BIOL 230: Cell & Molecular Biology
Fall 2019 17-205 MW, Sept. 9-11

http://accounts.smccd.edu/staplesn/biol230/

1. Pre-Lab writeups due each Mon. (for both M&W!!) at the start of lab. (*briefly*, **What**? **Why**? **How**? for each expt.). Question & **Hypothesis**?!

2. **LAB this week: LIBRARY today. ENZYMES on Wednesday!!!!! O_O**
   - **NO prelab collected this week. (5 & 6 next week!)**
   - **TODAY: Meet in Labat 2:10 PM, then walk to LIBRARY:**
     Start thinking about possible research topics!! ☺
     – ******Due Oct. 2, with 1 or 2 Professional, Primary Reference!!***

3. **Extra Credit: STEM SPEAKER SERIES, Weds. @ 5pm-6pm, Sept. 11- Nov. 6. (NOT Oct. 9) in 6-102. *Write 1 page summary by the following week, and upload to CANVAS*.**

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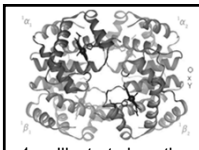

REVIEW

1. Illustrate how the chemical **structures** of carbohydrates, lipids, nucleic acids and proteins generate their various **functions**. Describe & draw specific examples. …..
   - Note the relative elemental content and functional groups of each macromolecule. (eg: DNA vs. RNA, lipids, CHOs)
2. Describe the **levels of protein structure**, and illustrate each with a specific example.

TODAY's Objectives: Students should be able t

1. Compare the structures and stabilities of **DNA and RNA**. How is each molecule suited to its biological function??
2. Describe the **Urey-Miller experiment**. What did it *prove*?
3. Diagram how **Louis Pasteur** conducted his experiments to determine how life truly arises. *What did he prove, and what did he disprove?*
4. State the **Cell Theory** and explain its implications for our understanding of life on earth. (Convert between **metric size units** of m, cm, mm, µm, & nm.)
5. List and describe, with diagrams, at least **8** important differences between **Prokaryotic and Eukaryotic Cells**. What are some similarities?
6. Diagram the structures and describe the functions of all of the major eukaryotic and prokaryotic **organelles & extracellular structures**.
7. Explain and describe the evidence for the **Theory that illustrates the origin of energetic organelles** in eukaryotic cells.
8. Diagram & describe the current **model for the structure of cellular membranes**. Explain the meaning of the name given to the theory.

❖ ***Objectives and Study Guide Questions are your HOMEWORK between classes!!! DUE every WED. at the end of Lecture!!***

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Nucleotides vs. Nucleosides

- In the nucleic acids, bases extend from a sugar–phosphate backbone.
- **DNA and RNA information resides in their base sequences**

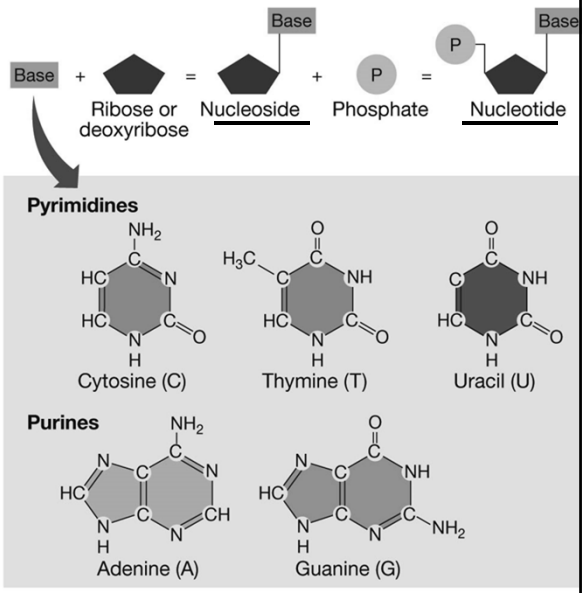

Figure 4.1 [4.1]

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4.2) DNA vs. RNA

DNA	RNA
1. Deoxyribose sugar	1. Ribose sugar
2. Bases ACGT	2. Bases ACGU
3. Double stranded	3. Single stranded
• (antiparallel)	4. Chemically labile
4. Chemically stable	

STRUCTURE → FUNCTION

4

RNA

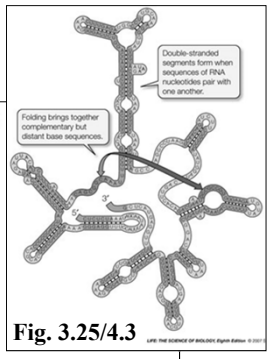
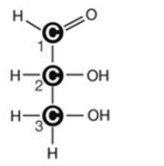


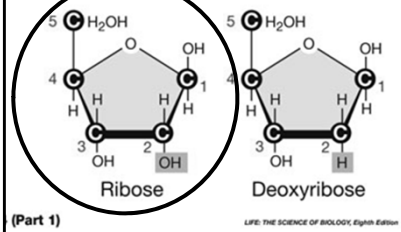
Fig. 3.25/4.3

Three-carbon sugar



Glyceraldehyde

Five-carbon sugars



(Part 1)

Fig. 3.14

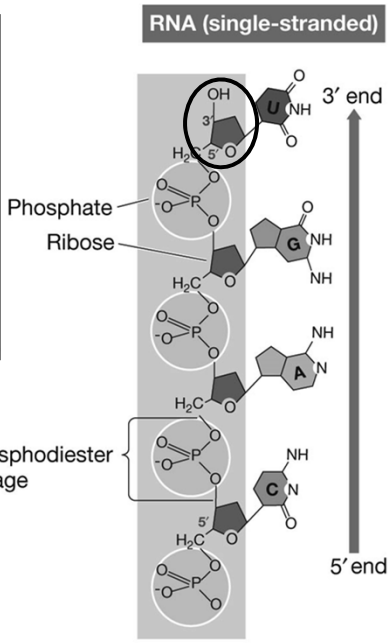


Figure 4.2 (Part 1)

