

Lectures 2 and 3 Introduction to cell biology

Readings:

F6-7, Ch. 2.1 to 2.5, 3.1 to 3.5

Participation

- Actively participate in ALP activities during each Lecture
 - 1st class doesn't count
 - 1 free absence in semester
- Quiz (2) – done online on Blackboard
 - Completing them gives you a free absence
 - Quiz 1 available Jan 14 and due Jan 20
 - Quiz 2 available online Jan 21 and due Jan 27

Objectives (After these 2 lectures and your readings, you should be able to answer these questions)

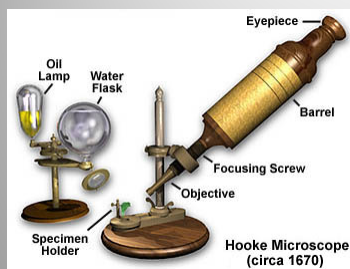
- What is a cell?
- What is it made of? Name the different organelles and the roles/functions for each
- What are the different scales/sizes for cells and organelles?
- Explain the theory of the cell and endosymbiosis
- What are the main groups or types of cells and how are they different?
- Understand different types of microscopy and their requirements for use in cell biology

BIO1140

Caroline Petit-Turcotte Winter 2016

3

What is a cell? Mid 1600s

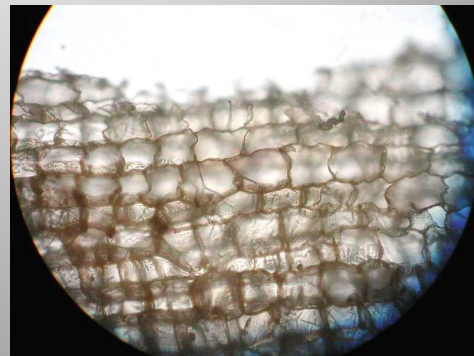


stevegallik.org

Robert Hooke



Small rooms = Cellulae = Cells



http://biology.clc.uc.edu/fankhauser/labs/cell_biology/cells_lab/cells.htm

BIO1140

Caroline Petit-Turcotte Winter 2016

4

How did we go from this:

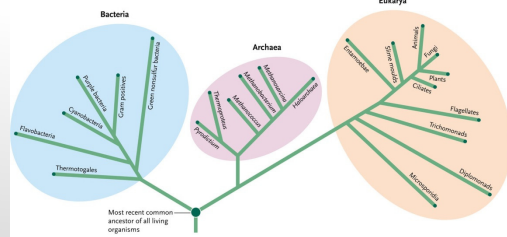
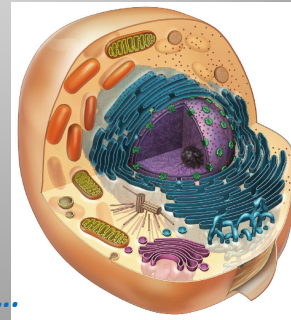


Figure 18.16 Three domains: the tree of life. Carl R. Woese's 1996 analysis of rRNA sequences suggests that all living organisms can be classified into one of three domains, identified here on branches with different background colours.

to a discipline called cell biology?

200 years of observations and gathering data....



Cell Theory – mid 1800s

- All organisms are composed of one or more cells
- The cell is the basic structural and functional unit of all living organisms (Schwann, 1839)
- Cells arise only from division of pre-existing cells (Virchow, 1855)

BIO1140

Caroline Petit-Turcotte Winter 2016

7

Cell features

Diversity

- Wide range of sizes (nm to m)
- Simple or complex shapes; related to function
- General or very specialized role

Common Characteristics

- Components
- Basic chemistry
- Metabolism (ATP)
- DNA

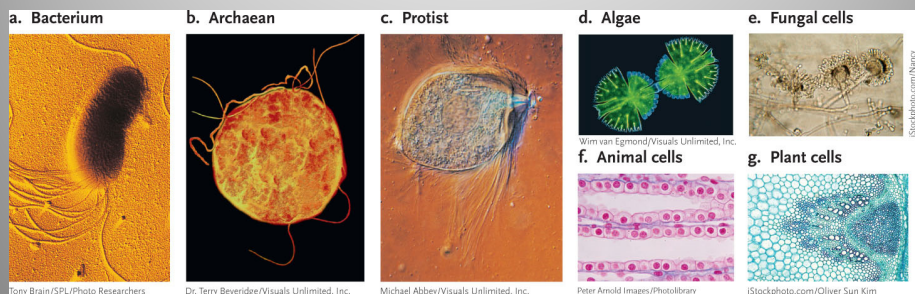


Figure 2.2
 Examples of the various kinds of cells. **(a)** A bacterial cell with flagella, *Pseudomonas fluorescens*. **(b)** An archaeon, the extremophile *Sulfolobus acidocaldarius*. **(c)** *Trichonympha*, a protist that lives in a termite's gut. **(d)** Two cells of *Micrasterias*, an algal protist. **(e)** Fungal cells of the bread mould *Aspergillus*. **(f)** Cells of a surface layer in the human kidney. **(g)** Cells in the stem of a sunflower, *Helianthus annuus*.

