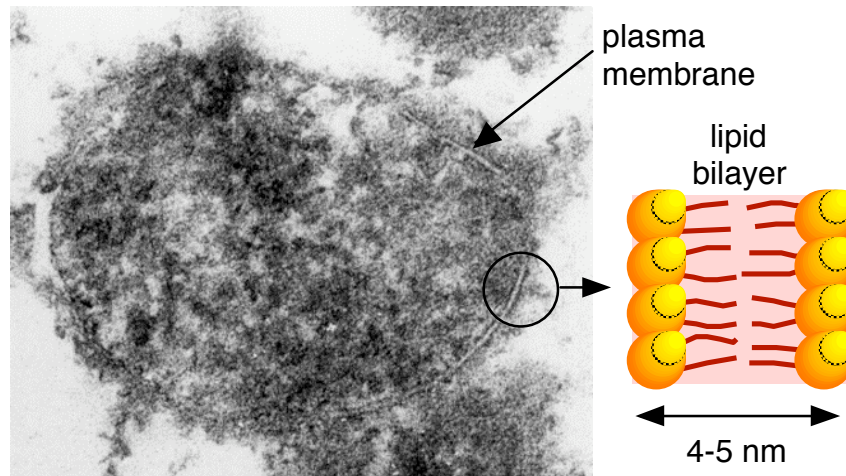
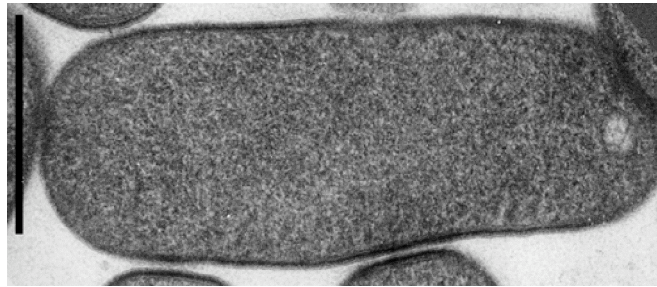


## PHYS 4xx Intro 1 - Cell sizes, shapes and structures

- Humans contain more than  $10^{13}$  cells that can be categorized into more than 200 different cell types, a remarkable outcome from a single fertilized egg!
- Smallest cells are mycoplasma, with diameters as low as  $0.4\ \mu\text{m}$ . *Archaeobacteria* and *eubacteria* represent about half of the biomass of the Earth

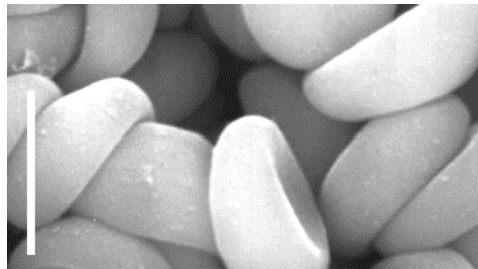


- Most bacteria are larger, with a linear dimension of  $1 - 5\ \mu\text{m}$ . Same general structure as small mycoplasma, but require a cell wall to withstand the internal pressure from the cytoplasm. No nucleus.



(*E. coli*, scale bar is  $0.9\ \mu\text{m}$ ; courtesy of Terry Beveridge)

- Nucleus-bearing cells are larger still and are called eukaryotes; dimensions of  $5\ \mu\text{m}$  and larger.



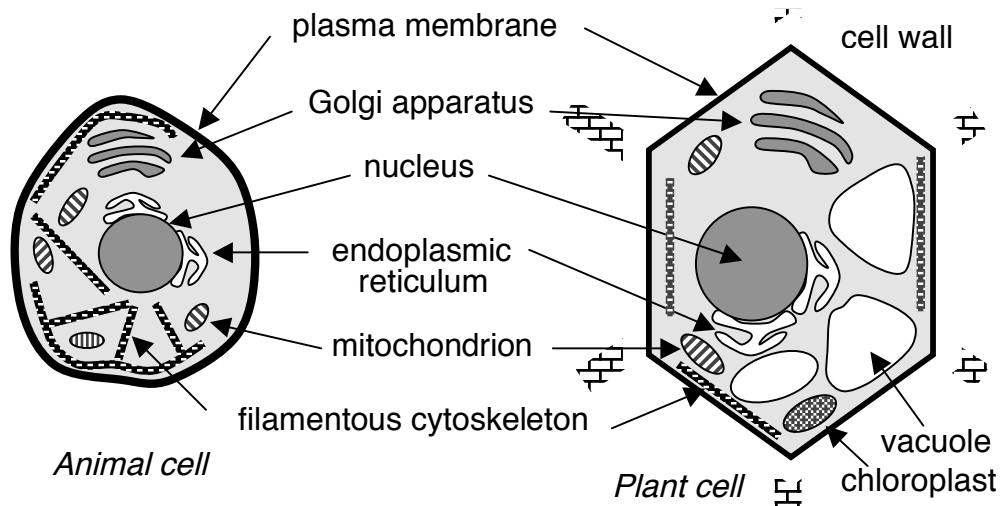
(human erythrocyte, scale bar is  $4\ \mu\text{m}$ )

In the circulatory system, the human erythrocyte has lost its nucleus (lousy example)

Cells are classified according to whether or not they possess a nucleus.

*Prokaryotes* do not have a nucleus and emerged early in the Earth's history, at least 3.5 Ga ago. This group contains archaeobacteria, eubacteria and modern bacteria.

*Eukaryotes* possess a nucleus and other organelles: they emerged much later in evolution, about 2 Ga ago. This group contains both plant and animal cells; these two cell types have many organelles in common, but the plant cells also have chloroplasts and vacuoles, as well as a cellulose-based cell wall for structural strength.