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DNA

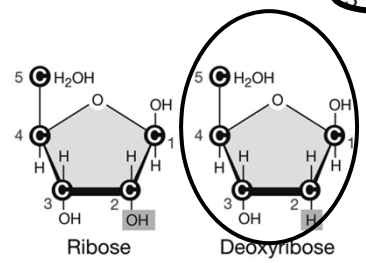


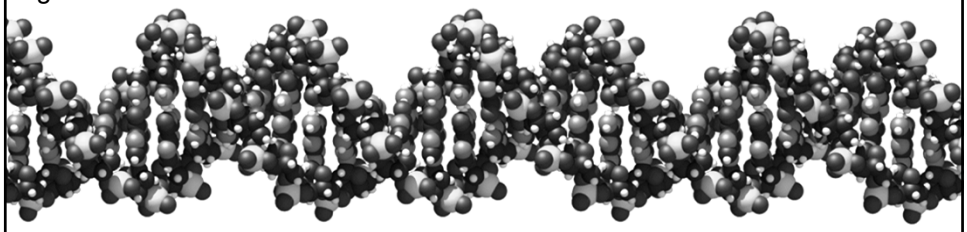
Figure 4.2 (Part 2)

6

DNA Double Helix

Yell = **P**hosphorus
Red = **O**xygen
White = **H**ydrogen
Lt. Blue = **N**itrogen
Dk. Blue = **C**arbon

Figure 4.4



- **Stacks of bases, H-bonded at center (attached to sugar)**
  - **Hydrophobically stabilizing the double helix**
- **Hydrophilic sugar-phosphate backbone outside helix**

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Nucleic Acids: Uses of DNA Sequence Information

- **Comparing the DNA base sequences of different species:**
  - → information on evolutionary relatedness
  - Some unpredictable relationships based on observable forms, bodies, etc.

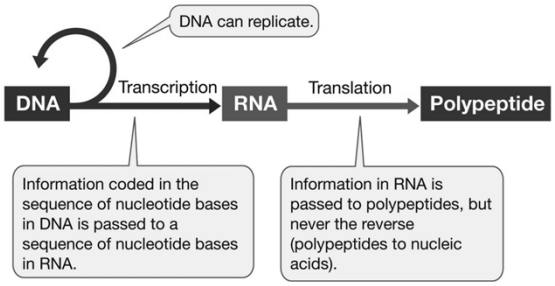

Figure 4.5 DNA Stores Information

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4.3) The Interactions of Macromolecules

- Both covalent and noncovalent linkages are found between the various classes
  - **Glycoproteins**
  - **Glycolipids**
  - **Lipoproteins**
  - **DNA-binding proteins, etc…**

    - .....energy, enzymes, and metabolism!!!.....

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4.4) Theories of the Origin of Life

A.) The theory of <u>CHEMICAL EVOLUTION</u>:

– conditions on the primitive Earth led to the formation of the large molecules unique to life.

❖ 1950s, **Stanley <u>Miller</u> and Harold <u>Urey</u>**

– Gases: experimental “primitive” atmosphere

– Energy: used a spark to simulate lightning

➢ Within days, the system contained numerous complex organic molecules.

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Figure 4.9: *Synthesis of Prebiotic Molecules in an Experimental Atmosphere*

- **Water vapor**
- **Nitrogen gas**
- **Methane**
- **Hydrogen gas**
- **Carbon Dioxide**
- **Ammonia**
- ***NO oxygen!!***

Amino acids, purines, pyrimidines

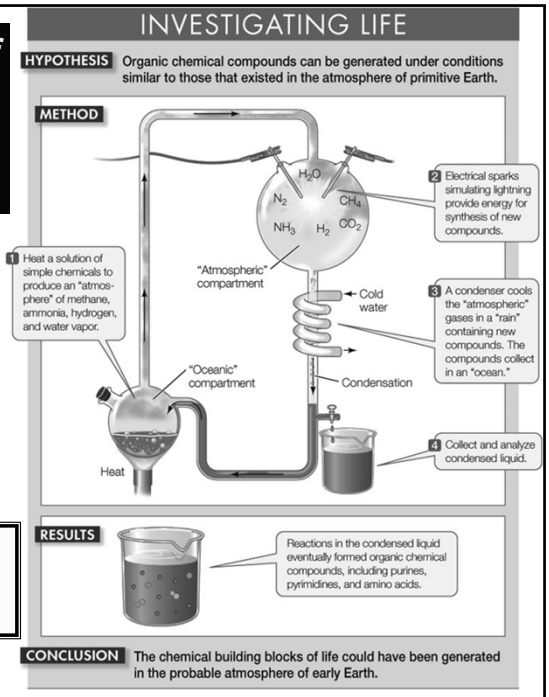

Figure 4.9

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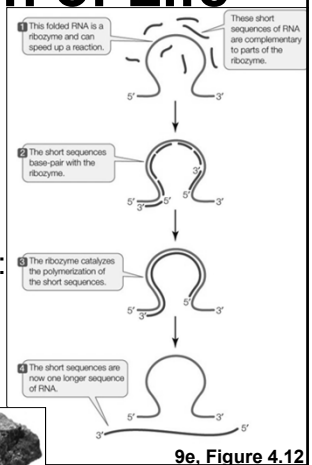
Theories of the Origin of Life

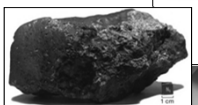
1. BIOCHEMICAL EVOLUTION:

– The results of the Miller-Urey experiments have undergone several interpretative refinements.
  - Eg: catalytic clays, CO_2, N_2, H_2S, SO_2
  - More complex organic compounds resulted!!!!
    – Vitamins, caboxylic acids, fatty acids, sugars, ribose!

- The earliest stages of **chemical evolution**:
  – **<u>"RNA World"!?</u>** –
    - **<u>Informational</u>, & 3D structures = <u>catalytic</u>!!**
  – emergence of monomers and polymers
    - (catalytic clays - silicates, hot vents/pools – Fe, Ni)
  – probably have remained generally unchanged for 3.8 billion years.