BIO1140

Caroline Petit-Turcotte Winter 2016

8

Cell size and scale

- Relevant units:

$1\mu\text{m} = 10^{-6}\text{m}$

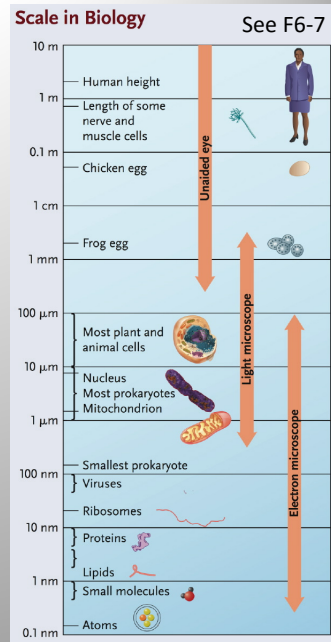
$1\text{nm} = 10^{-9}\text{m}$

- Typical cell sizes:

Prokaryote: 1-5 μm

Eukaryotes 10-100 μm

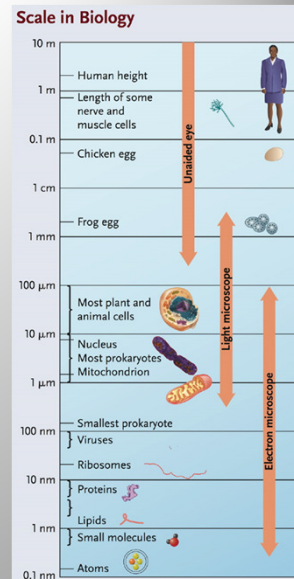
- *Why are cells small?*



Practice for yourself

Match the items below with the proper size from the list on the right

1. Ribosome diameter	a) 0.007 μm
2. Nucleus diameter	b) 30 nm
3. Mitochondrion length	c) 0.006 mm
4. Giraffe axon length	d) $1 \times 10^6 \mu\text{m}$
5. Microfilament diameter	e) $3 \times 10^{-6} \text{m}$



How do you look at cells?

- See section 2.1a and figure 2.4 to read up on microscopy
- You will also experiment with microscopy in the labs

Why are cells small?

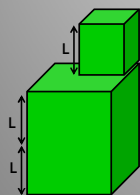
SA:V ratios

Rates of diffusion

Adequate concentrations or synthetic capacity

Time to 95% equilibration of O₂ by diffusion

X	time
0.1 mm	0.067s
1 mm	6.7 s
1 cm	10.9 min
1 m	78 d



Length = L
 Surface area = 6 · L · L = 6L²
 Volume = L · L · L = L³
 SA:V =

Length = 2L
 Surface area = 6 · 2L · 2L = 24L²
 Volume = 2L · 2L · 2L = 8L³
 SA:V =

(see Fig. 2.5)

Volume stays the same but surface area increases

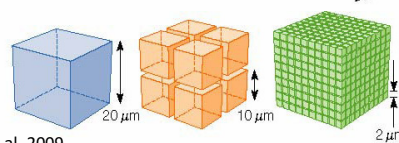
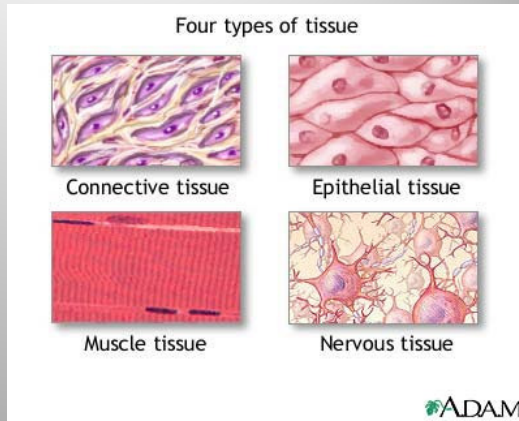
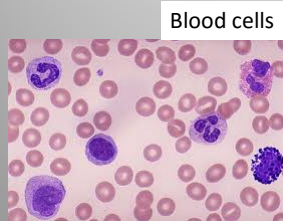


Fig. 4-1 Becker et al. 2009

Length of one side	20 μm	10 μm	2 μm
Total surface area (height x width x number of sides x number of cubes)	2400 μm ²	4800 μm ²	24,000 μm ²
Total volume (length x width x height x number of cubes)	8000 μm ³	8000 μm ³	8000 μm ³
Surface area to volume ratio (surface area ÷ volume)	0.3	0.6	3.0

What next?

Cells can remain individual (for example in blood) or assemble together to form functional tissues and organs



