Biology with an EE Perspective

Lecture 2

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The Cell

Broad outline of functions of cell components

Objectives

- A first pass look at cells
- Look at the cell top down
- As we go through, the class should identify processes that could be investigated with ECE tools

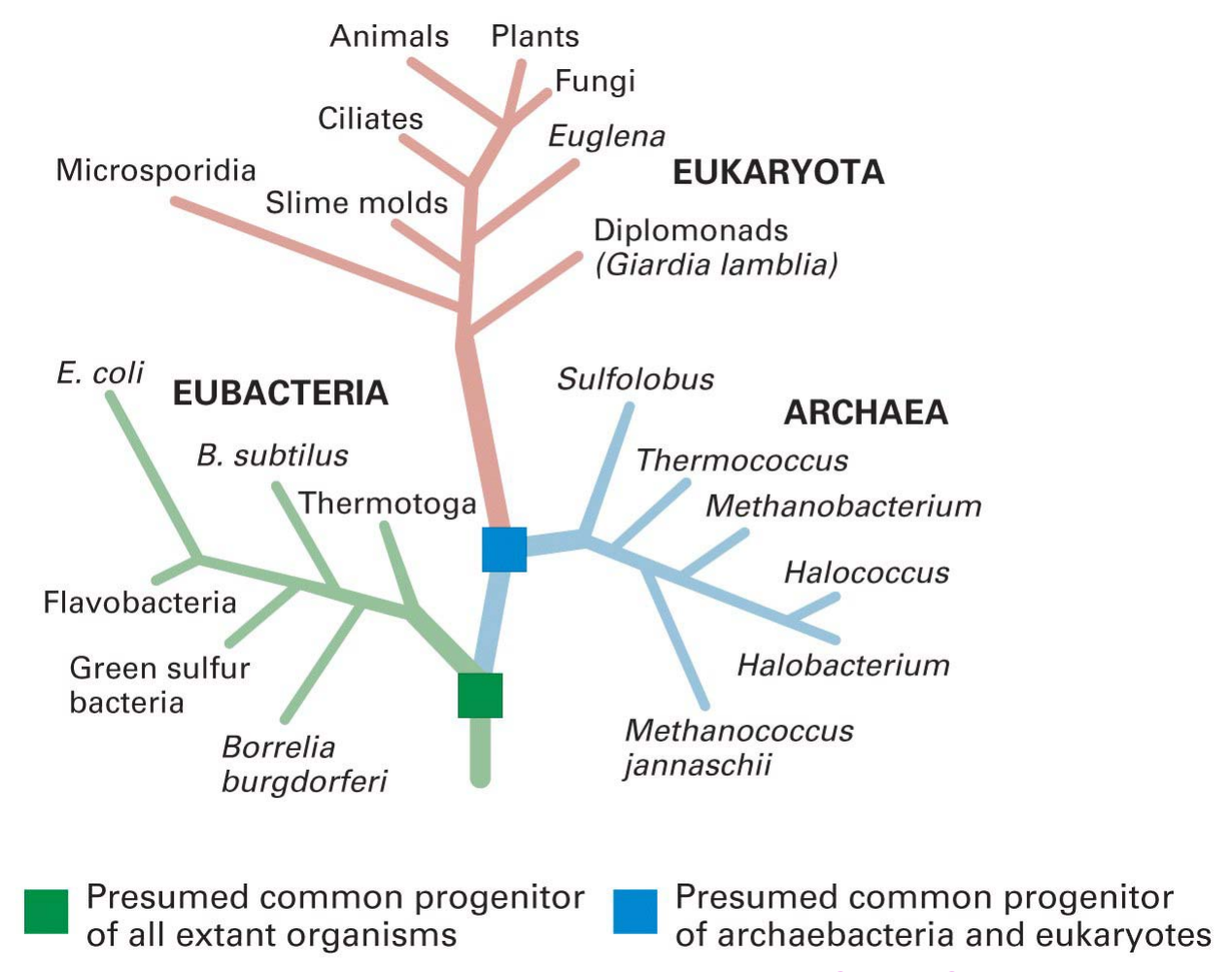
[Pictures and sketches from either the course text's website or wikipedia]

Living organisms

- Are a system of molecules that allow the system:
  - To respond to the environment it is in, in a fashion that helps it survive, and
  - Undergo cell division

Make a list of some basic functions and response to the environment that are necessary for survival

Tree of life!



This tree has both species & evolutionary information:

* The exact origin of life still under intensive debate & some research

* Time frame of evolutionary branching also under study

Evolution quick read: http://www.geocities.com/CapeCanaveral/Lab/2948/gould.html

More detailed at: http://tolweb.org/tree/home.pages/browsing.html

Broad classification of living organisms

- Prokaryota [*pro*-(before*)+karyon* (nut/kernel) + -*otos* (]: Organisms without a cell nucleus (!or any other membrane bound organelles!) – most are uni-cellular but some are multi-cellular
- Eukaryota: Organisms comprising of one or more cells containing a nucleus, that contains genetic material, plus other organelles that are membrane enclosed

Molecule classes [1/3]

- Small molecules
  - Dissolved gases (oxygen)
  - Saccharides -- sugars, carbohydrates
  - Vitamins
  - Hormones, neurotransmitters
  - Lipids, phospholipids, glycolipids

Molecule classes [2/3]

- Monomers
  - Amino acid
  - Nucleotides
  - Phosphates
  - Monosaccharides

Molecule classes [3/3]

- Polymers
  - Peptides, oligopeptides, polypeptides & proteins
  - Nucleic acids – DNA, RNA
  - Oligosaccharides & polysaccharides

