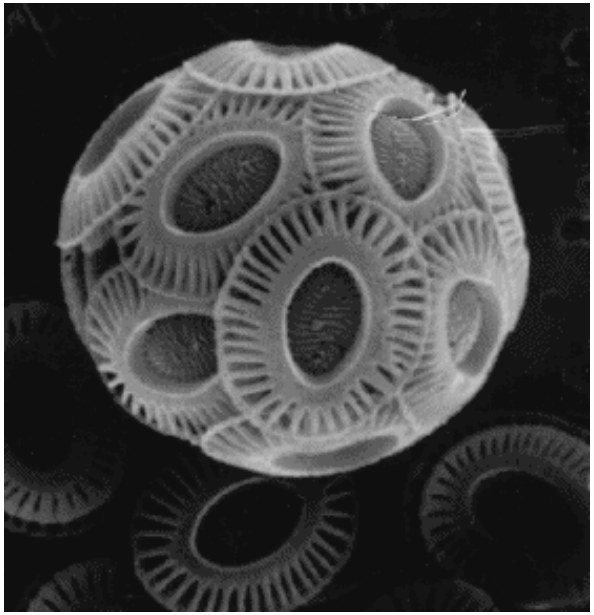
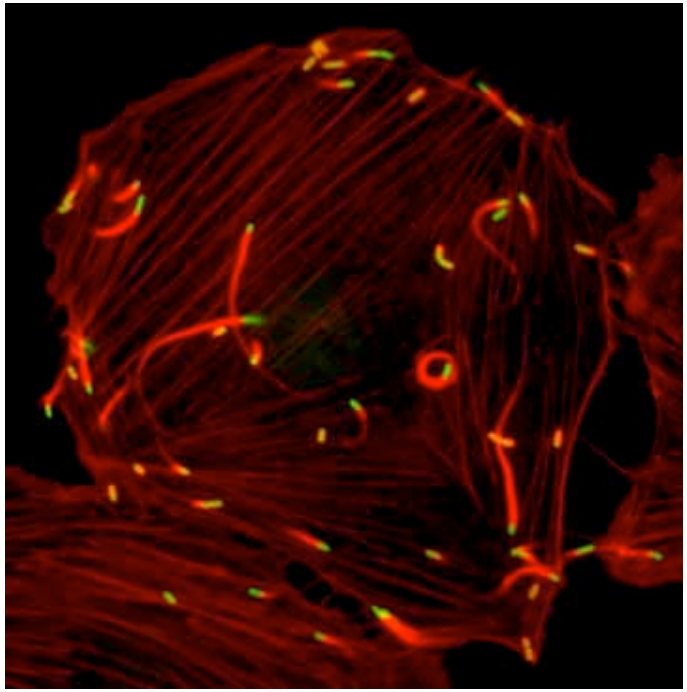
# Lecture 2: Cells and What They are Made of

*Quantitative Models of Biological Function*

***Sizing up Cells***



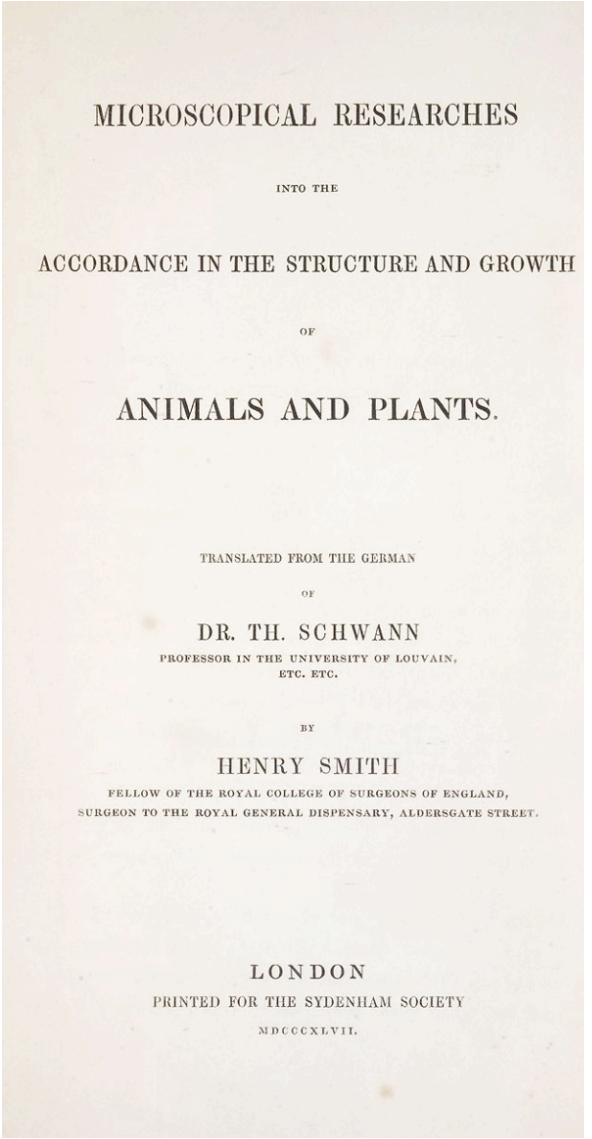


# *APh/BE161: Physical Biology of the Cell*

# Cell Theory: Cells as the Indivisble Units of Life

*Robert Hooke*

*Matthias Schleiden*



MICROSCOPICAL RESEARCHES

INTO THE

ACCORDANCE IN THE STRUCTURE AND GROWTH

OF

ANIMALS AND PLANTS.

TRANSLATED FROM THE GERMAN

OF

DR. TH. SCHWANN

PROFESSOR IN THE UNIVERSITY OF LOUVAIN,
ETC. ETC.

BY

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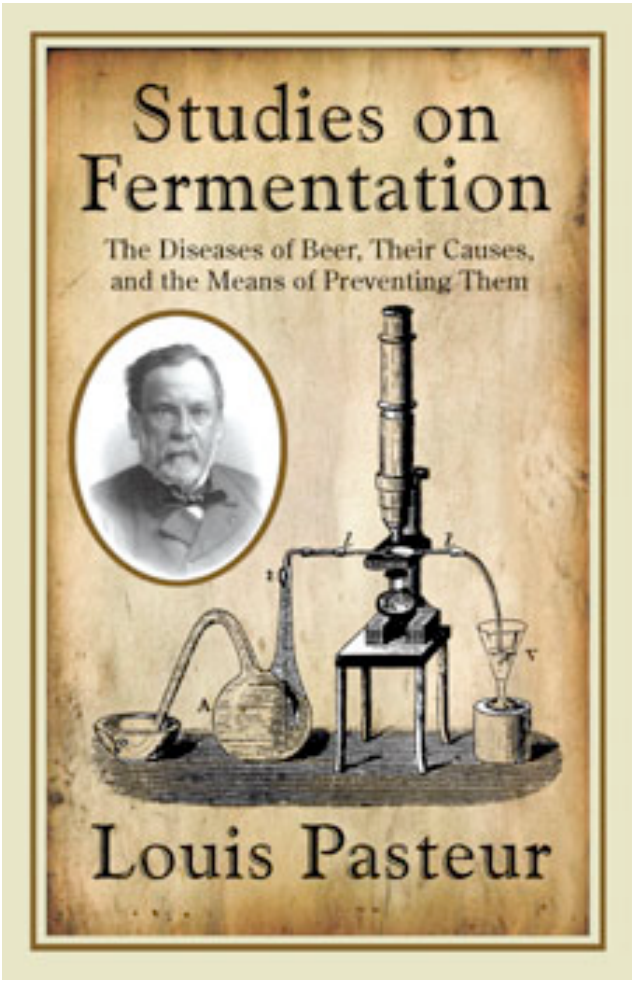
SURGEON TO THE ROYAL GENERAL DISPENSARY, ALDERSGATE STREET.

LONDON

PRINTED FOR THE SYDENHAM SOCIETY

MDCCCXLVII.

# Pasteur: The Slam Dunk - Fermentation to Pathogens



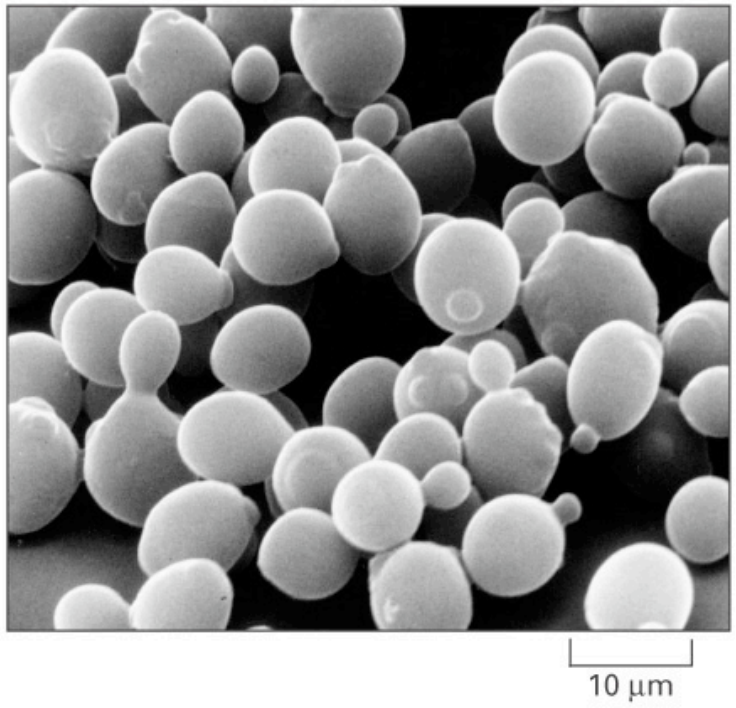

- *Louis Pasteur revealed unequivocally that microorganisms are cells.*
- *Many of the important domestic uses of microbes reflect their metabolism.*
- *Unity of biochemistry (unifying theme of biology)*