The tree of life: 3 domains

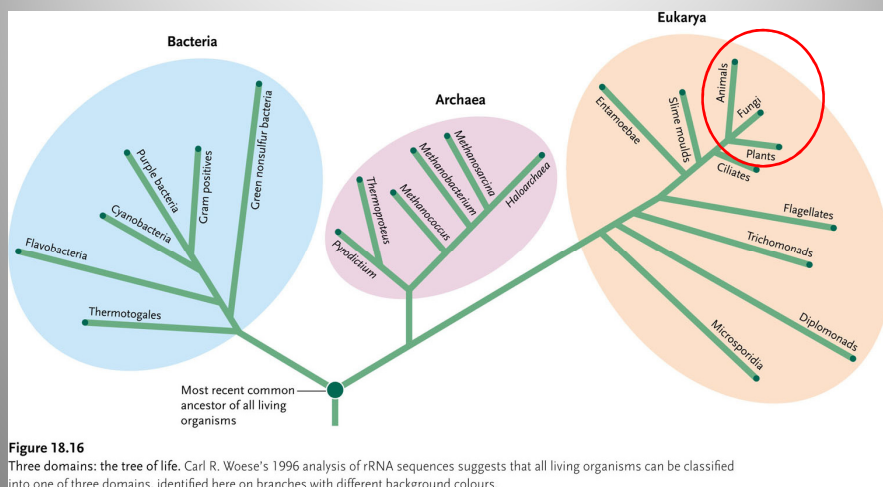
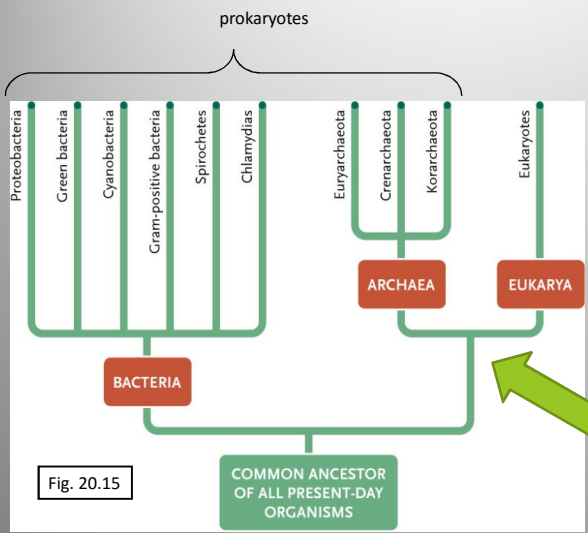


Figure 18.16
Three domains: the tree of life. Carl R. Woese's 1996 analysis of rRNA sequences suggests that all living organisms can be classified into one of three domains, identified here on branches with different background colours.

BIO1140 Caroline Petit-Turcotte Winter 2016 15

Prokarya; Bacteria and Archea



Archaea:
rRNA, membrane
phospholipids: more
similar to eukarya

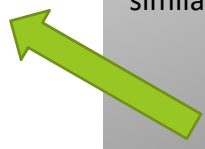
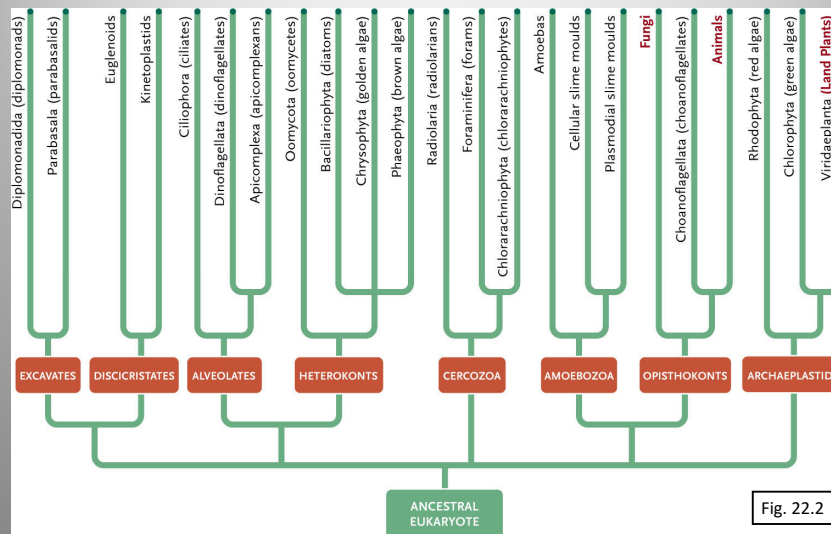


Fig. 20.15

Eukaryotes: Protists, fungi, plants and animals



BIO1140

Caroline Petit-Turcotte Winter 2016

17

Two main types of cells: Dealing with size

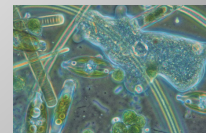
Prokaryotes

- Unicellular
- Bacteria
- Archea



Eukaryotes

- Unicellular (protists)
- Multicellular
 - Plants
 - Fungi
 - Animals



Campbell, Fig.1.15

BIO1140

Caroline Petit-Turcotte Winter 2016

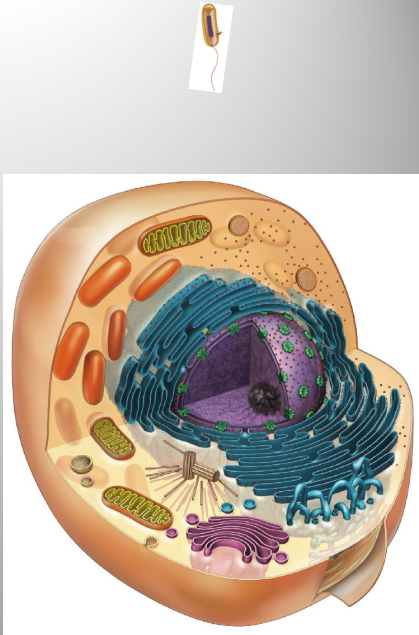
18

Prokaryotes

- Stay small (1 – 5 μm)
- Keep it simple
- Highly adaptable (extremophiles)
- Small genomes (10⁶ bp), plasmids

