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ANIMAL CELL

Although the earliest light microscopes showed the cell as hardly more than a mass of amorphous fluid enclosed within a membrane, modern research has shown that the cell is not only the structural unit of living organisms but also the functional unit. Each cell carries out all the physical and chemical reactions we associate with life. This plate is an artist's reconstruction of a typical animal cell as it might look with its upper half cut away. We see that the cell is organized into many distinct structures. These are called organelles, and each is specialized for a particular function. This plate gives you an overview of these organelles; the following plates will cover the details of structure and function.

Color title A and the cell membrane with a pale color.

The *cell membrane* (sometimes called the plasma membrane or plasmalemma) completely covers the entire cell and serves to hold it together. It also actively regulates what enters and leaves the cell. It is only about 10 nanometers thick, so its thickness has to be greatly exaggerated in the drawing to give you something thick enough to color. This is also true of the membranes within the cell. Everything else is drawn to scale.

Color titles and structures B through F. Color the pores (C) with a darker color. Color D and E in rather dark colors, and leave F uncolored (all the remaining space within the nucleus).

In animal cells (as well as in plant, protist, and fungus cells), the nucleus is separated from the rest of the cell by the *nuclear envelope*. Such cells are called eukaryotic (Greek: *eu*, "true"; *karyon*, "kernel" or "nucleus") to distinguish them from prokaryotic cells (Greek: *pro*, "before"), which lack a true membrane-enclosed nucleus and are more primitively organized. (Prokaryotic cells are found only among the bacteria and their close relatives.) The nuclear envelope is made up of two layers (not shown) of membrane. These are very similar to the cell membrane but have numerous *pores*. Within the nucleus is a prominent structure called the *nucleolus*—sometimes there are two or more nucleoli—and a network of thin threads called *chromatin*. The chromatin contains the hereditary material of the cell. The fluid that fills the rest of the space in the nucleus is called the *nuclear sap*.

Color the heading Cytoplasm and titles and structures G through N. Color over the lines that represent microfilaments.

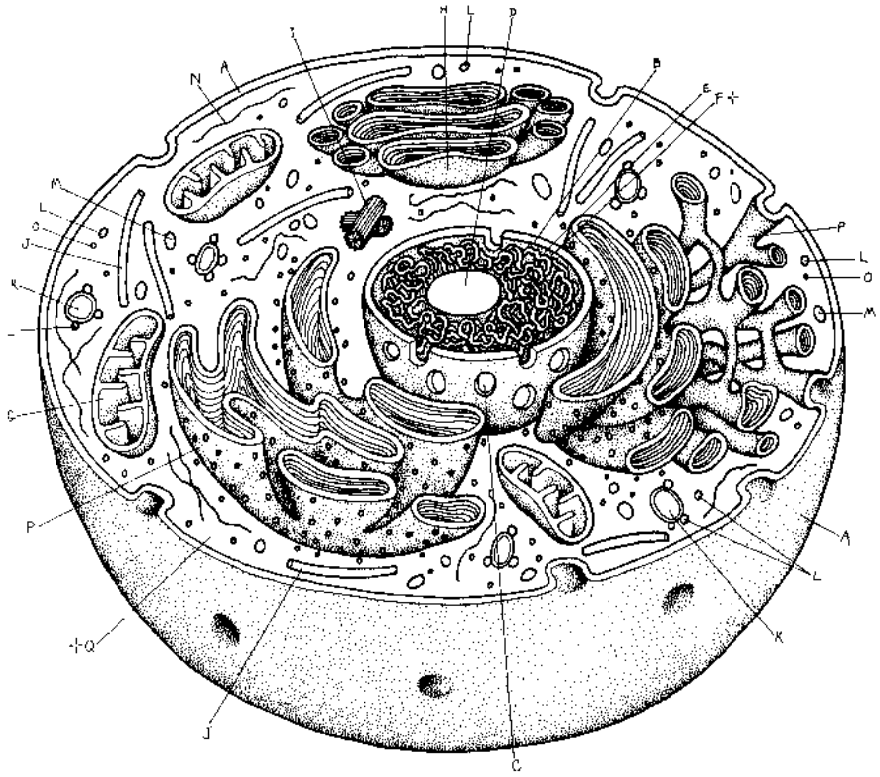
The term "cytoplasm" is still used to designate all of the cell contents outside the nucleus but inside the cell membrane, although we realize that cytoplasm is not the homogeneous substance it was once thought to be. One of the prominent organelles in the cytoplasm is the *mitochondrion*, often called the "powerhouse of the cell" because about 90 percent of the energy that eukaryotic cells get from oxidizing food molecules is developed there. The *Golgi complex* is a stack of membranous sacs in which various molecules are manufactured and packaged for "export" from the cell. *Centrioles* are cylindrical bundles of microtubules that seem to give rise to the longer spindle microtubules (not shown) that separate the two duplicate sets of chromatin at the time of cell division. Most animal cells have a pair of centrioles lined up at 90 degrees to each other. Additional *microtubules* are found singly or in groups elsewhere in the cytoplasm. They appear to provide structural support to the cell and may be involved in movement. *Vacuoles* are fluid-filled sacs of membrane that may contain anything from food being digested to oil droplets. *Lysosomes* look like small vacuoles but contain digestive enzymes. *Microbodies* look like small vacuoles as well but contain various enzymes not involved in digestion. *Microfilaments* are found in various places around the cytoplasm and are involved in movement and attachment to other cells.