# *Who Ruins the Beer and Wine?*

- *Pasteur demonstrated convincingly that microbes (other than yeast) were present in improperly fermenting solutions.*
- *Pasteur reasoned that putrefaction was the result of microbes and hence, disease (itself a kind of putrefaction) was the consequence of microbes.*
- *Pasteur thought each type of fermentation caused by a different microorganism (hence, bad fermentation the result of contaminating microorganism).*
- *``Memoire sur la fermentation appelée lactique'', Memoire sur la fermentation alcoolique''*

*``The obvious is that which is never seen until someone expresses it simply.'' - Christian Morgenstern*

# The Standard Eukaryote: S. cerevisiae



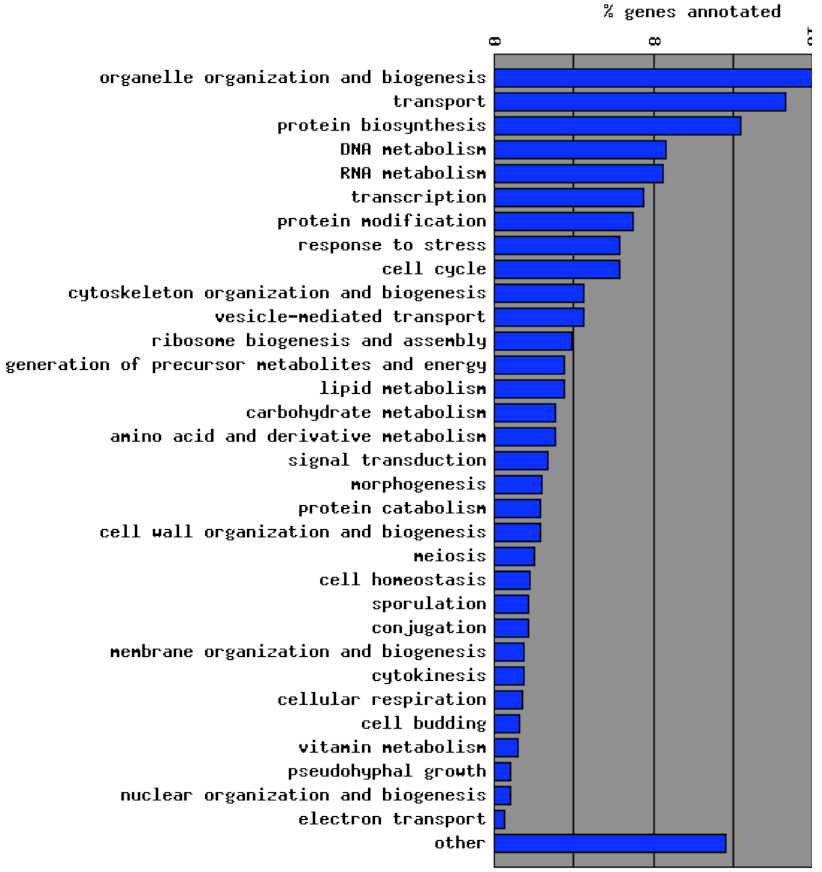
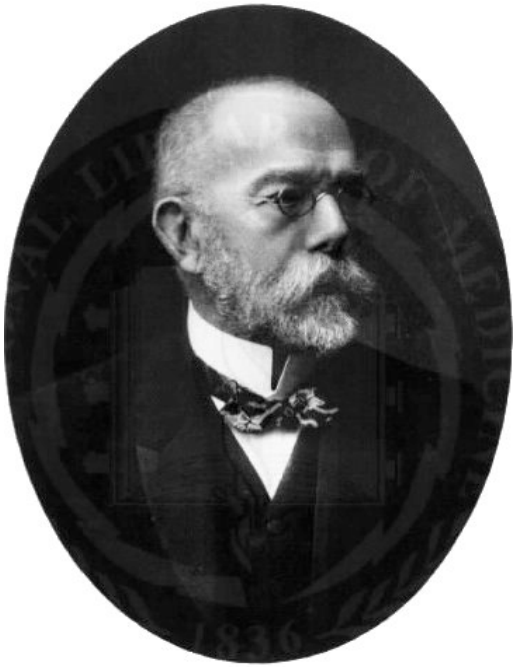




Figure 1-32 Essential Cell Biology, 2/e. (© 2004 Garland Science)

# Koch and His Rules

- *Koch formulated rules for proof that a particular microorganism is the pathogen of interest (i.e. the ``smoking gun''). These are:*
- *Found in all cases of the disease examined*
- *Can be prepared and maintained in a pure culture*
- *Capable of producing the original infection, even after several generations in culture*
- *Can be retrieved from an inoculated animal and cultured again.*
- *Koch used this kind of thinking in determining the causative agents of anthrax and tuberculosis.*



# Prokaryotes and Eukaryotes: The Modern Cell Theory

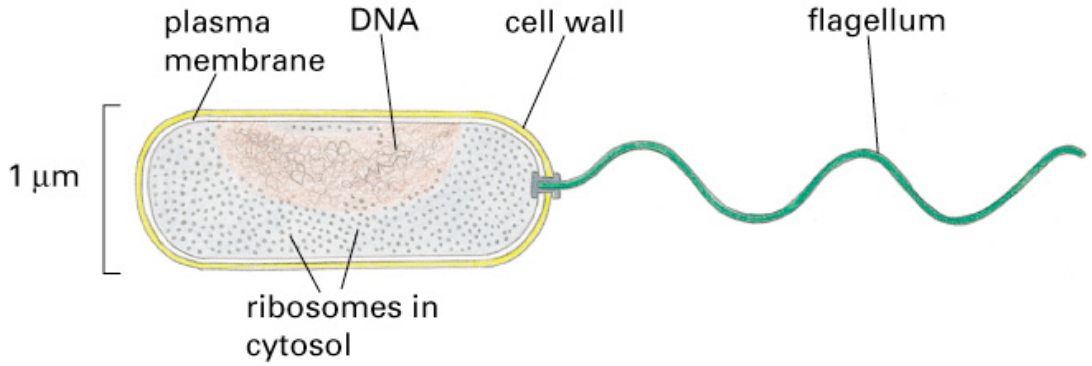
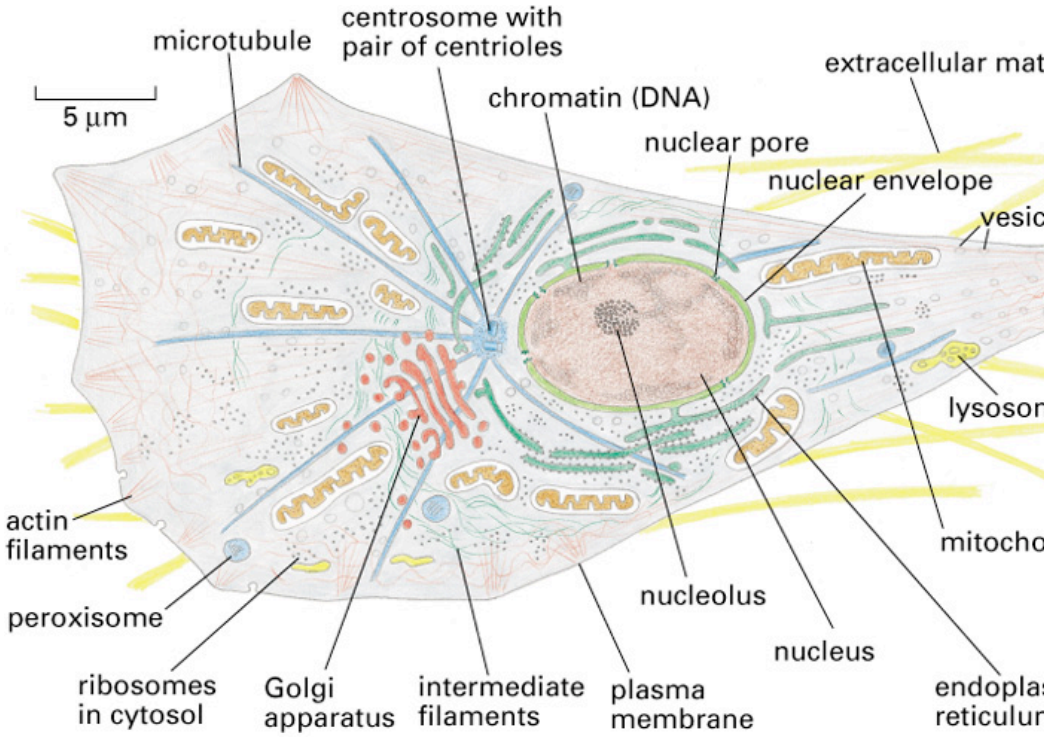


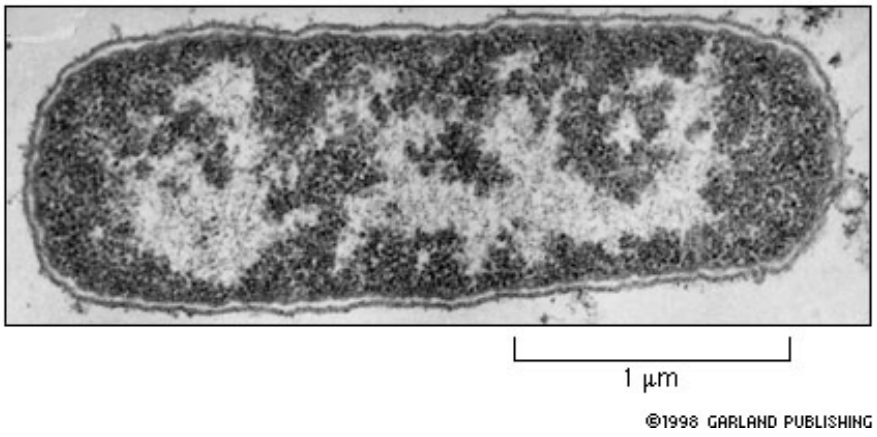

Figure 1–18 part 1 of 2. Molecular Biology of the Cell, 4th Edition.

