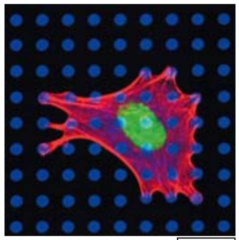
Topic 1 – Introduction to cell biology

- Reading
  - Chapter 2 (except 2.5)
  - Chapter 3
  - Purple pages F-52 to F-56
  - See BIO 1140 website
- Objectives
  - Cell Theory
  - Basic properties of cells
  - Cell diversity: prokaryotic vs eukaryotic cells


Karp 2008

What is a cell?

- Fundamental unit of life
  - Every organism either consists of cells or is itself a single cell
- Cell Theory
  - I. All organisms consist of one or more cells
  - II. The cell is the basic unit of structure for all organisms
    - Theodor Schwann,1839 (Matthias Schleiden, 1838)
  - III. All cells arise only from pre-existing cells (i.e. the cell is the basic unit of reproduction)
    - Rudolf Virchow, 1855

Ch 36, p876

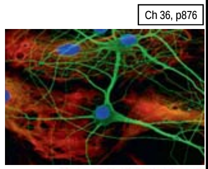



Fig. 20.2

Cells are the basis of life. They regulate their internal environment. Contain genetic material. Respond to the physical environment. Can replicate and evolve. Can mutate. Bounded by a membrane. Carries out metabolic processes.

Organelles inside the membrane (lipid bilayer) sit in a cytoplasm made of salts, organic molecules, and water

Schleidon and Schwann both discovered the cell while working independently

- Can one speak of *the* cell?
  - Enormous diversity in form, function and size
  - Similar basic chemistry (unity)

Ch 36, p876

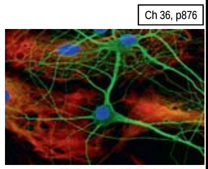
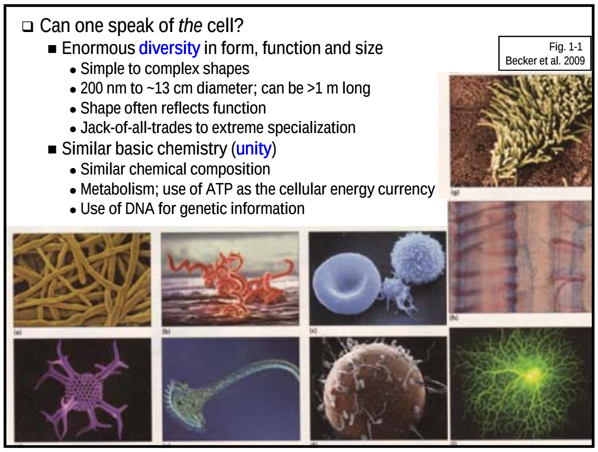



Fig. 20.2



Not all cells are small, some can be 13 cm diameter (example, an ostrich egg).

Eggs are considered single cells

typical prokaryote is 1-5 microns large

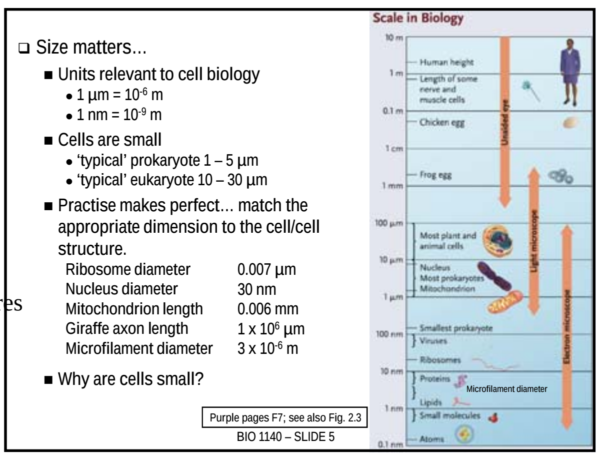
Axons of neurons can be 1 metre long (ex. in limbs of giraffes)

Multicellular organisms are highly diverse and have many types of cells which have many different functions.

