

## What sets limits on cell sizes?

### Lower limit

- Any cell must be large enough to **FIT** the necessary equipment to perform all the required metabolic (chemical) functions & cellular activities for life.

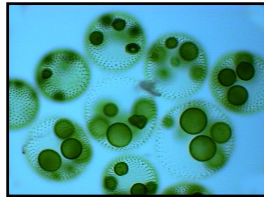
- smallest bacteria, mycoplasmas
  - 0.1 to 1.0  $\mu\text{m}$  = micrometer
- most bacteria
  - 1-10  $\mu\text{m}$



### Upper limit

- Metabolic (chemical) requirements impose an upper limit to the size of cells as well.

- eukaryotic cells
  - 10-100  $\mu\text{m}$
- micron = micrometer = 1/1,000,000 meter
- diameter of human hair = ~20 microns



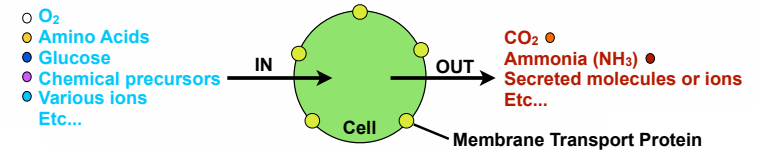
AP Biology

2005-2006

## What limits **MAXIMUM** cell size?

- In order for the necessary chemical reactions and proper molecular interactions to continue occurring at the correct **rates**, solutes must be present at **specific concentrations** inside the cell's cytoplasm (**volume**)

- Too few required resources will cause the metabolism inside the cell to fail while the accumulation of too many chemical waste products can also interfere with normal cell functioning.
- Some non-polar solutes like  $\text{O}_2$  gas can **diffuse** into the cell and waste products like  $\text{CO}_2$  can diffuse out of the cell, **crossing the membrane without assistance**.
- Most solutes, however, are partially or fully charged and need **proteins embedded inside the plasma membrane** to help **transport** them across into or out of the cell

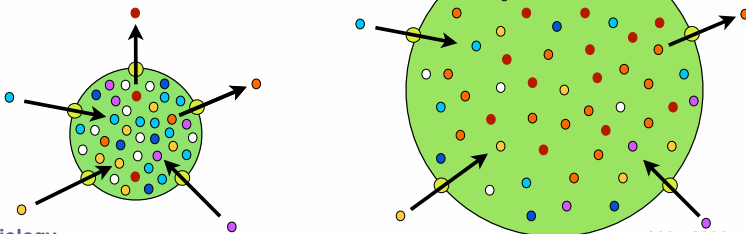


## What limits **MAXIMUM** cell size?

- As a cell gets bigger its volume increases faster proportionally to its surface area!

- As cell gets larger, volume increases cubically, but surface area only increases by squares.

- If a cell grows without increasing the rate of transport of substances into and out of the cell, the cell would not maintain the proper solute concentration of these substances.

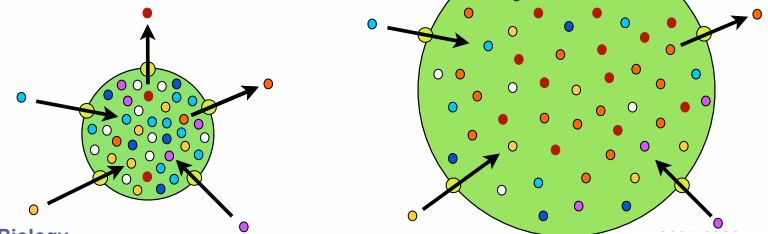


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## What limits **MAXIMUM** cell size?

