Surface area to volume ratio

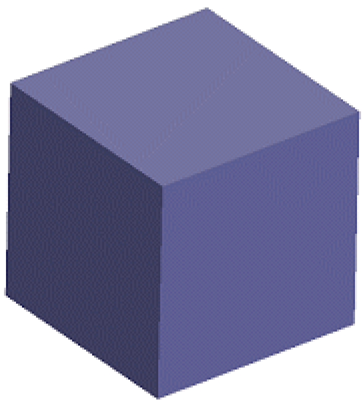
Organisms exchange **substances** and **heat** with their **environment** all the time, and this possibility is crucial to survival. The specific way in which this is achieved is very tightly related to the **shape and structure of the specific organism**, as well as its environment. For example, **unicellular organisms** are so small that molecules such as **oxygen** and **water** can readily **diffuse** in and out via the membrane, due to the short diffusion pathway. Could this be achieved by a human, or even a bee? No – they are simply too big.

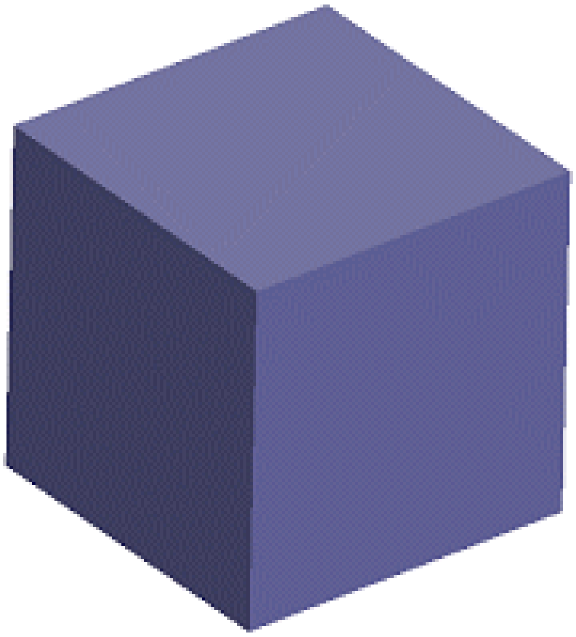
Two properties are important to consider here: the **volume** of an organism, and the **surface area** of an organism. The volume is what determines the amount of substances which need exchanging, while the surface area determines the amount which **can** be exchanged.

Surface area describes the number of **cells** in direct contact with the environment. **Volume** describes the space occupied by all **metabolically active cells.**

Key principle: as the size of an organism increases, the surface area to volume ratio decreases.

That might seem hard to really understand. Why use a ratio in the first place? Well, the ratio shows the relationship between surface area and volume ratio, i.e. how similar or dissimilar are they?





Maths Time

Small cube

Surface area = 1^2 x 6 = 6

Volume = 1^3 = 1

Surface area : volume = 6:1 = **6.00**

Big cube

Surface area = 2^2 x 6 = 24

Volume = 2^3 = 8

Surface area : volume = 24:8 = 3:1 = **3.00**

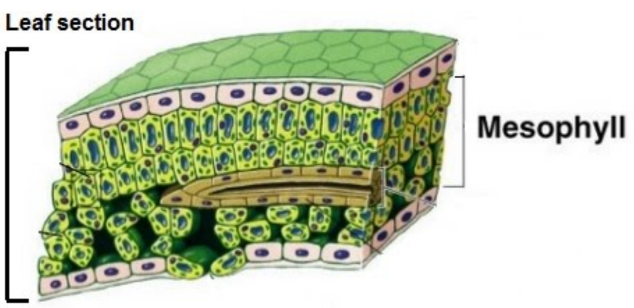
3 is smaller than 6, so as the cube/organism gets larger, the surface area to volume ratio decreases.