Eukaryotes

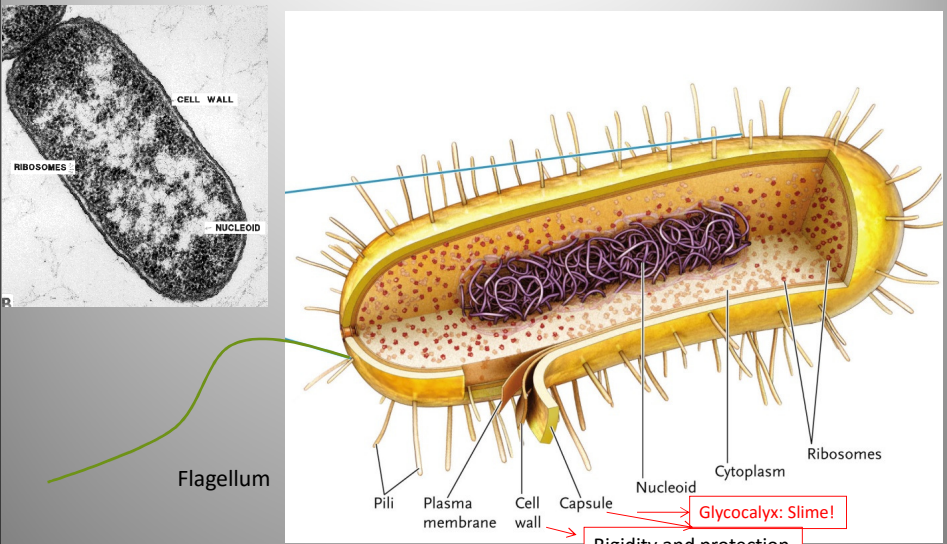
- Larger (10 – 100 μm or larger)
- Elaborate membranes allow compartments to organize cellular functions
- Transport systems
- Larger genomes (10⁶ to 10⁹ bp), linear, w. associated proteins