- Without adding more transport proteins in the plasma membrane, a cell that grows larger would experience problems:

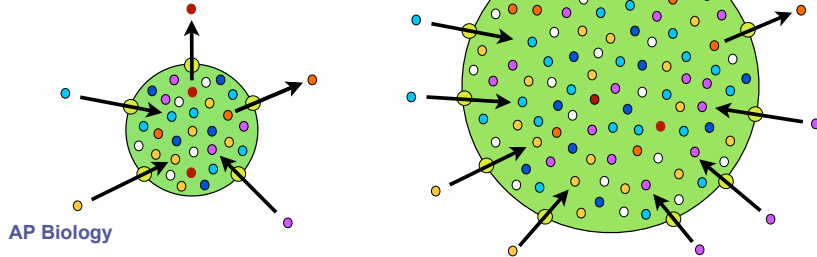
- Necessary resources would **not enter the cell at a fast enough rate** to maintain high enough internal concentrations
- Harmful waste products would **not exit the cell at a fast enough rate** and would accumulate to too high concentrations inside the cell
  - Concentration** = number of particles (mol) / amount of solvent (volume)



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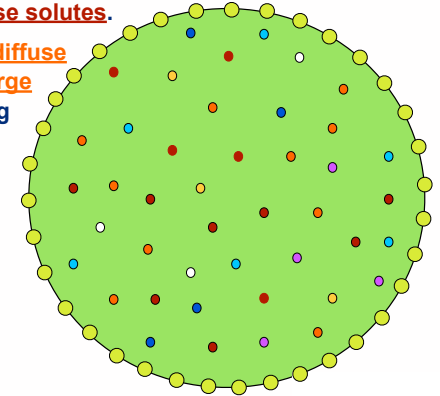
## What limits MAXIMUM cell size?

- As a cell grows, it **must have a large enough membrane surface area to volume ratio** so that enough transport proteins can be embedded in this plasma membrane to be able to bring in or remove substances at an adequate rate to maintain proper internal solute concentrations.
  - Substances that can cross the membrane without protein assistance must also not have to travel too long of a distance to reach the area in the cell where they are required.



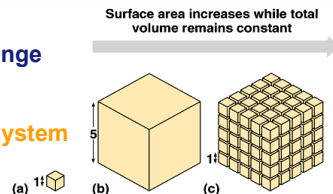
## What limits MAXIMUM cell size?

- Past a certain maximum volume, **a cell no longer has enough plasma membrane surface area** in which to embed enough membrane transport proteins in order to keep transporting in and out resources and waste products at a fast enough rate **to maintain adequate internal concentrations of these solutes**.
- The **distance solutes have to diffuse inside the cell becomes too large** as well, solutes taking too long to reach their destination inside the cell
  - The metabolic requirements of the cell can no longer be met.



## What limits MAXIMUM cell size?

- It is critically important for a cell to have a large enough **Surface(Area)-to-Volume Ratio**:
- Objects with smaller diameters have greater ratios of surface area to volume
  - The volume of the cell is metabolically demanding...it depends on rapid exchange of metabolites between the cell and its external environment.
    - The surface area is the exchange system
  - As cell gets larger, the surface area **cannot** keep up with demand.



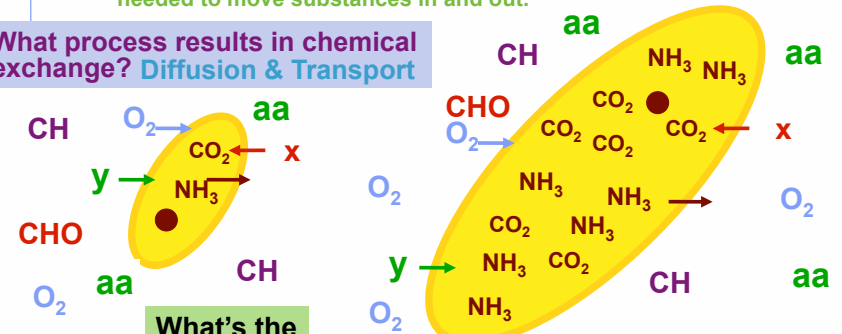
Total surface area (height x width x number of sides x number of boxes)	6	150	750
Total volume (height x width x length x number of boxes)	1	125	125
Surface-to-volume ratio (area ÷ volume) <b>SA/V</b>	<b>6</b>	<b>~1.2</b>	<b>6</b>

Why is a huge single-cell creature **not** possible?

## What limits MAXIMUM cell size?

- Metabolic requirements set upper limit**
  - if a cell grows too large, it cannot move material in [nutrients & gases] & out [waste products] of cell fast enough to support the internal chemistry of life
    - Enough Plasma Membrane, with its embedded transport proteins, is needed to move substances in and out.

