

Cell Size Notes

Cell size is limited in accordance with the ratio of cell surface area to volume.

Learning Objectives

- Describe the factors limiting cell size and the adaptations cells make to overcome the surface area to volume issue

Key Points

- As a cell grows, its volume increases much more rapidly than its surface area. Since the surface of the cell is what allows the entry of oxygen, large cells cannot get as much oxygen as they would need to support themselves.
- As animals increase in size they require specialized organs that effectively increase the surface area available for exchange processes.

Key Terms

- surface area:** The total area on the surface of an object.

At 0.1 to 5.0 μm in diameter, prokaryotic cells are significantly smaller than eukaryotic cells, which have diameters ranging from 10 to 100 μm . The small size of prokaryotes allows ions and organic molecules that enter them to quickly diffuse to other parts of the cell. Similarly, any wastes produced within a prokaryotic cell can quickly diffuse out. This is not the case in eukaryotic cells, which have developed different structural adaptations to enhance intracellular transport.

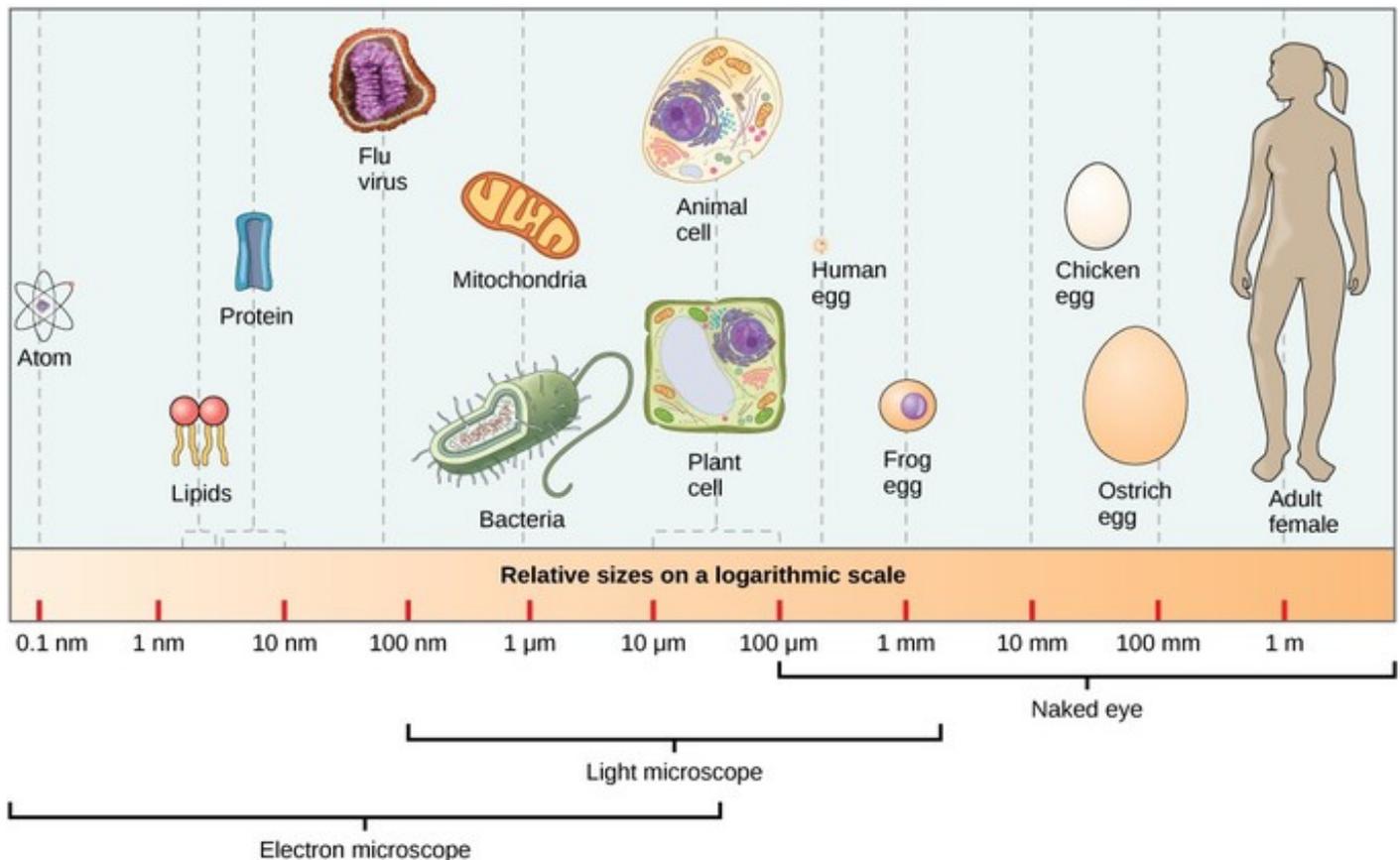


Fig 1: **Relative Size of Atoms to Humans:** This figure shows relative sizes on a logarithmic scale (recall that each unit of increase in a logarithmic scale represents a 10-fold increase in the quantity being measured).

In general, small size is necessary for all cells, whether prokaryotic or eukaryotic. Consider the area and volume of a typical cell. Not all cells are spherical in shape, but most tend to approximate a sphere. The formula for the surface area of a sphere is $4\pi r^2$, while the formula for

its volume is $4\pi r^3/3$. As the radius of a cell increases, its surface area increases as the square of its radius, but its volume increases as the cube of its radius (much more rapidly).