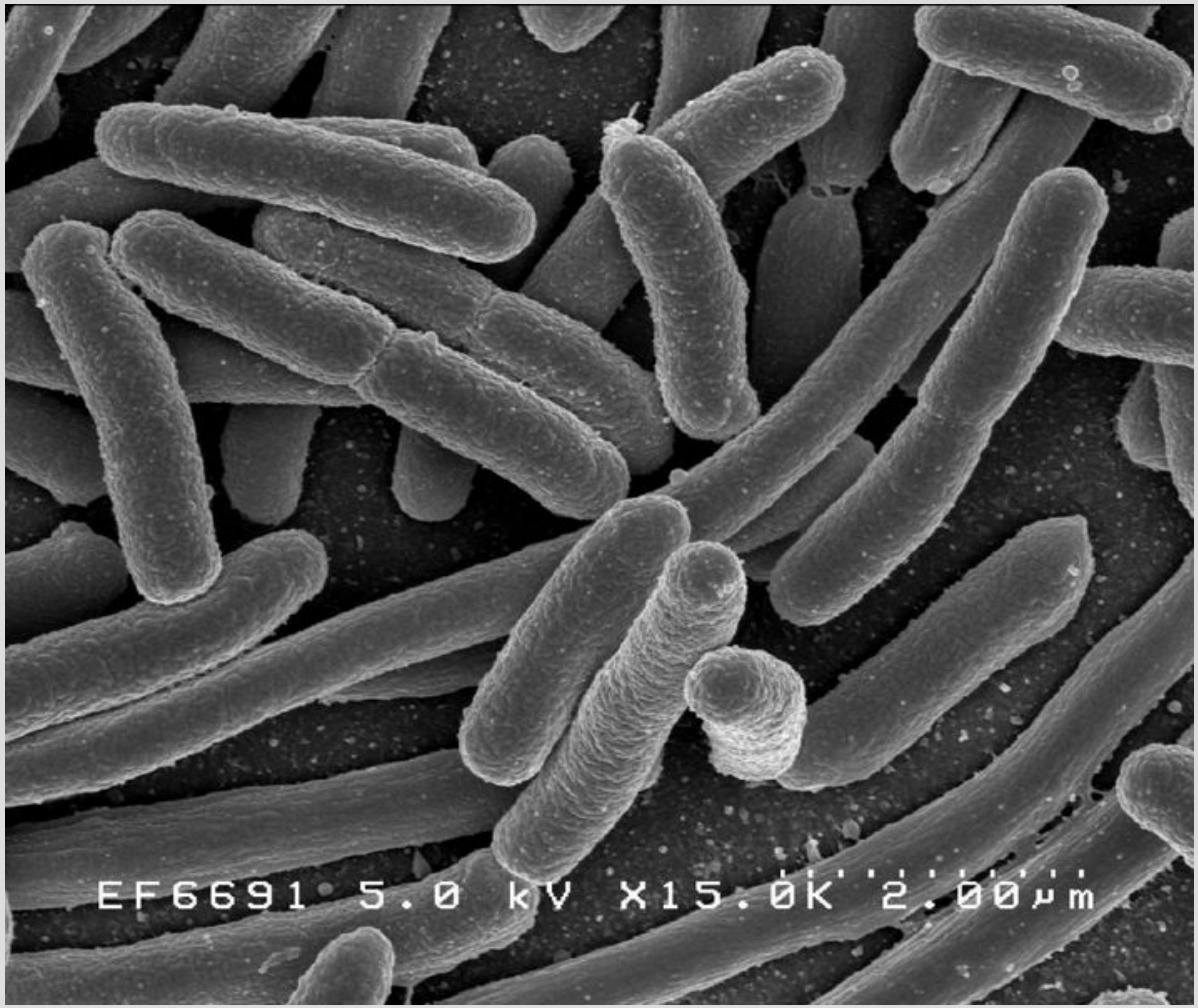
Other macromolecules such as prions

We will learn more about these molecules contextually in later classes

Molecule organization

- For an organism to respond in a coherent fashion to the environment, the molecules that make up an organism need to have a structure that enable molecular interaction in a more controlled environment
- The cell is the basic unit for molecular organization that enables life
