## Surface to volume ratios: Relationship to cell size

As cells increase in size, the surface area and volume do not usually increase proportionally to length. The greater the diameter of a single-celled organism, the lower the surface area to volume ratio. It is this relationship that restricts the size of a particular cell. Cells must be able to take up and eliminate substances rapidly and efficiently. They must also be able to distribute substances throughout the cell. Most of this distribution occurs by diffusion, which is relatively slow and dependent on random molecular motion.

In our experiment, we created three cubes: 3cm x 3cm, 2cm x 2cm, 1cm x 1cm
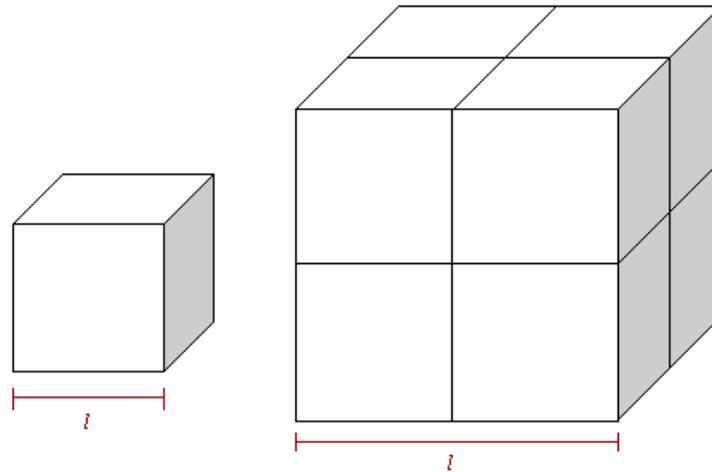
For the **cube**, **Surface Area** = length x width x # of sides & **Volume** = length x width x height