At the same time, cells are similar: energy transfer in the cell uses a common currency (ATP), all have a lipid membrane, proteins all made up of the same 20 amino acids, DNA is pretty much the same make up across all cells.

Fundamental similarities allow us to generalize from one cell to another.

match the cells and cell structures to their proper size



Microns (micrometres) and nanometres will be often used in this course.

Typical prokaryotes are 5-10 microns, eukaryotes are 10 -30 microns

Ribosomes --> 30nm

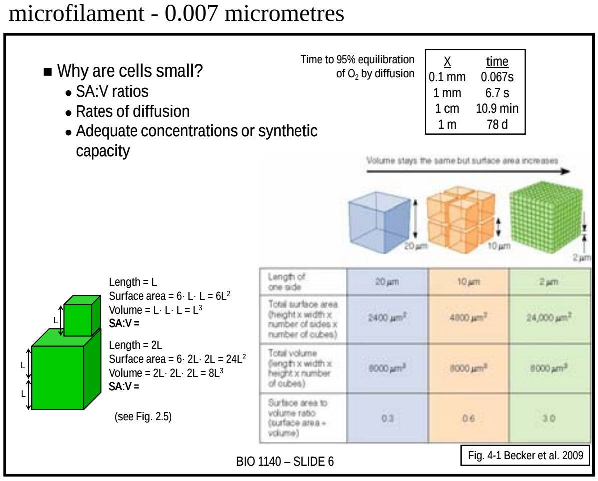
Ribosome - 30nm

mitochondria - 3 x 10^-6 m

Nucleus - 0.006mm

Giraffe axon - 1 x 10^6micrometres

microfilament - 0.007 micrometres



SA:V ratio: Volume of cell determines how much nutrients it needs and how much waste it must get rid of. This happens across the cell membrane. As the volume increases, the SA increase at a slower rate. Example of the two cube cells: SA:V (1) = 6 to 1 ratio, SA:V (2) = 3 to 1 ratio. Therefore, if volume gets too large, it will require too much nutrients that it can take in and release more waste than it can get rid of.

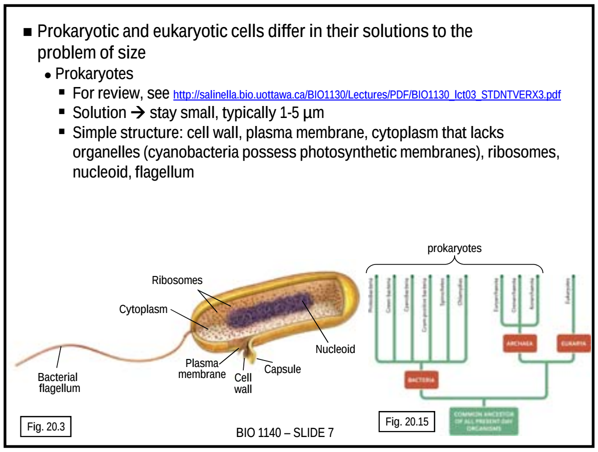
Rates of diffusion: nutrients move through the cell by diffusion (ex. oxygen). The longer the distance, the longer the time of diffusion is. Therefore, cells must be small in order for their rate of diffusion to properly meet their metabolic demands.

For a reaction to occur, you need adequate levels of a substrate in the context of the cell. The larger the cell, the more substrate is needed. If too large, there may not be enough substrate available.