- The *nucleus* contains most of the cell's DNA (mitochondria and chloroplasts also contain DNA). It is bounded by two membranes, attached at pores which allow the passage of material across the nuclear envelope. Within the nucleus is the nucleolus, the site of ribosome assembly (approximately 12 nm wide and 25 nm long, ribosomes are large complexes of proteins and RNA). Given all of its contents, the nucleus is somewhat large, with a diameter in the range of 3 to 10  $\mu\text{m}$ .

- The *endoplasmic reticulum* surrounds the nucleus and is continuous with its outer membrane. As a series of folded sheets, the *rough endoplasmic reticulum* has a small volume compared to its surface, on which lie chains of ribosomes engaged in protein synthesis. The *smooth endoplasmic reticulum* is more tubular and plays a role in lipid metabolism.

- Shaped like a stack of disks, the membrane-bounded *Golgi apparatus* is the site of protein sorting. Small vesicles pinch off from the Golgi and transport proteins and other material to various regions of the cell. The typical diameter of a disk is a few microns.

- Present in both plant and animal cells, *mitochondria* produce the cell's energy currency, ATP (adenosine triphosphate), formed through the reaction of oxygen and food molecules. Shaped roughly like a cylinder with rounded ends (typically 0.5  $\mu\text{m}$  in

diameter), a mitochondrion is bounded by a double membrane, of which the inner membrane contains many folds or cristae.

- Plant cells can obtain ATP from both mitochondria and *chloroplasts*, the site of photosynthesis. Bounded by a double layer of membrane, chloroplasts contain disklike compartments that are bounded by thylakoid membrane and organized into stacks called grana. Typical length of a chloroplast is 5  $\mu\text{m}$ .

- Another organelle found only in plant cells is the *vacuole*, a large fluid-filled vesicle bound by a single membrane. Vacuoles can occupy more than 50% of a plant cell's volume.

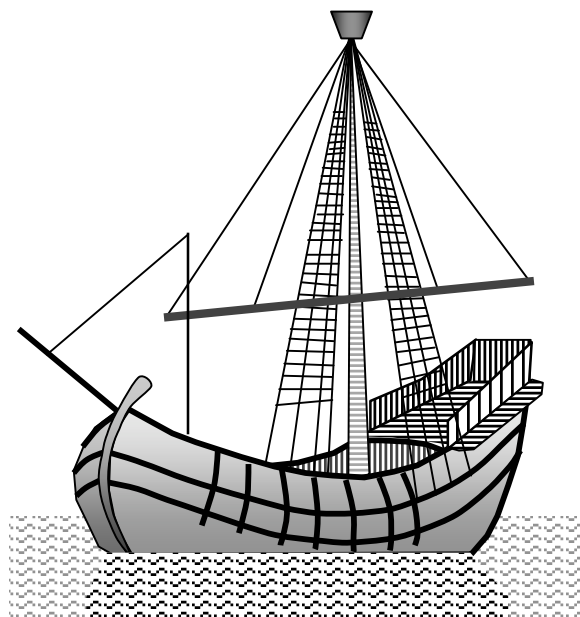
- The *cytoskeleton* is a network of protein filaments which may permeate the cytosol and/or may be associated with the plasma membrane. In most cells, the principal components of the cytoskeleton are hollow microtubules, intermediate filaments and actin filaments, with typical diameters of 25, 10 and 8 nm respectively.

- The *cell wall* of a plant cell is composed of cellulose, which forms a rigid mat whose thickness varies from 0.1 to 10 microns, depending on the cell. The cell wall is responsible for withstanding the internal pressure of the cell, and for providing mechanical strength to the multicellular plant.

## Design principles for the cell

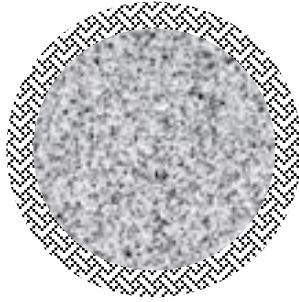
### Structure

- thin mechanical elements for materials efficiency
- reinforce as necessary
- employ tension-compression couplets

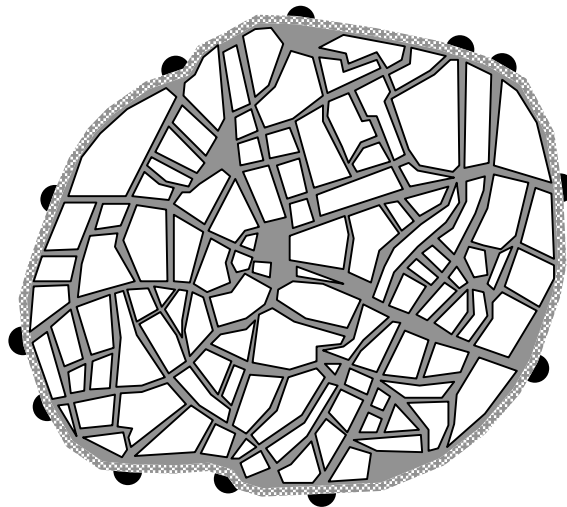


*Simplest design*

- pressurized interior
- tension-bearing membrane
- circular cells unless membrane is anisotropic

*Transportation*

- controlled entry to the cell's interior
- segregation of activities
- directed transport along microtubules
- at a speed of  $0.5 \mu\text{m/s}$ : 1 minute to cross a typical cell
- 500 hours to move 1 meter



walled city:  
restricted access  
roads for direct transport

(Malignes, Belgium)