Organization of Life:

Biosynthetic Precursors

We can classify organisms according to how they obtain the energy and carbon they need for synthesizing cellular material (as summarized in Fig. 3). There are two broad categories based on energy sources;

- ***Phototrophs:*** (Greek *trophe* "nourishment") trap and use sunlight &
- ***Chemotrophs:*** derive their energy from oxidation of a chemical fuel

Some chemotrophs oxidize inorganic fuels—HS^- to S^0 (elemental sulfur). For example, Phototrophs and chemotrophs may be further divided into those that can synthesize all of their biomolecules directly from CO_2 (autotrophs) and those that require some preformed organic nutrients made by other organisms (heterotrophs). We can describe an organism's mode of nutrition by combining these terms. ***For example,*** cyanobacteria are photoautotrophs; humans are chemoheterotrophs. Even finer distinctions can be made, and many organisms can obtain energy and carbon from more than one source under different environmental or developmental conditions.

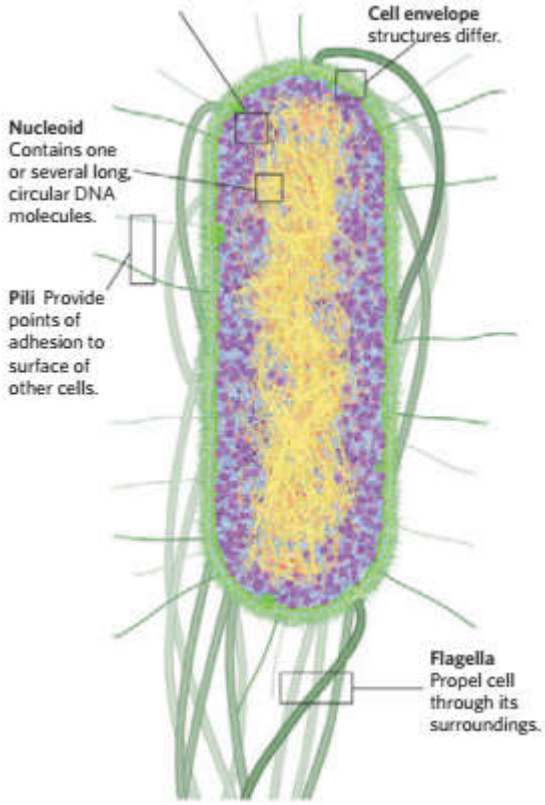

Fig 4a. Some common structural features of bacterial and archaeal cells. This correct-scale drawing of *E. coli* serves to illustrate some common features.

Common Features of Bacterial and Archaeal Cells

The best-studied bacterium, *Escherichia coli*, is a usually harmless inhabitant of the human intestinal tract. The *E. coli* cell (Fig. 4a) is an ovoid about 2 μm long and a little less than 1 mm in diameter, but other bacteria may be spherical or rod-shaped. It has a protective outer membrane and an inner plasma membrane that encloses the cytoplasm and the nucleoid. Between the inner and outer membranes is a thin but strong layer of a high molecular weight polymer (peptidoglycan) that gives the cell its shape and rigidity. The plasma membrane and the layers outside it constitute the cell envelope. The plasma membranes of bacteria consist of a thin bilayer of lipid molecules penetrated by proteins. Archaeal plasma membranes have a similar architecture, but the lipids can be strikingly different from those of bacteria.

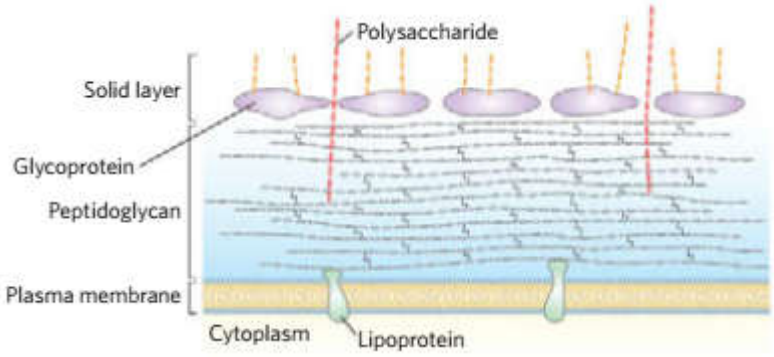

Fig 1–6. (b) The cell envelope of gram-positive bacteria is a single membrane with a thick, rigid layer of peptidoglycan on its outside surface.