*Shapes, sizes and contents of different types of cells.*



# The Standard Ruler: E. Coli

- ***The Standard Cell:*** ***"Not everyone is mindful of it, but cell biologists have two cells of interest; the one they are studying and Escherichia coli." – Schaechter et al.***
- ***Cells: There is nothing smaller that is alive, nothing bigger is more alive – paraphrasing J. Theriot.***



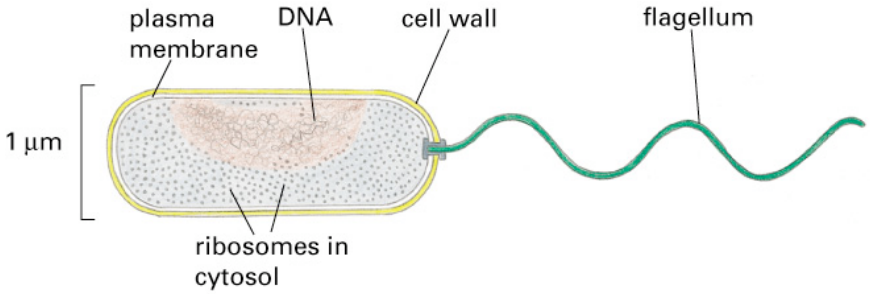




Figure 1–18 part 1 of 2. Molecular Biology of the Cell, 4th Edition.

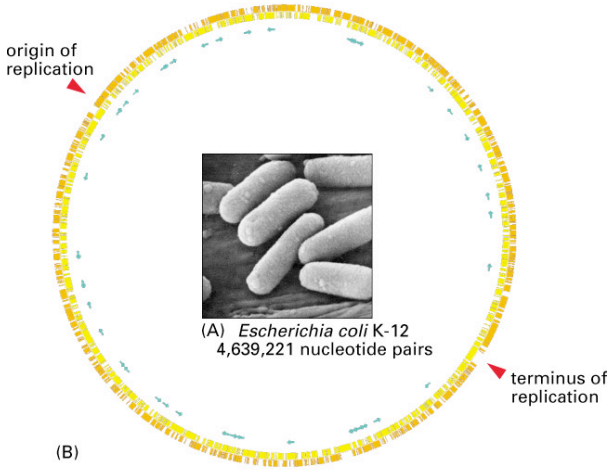
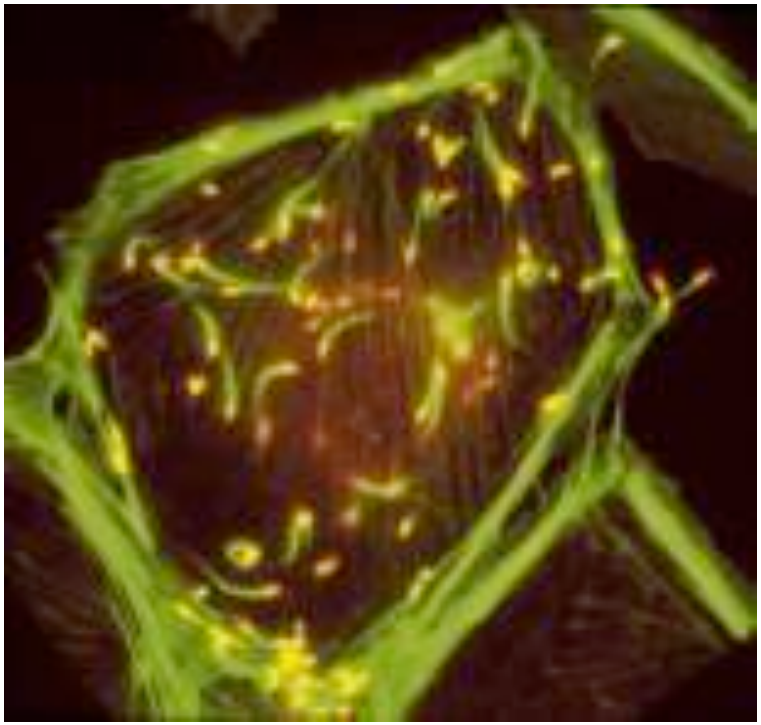
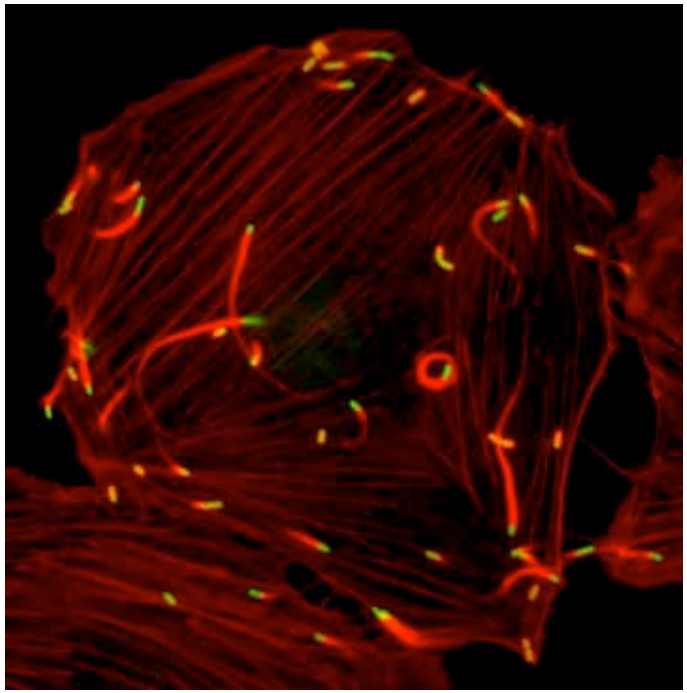



Figure 1–30. Molecular Biology of the Cell, 4th Edition.