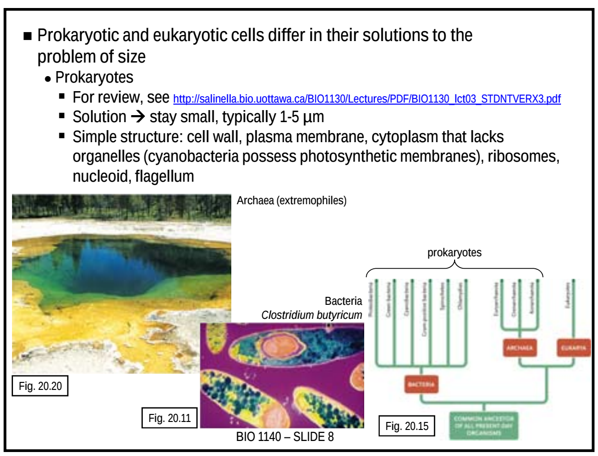
Organism overcomes SA:V problem by being composed of many cells rather than being one big cell. Or if single celled organisms, the cell would need a "fancy" membrane.

Organelles help cells overcome the adequate concentration problem.

Organelles do not add membrane to the cell, therefore do not increase SA, therefore do not aid in SA:V ration



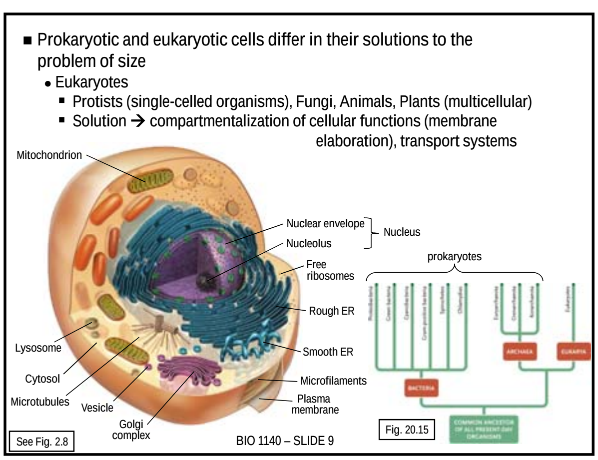
Prokaryotes are simple, and therefore small because they are constrained by the previous 3 factors. They have one single circular chromosome which contains their DNA. Chromosome is free floating (not bounded by a membrane) in the cytoplasm of the cell.



Prokaryotes/archaens - most uncommonly known are the extremophiles (examples; thermophiles, halophiles, methanogens (anaerobic) which release methane).

Other prokaryotes that are most known is bacteria. These are known to cause diseases, for example, ecoli bacteria. Other bacteria lead to the plague.

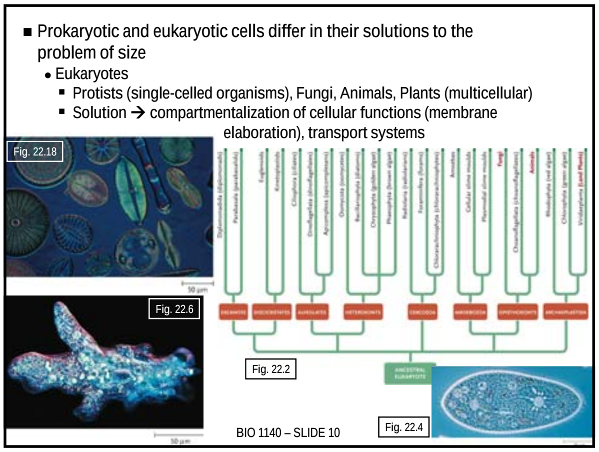
Some bacteria can be beneficial, ex. antibiotics



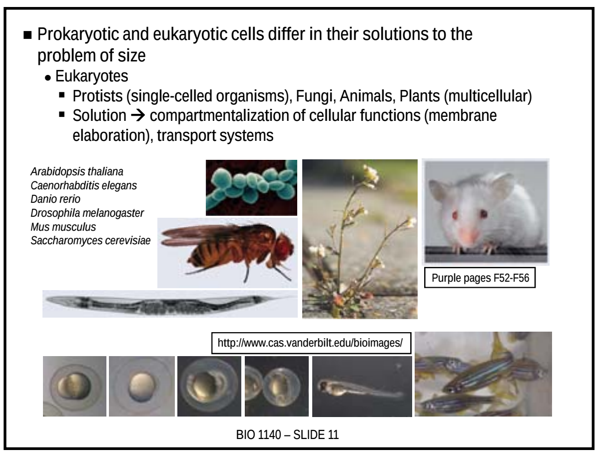
Eukaryotic cells - many membranes present within the cell membrane. The inside of the cell is divided up into different compartments by these membranes. Reactions can take place within these compartments.