  - Either an organism is a single cell – in which case the single cell needs to have the appropriate molecular processes to respond to environmental stimuli
  - Or it could be multicellular, in which case cell function might be different in different clusters of cells and the organism as a whole is best suited to adapt to the environment

Prokaryotic cell



http://en.wikipedia.org/wiki/Image:EscherichiaColi_NIAID.jpg

Eukaryotic cell

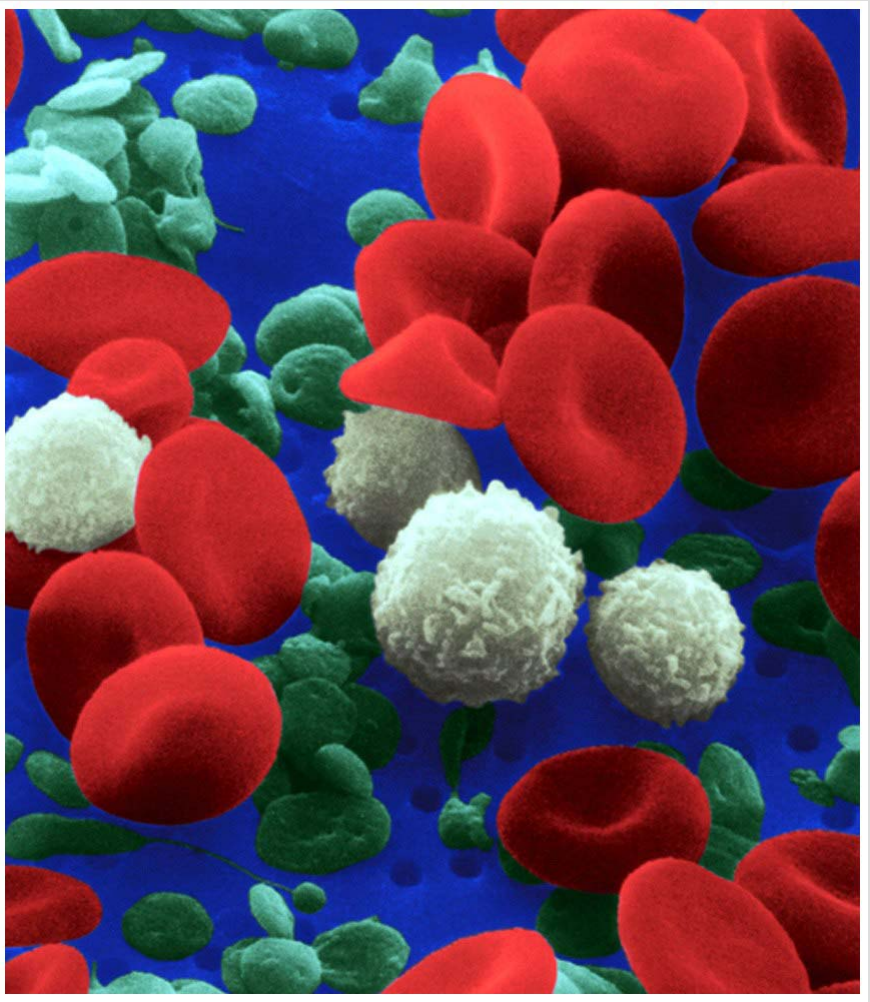
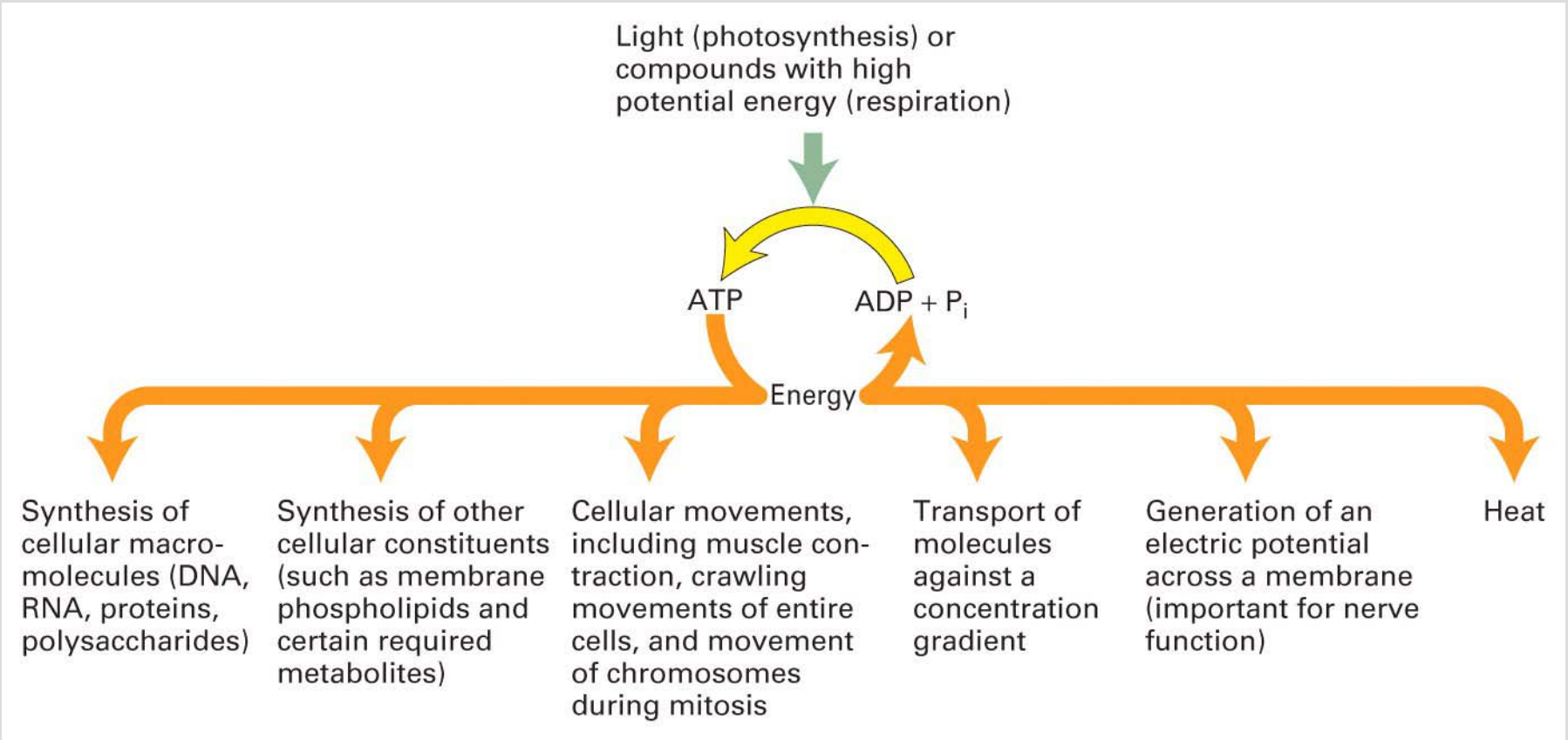
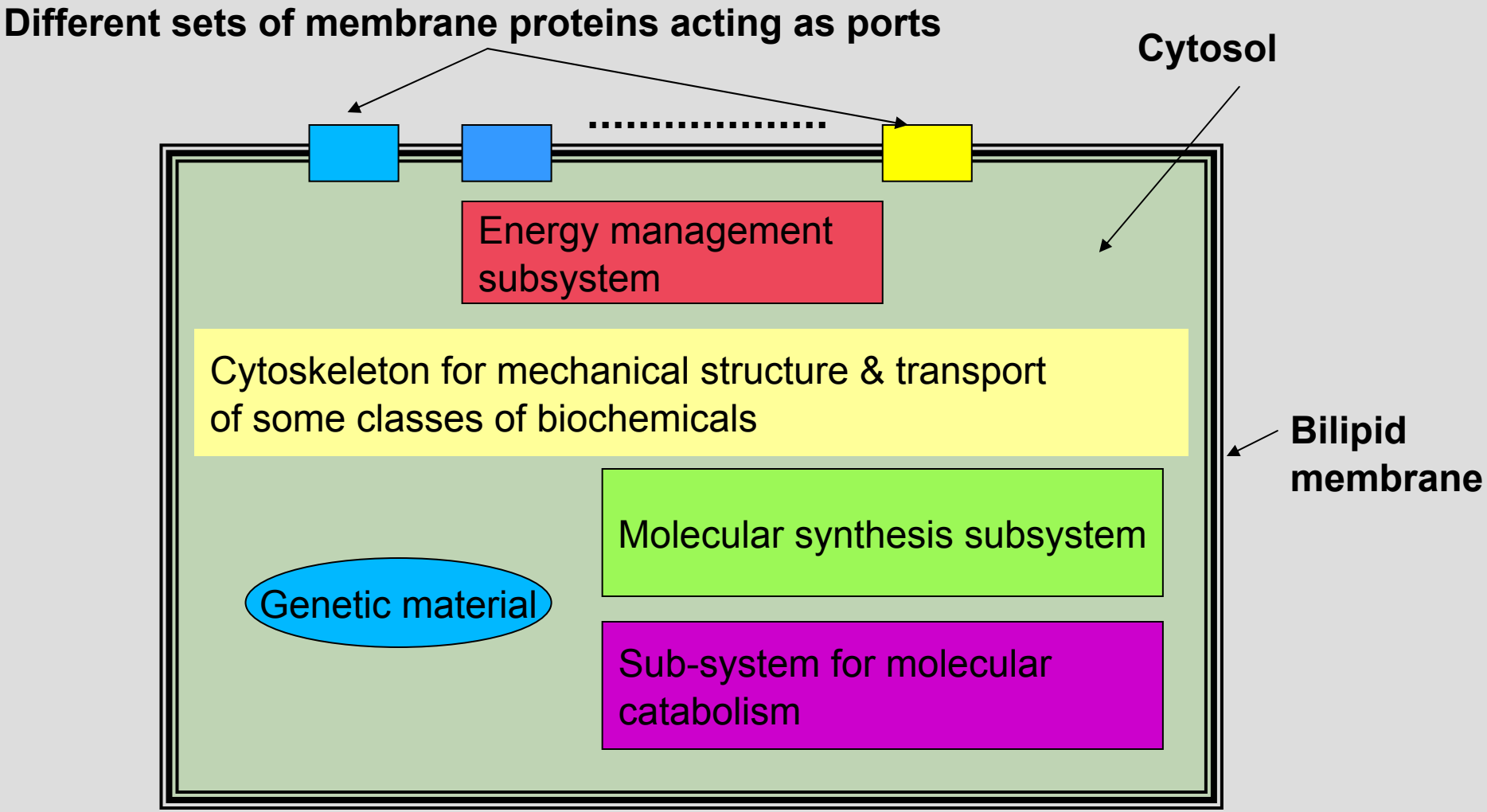


