

Cell Size and Shape - Advanced

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Printed: August 29, 2016

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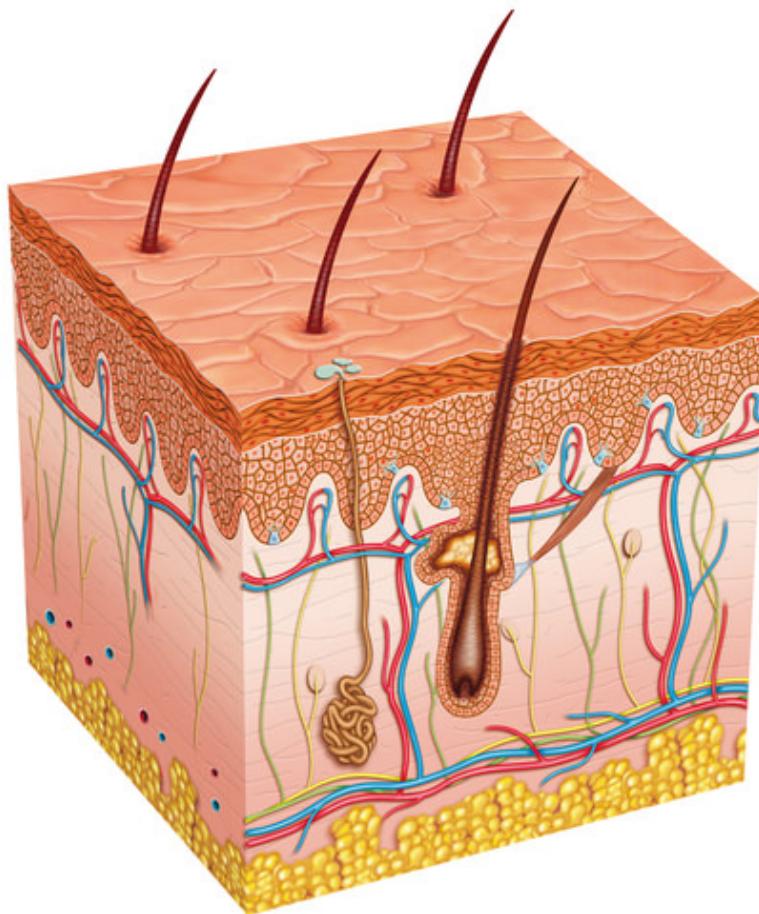


CHAPTER

1

Cell Size and Shape - Advanced

- Identify the limitations on cell size. Describe the relationship between volume and surface area.
- Discuss cell shape and its relationship to cell function.



What determines a cell's function?

The cell's structure has a lot to do with it. Notice in the representation of skin that there are different layers. These layers have different functions. Also notice the difference in cell shape within the different layers. The structure-function relationship is a central theme running throughout biology.

Diversity of Cells

Different cells within a single organism can come in a variety of sizes and shapes. They may not be very big, but their shapes can be very different from each other. However, these cells all have common abilities, such as obtaining and using food energy, responding to the external environment, and reproducing. In part, a cell's shape determines its function.

Cell Size

If cells are the main structural and functional unit of an organism, why are they so small? And why are there no organisms with huge cells? The answers to these questions lie in a cell's need for fast, easy food. The need to be able to pass nutrients and gases into and out of the cell sets a limit on how big cells can be. The larger a cell gets, the more difficult it is for nutrients and gases to move in and out of the cell.

As a cell grows, its volume increases more quickly than its surface area. If a cell was to get very large, the small surface area would not allow enough nutrients to enter the cell quickly enough for the cell's needs. This idea is explained in **Figure 1.1**. However, large cells have a way of dealing with some size challenges. Big cells, such as some white blood cells, often grow more nuclei so that they can supply enough proteins and RNA for the cell's requirements. Large, metabolically active cells often have lots of cell protrusions, resulting in many folds throughout the membrane. These folds increase the surface area available for transport of materials into or out of the cell. Such cell types are found lining your small intestine, where they absorb nutrients from your food through protrusions called **microvilli**.

