The organisms called *bacteria* (singular, *bacterium*) are made up of *prokaryotic* cells. Prokaryotic cells are very different from and much simpler than eukaryotic cells in their basic structure and organization. This difference between eukaryotic and prokaryotic organisms is the great divide in biology. At the cellular level, differences among animals, plants, fungi, and protists are almost negligible compared with the differences between these groups on the one hand and prokaryotes (bacteria) on the other.

Containing the cell: Cell membrane

A cell is bound by a membrane, the *cell membrane,* also called the *plasma membrane* or the *plasmalemma.* The cell membrane of all eukaryotes is made of *phospholipid* molecules. The molecules are made by cells, a process that requires energy. The molecules assemble spontaneously (without input of energy) into the membrane, obeying the forces of *polarity.* Turn to Chapter 16 for a discussion of polarity and how the membrane takes its distinctive form, often called the *phospholipid bilayer.*

Don't confuse *cell membranes* with *cell walls.* Every cell has a membrane, and a cell membrane is a fundamental characteristic of a cell. Some cells also have cell walls outside and separate from the cell membrane. No animal cells have cell walls, but some plant cells and fungal cells have them. They're dissimilar to cell membranes in structure and function.

Permeating the membrane: The fluid-mosaic model

The phospholipid bilayer is embedded with structures of many different kinds. Though the bilayer itself is essentially similar in all cells, the embedded structures are as various and specialized as the cells themselves. Some identify the cell to other cells (very important in immune system functioning); some control the movement of certain substances in or out of the cell across the membrane. Figure 3-2 is a diagrammatic representation of the phospholipid bilayer and embedded structures. This model of the cell membrane is called the *fluid-mosaic model.* "Fluid" describes the ability of molecules in the bilayer to move; "mosaic" pertains to the embedded structures.

The chemical properties of the phospholipid bilayer and the embedded structures contribute to a very important feature of the membrane: It's able to control which substances pass through it and which do not. This means the membrane is *semipermeable.*

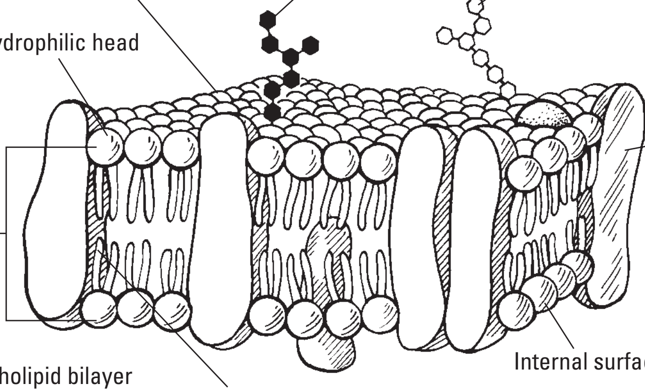

Figure 3-2: The fluid-mosaic model of the cell membrane.

Crossing the membrane passively

Some substances, mainly small molecules and ions, cross the membrane by a *passive transport* mechanism, meaning they more or less flow unimpeded across the bilayer, driven by the forces of "ordinary" chemistry, such as concentration gradients, random molecular movement, and polarity. Here are some ways that substances cross a membrane passively:

- **Diffusion:** A substance moves spontaneously down a *concentration gradient* (from an area where it's highly concentrated to an area where it's less concentrated). If you drop a teaspoon of salt into a jar of water, the dissolved sodium and chloride ions will, in time, *diffuse* (spread themselves evenly through the water). You can measure the time in seconds if you stir the solution or in days if you keep the solution perfectly still at room temperature. (To find out why, see Chapter 16.) Cellular and extracellular fluids are constantly being stirred and are at temperatures between 95 and 100 degrees Fahrenheit. Ions and molecules to which the cell membrane is permeable may diffuse into or out of the cell, constantly attempting to reach equilibrium.
- **Osmosis:** The diffusion of water molecules across a selectively permeable membrane gets a special name: *osmosis.* As with diffusion, a concentration gradient drives the mechanism. The pressure at which the movement of water across a membrane stops (that is, when the concentration of the solutions on either side of the membrane is equal) is termed the *osmotic pressure* of the system.

- **Filtration:** This form of passive transport occurs during capillary exchange. (*Capillaries* are the smallest blood vessels — they bridge arterioles and venules; see Chapter 9 for more on the circulatory system.) Capillaries are only one cell layer thick, and the capillary cell membrane acts as a filter, controlling the entrance and exit of small molecules. Small molecules dissolved in tissue fluid, such as carbon dioxide and water, diffuse through the capillary cell and into the blood, while substances dissolved in the blood, such as glucose and oxygen, diffuse into tissue fluid across the capillary cell membrane. The pulsating force of blood flow provides a steady agitation.

  The blood pressure in the capillaries is highest at the arterial end and lowest at the venous end. At the arterial end, blood pressure pushes substances through the capillary membrane and into the tissue fluid. At the venous end, lower blood pressure (thus higher net osmotic pressure) pushes waste products out of the cell and pulls water from the extracellular fluid into the capillary.