Bacteria and archaea have group-specific specializations of their cell envelopes (Fig. 4b-d). Some bacteria, called gram-positive because they are colored by ***Gram's stain*** (introduced by ***Hans Peter Gram*** in 1882), have a thick layer of peptidoglycan outside their plasma membrane but lack an outer membrane. Gram-negative bacteria have an outer membrane composed of a lipid bilayer into which are inserted complex lipopolysaccharides and proteins called porins that provide transmembrane channels for low molecular weight compounds and ions to diffuse across this outer membrane. The structures outside the plasma membrane of archaea differ from organism to organism, but they, too, have a layer of peptidoglycan or protein that confers rigidity on their cell envelopes. The cytoplasm of *E. coli* contains about 15,000 ribosomes, various numbers (10 to thousands) of copies of each of 1,000 or so different enzymes, perhaps 1,000 organic compounds of molecular weight less than 1,000 (metabolites and cofactors), and a variety of inorganic ions. The nucleoid contains a single, circular molecule of DNA, and the cytoplasm (like that of most bacteria) contains one or more smaller, circular segments of DNA called plasmids. In nature, some plasmids confer resistance to toxins and antibiotics in the environment. In the laboratory, these DNA segments are especially amenable to experimental manipulation and are powerful tools for genetic engineering.

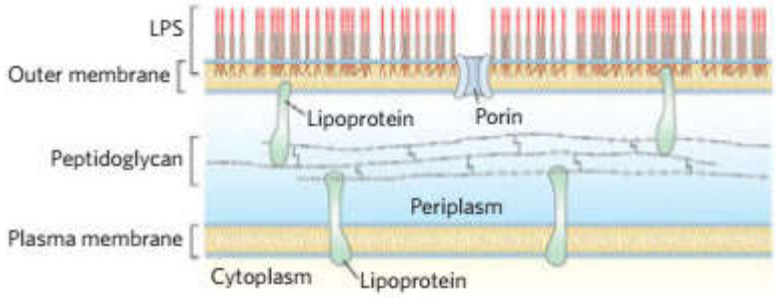

Fig 4c. *E. coli* is gram-negative and has a double membrane. Its outer membrane has a lipopolysaccharide (LPS) on the outer surface and phospholipids on the inner surface.

Other species of bacteria, as well as archaea, contain a similar collection of biomolecules, but each species has physical and metabolic specializations related to its environmental niche and nutritional sources. Cyanobacteria, for example, have internal membranes specialized to trap energy from light. Many archaea live in extreme environments and have biochemical adaptations to survive in extremes of temperature, pressure, or salt concentration. Differences in ribosomal structure gave the first hints that Bacteria and Archaea constituted separate domains. Most bacteria (including *E. coli*) exist as individual cells, but often associate in biofilms or mats, in which large numbers of cells adhere to each other and to some solid substrate beneath or at an aqueous surface. Cells of some bacterial species (the *myxobacteria*, for example) show simple social behavior, forming many-celled aggregates in response to signals between neighboring cells.

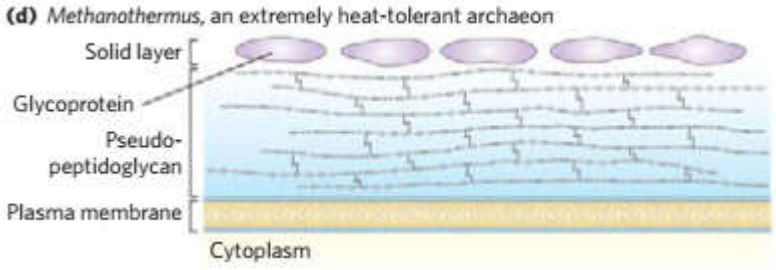

Fig 4d. Archaeal membranes vary in structure and composition, but all have a single membrane surrounded by an outer layer that includes either a peptidoglycan like structure, a porous protein shell (solid layer), or both.

Eukaryotic Cells Membranous Organelles

Typical eukaryotic cells are much larger than bacteria—commonly 5 to 100 μm in diameter, with cell volumes a thousand to a million times larger than those of bacteria. The distinguishing characteristics of eukaryotes are the nucleus and a variety of membrane-enclosed organelles with specific functions.

These organelles include mitochondria, the site of most of the energy extracting reactions of the cell; the endoplasmic reticulum and ***Golgi complexes****, which play central roles in the synthesis and processing of lipids and membrane proteins*; ***peroxisomes***, in which *very long-chain fatty acids are oxidized*; and ***lysosomes***, filled with *digestive enzymes to degrade unneeded cellular debris.* In addition to these, plant cells also contain ***vacuoles*** (which *store large quantities of organic acids*) and ***chloroplasts*** (*in which sunlight drives the synthesis of ATP in the process of photosynthesis*). Also present in the cytoplasm of many cells are granules or droplets containing stored nutrients such as starch and fat.

In a major advance in biochemistry, Albert Claude, Christian de Duve, and George Palade developed methods for separating organelles from the cytosol and from each other—an essential step in investigating their structures and functions. In a typical cell fractionation, cells or tissues in solution are gently disrupted by physical shear. This treatment ruptures the plasma membrane but leaves most of the organelles intact. The homogenate is then centrifuged; organelles such as nuclei, mitochondria, and lysosomes differ in size and therefore sediment at different rates. These methods were used to establish, for example, that lysosomes contain degradative enzymes, mitochondria contain oxidative enzymes, and chloroplasts contain photosynthetic pigments. The isolation of an organelle enriched in a certain enzyme is often the first step in the purification of that enzyme.