Figure out what these cells are?

Some important functions cells need to perform (every cell need not perform all)

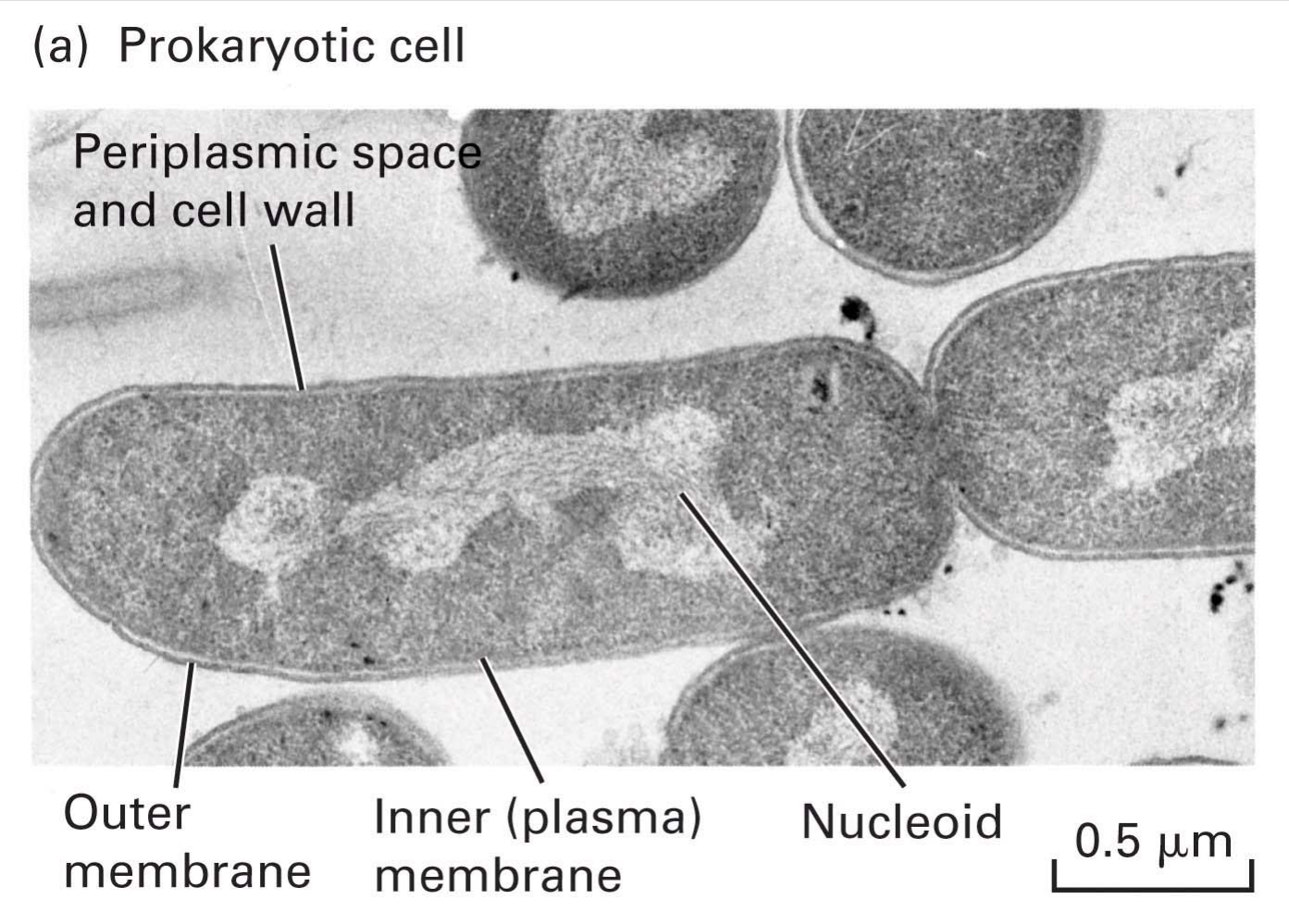


Block diagram of a cell

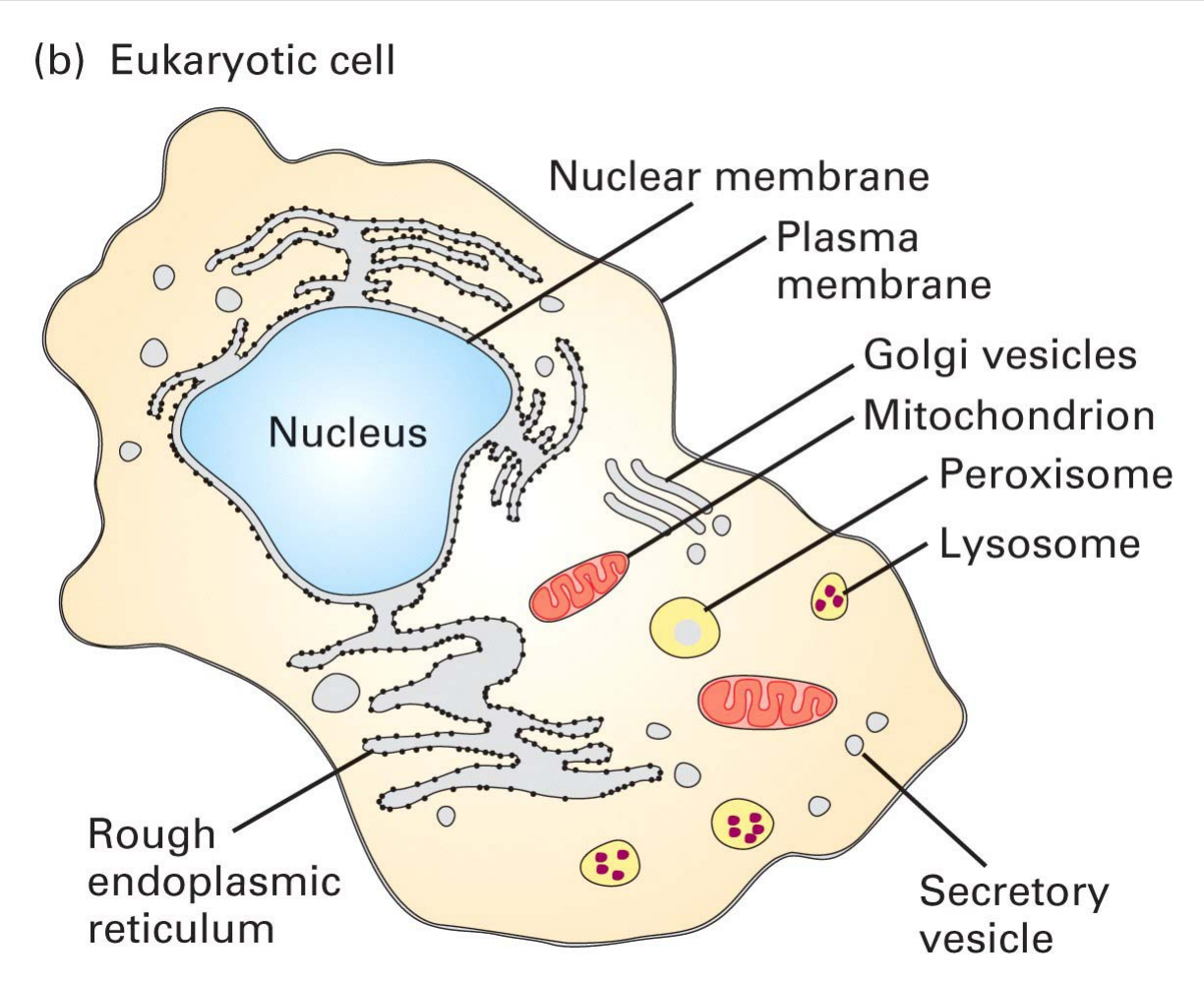


Some of these terms aren't terms a biologist would use!

Prokaryotic cell



Eukaryotic cell

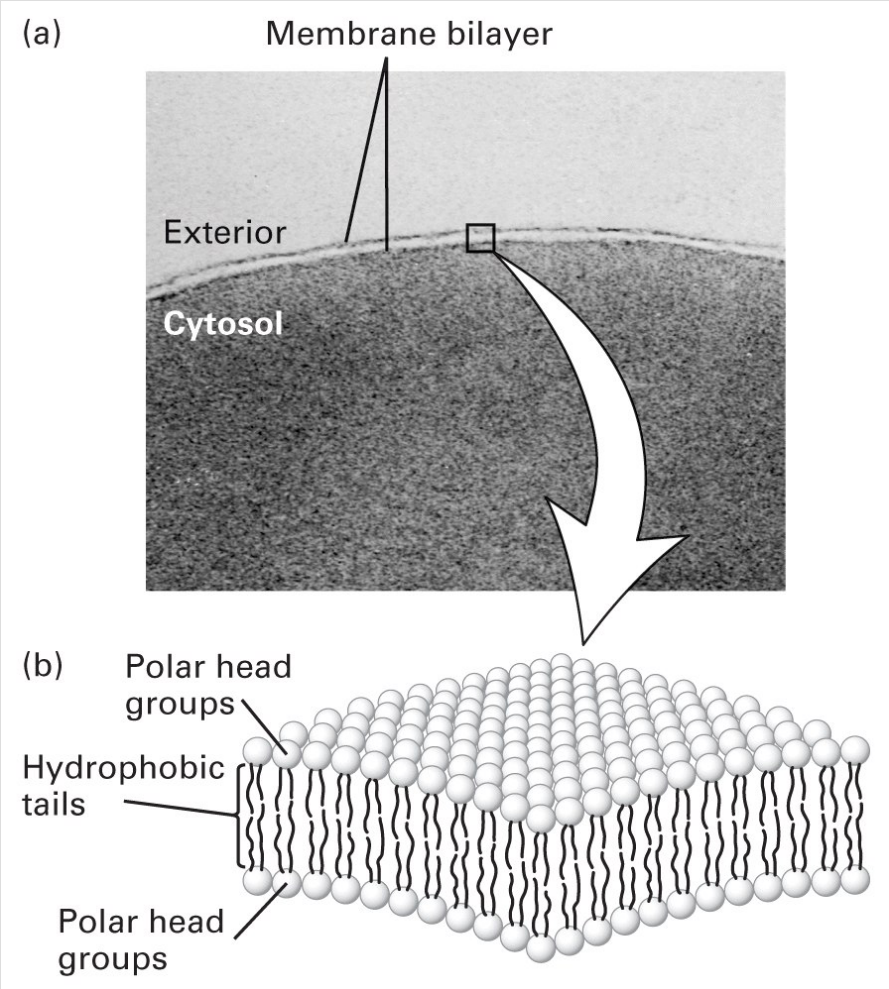


Some points to note

- There is little localization of function in the prokaryotic cell, because there are no organelles (at least that was the old picture)
- But some core functions for survival – such as energetics and reproduction – are similar;
  - So the functional block diagrams should be similar, and one should check out what fraction of processes are similar!

Cell components: Plasma membrane

- Comprises of a bilipid membrane and membrane proteins in what is called a fluid mosaic
- Partitions the cell contents from environment – something essential for its survival
- Water and some small molecules can diffuse through
- Membrane proteins control the transport of ions & larger molecules and enable biochemical signal transduction

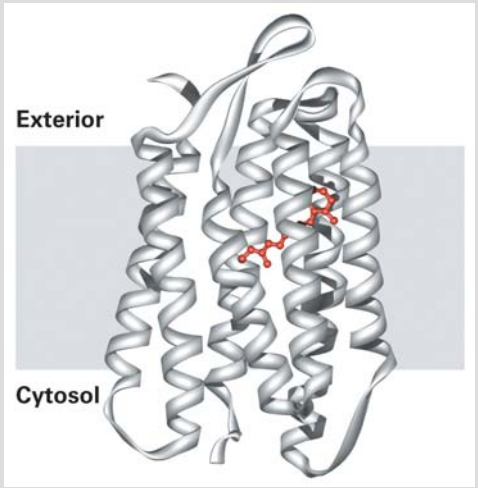


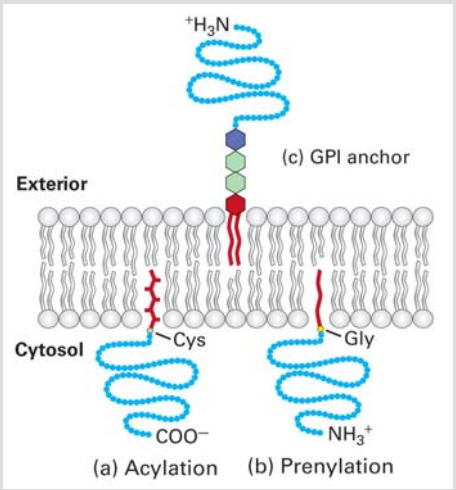
Questions & ideas: Plasma membrane

- What type of electrical models can one have for the plasma membrane?
  - SFE: http://biology.unm.edu/toolson/b435/equivcirc.html
    SFE= See For Example
- Can model parameters be obtained by simulation?
- What measurement set-ups can one use to test these models?
- For what physiological processes would such models be useful?

