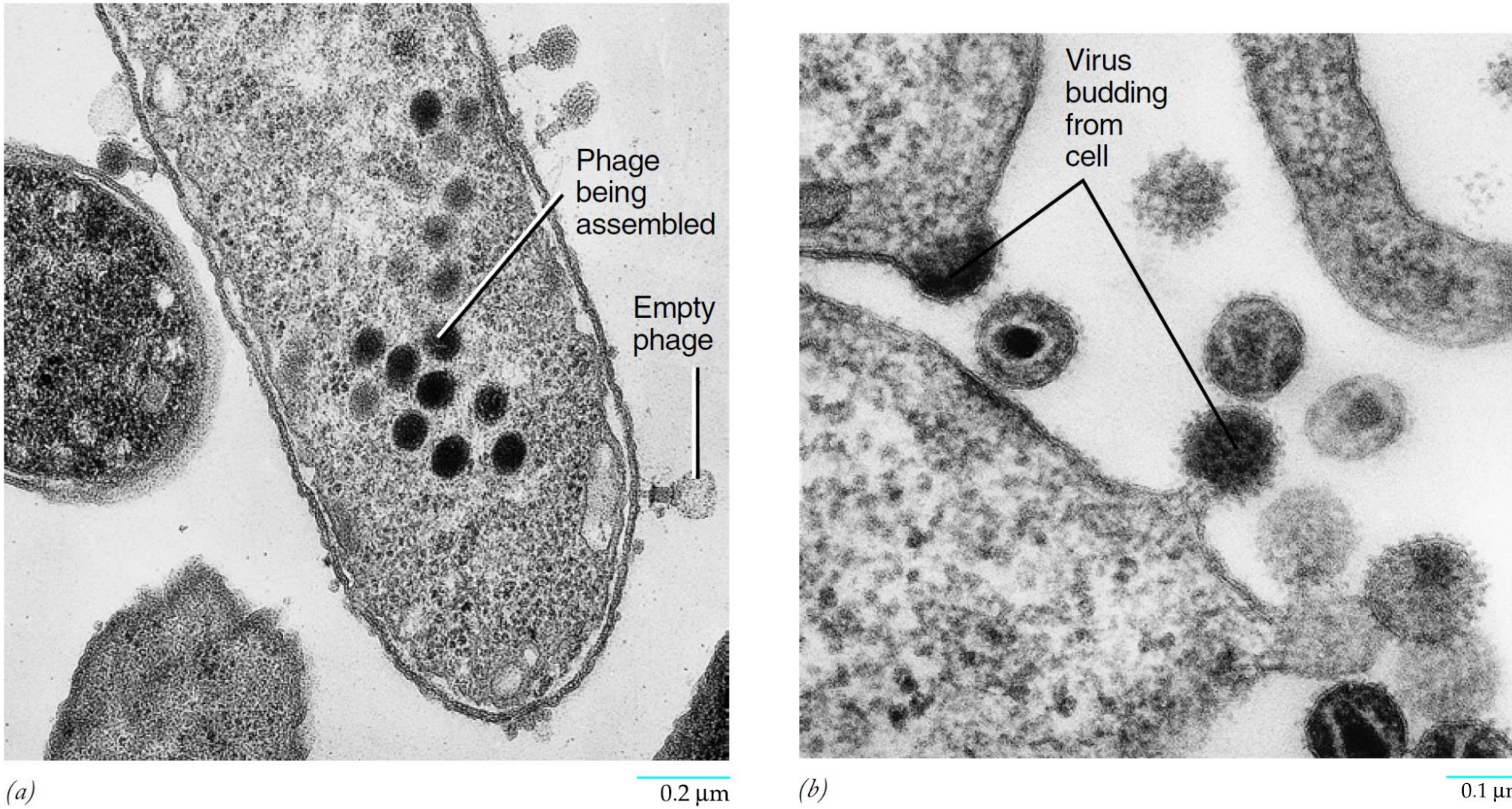
- (2) In other cases, the infecting virus does not lead to the death of the host cell, but instead inserts (integrates) its DNA into the DNA of the host cell's chromosomes.