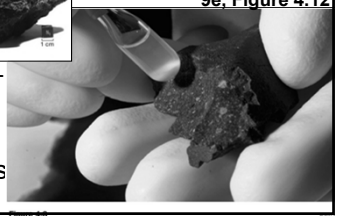
9e, Figure 4.12



2. <u>Life from outer space?:</u>

– **<u>Antarctic meteorite, ALH84001, from Mars</u>** – Martian gases, water, polycyclic aromatic hydrocarbons

- In 1969, fragments of a meteorite were found to contain molecules unique to life, including purines pyrimidines, sugars, and ten amino acids.



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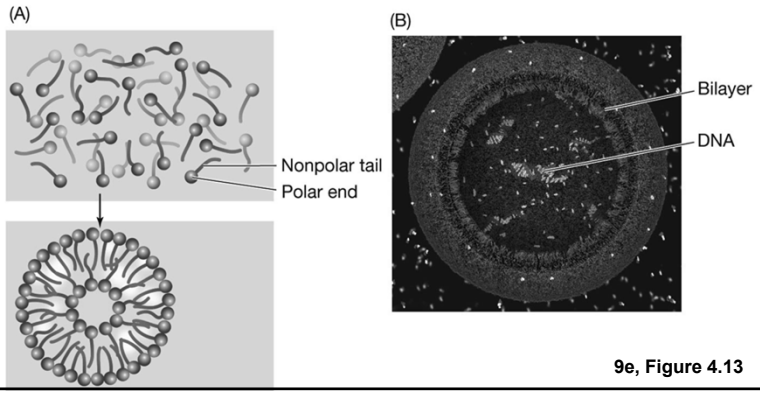
B. CELLULAR Evolution:

- In water, **fatty acids** will form a ***lipid bilayer*** around a compartment.
- These **protocells** allow small molecules such as sugars and nucleotides to pass through.
  - If short nucleic acid strands capable of self-replication are placed inside the protocells,
  - nucleotides can enter, and
  - become incorporated into new polynucleotide chains.



9e, Figure 4.13

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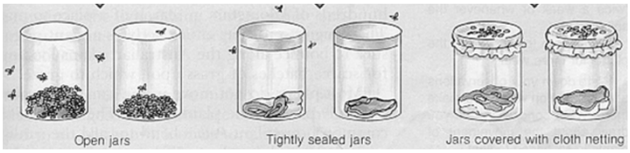
4.5) ** *All Life from Life!*

- ***Should we expect to see new life forms arise from the biochemical environment?***
- During the Renaissance,
  - most people thought that some forms of life arose directly from inanimate or decaying matter
  - by ***Spontaneous Generation.***



- In **1668, Francisco Redi** experimentally tested this hypothesis – filled six jars with decaying meat:

Conditions	**Results**
3 jars covered with fine net	No maggots
3 open jars	Maggots appeared
Conclude: No life from nonlife! (flies must lay eggs) but doubters remained.	

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All Life from Life

- The invention of the microscope……
  - **Antoni van Leeuwenhoek; R. Hook**
    - unveiled a vast new biological world which some scientists believed arose spontaneously from their rich chemical environment.

- In **1861**, **Louis Pasteur** completed experiments to disprove this idea……..
  - → ***Theory of Biogenesis***
  - ***Note:*** *Environmental and planetary conditions that exist on Earth today prevent life from arising from nonliving materials.*
    - ***Eg: conditions used in Urey-Miller Expt.***

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Figure 4.7: *Disproving the Spontaneous Generation of Life*

Boiling kills all microbes in beef broth

"swan neck" broken off

"swan neck" traps dust and microbes, but lets air in

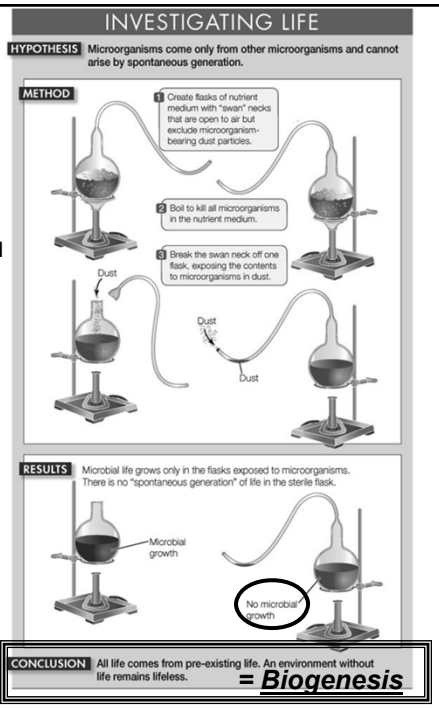

Figure 4.7

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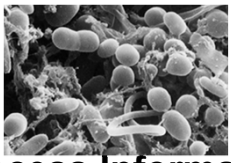
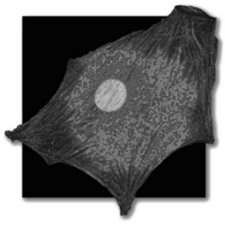
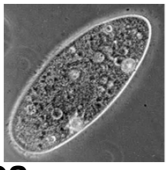
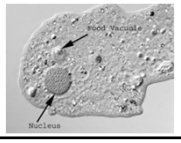
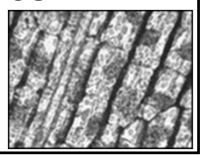
Ch. 5: Cells: The Working Units of Life

1. The Cell: The Basic Unit of Life
2. Prokaryotic Cells
3. Eukaryotic Cells
4. Organelles that Process Information
5. The Endomembrane System
6. Organelles that Process Energy
7. Other Organelles Enclosed by Membranes
8. The Cytoskeleton
9. Extracellular Structures



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5.1) The Cell Theory

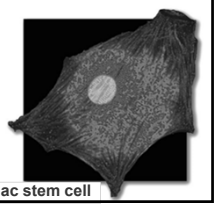
(Matthias Schleiden, Theodor Schwann & Rudolph Virchow)

http://www.cpschools.com/schools/osm/theory.htm

- The Cell is the basic unit of life (***All organisms are composed of cells***)
- ***All cells come from preexisting cells***
  - have certain processes, molecules, and structures in common
  - (***"Spontaneous Generation"*** disproven by Pasteur – all life must come from life!!)