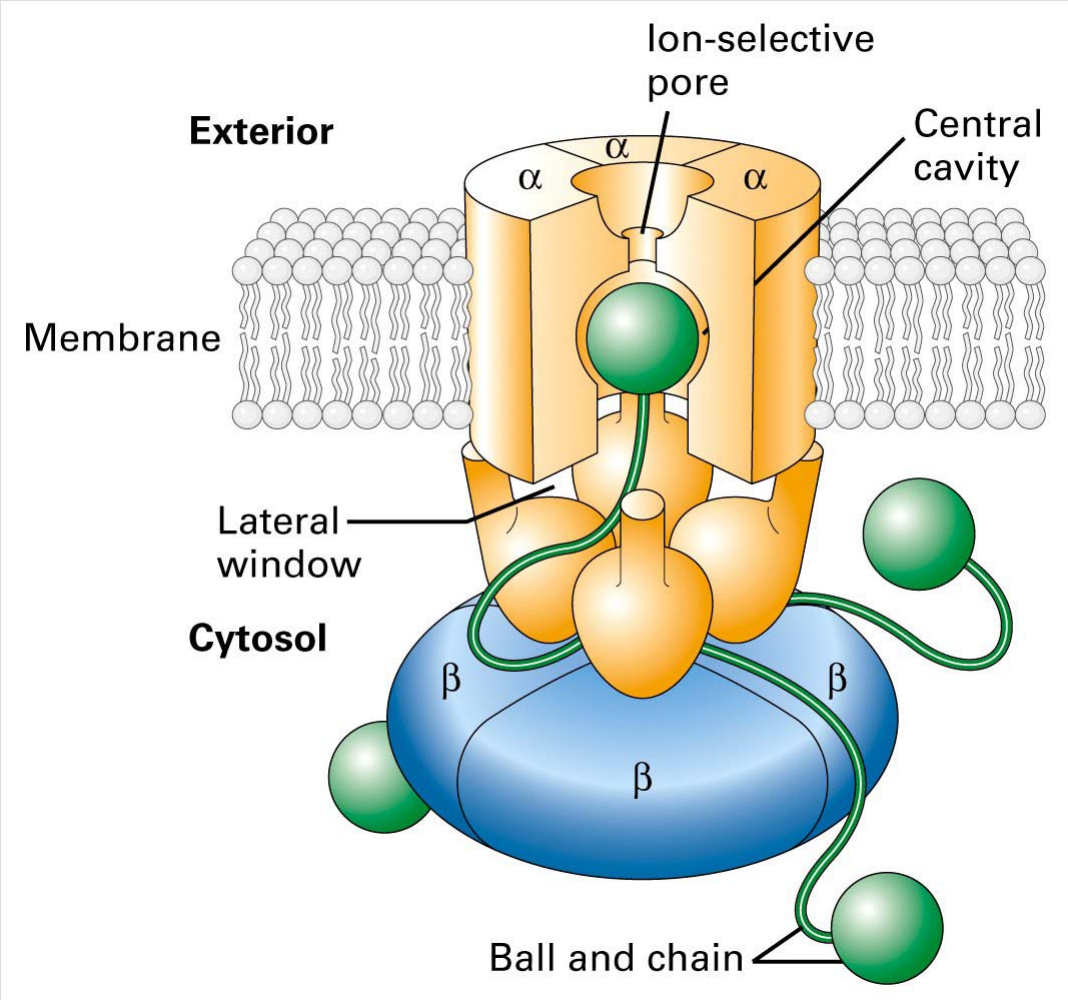
Cell components: Membrane proteins

- Integral membrane proteins
  - Transmembrane proteins: act as passive pores, gated ion-channels and ion pumps
  - Integral monotopic proteins
- Peripheral membrane proteins – attach transiently to the lipid bilayer or integral proteins