- The integrated viral DNA is called a provirus. An integrated provirus can have different effects depending on the type of virus and host cell. For example,

- Bacterial cells containing a provirus behave normally until exposed to a stimulus, that activates the dormant viral DNA, leading to the lysis of the cell and release of viral progeny.

- Some animal cells containing a provirus produce new viral progeny that bud at the cell surface without lysing the infected cell.

- Or, Some animal cells containing a provirus lose control over their own growth and division and become malignant.



A virus infection. (*a*) Micrograph showing a late stage in the infection of a bacterial cell by a bacteriophage. Virus particles are being assembled within the cell, and empty phage coats are still present on the cell surface. (*b*) Micrograph showing HIV particles budding from an infected human lymphocyte.

- Viruses have been used for decades as a research tool to study the mechanism of DNA replication and gene expression.

- In addition, viruses are now being used as a means to introduce foreign genes into human cells.

- Lastly, insect- and bacteria-killing viruses may play an increasing role in the war against insect pests and bacterial pathogens.

- It came as a surprise in 1971 to discover that viruses are not the simplest types of infectious agents.

- Viroids, small circular RNA molecules that totally lacks a protein have been found in potato spindle-tuber disease.

- Viroids are thought to cause disease by interfering with the cell's normal path of gene expression.

Cell Replacement Therapy

- Many human diseases result from the deaths of specific types of cells.

- Type 1 diabetes, for example, results from the destruction of beta cells in the pancreas; Parkinson's disease occurs with the loss of dopamine-producing neurons in the brain; and heart failure can be traced to the death of cadiac muscle cells (cardiomyocytes) in the heart.

- If we could isolate cells from a patient, convert them into the cells that are needed by that patient, and then infuse them back into the patient it is possible to restore the body's lost function.

- Bone marrow transplantation is used most often to treat lymphomas and leukemias, which are cancers that affect the nature and number of white blood cells.

- For the treatment, patient is exposed to a high level of radiation and as a side effect, this eliminates blood-forming cells which are particularly sensitive to radiation and toxic chemicals .

- Once a person's blood-forming cells have been destroyed, they are replaced by bone marrow cells transplanted from a healthy donor.

- Blood-forming cells in the bone marrow are termed hematopoietic stem cells (or HSCs).

- An increasing number of parents are saving the blood from the umbilical cord of their newborn baby in case that child should ever develop a disease that might be treated by administration of HSCs.

- Hematopoietic stem cells in the bone marrow are an example of an adult stem cell. Stem cells are defined as undifferentiated cells that

  - (1) are capable of self-renewal, that is, production of more cells like themselves, and

  - (2) are multipotent, that is, are capable of differentiating into two or more mature cell types.

- Cardiac stem cells have the potential to regenerate healthy heart tissue in a patient who had experienced a serious heart attack.

- Adult stem cells are an ideal system for cell replacement therapies because the cells are taken from the same patient in which they are used thus eliminating the possiblity of immune rejection.