* * * * * * * * * *

- **CELL = smallest unit that displays all of the characteristics of LIFE** –
  1. use DNA as hereditary material,
  2. proteins as catalysts,
  3. reproduce,
  4. transform matter and energy,
  5. respond to the environment/stimuli


Cardiac stem cell

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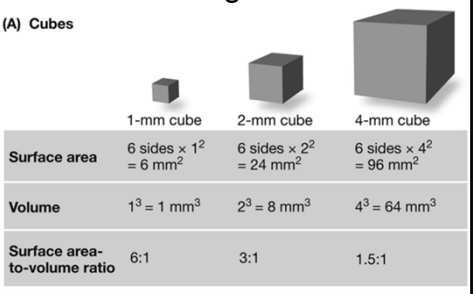
The Cell: The Basic Unit of Life

- To maintain adequate exchanges with its environment, a cell's surface area must be large compared with its volume
  - ***Cells favor high Surface:Volume ratio***
    - ➢ ***Smaller cells have higher S/A ratios!!!***
- Microscopes are needed to visualize cells.
  - Electron microscopes allow observation of greater detail than light microscopes do.



	1-mm cube	2-mm cube	4-mm cube
Surface area	6 sides × 1^2 = 6 mm^2	6 sides × 2^2 = 24 mm^2	6 sides × 4^2 = 96 mm^2
Volume	1^3 = 1 mm^3	2^3 = 8 mm^3	4^3 = 64 mm^3
Surface area-to-volume ratio	6:1	3:1	1.5:1

Fig. 5.2: Why cells are small.

LIFE 9e, Figure 5.2 (Part 1)

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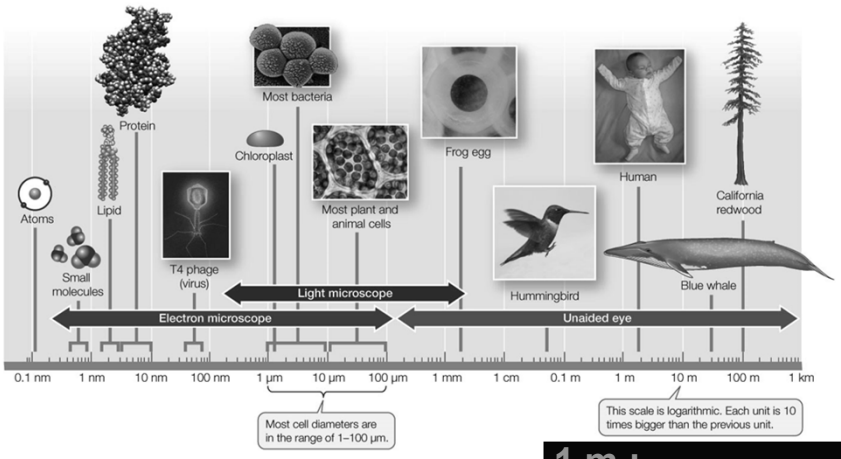
The Scale of Life



***LIFE 9e*, Figure 5.1**

1 m :
1 mm (milli) = 10^{-3} m
1 µm (micro) = 10^{-6} m
1 nm (nano) = 10^{-9} m
1 pm (pico) = 10^{-12} m

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5.2) Prokaryotic Cell: DOMAINS Eubacteria and Archaea

- ***Pro-Karyon = "Before Nucleus"***
- Prokaryotic cells lack internal compartments

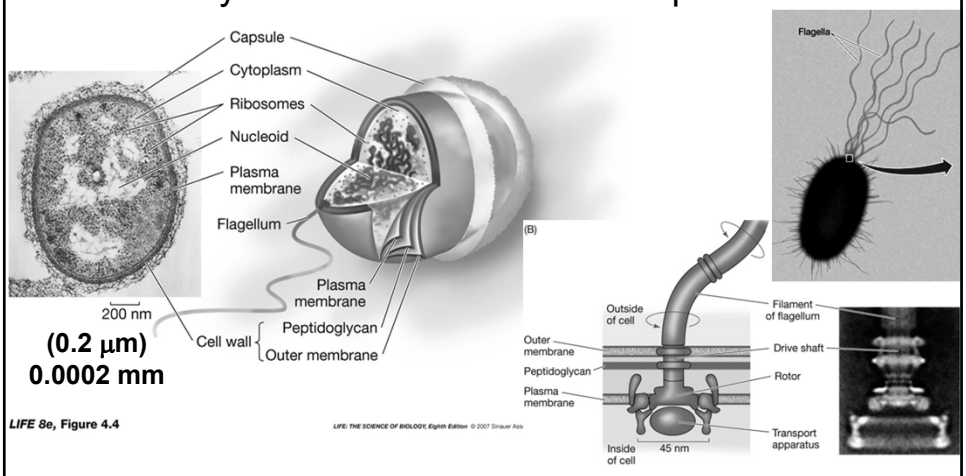

Fig. 5.4

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Prokaryotic Cells

- **All have:**
  1. Plasma membrane,
  2. Nucleoid region with DNA,
  3. Cytoplasm – ribosomes, dissolved enzymes, water, and small molecules

- **Some have:**
  1. Cell wall (most)
  2. Outer membrane – porous
  3. Capsule – polysaccharide
  4. Photosynthetic membranes
  5. Flagella
  6. Pili or fimbriae
  7. Actin-like cytoskeleton (rods/bacilli)

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5.3) Eukaryotic Cells

1. Like prokaryotic cells:

a. plasma membrane
b. cytoplasm
c. Ribosomes

2. Unlike prok. Cells:

a. larger
b. many membrane-enclosed organelles

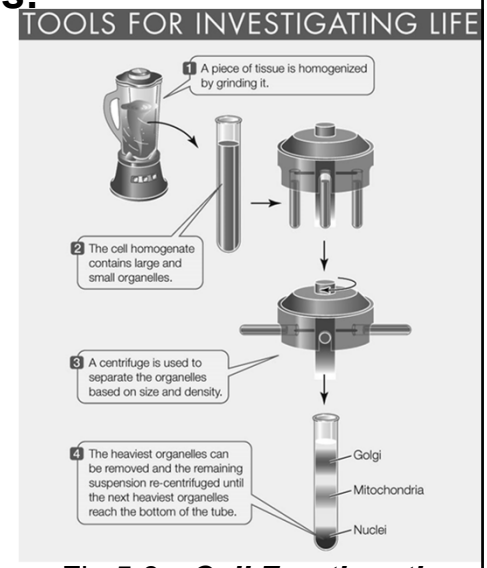

Fig 5.6: ***Cell Fractionation.***

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Prokaryotic vs. Eukaryotic Cells