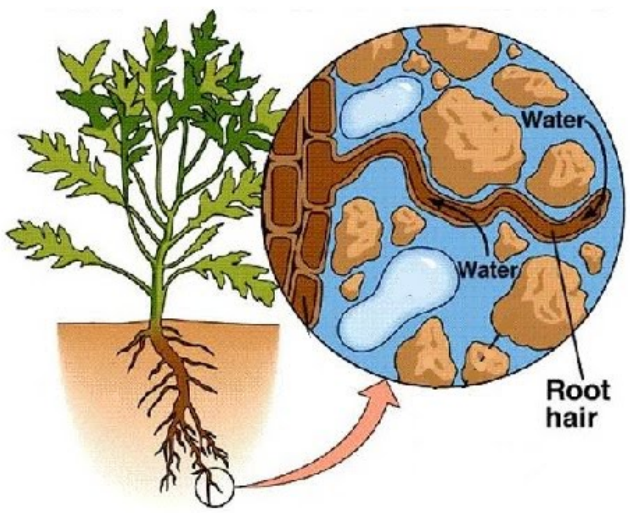
What this basically means is that the larger an organism gets, the less surface area is available to serve its increasing needs due to its increasing volume. So what adaptations do larger organisms have to cope with the large demand for substance and heat exchange?

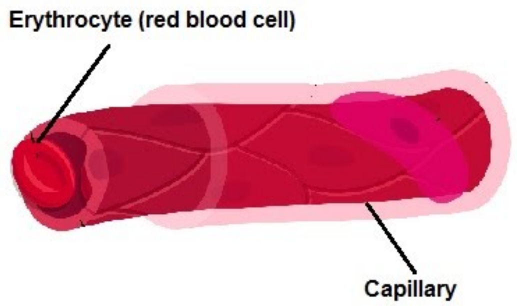
For one, mere diffusion directly into and out of the organism is not possible. Insects, for example, have a system of **tubules** which distribute air within the body so that it reaches all the different parts. Mammals have **lungs** and **blood vessels**. Fish have **gills**. All these are systems are specifically aimed at making it possible to exchange substances such as oxygen, carbon dioxide, nutrients, as well as heat, between an organism and its environment.

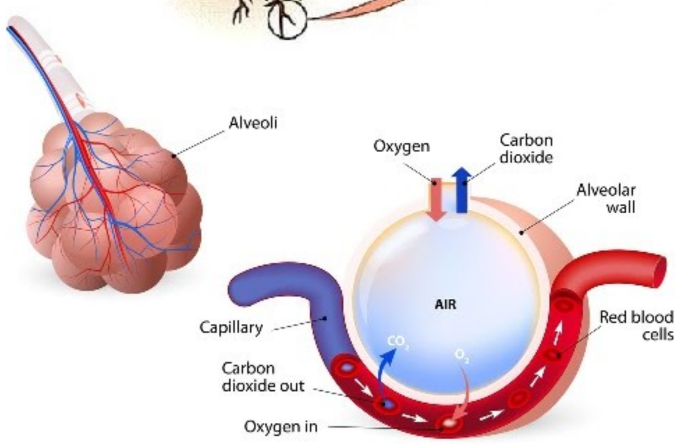
In fact, the reason behind insects' limited size is that their tubule system can only work for those sizes. Otherwise, we might just have gigantic wasps flying around. Be thankful for surface area to volume ratio!

Coping with increasing distance between cells and nutrients involves minimising the diffusion pathway by employing **thin** structures e.g. cells, vessels, membranes, as well as increasing the available **surface area** for reactions e.g. leaf area, and maintaining **concentration gradients** to enable **passive** and **active transport** in cells.









This is exemplified by the **leaf mesophyll** where cells are tightly packed, **root hairs** that increase surface area of cells in contact with the environment for water and ion absorption, **capillaries** that are just 1-cell thick to the point where red blood cells must fold to pass through, and **alveoli** in the lungs. All these diverse structures are adapted to have a small diffusion pathway, large surface area and maintain steep concentration gradients.