BIO1140 Caroline Petit-Turcotte Winter 2016 19

Typical bacteria: *Escherichia coli*

www.ucmp.berkeley.edu

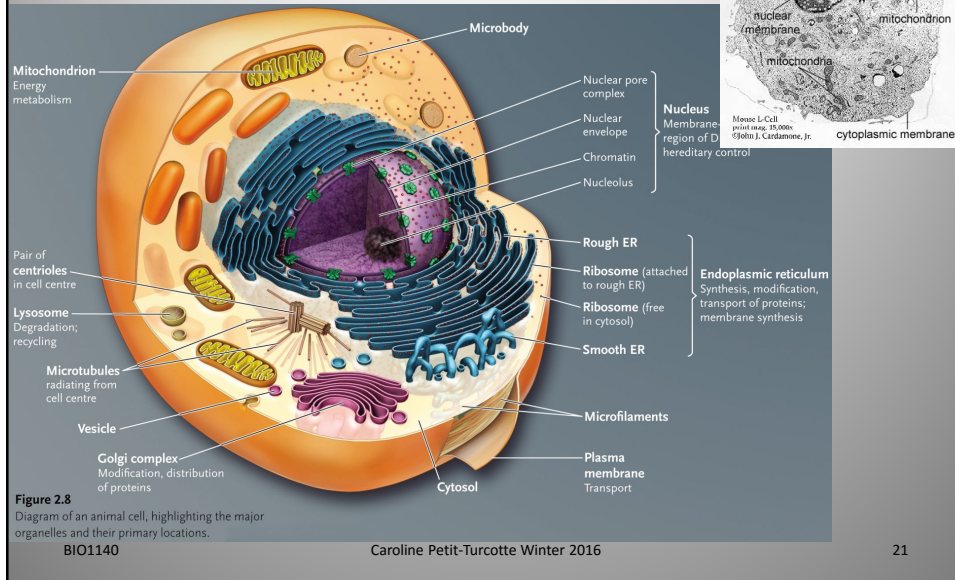


Flagellum

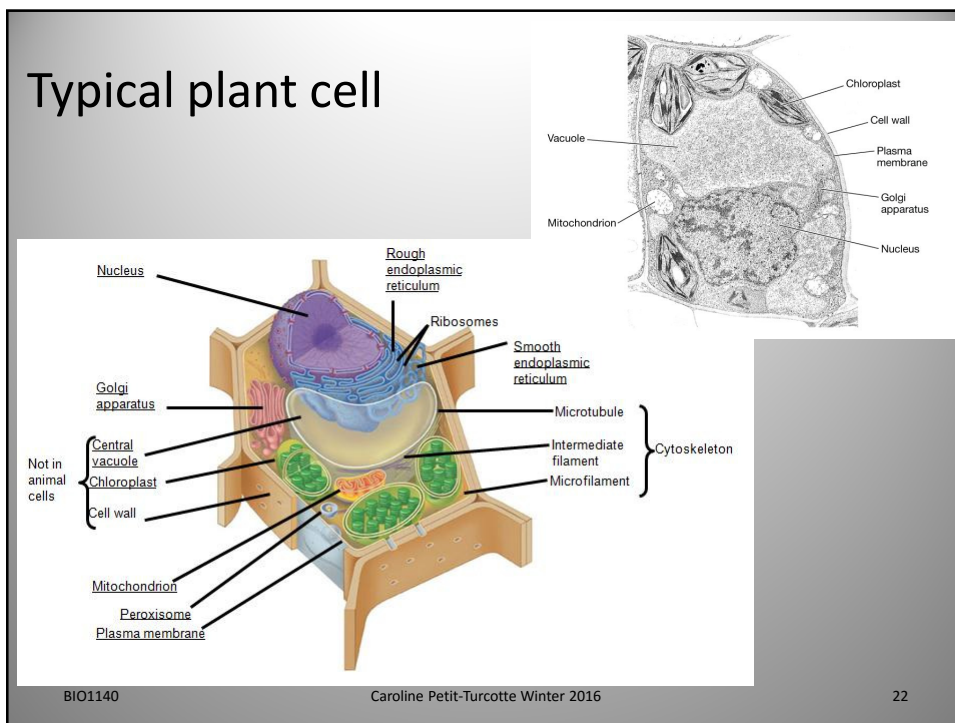
Rigidity and protection

BIO1140 Caroline Petit-Turcotte Winter 201 20

Typical animal eukaryotic cell



Typical plant cell



Things you can already organize:

	Prokaryotes	Eukaryotes
Cell size		
Cellular organization		
Genome		
Organelles		

Eukaryotic cell organelles

- Subcellular compartments within the cytosol surrounded by a membrane
- Single subcellular compartment without a membrane: Ribosomes
- Their functions are varied, and depend on the cell's role

Next Lecture

- Please make sure you have done your readings – I will not go over each organelle in detail; we will do it by various activities.
- You can also watch the video that gives an overview of a cell on blackboard under additional reading material (Tour of an animal cell)

Nucleus

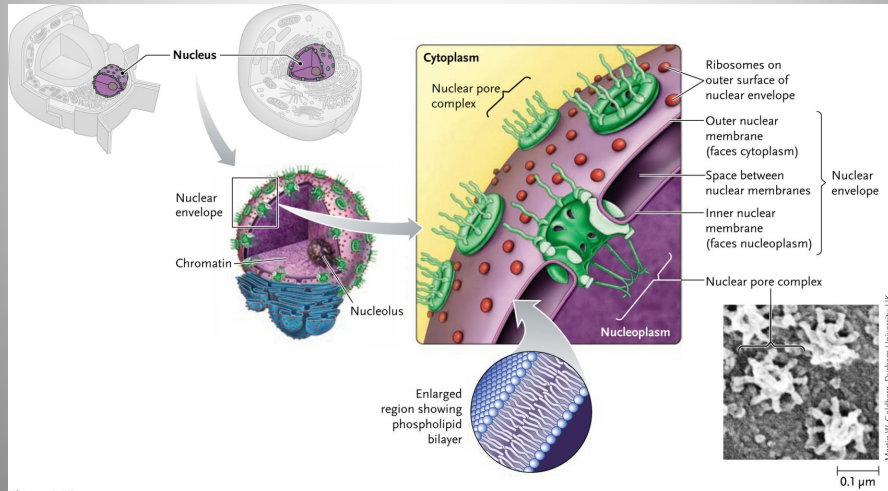


Figure 2.10
The nuclear envelope, which consists of a system of two concentric membranes with nuclear pore complexes embedded. Nuclear pore complexes are octagonally symmetrical protein structures with a channel—the nuclear pore—through the centre. They control the transport of molecules between the nucleus and cytoplasm.

Ribosomes

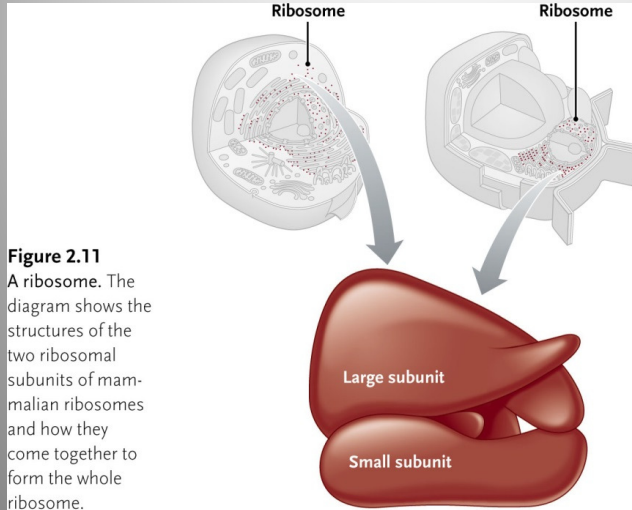


Figure 2.11
A ribosome. The diagram shows the structures of the two ribosomal subunits of mammalian ribosomes and how they come together to form the whole ribosome.