What process results in chemical exchange? **Diffusion & Transport**



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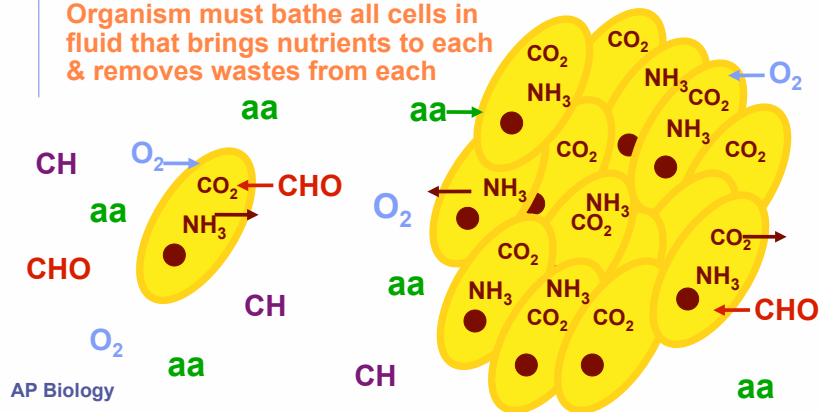
Cells divide to keep SA/V ratios of cells high!

## So how do organisms get bigger?

- Become **multi-cellular** (cell divides)

**But what challenges do you have to solve now?**

Organism must bathe all cells in fluid that brings nutrients to each & removes wastes from each



## Cell membrane

- Exchange “organelle”

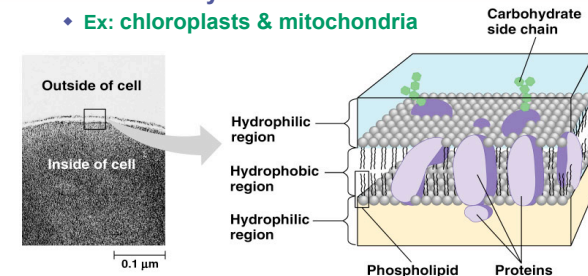
- ♦ **plasma membrane** functions as selective barrier (**SEMIPERMEABLE**)

- allows passage of  $\text{O}_2$ , nutrients, & wastes

- ♦ **Membranes as sites for chemical reactions**

- unique combinations of **lipids & proteins**
- embedded enzymes & reaction centers

- ♦ Ex: **chloroplasts & mitochondria**



## Organelles & Internal membranes

- **Eukaryotic cell**

- ♦ **internal membranes**

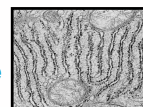
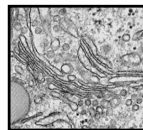
- partition cell into compartments
- create different local environments, distinct from that of the cytosol

- ♦ separate pH, different concentrations of solutes
- ♦ allow for distinct & incompatible functions to take place
  - lysosomal digestive enzymes must be activate in the lysosome only and not be activated outside of a lysosome or they will digest critical macromolecules elsewhere in the cell

- compartmentalize functions

- membranes for different compartments are specialized for their function

- ♦ different structures for specific functions
- ♦ Each organelle's membrane has a unique combination of lipids & proteins



## Cells gotta work to live!

- **What jobs do cells have to do?**

- ♦ **make proteins**

- proteins control **every** cell function

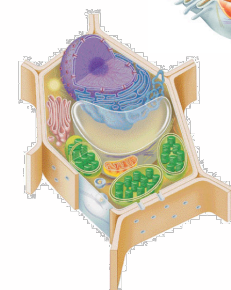
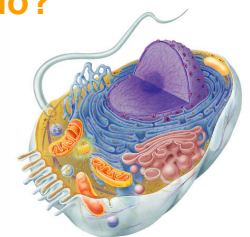
- ♦ **convert energy**