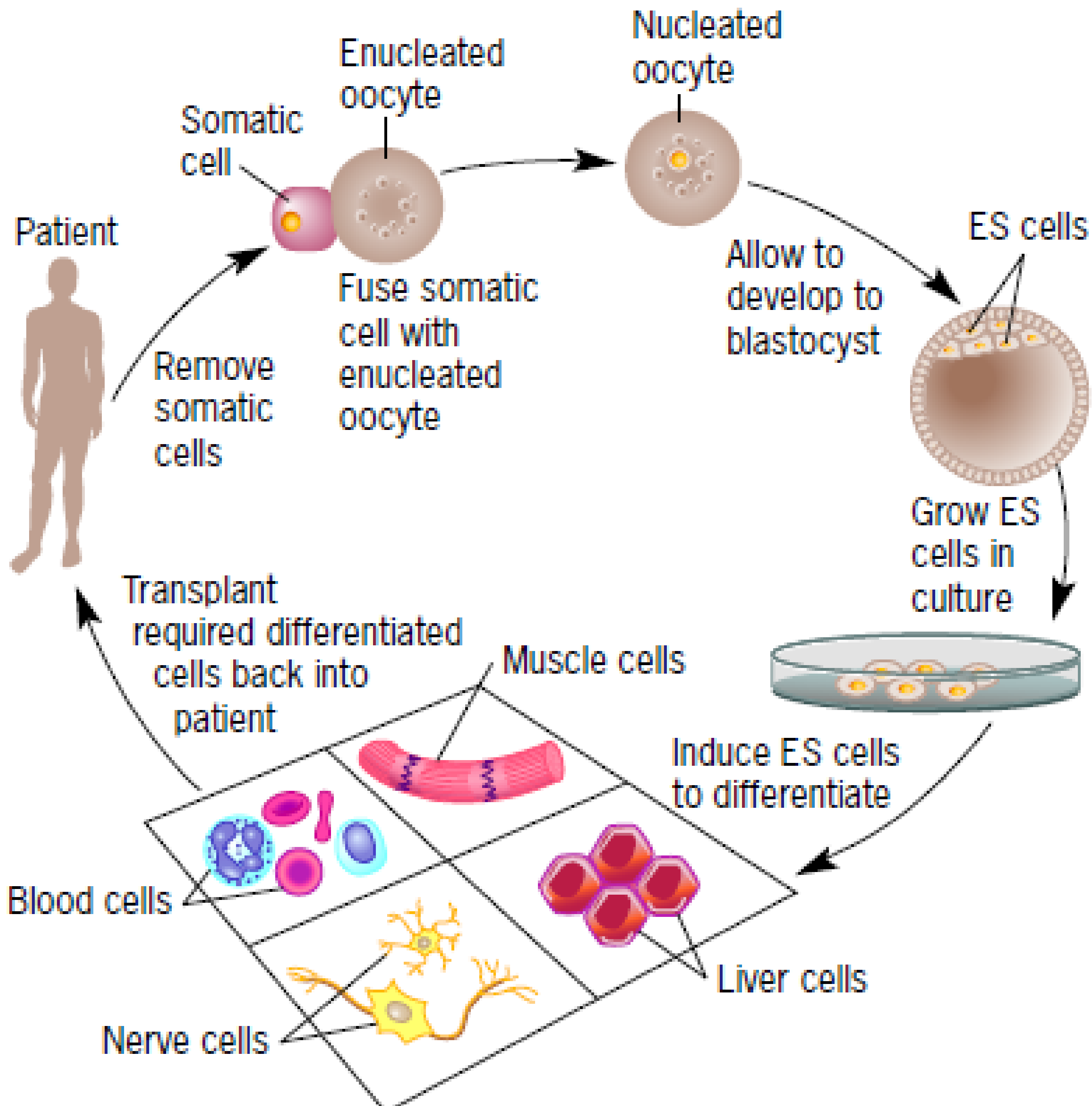
- Embryonic stem (ES) cells are a type of stem cell isolated from very young mammalian embryos.

- These are the cells in the early embryo that give rise to all of the various structures of the mammalian fetus.

- Unlike adult stem cells, ES cells are pluripotent; that is, they are capable of differentiating into every type of cell in the body.

- The primary risk with the therapeutic use of ES cells is the unnoticed presence of undifferentiated ES cells among the differentiated cell population.