# Other Hall of Fame Cells: Prokaryote - Listeria monocytogenes

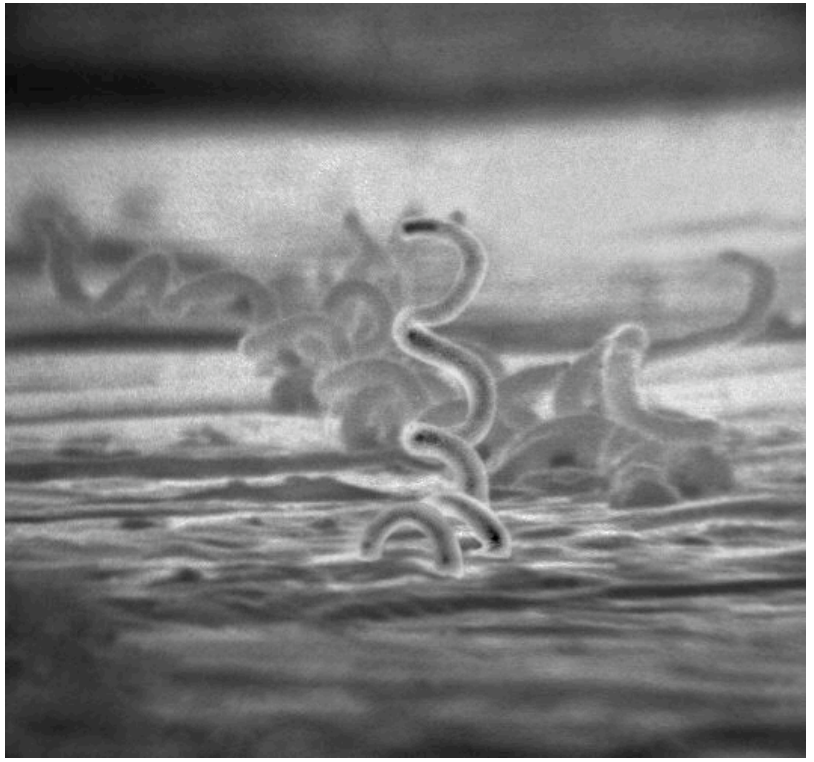




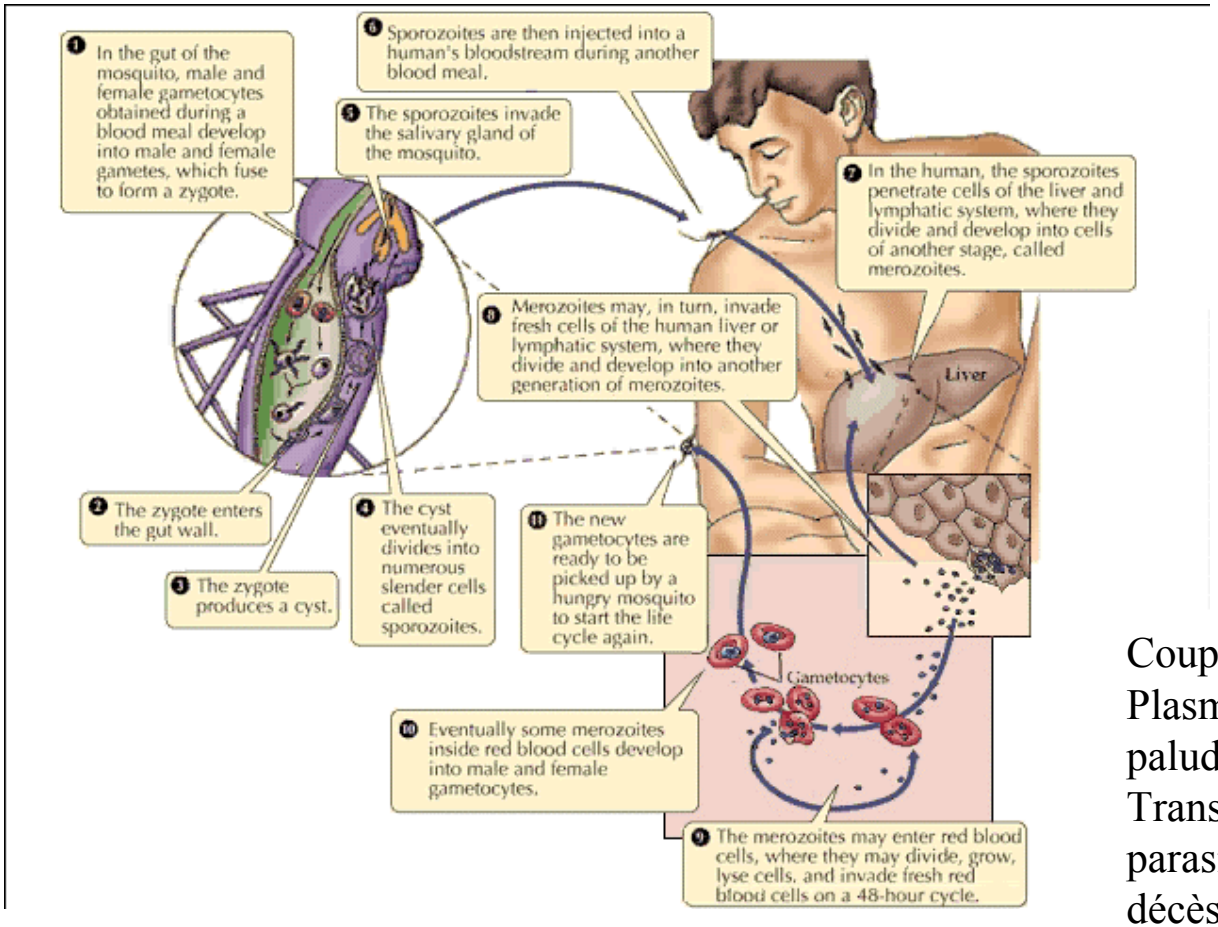
Theriot Lab - Stanford University, see their amazing movies

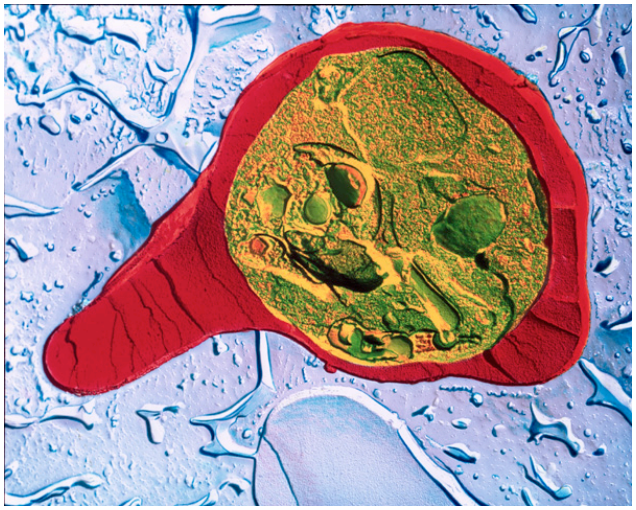
# *Other Hall of Fame Pathogens: Treponema pallidum*

- *Otherwise known as the cause of Syphilis.*
- *Note that prokaryotes come in a dazzling variety of shapes.*



# Other Hall of Fame Cells: Plasmodium falciparum

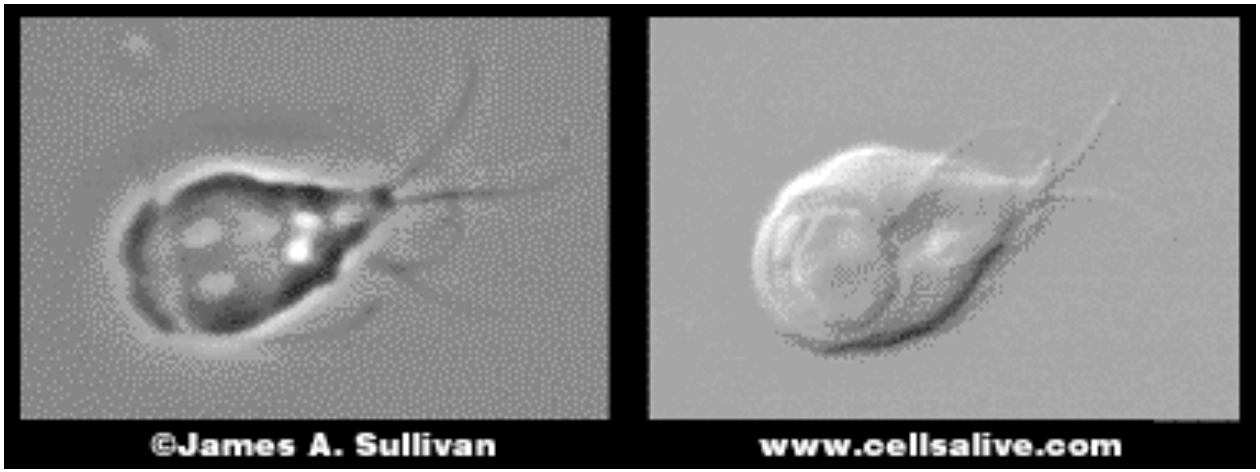


Coupe d'un globule rouge infecté par le parasit
Plasmodium falciparum (en vert), responsable
paludisme, prise au microscope électronique.
Transmise par les moustiques, c'est la maladie
parasitaire la plus meurtrière : plus d'un millio
décès par an dans le monde.
© Dr. Tony Brain / SPL / COSMOS

from Purves, Orians, Heller, and Sadava, Life: The Science of Biology.
© 1998, Sinauer Associates, Inc.