Color titles and structures O and P. Be sure to use a pale color for P to avoid obscuring the ribosomes (O). Do not color Q.

Throughout the cytoplasm are many tiny structures called *ribosomes*, which manufacture proteins. Some are free in the fluid portion of the cytoplasm, but many others are attached to the *endoplasmic reticulum* (ER), a system of membranes that extends throughout much of the cytoplasm. Some parts of the endoplasmic reticulum (known as the rough ER) have many ribosomes attached; other parts (known as the smooth ER) have none. The remaining portion of the cytoplasm, which seems to be a structureless fluid, is called the *hyaloplasm*. (Some biologists call it the cell sap or the cell matrix.)

ANIMAL CELL

CELL MEMBRANE A
NUCLEUS * (membrane)
NUCLEAR ENVELOPE B
NUCLEAR PORE C
NUCLEOLUS D
CHROMATIN E (Chromosomes)
NUCLEAR SAP F
CYTOPLASM *
MITOCHONDRION G
GOLGI COMPLEX H (body)
CENTRIOLE I
MICROTUBULE J
VACUOLE K
LYSOSOME L
MICROBODY M
MICROFILAMENT N
RIBOSOME O
ENDOPLASMIC RETICULUM P
HYALOPLASM Q



31 PLANT CELL

In a typical plant cell we see virtually all of the structures found in animal cells except for centrioles and certain protrusions used for locomotion or absorption. On the other hand, plant cells contain certain structures not found in animal cells at all.

Color titles and structures A through H, including the heading Plastids. Use green for F and a light color for D and D¹. In nature, G is white. Color H with any bright color you wish. (If this were a ripening tomato, H would be red.)

The plant *cell membrane* is essentially the same as an animal cell membrane. Immediately outside the plant cell membrane, however, is a *cell wall* consisting mostly of fibers of cellulose, although other kinds of molecules also become incorporated into it. When a cell is first formed by division of its parent cell, the cell wall is relatively elastic and is called a primary cell wall. As the cell grows, the wall is made thicker and more rigid and becomes known as a secondary cell wall (shown in this plate). The cell wall is perforated by numerous small pores called *plasmodesmata* (singular, plasmodesma), which appear to allow a direct bridge of cytoplasm from one cell to the next.

Although animal cells often contain some small vacuoles, plant cells usually contain one or a few very large ones. As plant cells mature, the vacuoles tend to get larger and usually fuse to form a single very large *vacuole* that may comprise up to 90 percent of the cell's volume. These large vacuoles are sometimes called "water vacuoles" because they contain large quantities of water. However, they also contain a wide variety of dissolved substances, including nutrients stored for later use and toxic substances, which may be broken down into harmless subunits in the vacuole. It is because of the dissolved substances that water flows into the vacuole and creates osmotic pressure, which is responsible for the rigidity ("turgor") of plants. When water is in short supply, the vacuoles lose their osmotic pressure, and the plant wilts (see Plate 34). Sometimes substances are stored in vacuoles as solid *crystals*, and many flowers receive their coloring from the pigments dissolved or crystallized in their vacuoles. The membrane of the vacuole is often called the *tonoplast*.

Plants are also colored by their plastids, but *chloroplasts*, which are green, have a much more important function than merely making plants green. They trap light energy and convert it to chemical energy for the manufacture of food in the process called photosynthesis. *Leucoplasts* are whitish in color and serve to store starch, lipid, or protein. *Chromoplasts* are plastids that produce and store other pigments that impart color to particular parts of a plant, as when fruit ripens or leaves turn color in the fall. They are formed by modification of chloroplasts or leucoplasts.

Color all the remaining titles and structures in the plate, including the heading Nucleus. Use a dark color for J, light colors for K and R, and a very light color for Q.

Golgi complexes in plant cells are usually called dictyosomes. They are very much like the Golgi complexes in animal cells except that they are usually smaller and more numerous. In addition to synthesizing various complex molecules needed within the cell, they appear to be responsible for manufacturing the components of the cell wall, which animal cells never have. All the remaining structures are virtually identical to those found in animal cells: *ribosomes* synthesize proteins and are found attached to the *endoplasmic reticulum* and free in the cytoplasm; *mitochondria* provide energy by oxidizing the carbohydrate made in the chloroplasts; *microtubules* and *microfilaments* seem to provide support and produce movement; *lysosomes* and *microbodies* contain enzymes; and the apparently structureless fluid making up the rest of the cytoplasm is called the *hyaloplasm*. The nucleus, too, is virtually the same; for that reason, this plate shows only the exterior of the *nuclear envelope* with its numerous *pores*.

PLANT CELL

CELL MEMBRANE$_A$
CELL WALL$_B$
PLASMODESMA$_C$
VACUOLE$_D$
TONOPLAST$_{D'}$
CRYSTAL$_E$
PLASTIDS$_\star$
CHLOROPLAST$_F$
LEUCOPLAST$_G$
CHROMOPLAST$_H$
GOLGI COMPLEX (bodies)
RIBOSOME
ENDOPLASMIC RETICULUM$_K$
MITOCHONDRION$_L$
MICROTUBULE$_M$
MICROFILAMENT$_N$
LYSOSOME$_O$
MICROBODY$_P$
HYALOPLASM$_Q$ (cytoplasm)
NUCLEUS$_\star$
NUCLEAR ENVELOPE$_R$
NUCLEAR PORE$_S$