Can move nutrients and solutes through cell without relying on diffusion (a reason why they are larger than prokaryotes.

Four groups of eukaryotes.



Protists (ex. ameoba) --> has a nucleus, but is single celled. Is a diverse group.

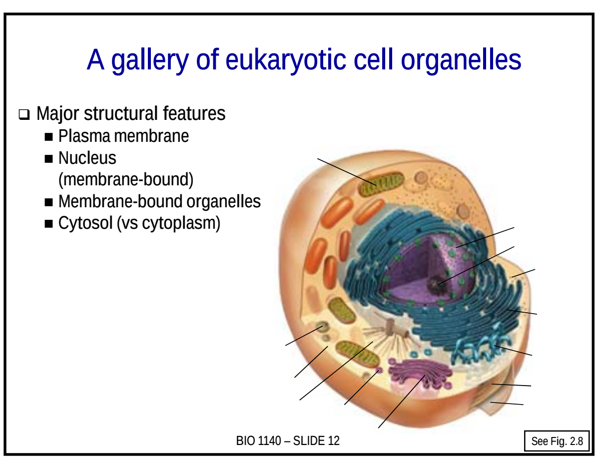


Why research Zebra fish? --> zebra fish heart repairs itself!!!!!

Multicellular groups: Fungi, plants, and animals
A model species: good for experimentation. Ex. the plant arabidopsis, has a small genome (tractable to work with), maturity reaches quickly, it's small and wheaty.

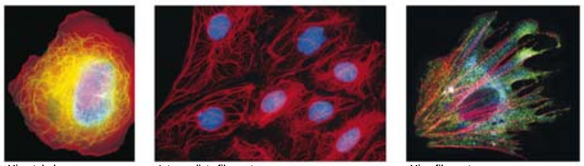
Saccharomyces cerevisiae --> model fungus --> is yeast --> creates bread and beer. Is very easy to work with, grows easy
Caenorhabditis elegans --> nematode (round worm). Grows easy, Has exactly 959 cells. We know the developmental fate of each one of the 959 cells. Makes it east to work with. It develops, ages, and shows behavior. It's a very simple organism that lives in a petri dish which is great to study.

Drosophila melanogater --> fruit fly --> great for studying genetics
Mus musculus --> mouse --> good because they are small, don't demand a lot, easy to take care of. Mature quickly. Good for biomedical research! Since they are mammals, the work well as substitutes for human research.
Danio Rerio - zebra fish --> external fertilizers, eggs are optically clear, therefore can observe embryo development. Animals go from fertilized egg to hatching larvae in 48 hours. They are small, so can hold 1000s of them in a small space. They reproduce easily.



be able to label this diagram.
Cytosol makes up the cytoplasm. It is the semi solid gel like solution of water, salt, and inorganic materials. Cytoplasm is the cytosol and the organelles in the cytosol.

- Non-membrane bound organelles
  - Cytoskeleton
    - Support/shape, internal organization, movement of cell, movement within cell
    - Microfilaments, microtubules, intermediate filaments
  - Ribosomes
    - Protein synthesis



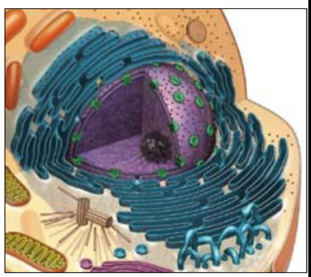
BIO 1140 – SLIDE 13

Fig. 2.18

Eukaryotic ribosomes are larger and more than those of prokaryotes (because they have more subunits.