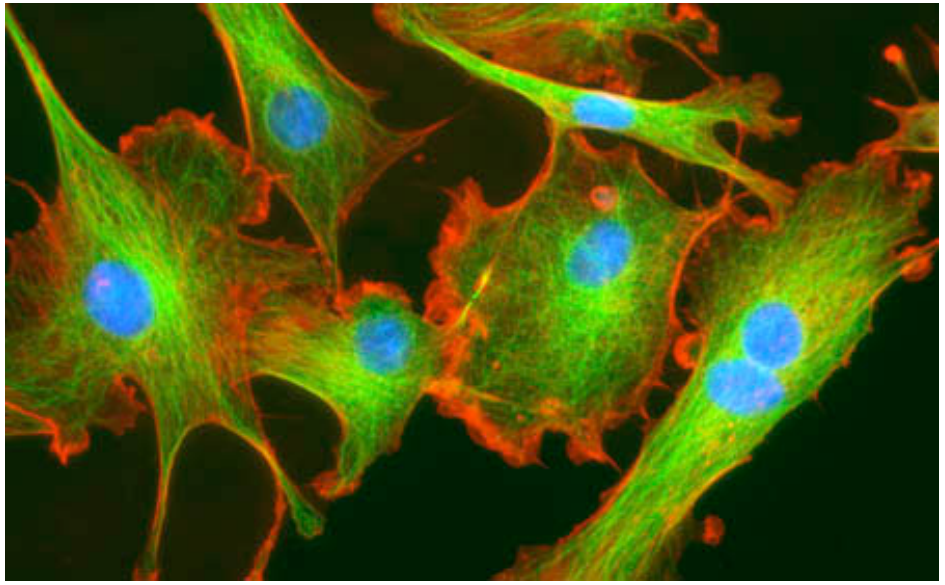
# Other Hall of Fame Pathogens: Giardi

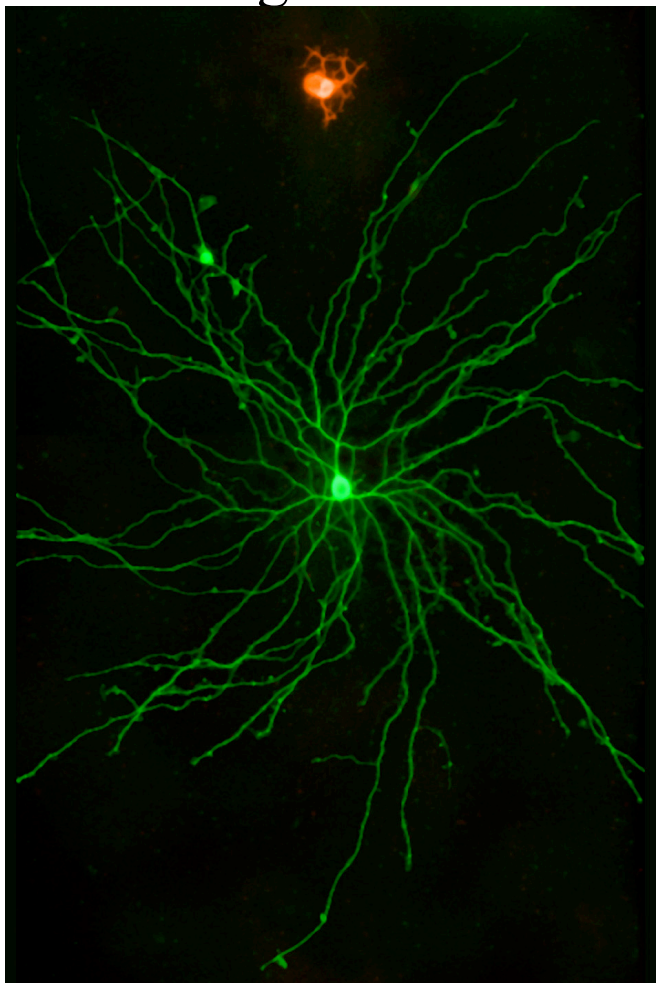


# Other Hall of Fame Cells: Eukaryotes

http://www.utah.edu/unews/news_images/070101_nerv

***Structure and function intimately related***

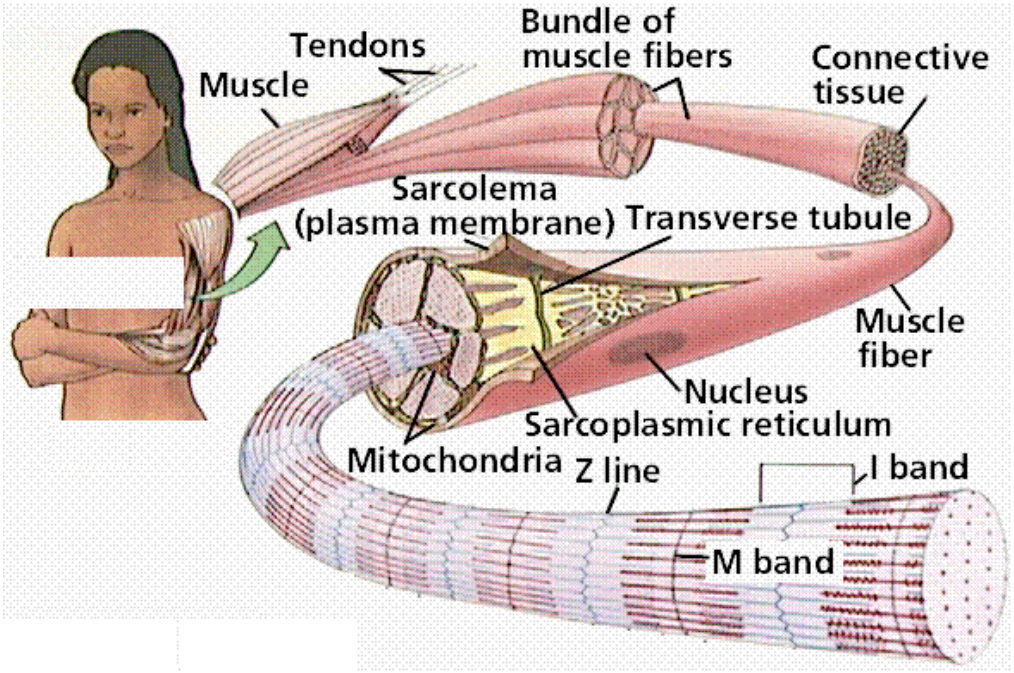


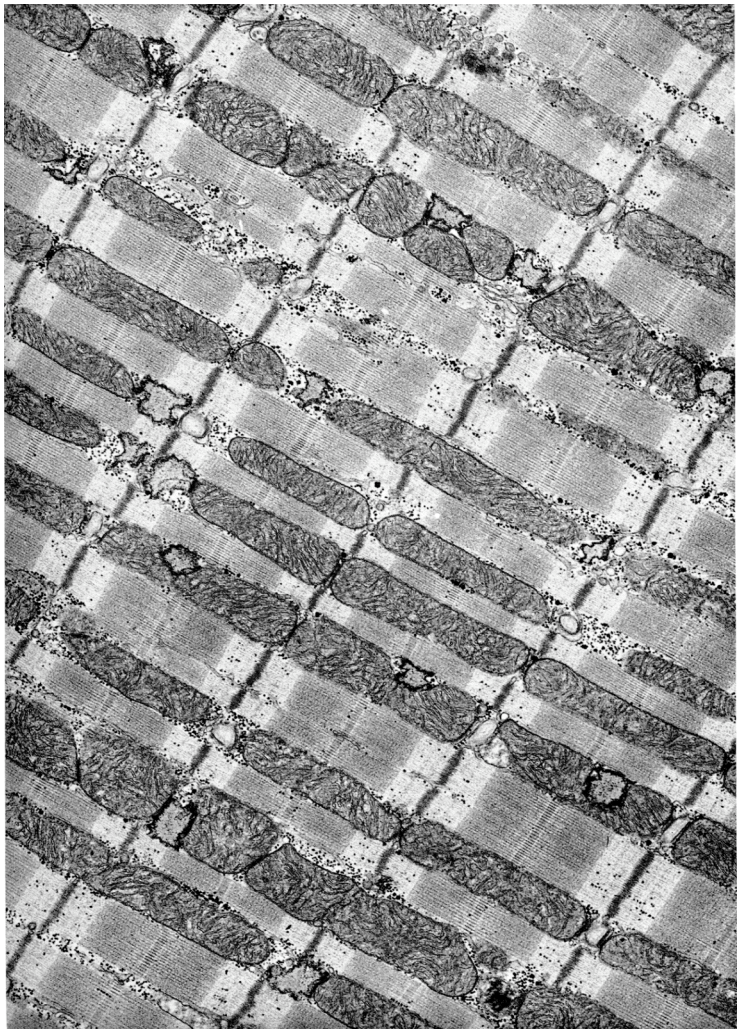


***Annoying feature: no scale bars!***

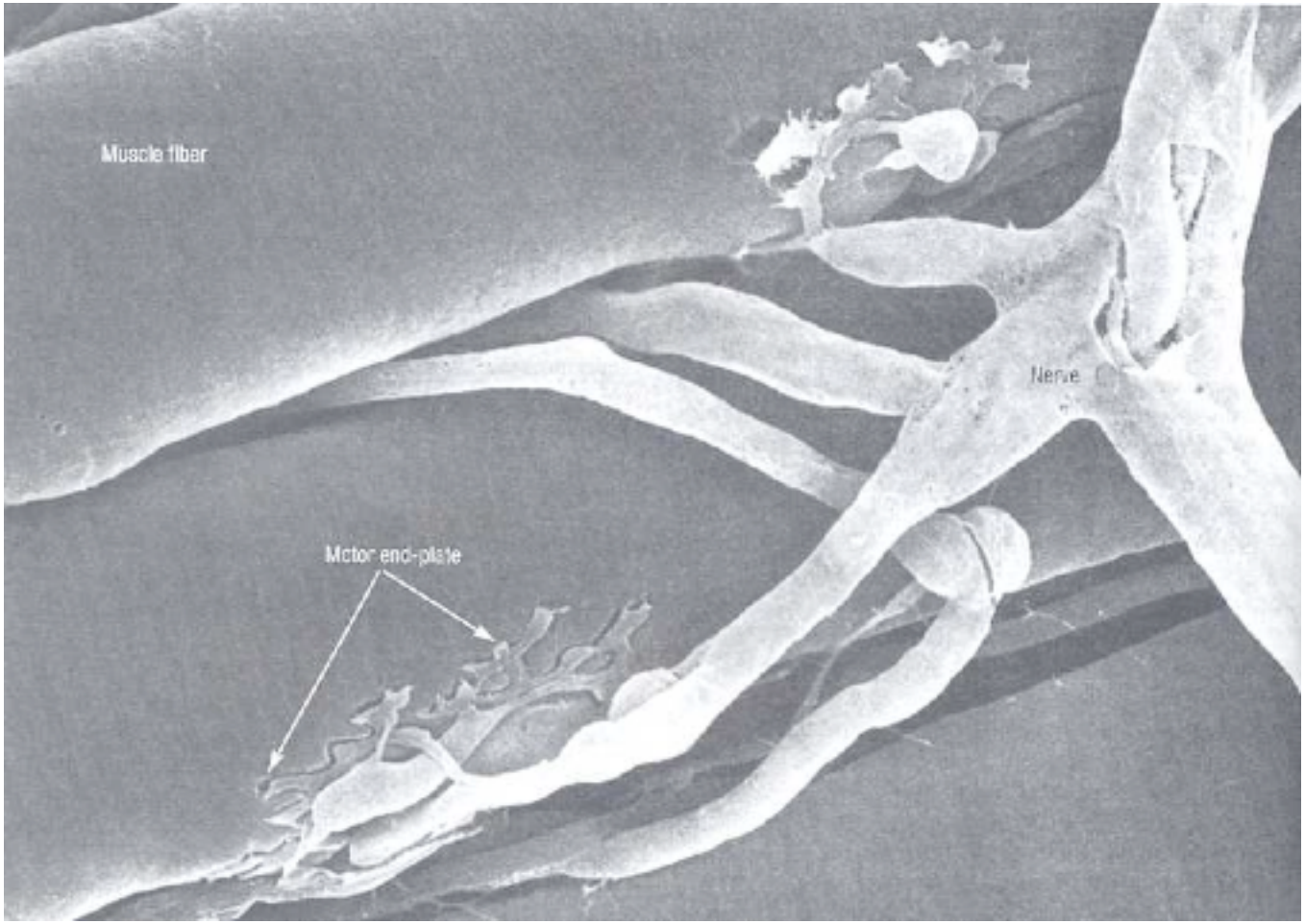
http://www.cimaging.net/Examples/D1_Cells/FAC1_Protein/Fibroblast/fibroblast.html