1. No true nucleus – "*nucleoid*"	1. True Nucleus (nuc. envelope)
2. No memb.-bound organelles	2. Memb.-bound nucleus and other organelles
3. Single, circular chromosome	3. Many linear chromosomes
4. No histones	4. Chromosomes bound by histones
5. 70S Ribosomes	5. 80S Ribosomes (larger)
6. Unique cell wall (PG)	6. Plants and Fungi – polysaccharide CW's
7. Unique flagella *(flagellin)*	7. Microtubule flagella (or cilia)
8. Outer Membrane (gram -)	8. No O.M.
9. Only unicellular	9. Many spp. Multicellular
10. Small (1-5 μm diameter)	10. Larger (10-100 μm diameter)

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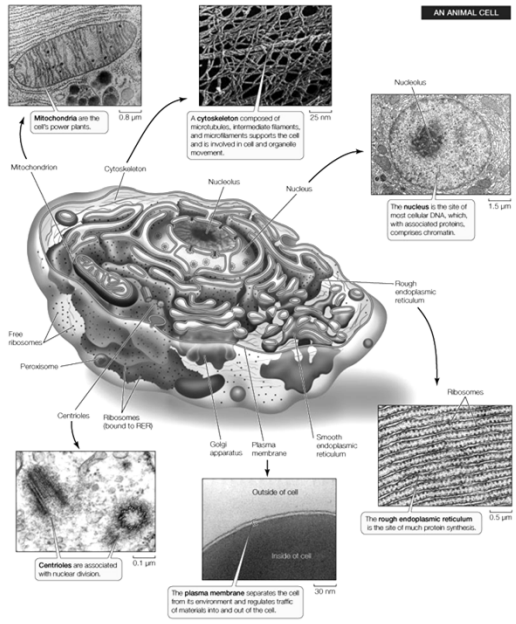
Eukaryotic cells: Plants, Animals, Fungi, Protists

Eu-Karyon = "True Nucleus"

- have many membrane-enclosed compartments, including a nucleus containing DNA.
- **(Animal Cell:) →**



5.7 (1)

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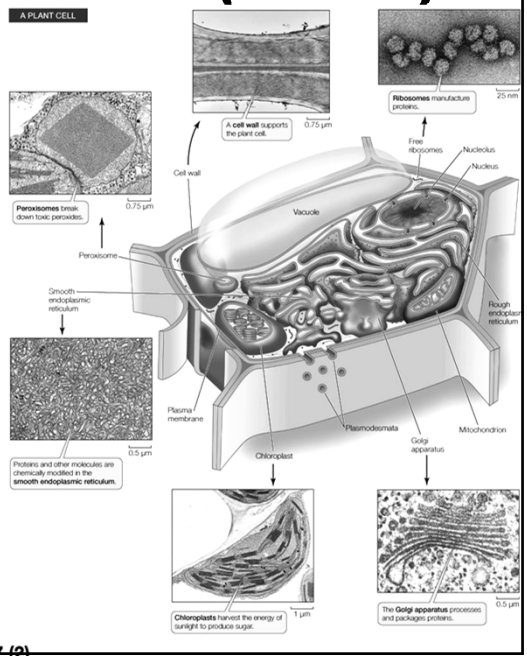
Eukaryotic Cell (Plant)

- ***Membranes*** **that envelop organelles:**
  - = partial (selective) barriers
    - ensure that the chemical composition of the organelle's interior
    - differs from that of the surrounding cytoplasm



5.7 (2)

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A.) Organelles that Process Information: the NUCLEUS

1. The **NUCLEUS** is usually the largest organelle in a cell.
   - surrounded by the ***Nuclear Envelope***
   - ***Nucleolus*** (inside) = source of cytoplasmic ribosomes (synthesized there)

2. The nucleus contains most of the cell's DNA as chromatin.
   - ***Chromatin*** = DNA/protein complex
     a) diffuse throughout the nucleus (like fine, loose spaghetti).
     b) condenses just before cell division to form chromosomes.

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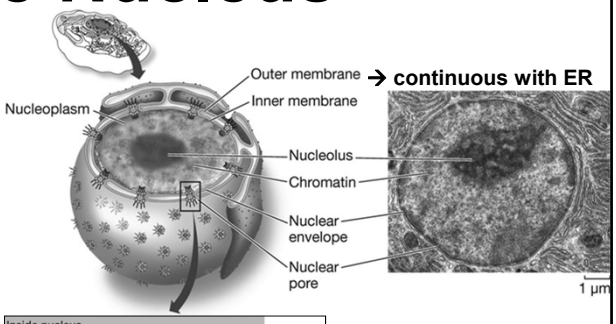
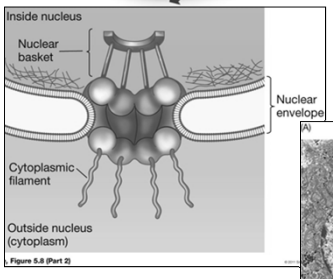
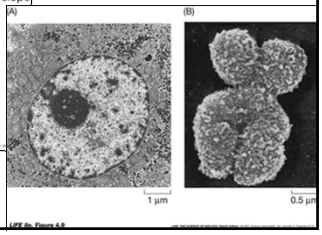
The Nucleus

- **Nuclear pores** –
  - complex structures governing what enters and leaves the nucleus.



❖ **Nuclear lamina** –
  - Protein matrix (***lamins***).
  - supports nuclear envelope.
  - Binds chromatin.