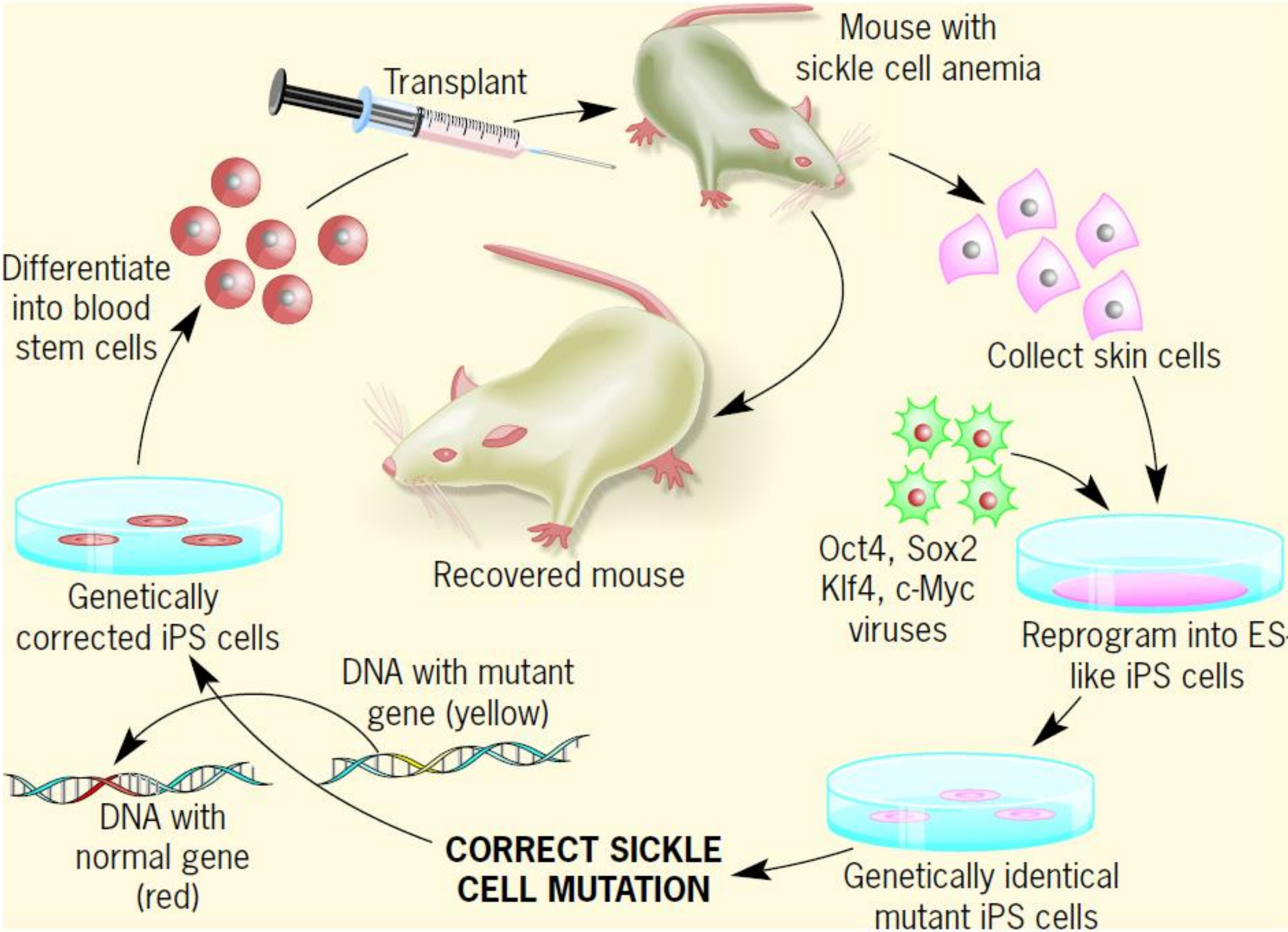
- Undifferentiated ES cells are capable of forming a type of benign tumor, called a teratoma, which may contain a bizarre mass of various differentiated tissues, including hair and teeth.