# Muscle Organization



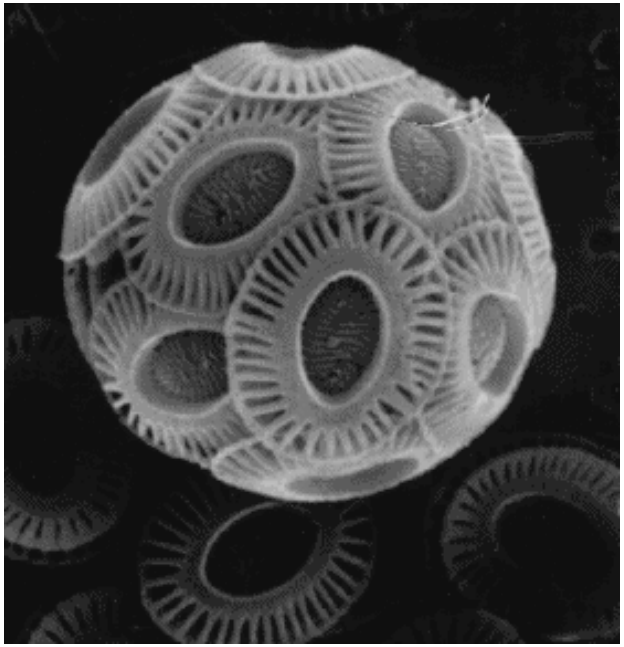



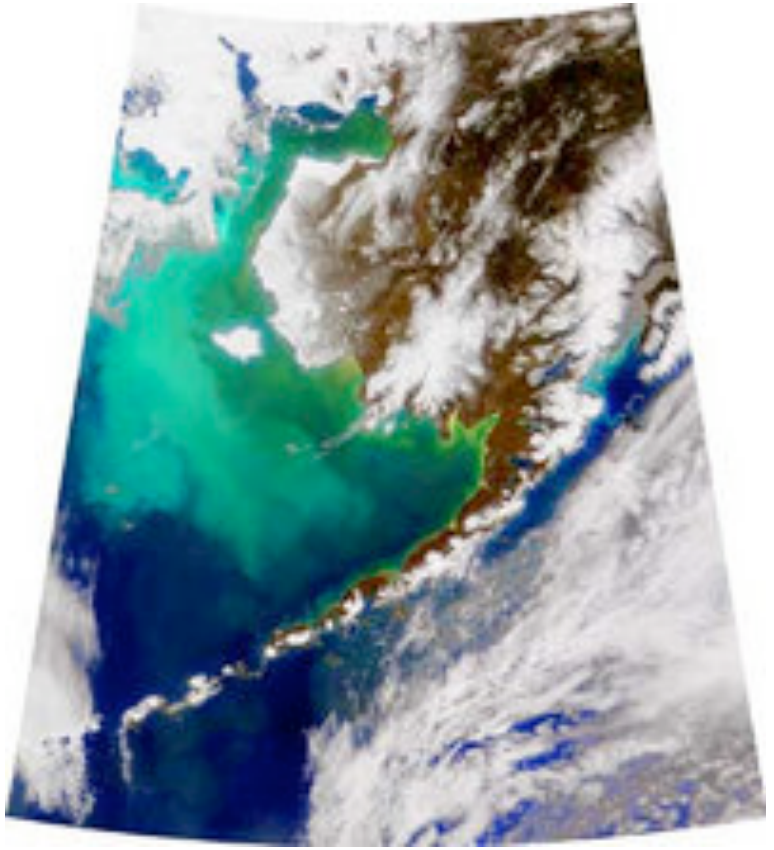
# Nueromuscular Junction



# Other Hall of Fame Cells: Eukaryotes

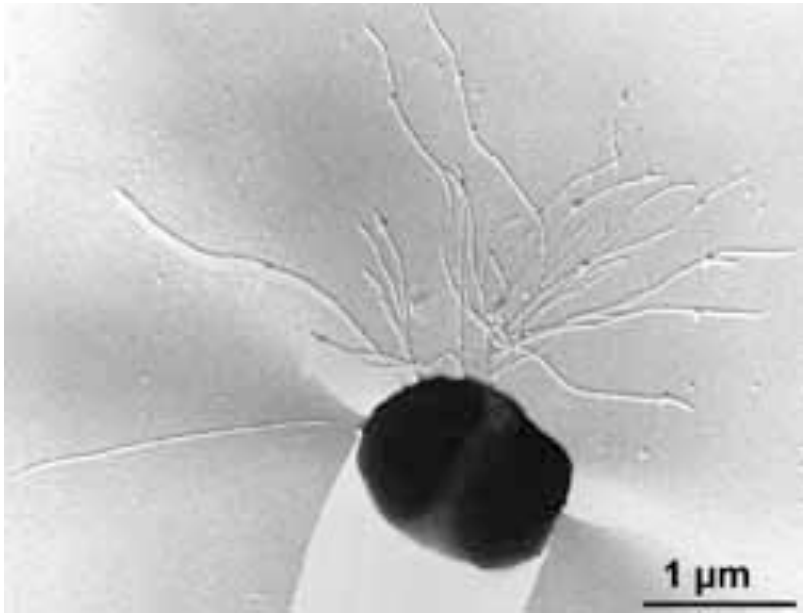
http://www.exn.ca/Stories/1998/09/21/58.asphttp://www.exn.ca/Stories/1998/09/21/58.asp

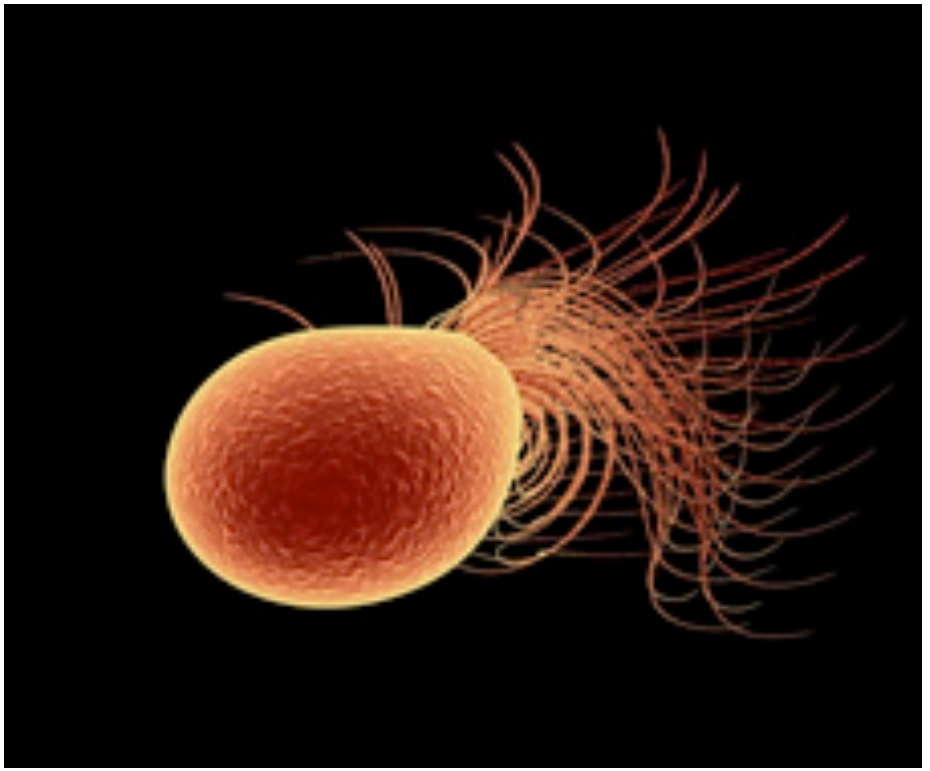


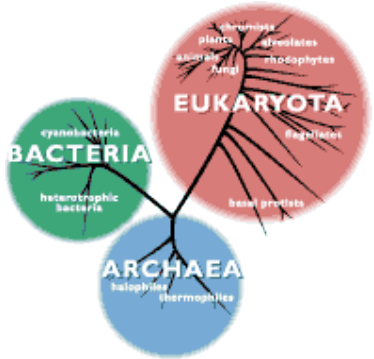


***Emiliana huxleyi - coccolithophore***

# Other Hall of Fame Cells: Archaea

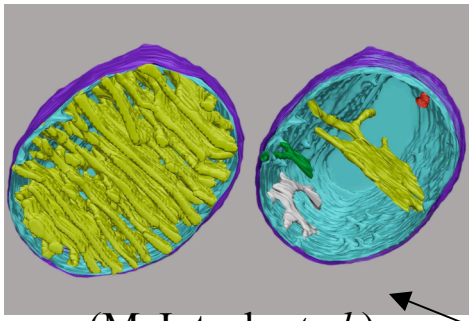


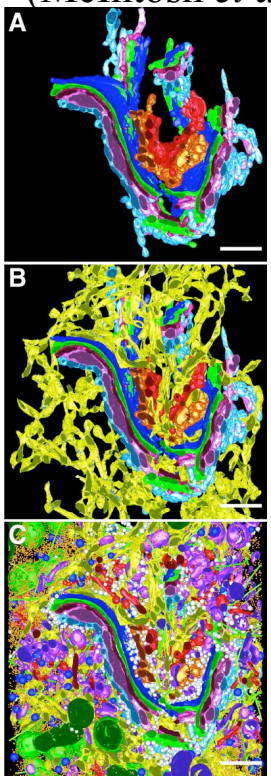


# What Are Cells Made Of?

(Frey *et al.*)



(McIntosh *et al.*)