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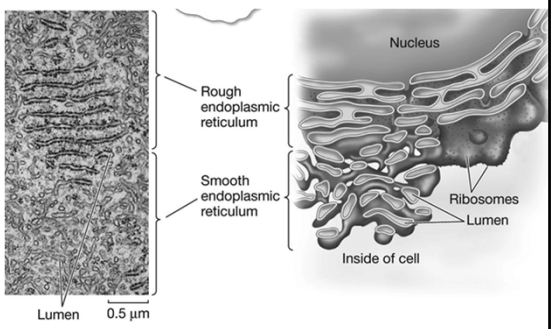
B.) The Endomembrane System

- The endomembrane system = a series of interrelated membranes and compartments.

1. **Rough ER:**
   - has ribosomes – synthesize proteins (for export)
2. **Smooth ER:**
   - lacks ribosomes.
   - site of lipid synthesis.



LIFE 8e, Figure 4.10

3. **Golgi apparatus:**
   - adds signal molecules to proteins -- directing them to destinations.
   - receives materials from the rough ER via vesicles that fuse with the *cis* region of the Golgi.

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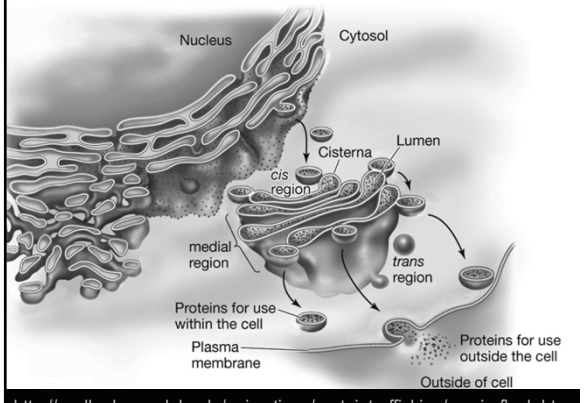
* Golgi Apparatus

- 3 Regions: ***cis, medial, trans.***
- ***Vesicles originating from the trans region of the Golgi contain proteins for different cellular locations*.**
  - Some fuse with the plasma membrane and release their contents outside the cell.



http://vcell.ndsu.nodak.edu/animations/proteintrafficking/movie-flash.htm

9e, Figure 5.10 (Part 2)

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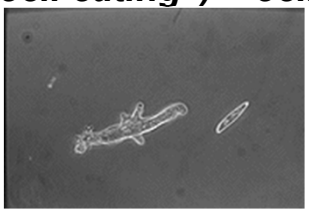
4. Lysosomes & Phagocytosis

- ***Phagocytosis ("cell eating") = cell engulfs large particles.***



- **Lysosomes** fuse with the **phagosomes** to form *secondary lysosomes (**phago-lysosomes**):*
  - Engulfed particles are digested in phagolysosome
    - Digested products released into cytoplasm for use
  - Undigested materials are secreted from the cell
    - phagolysosome fuses with the plasma membrane

http://highered.mcgraw-hill.com/sites/0072495855/student_view0/chapter2/animation__lysosomes.html
http://www.stolaf.edu/people/giannini/flashanimat/cellstructures/phagocitosis.swf
http://www.sumanasinc.com/webcontent/animations/content/organelles.html

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Phagocytosis and Intracellular Digestion

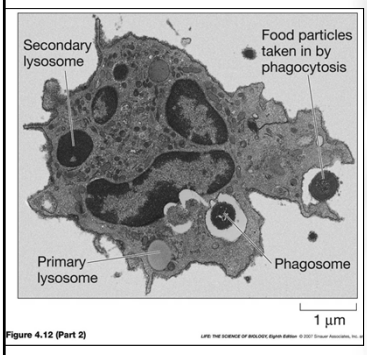
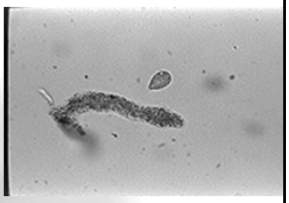


Figure 4.12 (Part 2)



LIFE 9e, Figure 5.11 (Part 1)

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C.) Organelles that Process Energy

1. Mitochondria are enclosed by
   - outer membrane &
   - inner membrane – folds inward to form ***cristae.***
     - ➢ contain proteins needed for cellular respiration and generation of ATP.

http://www.stolaf.edu/people/giannini/cell.html

http://www.stolaf.edu/people/giannini/biological%20anamations.html

http://www.stolaf.edu/people/giannini/movies.html

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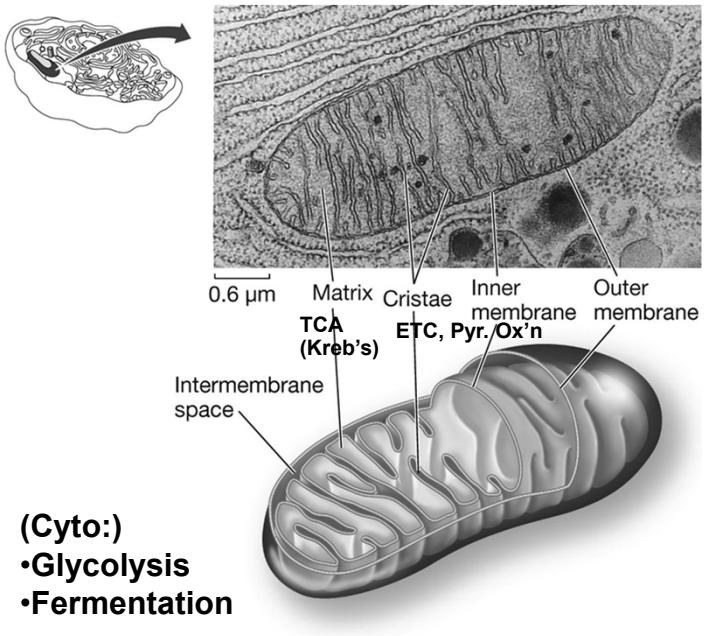
1. Mitochondrion



(Cyto:)
•Glycolysis
•Fermentation

9e, Figure 5.12

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2. The Chloroplast (a Plastid)

a) **Plastids** = chloroplasts, chromoplasts, leucoplasts ("amyloplasts").

b) Green plant & algae cells contain ***chloroplasts***:
   i. enclosed by double membranes.
   ii. contain an internal system of thylakoids.

c) Thylakoids – organized as grana.
   - contain the *chlorophyll* and proteins that harvest light energy for photosynthesis.