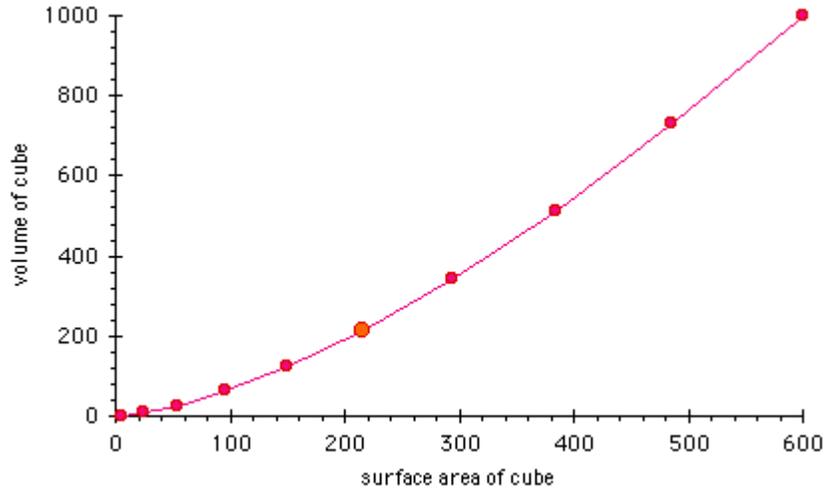For a **sphere** (cell), **Surface Area** = $4\pi r^2$ & **Volume** = $4\pi r^3/3$
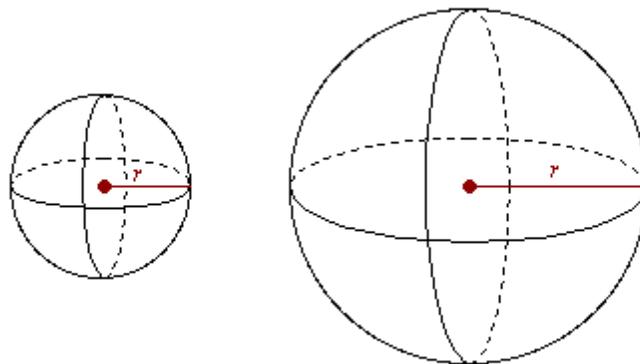
As the length or radius of the sphere increases, the increase in the surface area is squared (X^2) and the increase in the volume is cubed (X^3). This means that the increase is not proportional and the volume increases much more rapidly than the surface area. At some point, the cell will reach a size at which substances cannot enter or leave the cell in sufficient time to sustain life. Also, the volume of the cell will be so large that the diffusion rate will be too low to distribute necessary substances throughout the cell within a reasonable time. The importance of diffusion rate is evident in the structural adaptations in the small intestines. In order to facilitate the uptake of nutrients in the time it takes for food to traverse the small intestines, an enormous amount of surface area is needed. The body accomplishes this by a series of folds, including microvilli on the apical surface of each cell, villi in the tissue lining the gut, and plicae circularis.
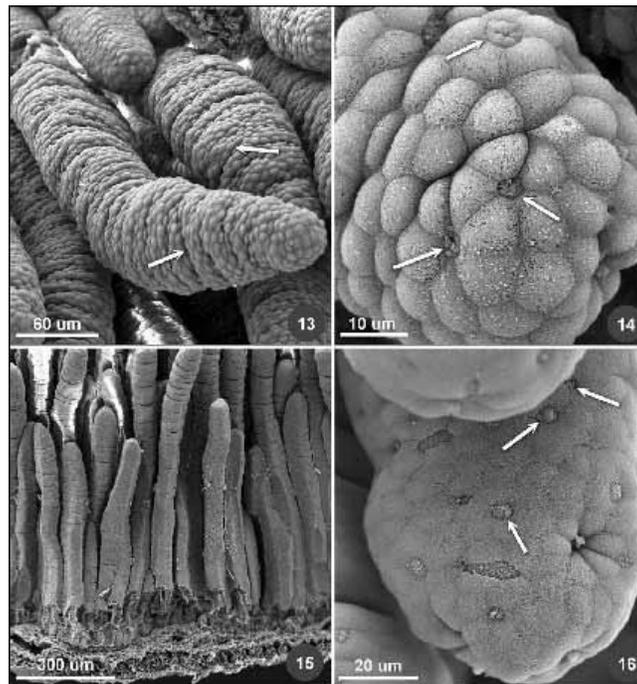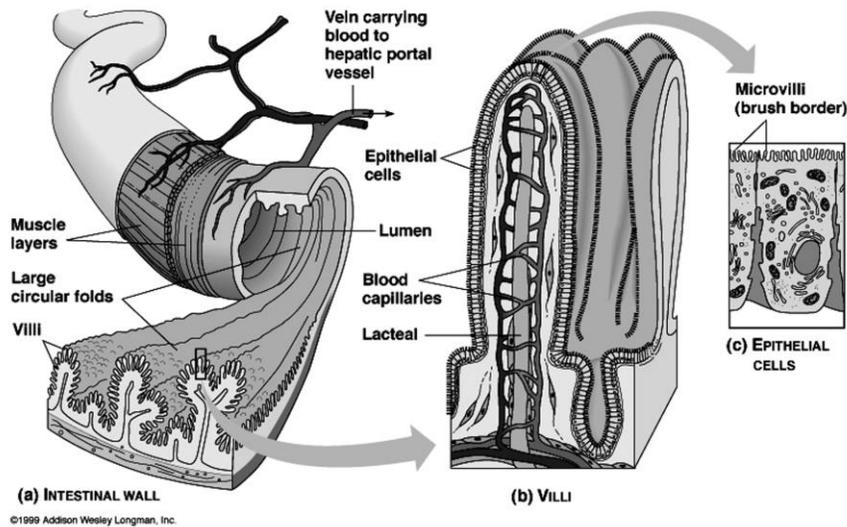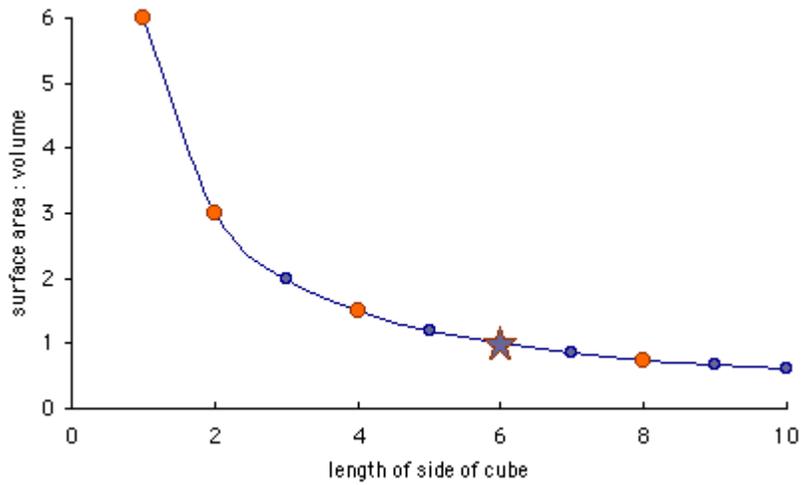

microvilli

Compare the following graphs showing the relationship between the **volume** and **surface area** of a cube **(A)**, and the **surface area: volume ratio** and **length** of the side of the cube (B). It is clear from these graphs that as the length of the side of the cube increases, the surface area: volume ratio decreases.

(A)

(B)