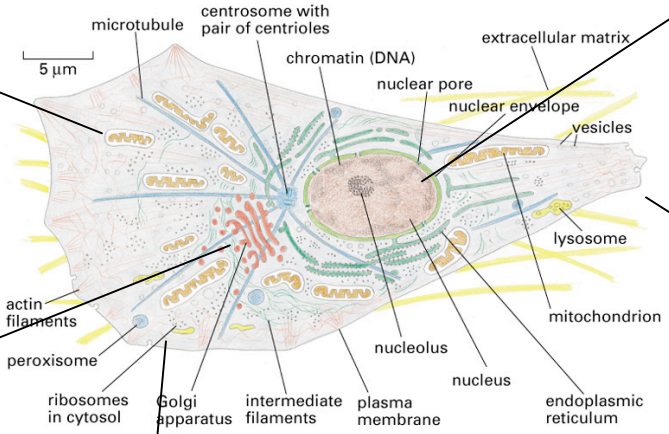
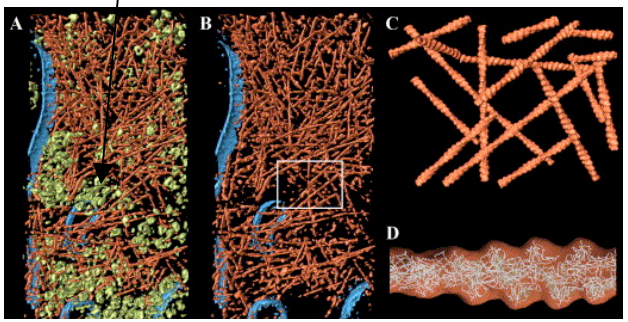
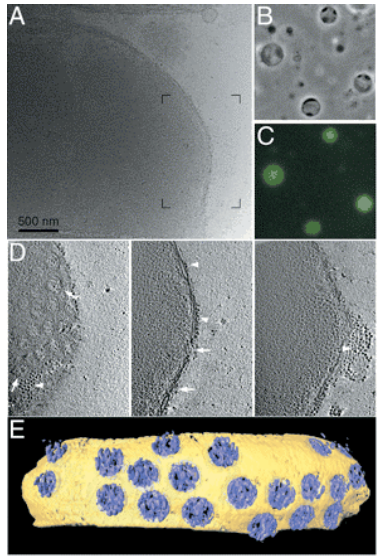
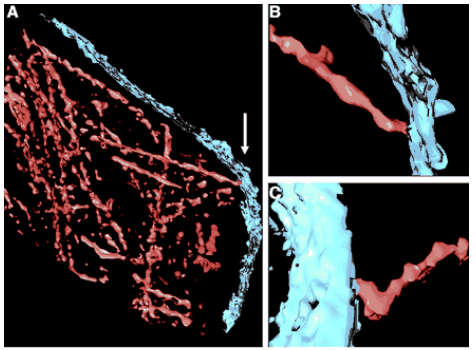




Figure 1–31. Molecular Biology of the Cell, 4th Edition.




(Medalia *et al.*)

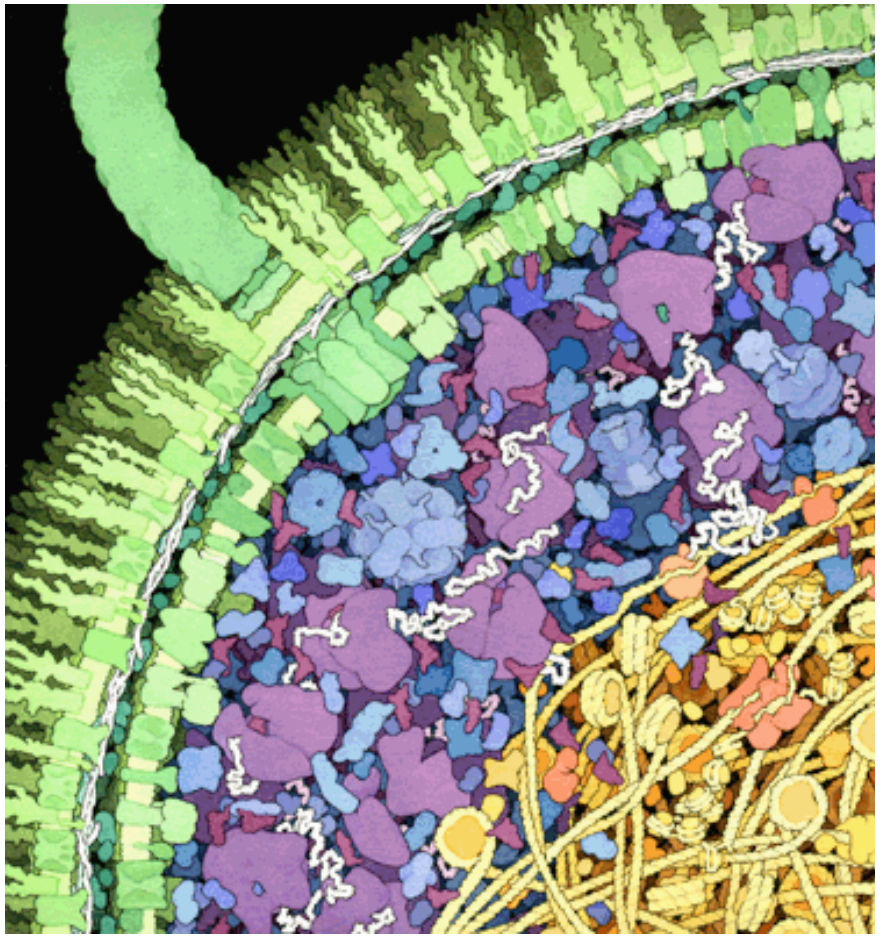


# What's Inside of a Cell?

Main macromolecular constituents of *E. coli* and HeLa cells

| Component | Amount per HeLa cell | Amount per *E. coli* cell |
|---|---|---|
| Total dry weight | 400 pg | 0.4 pg |
| Total DNA | 15 pg | 0.017 pg |
| Total RNA | 30 pg | 0.10 pg |
| Total protein | 300 pg | 0.2 pg |
| Cytoplasmic ribosomes | $4 \times 10^6$ | $3 \times 10^4$ |
| Cytoplasmic tRNAs | $6 \times 10^7$ | $4 \times 10^5$ |
| Cytoplasmic mRNAs | $7 \times 10^5$ | $4 \times 10^3$ |

source: Lodish et al., Molecular Cell Biology 3rd ed.



Composition of an *E. coli* cell

| Component | Molecules per cell | Kinds of molecules |
|---|---|---|
| Protein | 2,360,000 | 1050 |
| RNA | | |
| r R N A | 56,100 | 3 |
| tRNA | 205,000 | 60 |
| mRNA | 1,380 | 400 |
| Lipid | 22,000,000 | 4 major |
| Lipopolysaccharide | 1,200,000 | 1 |
| Metabolites, cofactors, ions | > 400,000,000 | 800+ |

source: Moran et al., Biochemistry 2nd ed.