Does passive transport contradict the idea that the cell controls what comes in and out through the membrane? No. The substances that move by passive mechanisms are "ordinary" small molecules and ions that are always present in abundance within and between every cell and kept within a physiologically healthy concentration range by the forces of homeostasis, the first line of defense against physiological abnormality. If at any time the physiological levels get too high or too low, the cell has protein pumps that can counteract the passive transport. You could say that the cell hasn't wasted energy evolving mechanisms to control things that are unlikely to get out of control and for which other remedies are available when they do.

Crossing the membrane actively

Active transport allows a cell to control which big, active, biological molecules move in and out of the cytoplasm. Active transport is a fundamental characteristic of living cells (whereas you can set up a system for diffusion, as we note earlier, in a jar of water).

Like many matters in cell biology, active transport mechanisms are numerous and widely varied. A simple active import mechanism has a molecule outside the cell that the cell needs for its functioning, as well as a membrane-embedded structure that can identify that molecule with unerring specificity, frequently using a kind of lock-and-key mechanism, and can communicate its presence to another membrane-embedded structure. The second structure then opens a channel that only that molecule can pass through, and the channel closes until the structure gets another reliable message to open up. A slightly more complex variation involves a transport molecule that brings the molecule from the cell where it was made to the cell where it's used.

The products made in a cell, whether *anabolites* (built by the cell for a useful purpose) or *catabolites* (wastes and byproducts of anabolic reactions), may be pushed out of the cell across the membrane by active transport mechanisms involving transport molecules.

Controlling the cell: Nucleus

As we mention previously, the defining characteristic of a eukaryotic cell is the presence of a nucleus (plural, *nuclei*) that directs the cell's activity. The largest organelle, the nucleus is oval or round and is plainly visible under a microscope. Refer to Figure 3-1, earlier in the chapter, to see the relationship of the nucleus to the cell; Figure 3-7, later in the chapter, shows a closer view of the nucleus's structure.

All cells have one nucleus, at least at the beginning of their life cycle. As a cell develops, it may lose its nucleus, as do red blood cells and the keratinocytes of the integument; or the cell may merge with other cells, with the merged cell retaining the nuclei of all the cells, such as the fibers of skeletal muscle. This type of cell is called a *syncytium.*

Just as all cells arise from other cells, each nucleus arises from the division of a nucleus. The nucleus contains one complete (diploid) copy of the organism's *genome* — the DNA that embodies the organism's unique genetic material. Every nucleus of every cell in an organism has its own complete and exact copy of the entire genome. It's bound by a semipermeable membrane called the *nuclear envelope.*

The cells produced from this identical DNA are unimaginably varied in structure, in function, and in the substances they produce (proteins, hormones, and so on). The differentiation of the cell (the structure it takes on) and everything about its products are directed by the nucleus, which controls *gene expression,* the selective activation of individual genes.

Keep in mind the relationship between the *genome* and *gene expression.* The genome (DNA) is identical in each cell and remains the same through the organism's life. Within any one cell, only a very few genes are ever expressed. Every cell contains the genes ("instructions") for making a hair, but only a few cells ever express those genes — that is, make a hair. The expression of individual genes within each of the trillions of active cells in an organism changes constantly, moment to moment and throughout the organism's life span. Gene expression is the fundamental process of metabolism.

Cytoplasm

Within the cell membrane, between and around the organelles, is a fluid matrix called *cytoplasm* or *cytosol* and an internal scaffolding made up of *microfilaments* and *microtubules* that support the cell, give processes the space they need, and protect the organelles. The organelles are suspended in the cytoplasm.

The cytoplasm is gelatinous in texture because of dissolved proteins. These are the enzymes that break glucose down into *pyruvate molecules* in the first steps of cellular respiration (see Chapter 2). Other dissolved substances are fatty acids and amino acids. Waste products of respiration and protein construction are first ejected into the cytoplasm and then enclosed by vacuoles and expelled from the cell.

Organelles — including the nucleus, the mitochondria, the endoplasmic reticulum, and the Golgi body — contain a fluid with a particular composition, similar to the cytosol and to one another but each suited to the particular organelle's needs.

Internal membranes

The plasma membrane isn't the only membrane in a cell. Phospholipid bilayer membranes (not bedizened with a "mosaic" of embedded structures) are present all through the cell, encapsulating each organelle and floating around, waiting to be useful. The network of membranes is sometimes called the *endomembrane system.* When an organelle makes a substance that must be expelled from the cell, a piece of bilayer moves in and encapsulates (surrounds) the material and moves toward the cell membrane. Arriving there, it merges with the membrane (which is fluid, remember), opens up, and releases the formerly encapsulated substance into the extracellular fluid. The Golgi apparatus, lysosomes, and vacuoles all make use of this transport mechanism.

Similarly, a fragment of the bilayer in the cell membrane may encapsulate a molecule in the extracellular fluid, extend into the cytoplasm, pinch itself off into a separate *vesicle* (membrane-bound subcellular structure), and then release the substance into the cytoplasm or within the membrane of an organelle.

Powering the cell: Mitochondria

A *mitochondrion* (plural, *mitochondria*) is an organelle that transforms energy into a form that can be used to fuel the cell's metabolism and functions. It's often called the cell's "powerhouse." We discuss the role of the mitochondrion in cellular respiration in Chapter 2.