Ribosomes will be very important in part 2 of the course when we deal with translation

Endoplasmic reticulations

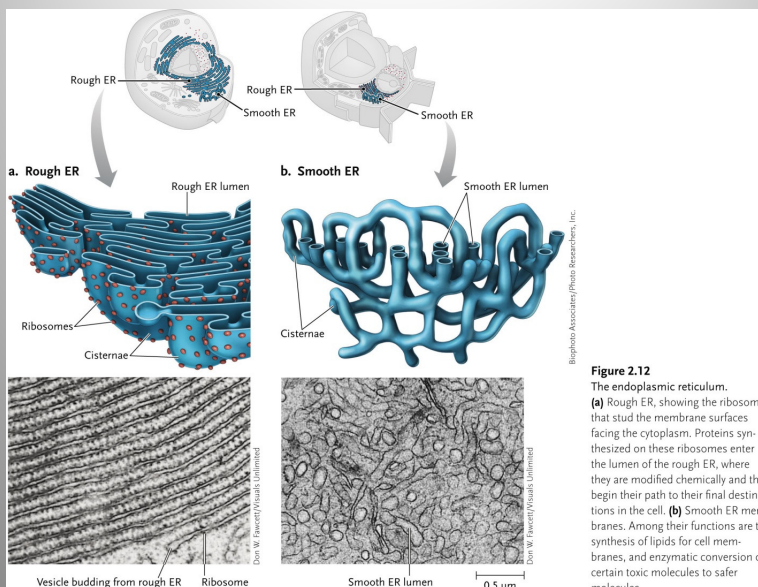
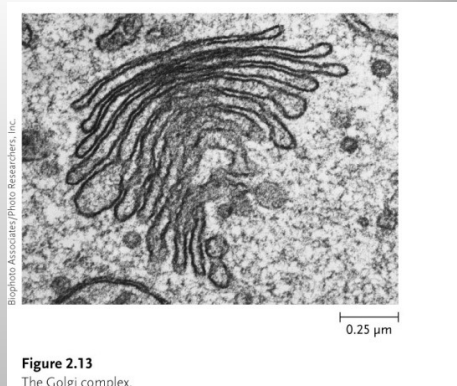
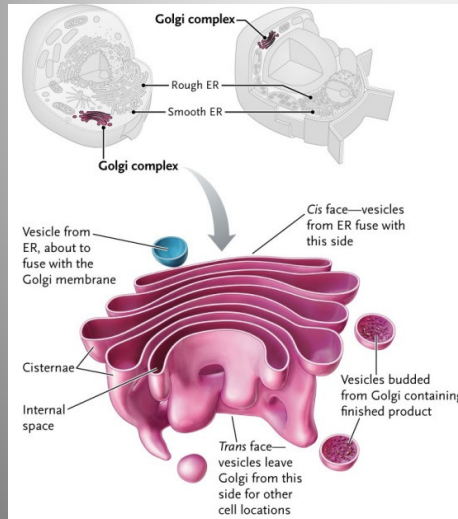


Figure 2.12
The endoplasmic reticulum.
(a) Rough ER, showing the ribosomes that stud the membrane surfaces facing the cytoplasm. Proteins synthesized on these ribosomes enter the lumen of the rough ER, where they are modified chemically and then begin their path to their final destinations in the cell. **(b)** Smooth ER membranes. Among their functions are the synthesis of lipids for cell membranes, and enzymatic conversion of certain toxic molecules to safer molecules.

Golgi complex



We will discuss the ER/Golgi again in the last few lectures of the course when we deal with protein sorting

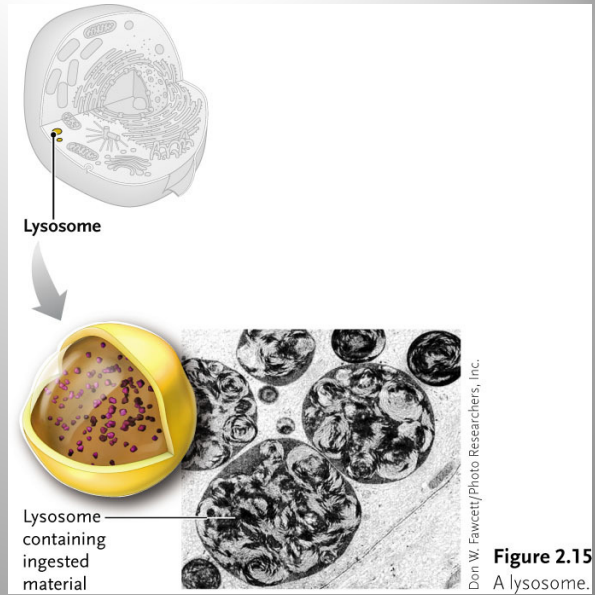
Lysosome

This is the digestive unit of the cell:

Enzymes will breakdown macromolecules

Bud-out from the Golgi

pH in lysosome is more acidic than in cytosol



Mitochondria

We will study mitochondria in detail in a few weeks...