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Chloroplasts

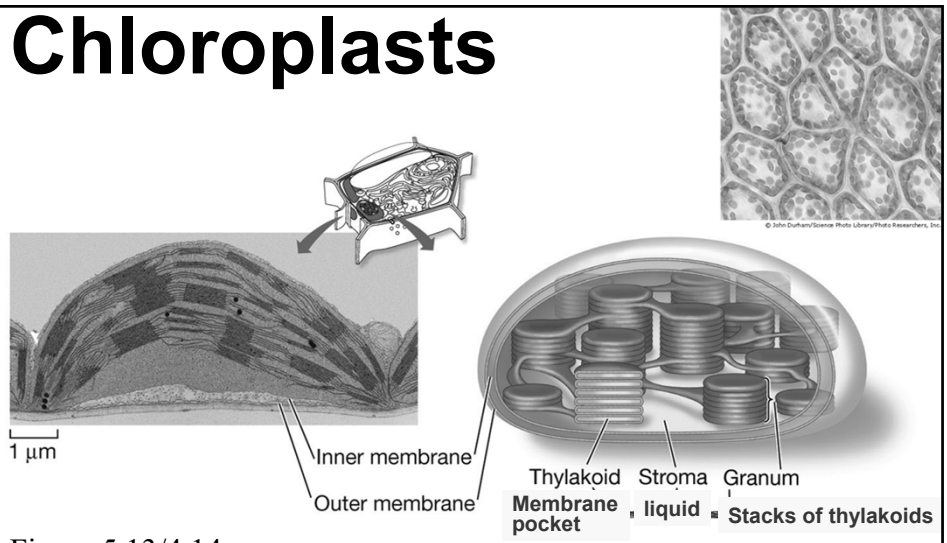

Figure 5.13/4.14

Two-Membrane Organelles:
- **Nuclei**
- **Mitochondria**
- **Chloroplasts**

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Mitochondria and Chloroplasts: …some early observations…

1. Have Double-membranes
2. Contain their own DNA and ribosomes!!
3. Can make some of their own proteins
4. Divide at their own rate ……

- *Possible scientific explanation??….*

http://www.sumanasinc.com/webcontent/animations/content/organelles.html

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Endo-sym-biosis Theory

1. The evolution of mitochondria and chloroplasts:
   - large prokaryotes engulfed (by "***endocytosis***"), but did not digest, smaller ones → DOUBLE MEMBRANE (from host & endosymbiont)
2. ***Mutual benefits permitted this symbiotic relationship to evolve into eukaryotic organelles of today***
   - Home & protection for small cell
   - New, powerful energy source for larger cell

http://www.sumanasinc.com/webcontent/animations/content/organelles.html

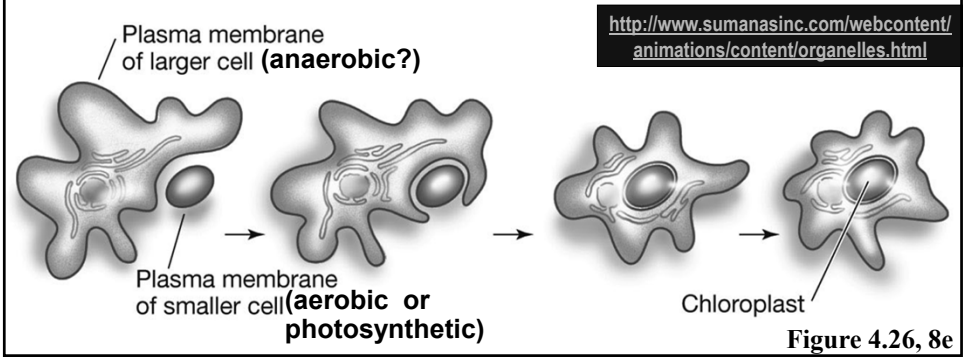

Figure 4.26, 8e

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Evidence for Endosymbiotic Origin of Mitochondria & Chloroplasts

1. Approximately the **same size and shape** of known prokaryotes ("bacteria").
2. Bacteria-like genetic information (chromosomal DNA):
   a) **Closed, circular DNA** (not linear, like Euk.)
   b) Encode own: metabolic proteins, prok.-type ribosomes
3. **Prok.-like division** mechanisms (***ftsZ*** gene)
   - **http://www.ncbi.nlm.nih.gov/** → **PubMed**, **Advanced** → "***ftsZ*** gene" → Article. Type: "**Review**"
   - **https://www.ncbi.nlm.nih.gov/pubmed/24266848** 2013
   - **https://www.ncbi.nlm.nih.gov/pubmed/24631929** 2013
4. Many organelle genes seem to have been lost to the Nuclear genome. (Eg: ribosomal genes)
   – ***Organelle genes in nucleus are more closely related to bacterial genes than to euk. genes in the same cell!***
5. ** Discovery of a single-celled eukaryote, *Hatena,* that ingests a green alga, *Nephroselmis.*
   – loses most of its structures and acts as a chloroplast.

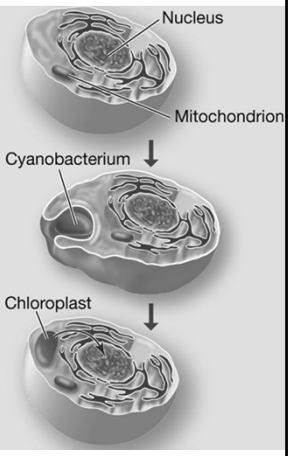

Figure 5.26, 9e
Origin of Organelles (B)

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D. Other Organelles Enclosed by Membranes

- ***Peroxisomes*** (very small) = store toxic peroxides – waste products of some rxns.
- ***Vacuoles*** = membrane-enclosed compartment of water and dissolved substances.
  - take in water and enlarge
    - Provide pressure to stretch the cell wall - growth
    - Provide structural support for a plant. ("***turgor pressure***")
  - Store **anthocyanins** (pink & blue pigments)
    - in flowers and fruits; colors attract pollinators
  - Vacuoles in seeds
    - have **digestive enzymes**
      - hydrolyze stored food for early growth