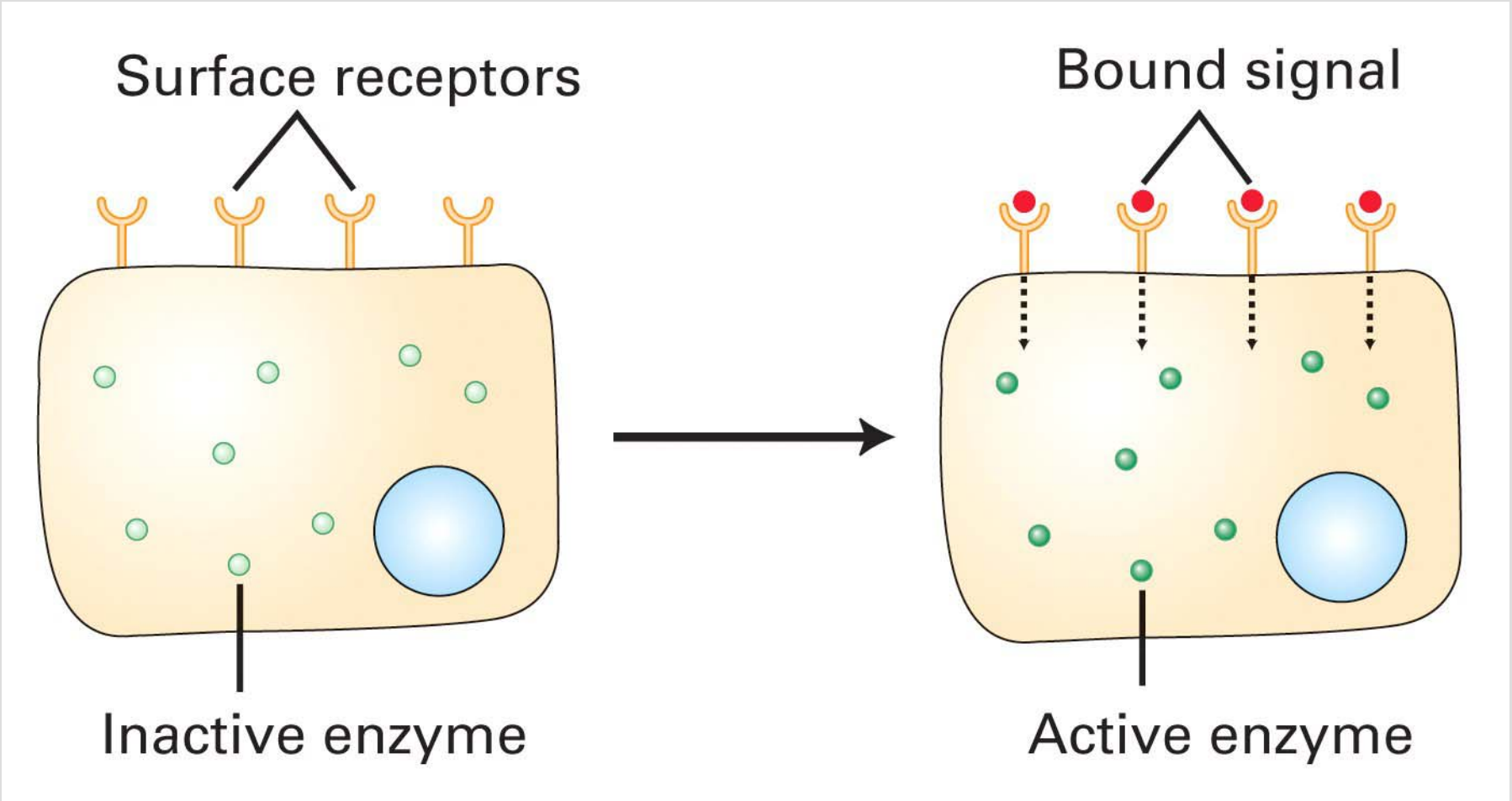




A membrane protein as an ion channel



An example of signaling

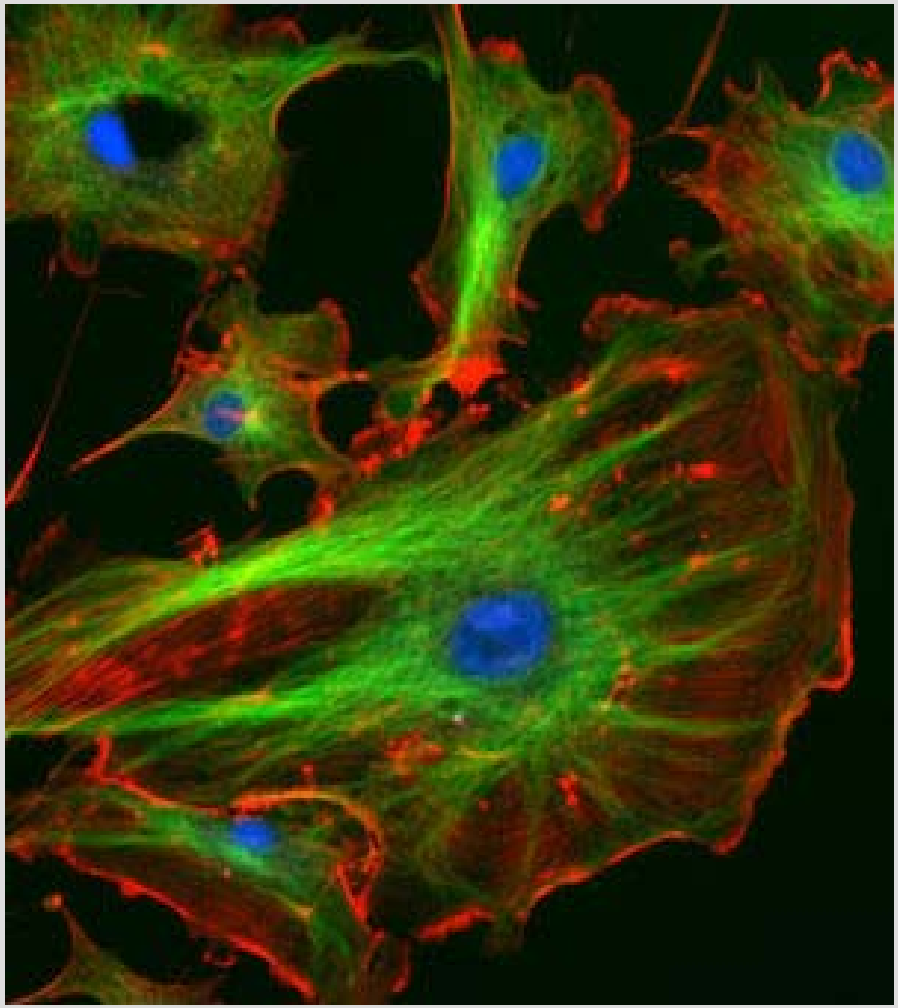


Questions and ideas: Membrane proteins

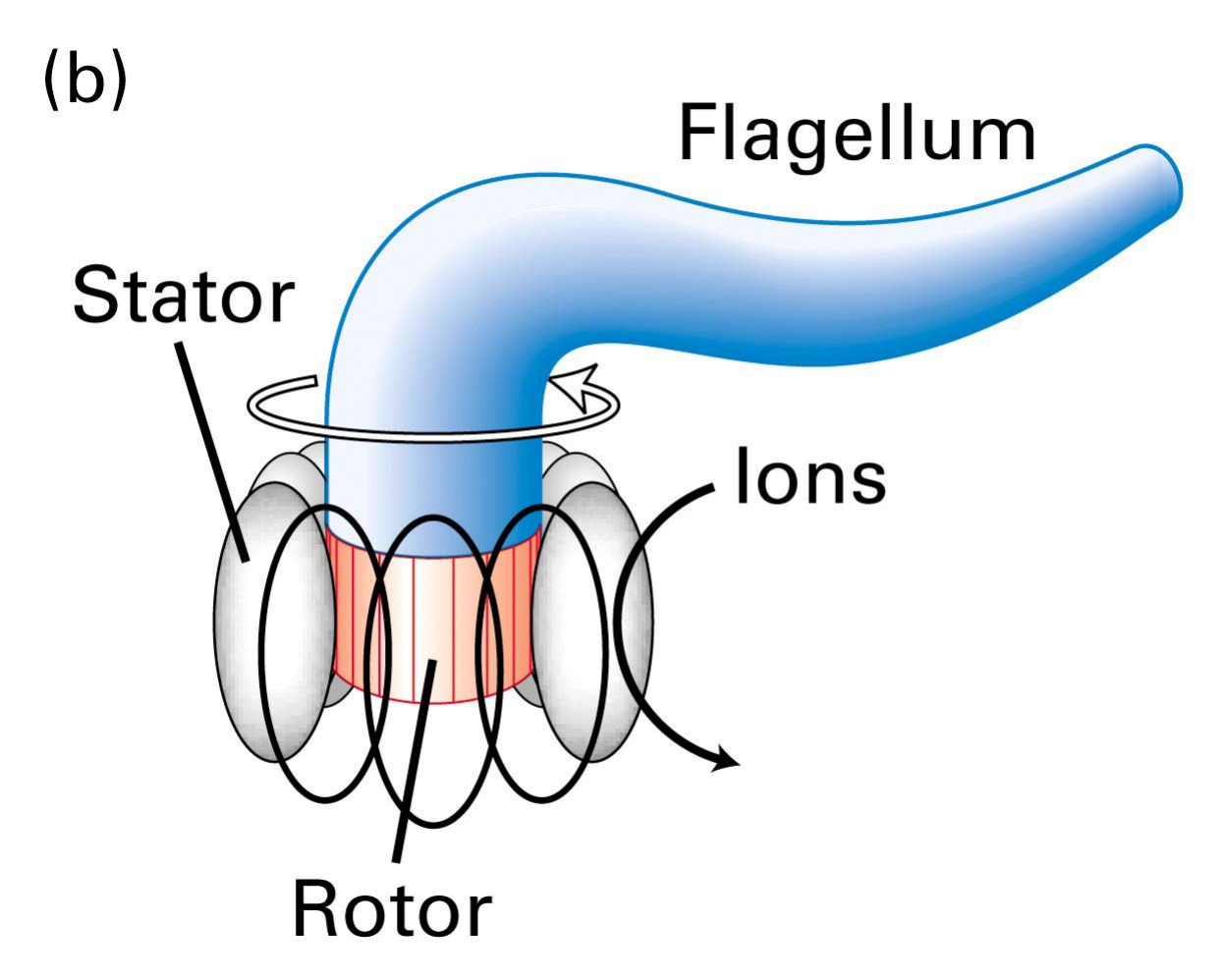
- How would membrane proteins modify electrical parameters of membranes
- What would be suitable models of membrane proteins
  - SFE: http://www.springerlink.com/content/q0k7219g8764u402/fulltext.pdf
- Modeling signaling networks as finite state machines
  - SFE: http://www.informatics.indiana.edu/schnell/papers/pbmb86_5.pdf
- Checking out similarity of signaling processes for different suites of membrane molecules

Cell components: Cytoskeleton

- The cytoskeleton:
  - comprises of protein filaments and microtubules
- They function as:
  - Cellular scaffolding that maintains cell shape
  - Can enable cell motion
  - Help transport molecules within the cell
  - Major role during cellular division



Molecular motor



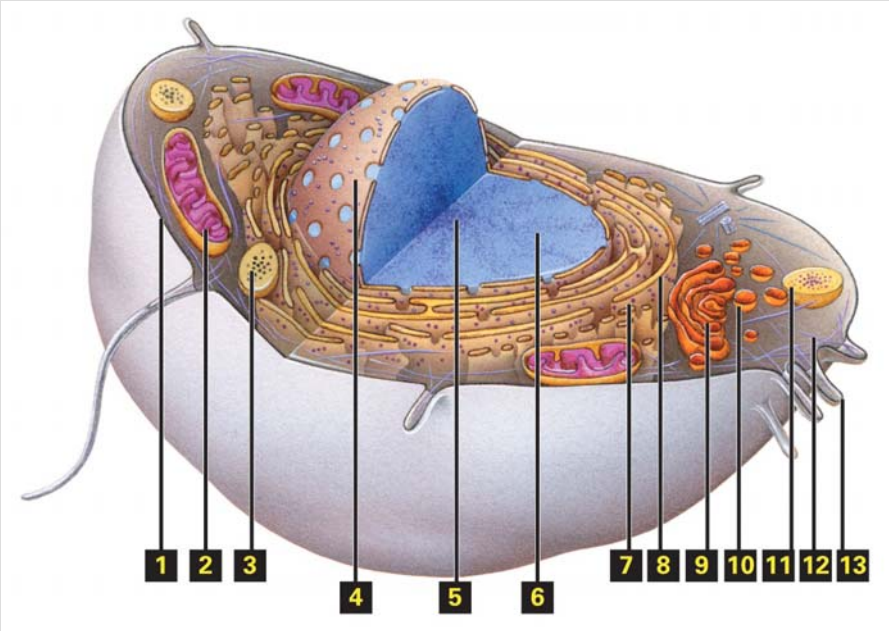
A intro molecular motors: http://www.iop.org/EJ/article/1478-3975/1/1/T01/ph4_1_t01.html