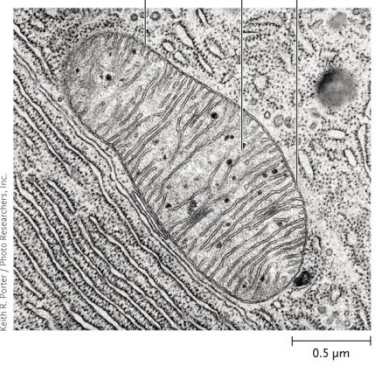
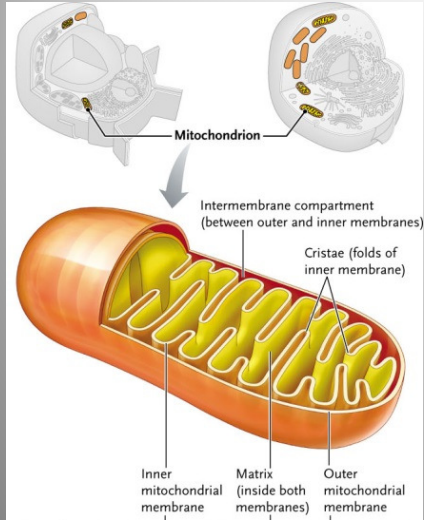
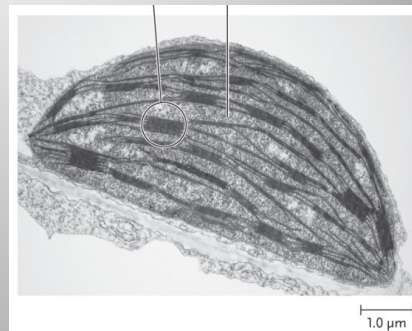
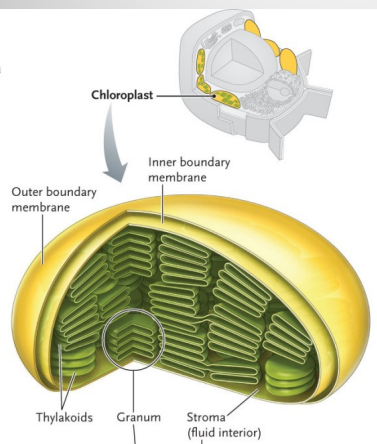


Figure 2.17 Mitochondria. The electron micrograph shows a mitochondrion from a rat pancreas, surrounded by cytoplasm containing rough...

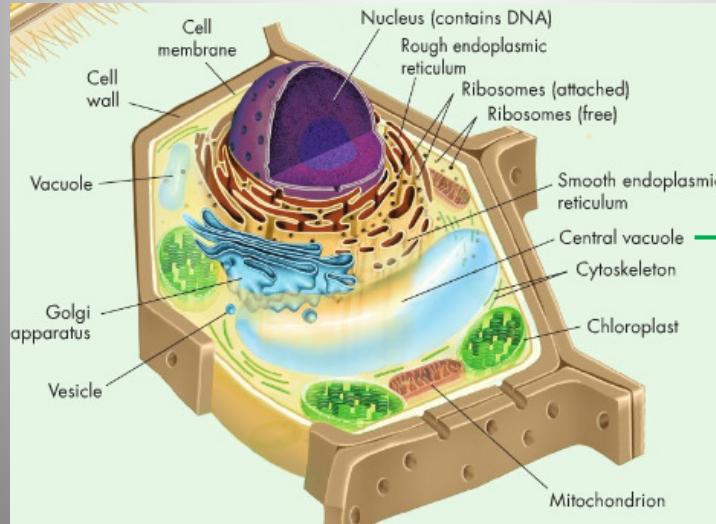
Chloroplasts

Plastids: Chloroplasts, Amyloplasts, Chromoplasts

Figure 2.24 Chloroplast structure. The electron micrograph shows a maize (corn) chloroplast.



Central Vacuole (plant's lysosome and more!)



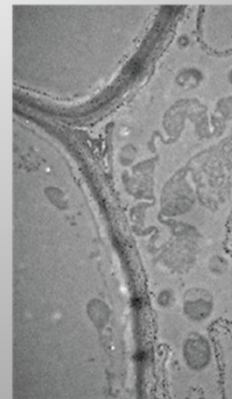
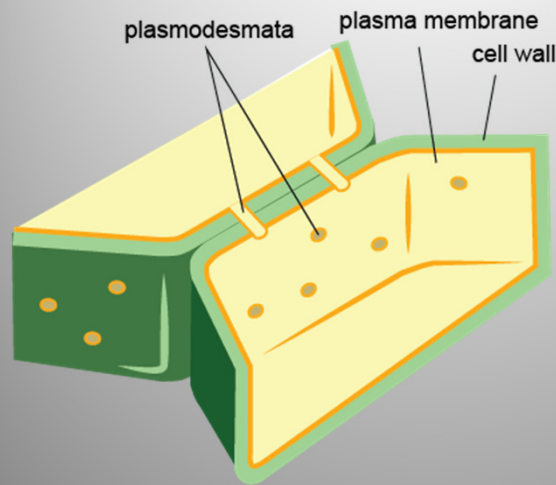
Surrounded by tonoplast

BIO1140

Caroline Petit-Turcotte Winter 2016

37

Cell wall



TEM image of cell wall structure in plant roots

[Paungfoo-Lonhienne et al. PLoS ONE. 2010; 5\(7\).](#)

BIO1140

Caroline Petit-Turcotte Winter 2016

38

Cytoskeleton



Figure 2.18
Cytoskeletons of eukaryotic cells, as seen in cells stained for light microscopy. (a) Microtubules (yellow) and microfilaments (red) in a pancreatic cell. (b) keratin intermediate filaments viewed by immunofluorescence microscopy in the rat kangaroo cell line PK12. The nucleus is stained blue in these cells. (c) Microfilaments (red) in a migrating mammalian cell.