Scale of Measurements

- 1 centimeter (cm) = 10 millimeters (mm) = 10^{-2} meters (m)
- 1 mm = 1000 micrometers (μm) = 10^{-3} m
- 1 μm = 1000 nanometers (nm) = 10^{-6} m
- 1 nm = 10^{-3} μm

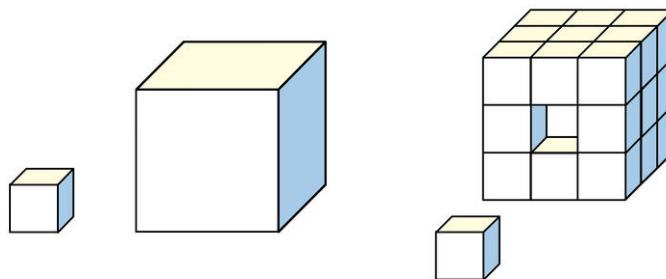


FIGURE 1.1

A small cell (left), has a larger surface-area to volume ratio than a bigger cell (center). The greater the surface-area to volume ratio of a cell, the easier it is for the cell to get rid of wastes and take in essential materials such as oxygen and nutrients. In this example, the large cell has the same area as 27 small cells, but much less surface area.

Imagine cells as little cube blocks. If a small cube cell like the one in **Figure 1.1** is one unit (u) in length, then the total surface area of this cell is calculated by the equation:

- height \times width \times number of sides \times number of boxes
- $1\text{u} \times 1\text{u} \times 6 \times 1 = 6\text{u}^2$

The volume of the cell is calculated by the equation:

- height \times width \times length \times number of boxes
- $1\text{u} \times 1\text{u} \times 1\text{u} \times 1 = 1\text{u}^3$

The surface-area to volume ratio is calculated by the equation:

- area \div volume

- $6 \div 1 = 6$

A larger cell that is 3 units in length would have a total surface area of

- $3u \times 3u \times 6 \times 1 = 54u^2$

and a volume of:

- $3u \times 3u \times 3u \times 1 = 27u^3$

The surface-area to volume ratio of the large cell is:

- $54 \div 27 = 2$

Now, replace the three unit cell with enough one unit cells to equal the volume of the single three unit cell. This can be done with 27 one unit cells. Find the total surface area of the 27 cells:

- $1u \times 1u \times 6 \times 27 = 162u^2$

The total volume of the block of 27 cells is:

- $1 \times 1 \times 1 \times 27 = 27u^3$

The surface-area to volume ratio of the 27 cells is:

- $162 \div 27 = 6$

An increased surface area to volume ratio means increased exposure to the environment. This means that nutrients and gases can move in and out of a small cell more easily than in and out of a larger cell.

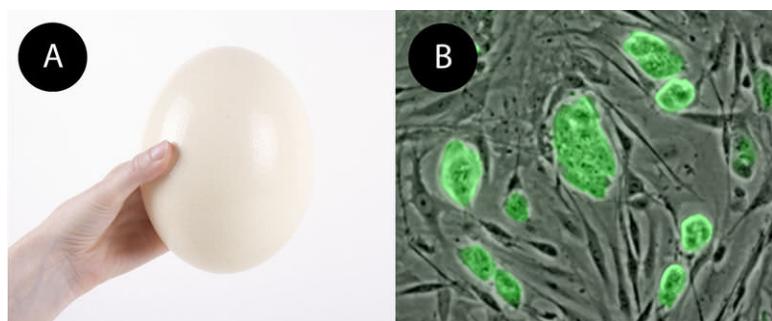


FIGURE 1.2

Ostrich eggs (A) can weigh as much as 1.5 kg and be 13 cm in diameter, whereas each of the mouse cells (B) shown at right are each about $10 \mu\text{m}$ in diameter, much smaller than the period at the end of this sentence.

The cells you have learned about so far are much smaller than the period at the end of this sentence, so they are normally measured on a very small scale. The smallest **prokaryotic cell** currently known has a diameter of only 400 nm. **Eukaryotic cells** normally range between 1- $100 \mu\text{m}$ in diameter. The mouse cells in **Figure 1.2** are about $10 \mu\text{m}$ in diameter. One exception, however, is **eggs**. Eggs contain the largest known single cell, and the ostrich egg is the largest of them all. The ostrich egg in **Figure 1.2** is over 10,000 times larger than the mouse cell.

Cell Shape

The variety of cell shapes seen in prokaryotes and eukaryotes reflects the functions that each cell has, confirming the **structure-function relationship** seen throughout biology. Each cell type has evolved a shape that is best related to its function. For example, the **neuron** in **Figure 1.3** has long, thin extensions (**axons** and **dendrites**) that reach out to other nerve cells. The extensions help the neuron pass chemical and electrical messages quickly through the body. The shape of the red blood cells (**erythrocytes**) enable these cells to easily move through **capillaries**. The spikes on the pollen grain help it stick to a pollinating insect or animal so that it can be transferred to and pollinate another flower. The long whip-like **flagella** (tails) of the algae *Chlamydomonas* help it swim in water.