Questions & ideas: Cytoskeleton

- The cytoskeleton serves a mechanical function & I have papers that discuss its mechanical properties
- Can one investigate its electrical properties and see if it modifies the impedance of cells?
- The cytoskeleton serves as a ‘monorail’ system for transporting molecules within a cell – can one see how could model such a molecular motor

Cell components: Nucleus

- The nucleus contains the genetic material and related molecular machinery that is used during synthesis of proteins and other molecules
- Essentially serves to control cellular activity
- It is replicated during cell reproduction

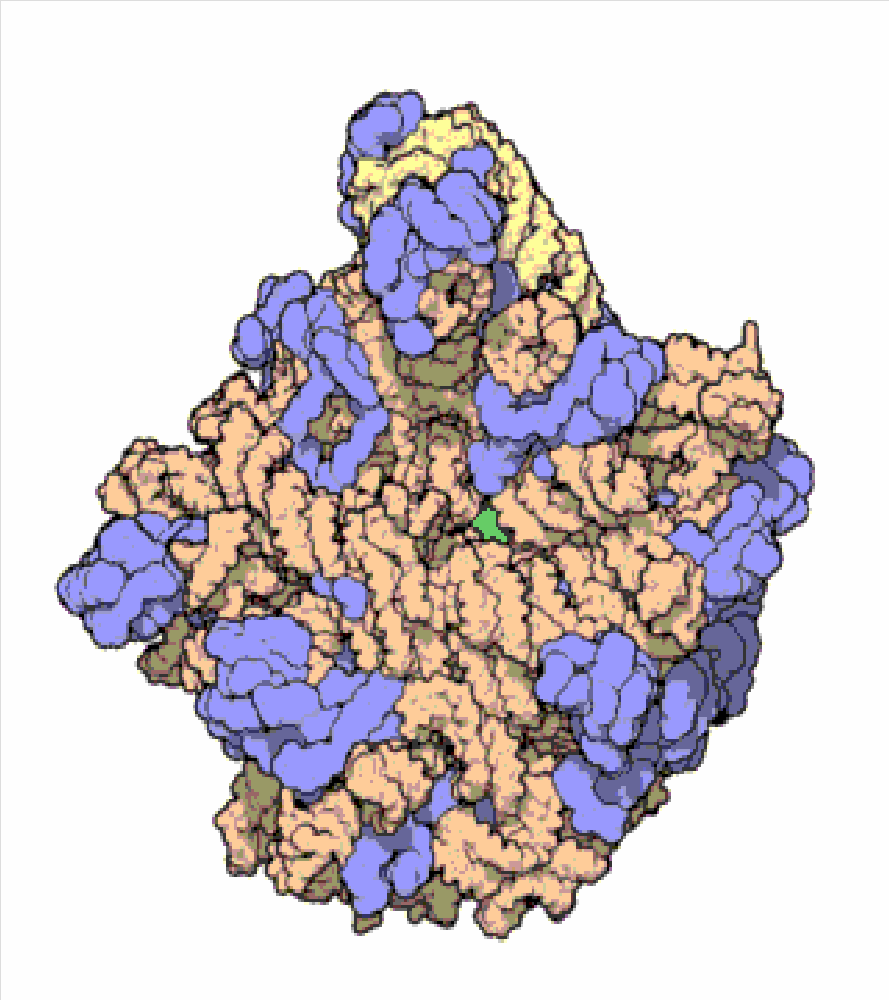


Questions & ideas: Nucleus

- One could look at information content related issues
- One could look at modeling of control mechanisms during gene expression or cell division
- Also interesting models for distances between organisms based on DNA sequences

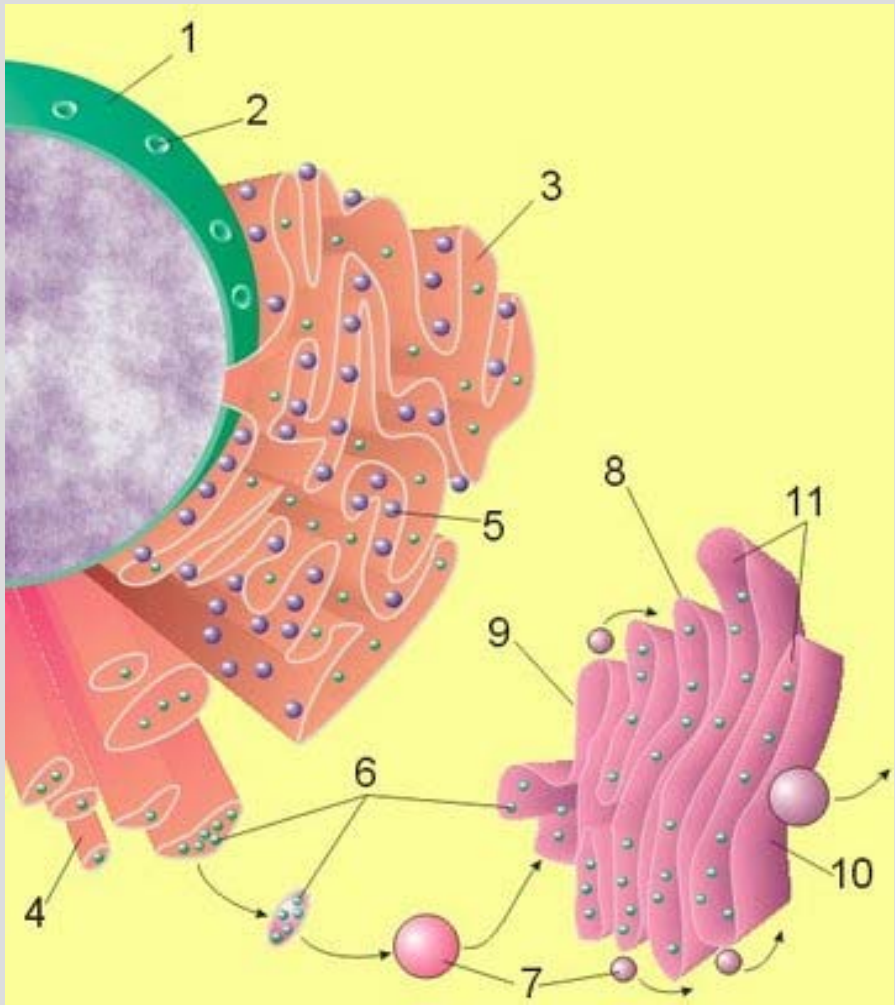
Cell components: Ribosomes

- Ribosomes are made up of proteins and RNA
- It is an organelle that synthesizes proteins