Therefore, as a cell increases in size, its surface area-to-volume ratio decreases. This same principle would apply if the cell had the shape of a cube (below). If the cell grows too large, the plasma membrane will not have sufficient surface area to support the rate of diffusion required for the increased volume. In other words, as a cell grows, it becomes less efficient. One way to become more efficient is to divide; another way is to develop organelles that perform specific tasks. These adaptations lead to the development of more sophisticated cells called eukaryotic cells.

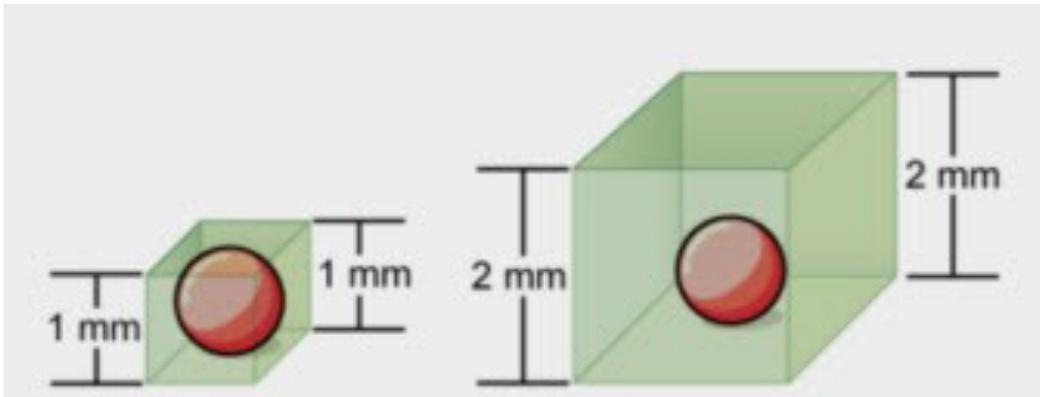


Figure 2.: **Surface Area to Volume Ratios:** Notice that as a cell increases in size, its surface area-to-volume ratio decreases. When there is insufficient surface area to support a cell's increasing volume, a cell will either divide or die. The cell on the left has a volume of 1 mm³ and a surface area of 6 mm², with a surface area-to-volume ratio of 6 to 1, whereas the cell on the right has a volume of 8 mm³ and a surface area of 24 mm², with a surface area-to-volume ratio of 3 to 1.

- Smaller single-celled organisms have a high surface area to volume ratio, which allows them to rely on oxygen and material diffusing into the cell (and wastes diffusing out) in order to survive.
- The higher the surface area to volume ratio they have, the more effective this process can be. Larger animals require specialized organs (lungs, kidneys, intestines, etc.) that effectively increase the surface area available for exchange processes, and a circulatory system to move material and heat energy between the surface and the core of the organism.
- Increased volume can lead to biological problems. King Kong, the fictional giant gorilla, would have insufficient lung surface area to meet his oxygen needs, and could not survive. For small organisms with their high surface area to volume ratio, friction and fluid dynamics (wind, water flow) are relatively much more important, and gravity much less important, than for large animals.
- However, increased surface area can cause problems as well. More contact with the environment through the surface of a cell or an organ (relative to its volume) increases loss of water and dissolved substances. High surface area to volume ratios also present problems of temperature control in unfavorable environments.