Microfillaments, microtubules, and intermediate filaments are unique to eukaryotes. They allow for eukaryotes to grow larger due to their roles in transportaion inside the cell. These make up the cytoskeleton

- Membrane bound organelles
  - Nucleus
    - Nuclear envelope
    - Nuclear pores
    - Nucleolus
    - DNA and protein organized into chromosomes (chromatin)
  - Endoplasmic reticulum
    - Tubular membranes and cisternae
    - Rough – ribosomes, for membrane protein and secreted protein synthesis
    - Smooth – for lipid and steroid synthesis, detoxification



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See Fig. 2.8

Nuclear envelope - double membrane

Nucleolus inside nucleus is the site of ribosome synthesis, These ribosomes will migrate out of the nucleus and into the cell through the nuclear pores.
Membrane encloses the chromatin. All of this makes us the nucleus,

The outer membrane of the nuclear envelope is continuous with the endoplasmic reticulum. Rough endoplasmic reticulum has ribosomes attached to it, it is responsible for protein synthesis. Smooth endoplasmic reticulum lack ribosomes and are responsible for lipid and steroid synthesis, as well as, detoxification (smooth would be found in large amounts in liver)

Prokaryotes - only have DNA in the nucleus vs. Eularyotes - have both DNA and proteins in nucleus.

- Golgi complex
  - Stack of flattened vesicles
  - Sorting, modification and packaging of proteins
- Vesicles
  - Transport among organelles and/or to plasma membrane
- Lysosomes, peroxisomes
  - Contain hydrolases, catalases
- Vacuole
  - Temporary storage
  - Turgor pressure in plant cells

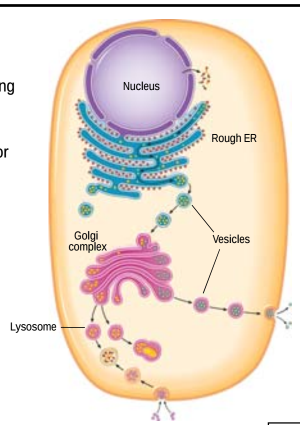

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Fig. 2.16

Proteins synthesized often go to the golgi complex to be further specialized. Golgi complex packages proteins into vesicle.

Lysosomes (contain hydrolases) and peroxisomes (contain catalases) are responsible for breaking things down

Vacuoles are much larger in plant cells. there store water and nutrients.

- Golgi complex
  - Stack of flattened vesicles
  - Sorting, modification and packaging of proteins
- Vesicles
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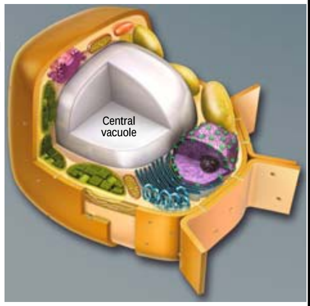

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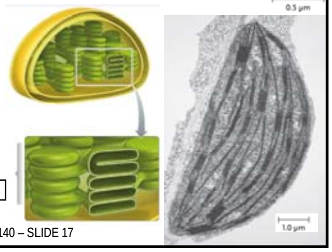
Fig. 2.9

This is a plant cell
Central vacuole - as it fills, pushes the cell contents against the cell wall causing tugor pressure, this turgor pressure causes the cell (and thus the plant) to become stiff/rigid. This allows plants to stand upright. If there was less/no turgor pressure, the cell would become soft, causing the plant to wilt, and thus die.