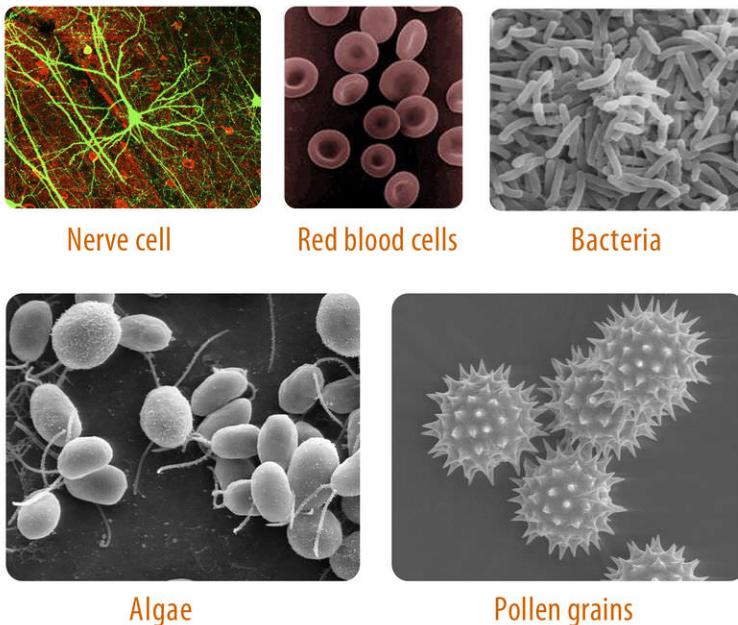


FIGURE 1.3

Cells come in very different shapes. Left to right, top row: Long, thin nerve cells; biconcave red blood cells; curved-rod shaped bacteria. Left to right, bottom row: oval, flagellated algae and round, spiky pollen grains are just a sample of the many shapes.

Summary

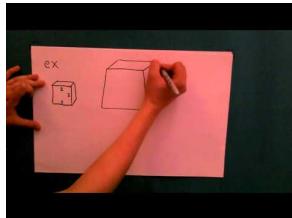
- Cell size is limited by a cell's surface area to volume ratio. A smaller cell is more effective at transporting materials, including waste products, than a larger cell.
- Cells come in many different shapes. A cell's function is determined, in part, by its shape.

Review

1. What limits the size of a cell? Why?
2. A cell has a volume of 64 units, and total surface area of 96 units. What is the cell's surface area to volume ratio?
3. What is the largest single cell?
4. Describe the relationship between cell shape and function? Give an example of cell shape influencing cell function.

Explore More

Use this resource to answer the questions that follow.



MEDIA

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1. Describe the relationship between the cell surface area and cell membrane.
2. Why is a smaller volume of the cell better?
3. What are ways to "get around" the SA:V ratio?

References

1. Niamh Gray-Wilson. [CK-12 Foundation](#) . CC BY-NC 3.0
2. (A) Lenore Edman (Flickr:1lenore); (B) National Science Foundation. (A) <http://www.flickr.com/photos/lenore-m/6123190318/>; (B) http://commons.wikimedia.org/wiki/File:Mouse_embryonic_stem_cells.jpg . (A) CC BY 2.0; (B) Public Domain
3. Nerve cell: WA Lee et al.; Blood cell: Courtesy of National Institute of Health; Bacteria: TJ Kirn, MJ Lafferty, CMP Sandoe, and RK Taylor; Algae: EF Smith and PA Lefebvre; Pollen: L Howard and C Daghlian. Nerve cell: <http://en.wikipedia.org/wiki/File:GFPneuron.png>; Blood cell: <http://commons.wikimedia.org/wiki/File:Redbloodcells.jpg>; Bacteria: <http://remf.dartmouth.edu/images/bacteriaSEM/source/1.html>; Algae: <http://remf.dartmouth.edu/images/algaeSEM/source/1.html>; Pollen: <http://remf.dartmouth.edu/images/botanicalPollenSEM/source/10.html> . Nerve cell: CC-BY 2.5; Blood cell: Public Domain; Bacteria: Public Domain; Algae: Public Domain; Pollen: Public Domain