Nucleated oocyte
Enucleated oocyte
Somatic cell
Patient
Fuse somatic cell with enucleated oocyte
Allow to develop to blastocyst
ES cells
Remove somatic cells
Grow ES cells in culture
Transplant required differentiated cells back into patient
Muscle cells
Induce ES cells to differentiate
Blood cells
Liver cells
Nerve cells

- It had long been thought that the process of cell differentiation in mammals was irreversible; once a cell had become a fibroblast, or white blood cell, or cartilage cell, it could never again revert to any other cell type.

- This concept was shattered in 2006 when Shinya Yamanaka and co-workers of Kyoto University announced a stunning discovery; his lab had succeeded in reprogramming a fully differentiated mouse cell—in this case a type of connective tissue fibroblast—into a pluripotent stem cell.

- They called this new type of cells induced pluripotent cells (iPS cells) and demonstrated that they were indeed pluripotent by injecting them into a mouse blastocyst and finding that they participated in the differentiation of all the cells of the body, including eggs and sperm.


Mouse with
sickle cell anemia
Transplant
Differentiate
into blood
stem cells
Collect skin cells
Recovered mouse
Oct4, Sox2
Klf4, c-Myc
viruses
Genetically
corrected iPS cells
Reprogram into ES-
like iPS cells
DNA with mutant
gene (yellow)
DNA with
normal gene
(red)
CORRECT SICKLE
CELL MUTATION
Genetically identical
mutant iPS cells

- In 2008 the field of cellular reprogramming took another unexpected turn with the announcement that one type of differentiated cell had been converted directly into another type of differentiated cell, a case of “transdifferentiation.”

- In this report, the acinar cells of the pancreas, which produce enzymes responsible for digestion of food in the intestine, were transformed into pancreatic beta cells, which synthesize and secrete the hormone insulin.

- The reprogramming process occurred directly, in a matter of a few days, without the cells passing through an intermediate stem cell state—and it occurred while the cells remained in their normal residence within the pancreas of a live mouse.

- This feat was accomplished by injection into the animals of viruses that carried three genes known to be important in differentiation of beta cells in the embryo.

Synopsis

- The cell theory has three tenets. (1) All organisms are composed of one or more cells; (2) the cell is the basic organizational unit of life; and (3) all cells arise from preexisting cells.

- The properties of life, as exhibited by cells, can be described by a collection of properties. Cells are very complex and their substructure is highly organized and predictable. The information to build a cell is encoded in its genes. Cells reproduce by cell division; their activities are fueled by chemical energy; they carry out enzymatically controlled chemical reactions; they engage in numerous mechanical activities; they respond to stimuli; and they are capable of a remarkable level of self-regulation.

Synopsis

- Cells are either prokaryotic or eukaryotic.

- Prokaryotic cells are found only among archaebacteria and eubacteria, whereas all other types of organisms—protists, fungi, plants, and animals—are composed of eukaryotic cells.

- Prokaryotic and eukaryotic cells share many common features, including a similar cellular membrane, a common system for storing and using genetic information, and similar metabolic pathways.

- Prokaryotic cells are the simpler type, lacking the complex membranous organelles (e.g., endoplasmic reticulum, Golgi complex, mitochondria, and chloroplasts), chromosomes, and cytoskeleton characteristic of the cells of eukaryotes.

Synopsis

- The two cell types can also be distinguished by their mechanism of cell division, their locomotor structures, and the type of cell wall they produce (if a cell wall is present).

- Complex plants and animals contain many different types of cells, each specialized for particular activities.

- Cells are almost always microscopic in size. Bacterial cells are typically 1 to 5 µm in length, whereas eukaryotic cells are typically 10 to 30 µm.

- Viruses are noncellular pathogens that can only reproduce when present within a living cell.

- Outside of the cell, the virus exists as amacromolecular package, or virion.

- Viral infections may lead to either (1) the destruction of the host cell with accompanying production of viral progeny, or (2) the integration of viral nucleic acid into the DNA of the host cell.