- for life's daily work

- ♦ **make more cells**

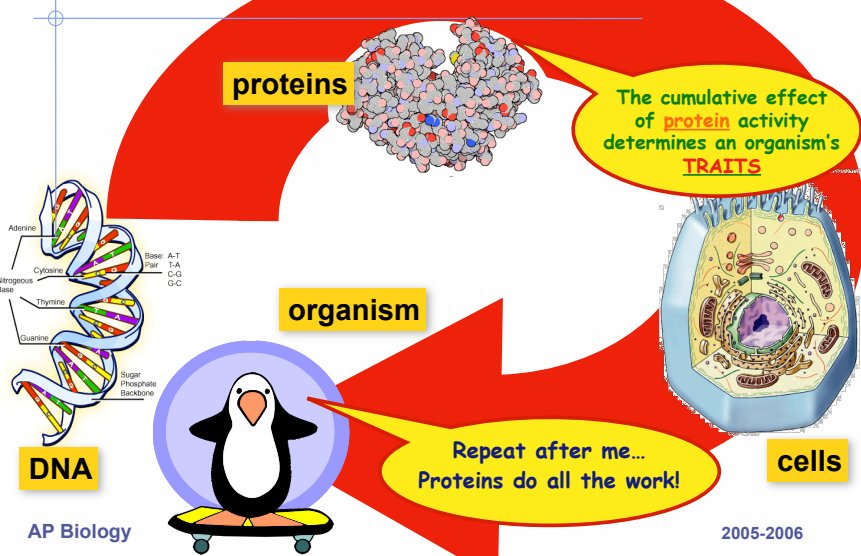
- growth
- repair
- renewal
- reproduction

AP Biology ♦ **And more...**



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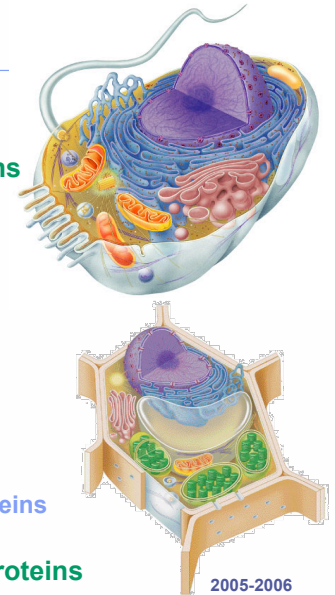
# Proteins do all the work!



## Cells functions

### Why build proteins?

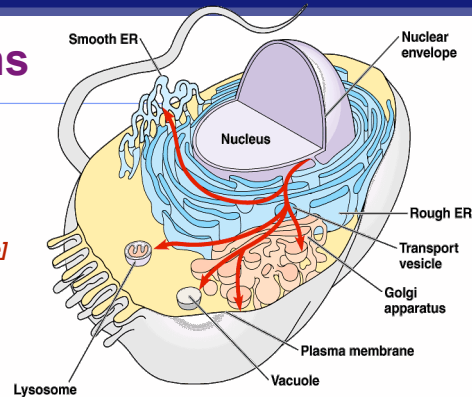
- ♦ read & copy DNA instructions
- ♦ help make RNA molecules
- ♦ help make other proteins
- ♦ process polypeptides
  - folding
  - modifying
    - ♦ removing amino acids
    - ♦ adding other molecules to proteins
      - e.g, making glycoproteins for cell membranes
- ♦ Address label & transport proteins



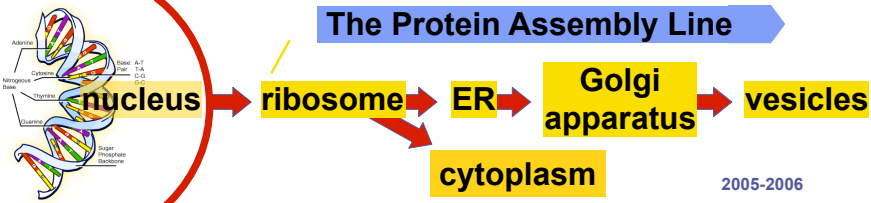
## Building Proteins

### Organelles & Structures involved:

- ♦ nucleus
- ♦ ribosomes [not an organelle]
- ♦ endoplasmic reticulum (ER)
- ♦ Golgi apparatus
- ♦ Vesicles [for transport]



### The Protein Assembly Line



- ♦ So protein action determines cell shape/activity, but what role do the internal compartments of Eukaryotes play in overall cell function?