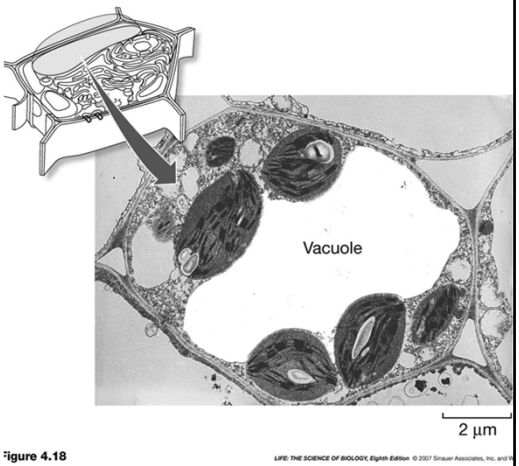

Figure 5.16 Vacuoles in Plant Cells Are Usually Large

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E. The Cytoskeleton

- Within the cytoplasm of eukaryotic cells
- Provides shape, strength, and movement
  - Holds organelles in position.
  - Moves organelles; Involved in cytoplasmic streaming.
  - Interacts with extracellular structures to hold cell in place.
- Consists of **three** interacting **types** of **protein fibers**:
  1) **Microfilaments** (***actin***) = 7 nm thick (diameter).
  2) **Intermediate Filaments** (***keratin, lamins***) = 8-12 nm thick.
  3) **Microtubules** (***tubulin***; hollow) = 25 nm thick.

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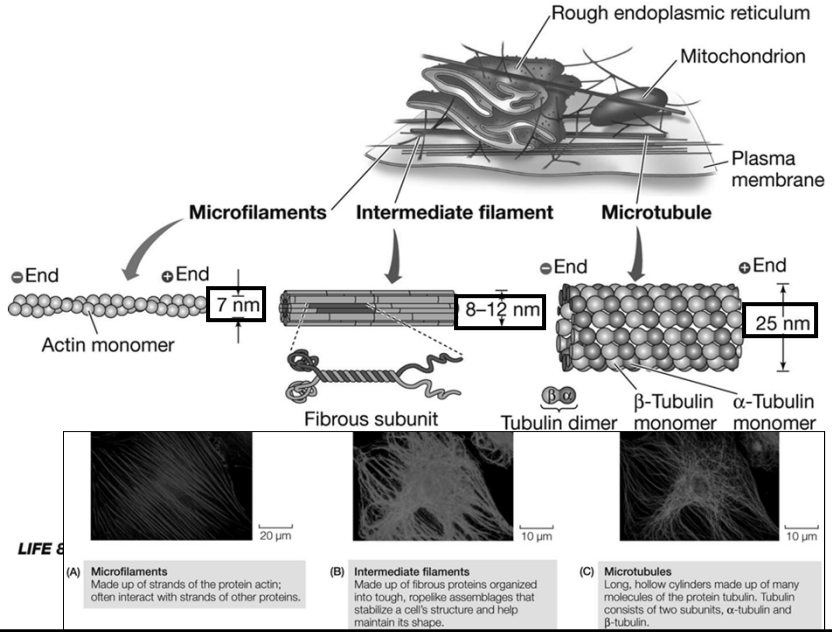
Cytoskeleton

Figure 5.17



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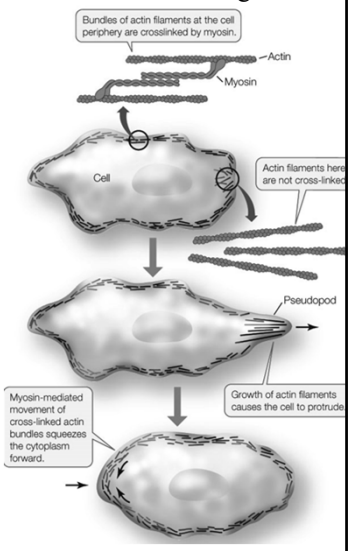
The Cytoskeleton

Figure 5.18

A. Microfilaments:

- = 2 chains of ***actin*** units forming a double helix.
- strengthen cellular structures
- provide movement in animals…
  1) **cell division,**
  2) **cytoplasmic streaming**
     - **(cyclosis),**
  3) **pseudopod extension**
     - **(amoeba, white blood cells)**
  4) **Actin/Myosin → muscle movement**

❖ occur as individual, bundled, or networked fibers



http://micro.magnet.fsu.edu/moviegallery/pondscum/protozoa/amoeba/t1/amoeba05.html

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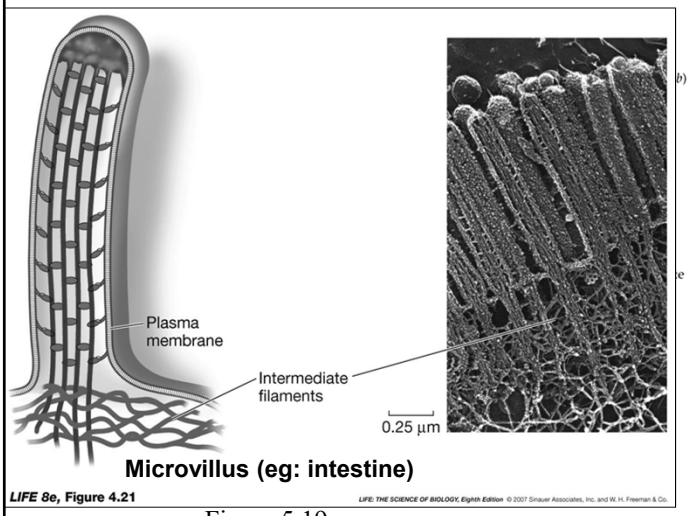
Microfilaments – microvilli



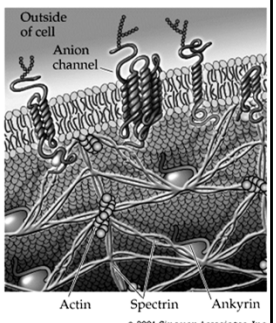


Figure 5.19

http://www.scripps.edu/cb/milligan/research/movies/myosin_mov.html

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