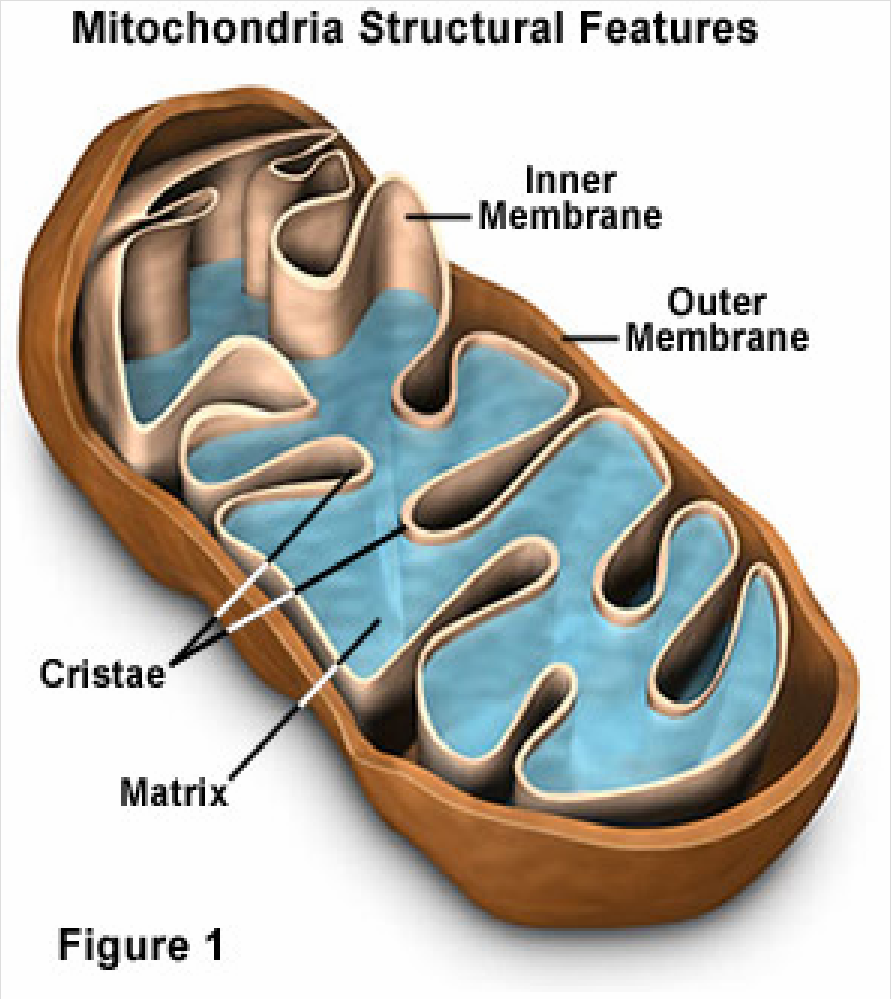
Cell components: Endoplasmic reticulum

- An interconnected network of tubules, vesicles & cisternae
- Used for:
  - Translation, folding and transport of membrane proteins or proteins that have to be secreted (example digestive enzymes)
  - Sequestration & storage of calcium



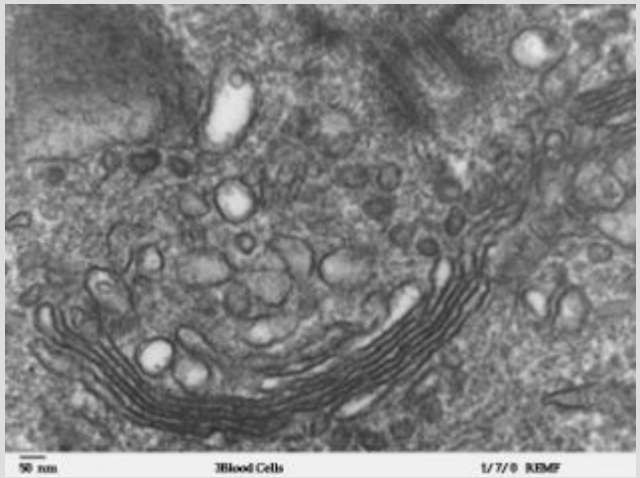
Cell components: Mitocohondrion

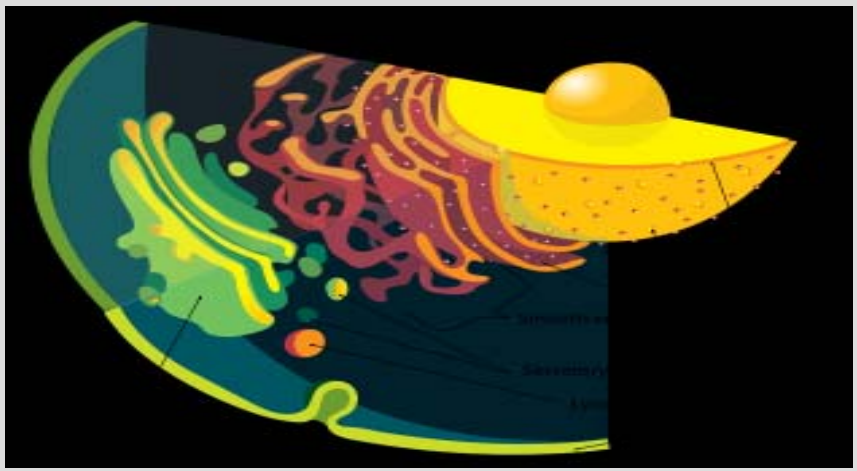
- Organelle with a large surface area inner membrane – cristae – used to produce ATP that is used as the energy carrier
- Interesting: Has its own circular DNA that it uses to synthesize some molecules required



Cell components: Golgi vesicles

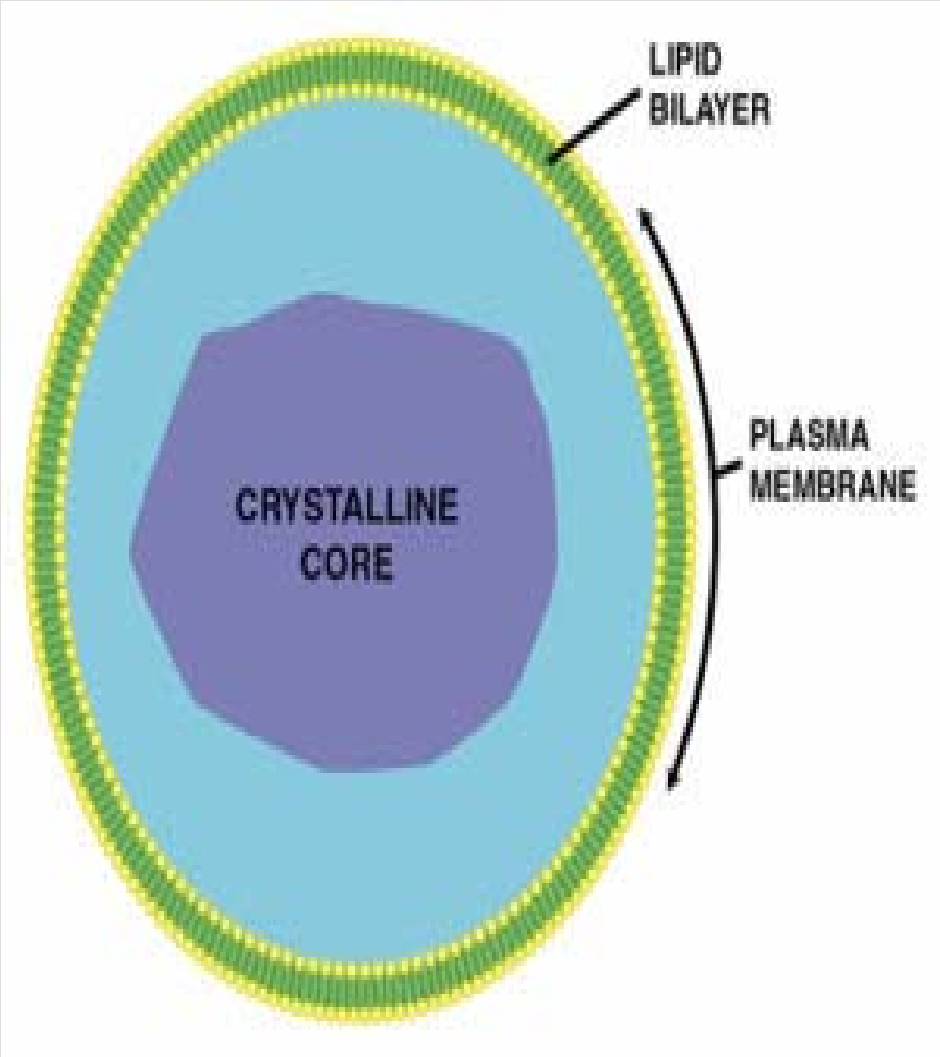
- Composed of membrane-bound cisternae
- Used for modifying, sorting and packaging proteins for cell secretion or use in cells





Cell components: Peroxisomes

- Peroxisomes have a single lipid bilayer membrane
- They have enzymes that convert toxic substances such as peroxide to water



Cell components: Lysosomes

- Organelles that contain digestive enzymes (such as hydrolases) that digest used up organelles, food particles, bacteria & viruses

Questions & ideas: Molecular synthesis & catabolism

- Control models
- Signaling mechanisms
  - ✧ SFE a comparison of bio & MEMS sensors: http://ieeexplore.ieee.org/iel5/5/20336/939817/939817.plain.html
- Mass transport

[A lot of these issues would really be close to the heart of a chemical engineer]

To read

- Read Chapter 1 from Lodish et al. and then do a quick read of the papers on modeling in this talk
- I don't find Lodish yet in the reserve collection and you could begin with:
  - http://www.microscopy.fsu.edu/cells/animalcell.html
  - http://en.wikipedia.org/wiki/Cell_(biology) and
  - If you have the patience: http://www.britannica.com/eb/article-9106125/cell

Some interesting links

- Chronology of events leading upto the development of modern biology: http://www.whatislife.com/education/fact/history_table.html
  - I would include the first observation of the cell as an important landmark too!