- Mitochondrion
  - ~2 µm
  - Double membrane, cristae
  - Oxidative metabolism yielding ATP
  - Circular mDNA
  - Reproduce by fission
- Chloroplast
  - ~5 µm
  - Double membrane + thylakoids
  - Conversion of light energy to chemical energy (complex carbohydrates)
  - Circular cpDNA
  - Reproduce by fission

Figs. 6.8, 2.17



Figs. 7.3, 2.24

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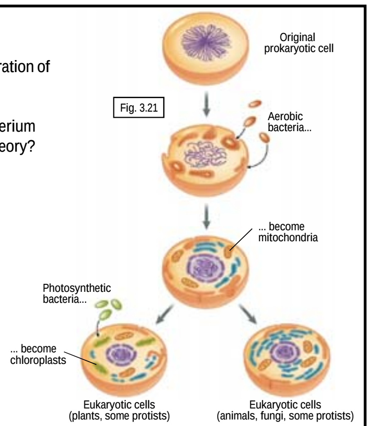
Both of these organelles are relatively large. Both are bounded by a double membrane. Inner layer of mitochodria creates folds called cristae which house enzymes and proteins.

Inner layer of chloroplast is a third layer of thlakoids which will house chlorophyll that is used to convert light energy (sun) into chemical energy.
Both mitochondria and chloroplasts have their own DNA and ribsomes (can synthesize their own proteins). These ribosomes are smaller and less complex than that of a standard eukaryotic cell. Have a circular genome. Mitochondria and chloroplasts are very similar to bacteria.

- Endosymbiont theory
  - Mitochondria from incorporation of aerobic prokaryote
  - Chloroplast from (later) incorporation of cyanobacterium
  - Evidence to support this theory?

Fig. 3.21



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Endosymbiont theory: the was a bacteria the engulfed an aerobic bacteria which did not get broken down for some reason. This smaller bacterium continued to live inside the larger cell and began to produce and thrive in the safe environment of the large cell. The large cell gained a more efficient ATP thesis through the aerobic bacteria. Over time, there was genetic information exchange. Eventually this small bacteria became bacteria. It is thought that a second event of this nature occurred, but instead of a aerobic bacteria being engulfed, it was a small photo bacteria (perhaps a cyanobacterium?). This eventually became a chloroplast.

Fossil records suggest that prokarytic cells came before eukaryotic cells.
These two cell types are very similar --> must be a common ancestor -->Eukaryotes evolved from prokaryotes?

Endosymbiont theory

- Mitochondria from incorporation of aerobic prokaryote
- Chloroplast from (later) incorporation of cyanobacterium
- Evidence to support this theory?

See: Rumpho et al. 2011 JEB 214, 303-311

Present day examples of endosymbiosis:
- symbiotic animals containing green photobionts (e.g. some sponges, *Hydra*, the salamander *Ambystoma maculatum*)
- solar-powered sea slugs (kleptoplasty in *Elysia chlorotica*)

Rumpho et al. 2008 PNAS 105, 17867-17871

Solar powered sea slug! This is an animal that carries out photosynthesis because it has chloroplasts.

When they are born, they are brown, however as they grow older, they eat algae and become green because they steal the chloroplasts from the algae of which it feeds.

These chloroplast spread out along the slug's intestine which covers the slug's whole body, thus the whole body becomes green. Eventually, the slug no longer needs to eat, it can survive completely on photosynthesis. Sea slug incorporates the chloroplasts into itself (endosymbiosis) and thrives by doing so. This type of endosimbiosis is called kleptoplasty

- Pause for reflection
  - How does kleptoplasty in *Elysia chlorotica* differ from the endosymbiotic origin of chloroplasts?

In terms of the sea slug, the chloroplasts aren't passed from one generation to the next, the sea slug must go out and eat the algae to gain it's photosynthetic ability. Where in the photo cells, chloroplasts are seen in every generation from the start.

Multicellular animal acquiring chloroplasts vs, single cell engulfing another cell

Absorbing whole cell vs. just absorbing chloroplasts.

Can you meet these objectives?

- By the end of this lecture you will be able to...
  - Answer the question: what is a cell?
  - Describe the cell theory
  - Describe the basic properties of cells
  - Explain why cells are small
  - Contrast and compare prokaryotes and eukaryotes
  - List and briefly describe the organelles of eukaryotic cells
  - Describe, with support, one theory on the origins of eukaryotic cells