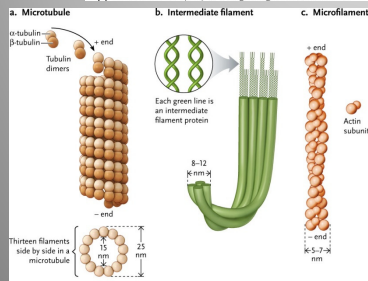


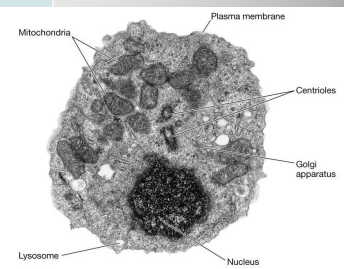
Figure 2.19
The major components of the cytoskeleton. (a) A microtubule, assembled from dimers of α - and β -tubulin proteins. (b) An intermediate filament. Eight protein chains wind together to form each subunit, shown as a green cylinder. (c) A microfilament, assembled from two linear polymers of actin proteins wound around each other into a helical spiral.

Another story to be continued shortly....

roline Petit-Turcotte Winter 2016

39

Organelle	Role	Cell types
Nucleus	Store DNA (w. membrane)	E
Nucleoid	Area (no membrane) where DNA stored	P
Nucleolus	Assembly of ribosomes	E
Mitochondria	Energy metabolism	E
Lysosomes	Degradation and recycling	E
Rough endoplasmic reticulum (RER)	Protein synthesis, maturation, sorting	E
Smooth endoplasmic reticulum (SER)	Lipid synthesis, detoxification	E
Ribosome	Protein synthesis (translation)	E + P
Golgi complex	Protein maturation and sorting	E
Cytoskeleton	Structure, support, signalling	E
Central vacuole	Digestion, cell growth, support, storage	E (Plants, fungi)
Chloroplast	Photosynthesis, starch storage	E (Plants)
Membrane	Specific differences	E + P
Cytosol	Aqueous media within cell	E + P



www.scienceclarified.com

40

What distinguishes eukaryotes from bacteria and archea?

1. Nuclear envelope (separating DNA from rest of intracellular components)
 2. Membranous compartments with specific roles (ER, mitochondria, etc.)
- All eukaryotic cells have some sort of energy-transforming unit (mitochondria, chloroplasts).
 - Could this be the key to evolving from the common ancestor?

Theory of Endosymbiosis

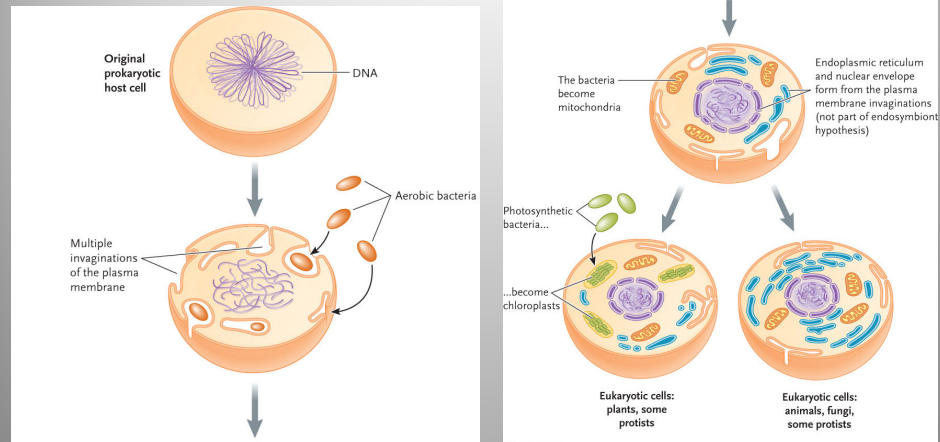


Figure 3.21

The theory of endosymbiosis. The mitochondrion is thought to have originated from an aerobic prokaryote that lived as an endosymbiont within an anaerobic prokaryote. The chloroplast is thought to have originated from a photosynthetic prokaryote that became an endosymbiont within an aerobic cell that had mitochondria.

BIO1140

Caroline Petit-Turcotte Winter 2016

43

Theory of Endosymbiosis: Evidence

1. **Morphology:** Shape of mitochondria and chloroplasts and size (μm) are similar to bacteria and archea
2. **Reproduction:** Only by binary fission
3. **Genome:** circular mDNA and cpDNA
4. **Transcription and translation:** machinery in place
5. **Electron transport:** double membrane with ETC
6. **Sequence:** bacterial branch on tree of life (mitochondria = proteobacteria; chloroplasts = cyanobacteria)

BIO1140

Caroline Petit-Turcotte Winter 2016

44

What about today?

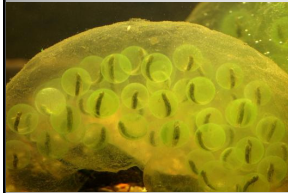
- Can you find any current examples of endosymbiosis in nature?

BIO1140

Caroline Petit-Turcotte Winter 2016

45

What about today?



The spotted salamander *Ambystoma maculatum* and green algae are endosymbiotic; algae cells infiltrate the embryos. They provide the O₂, while they use the N₂ produced by the salamanders.



Elysia chlorotica (sea slug) steals the chloroplasts from *Vaucheria litorea* (process is termed Kleptoplasty)



Coral reefs are clusters of animals related to anemones; they harbour zooxanthella (an algae) that exchanges housing protection with sugar (produced by photosynthesis) as a source of nutrient for the coral.

[Rumpho et al. 2011 JEB 214, 303-311](#)

Rumpho et al. 2008 PNAS 105, 17867-17871

BIO1140

Caroline Petit-Turcotte Winter 2016

46