# DNA Structure

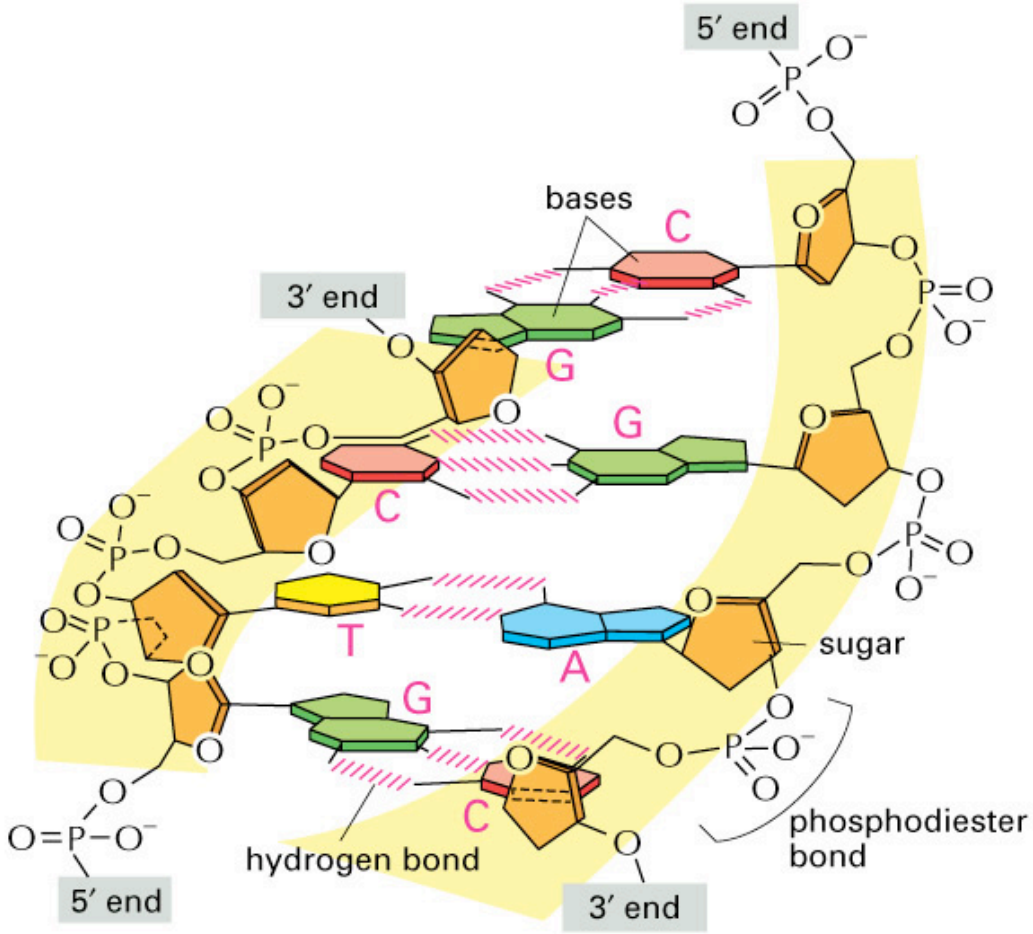
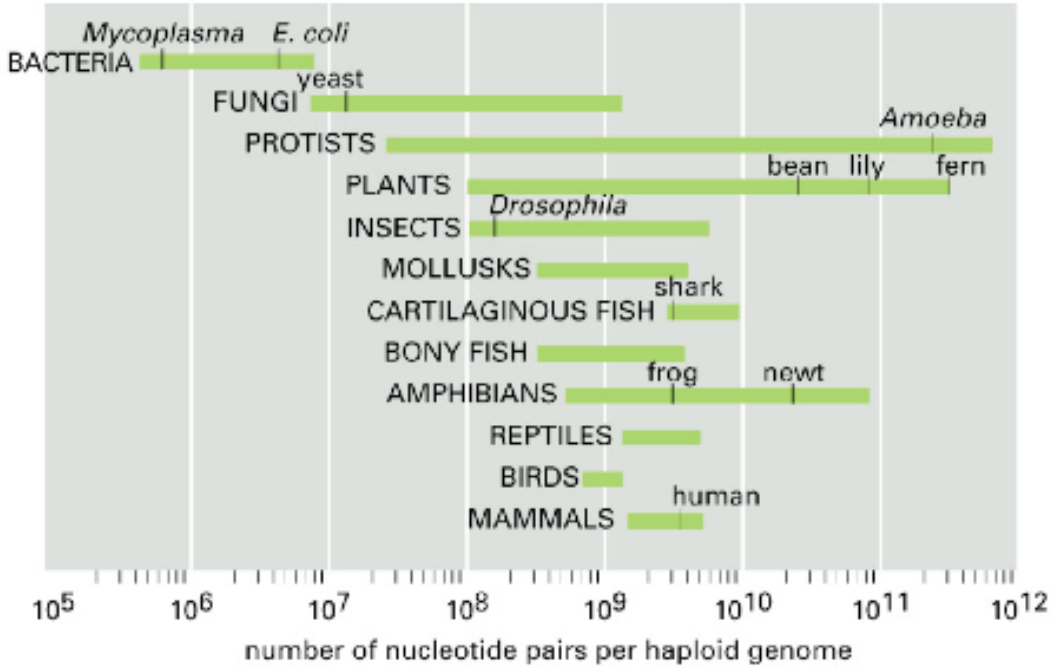
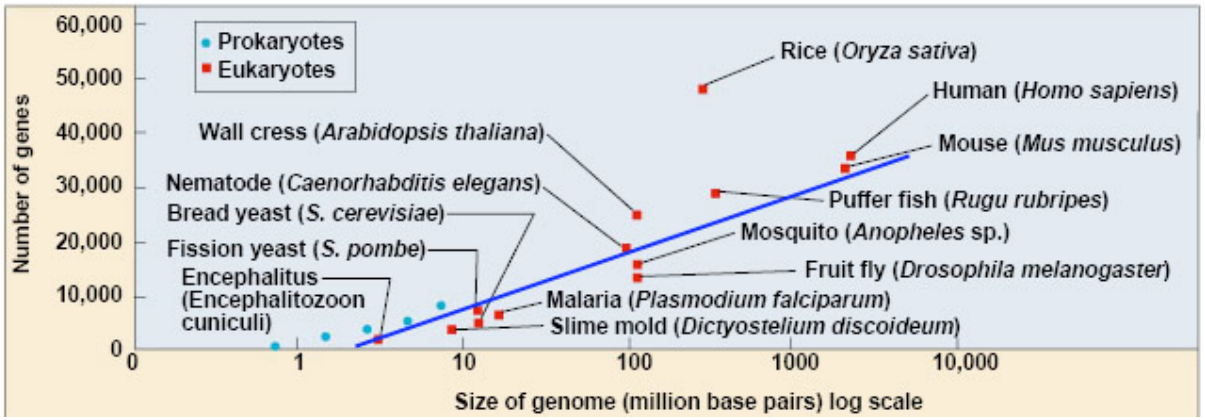


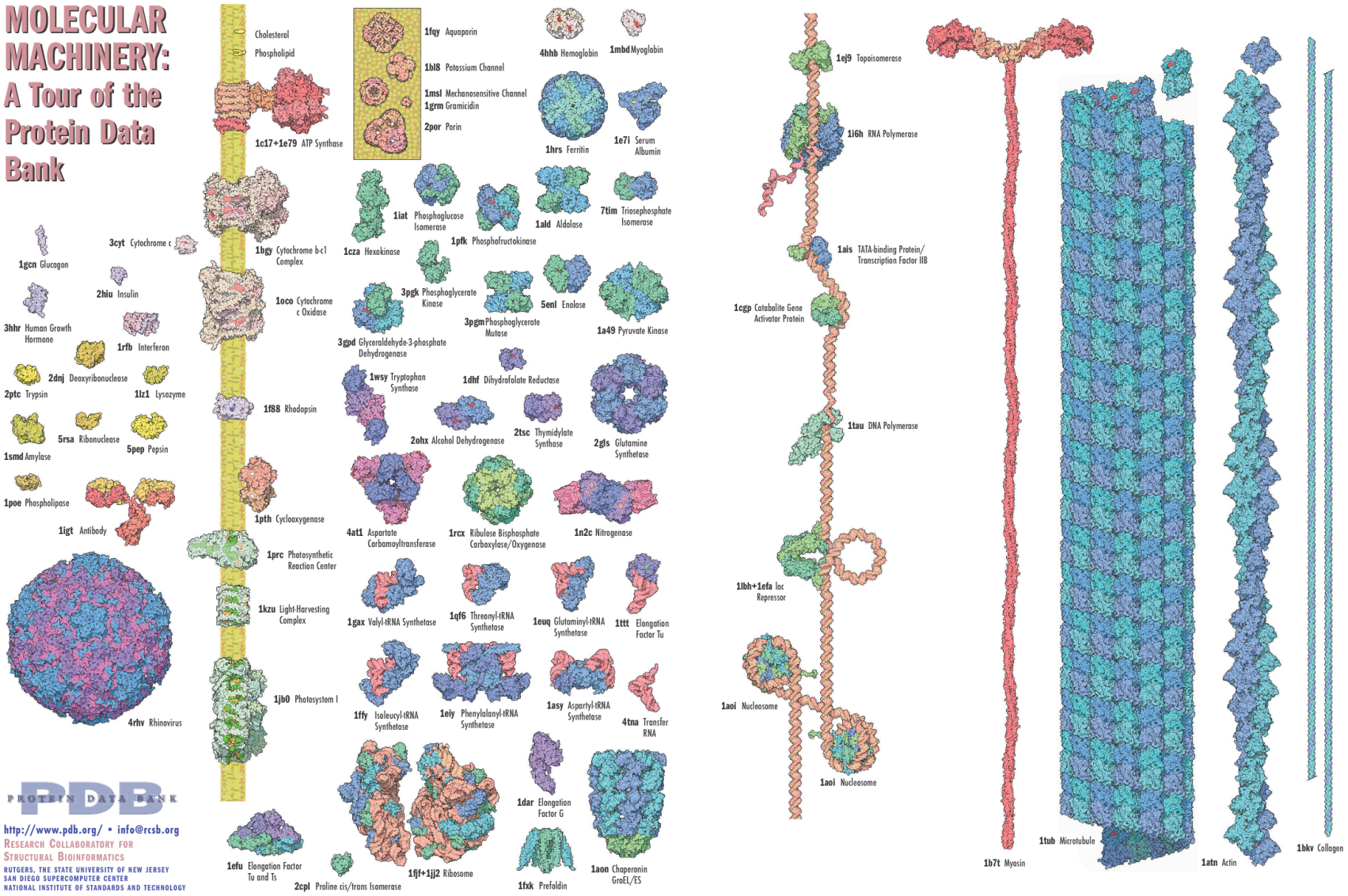

Figure 5-7 Essential Cell Biology, 2/e. (© 2004 Garland Science)

# Genome Sizes: How DNA Is Used



# A Tour of Some of the Macromolecules of Life: Goodsell's Cartoons



# A Single Molecule Census of the Cell: The Parts List

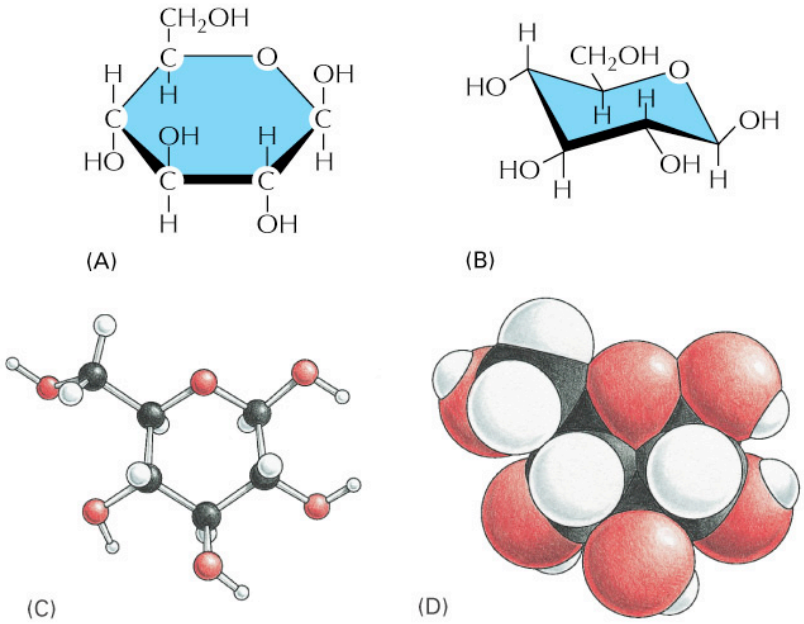



Figure 2.16 Essential Cell Biology, 2/e. (© 2004 Garland Science)

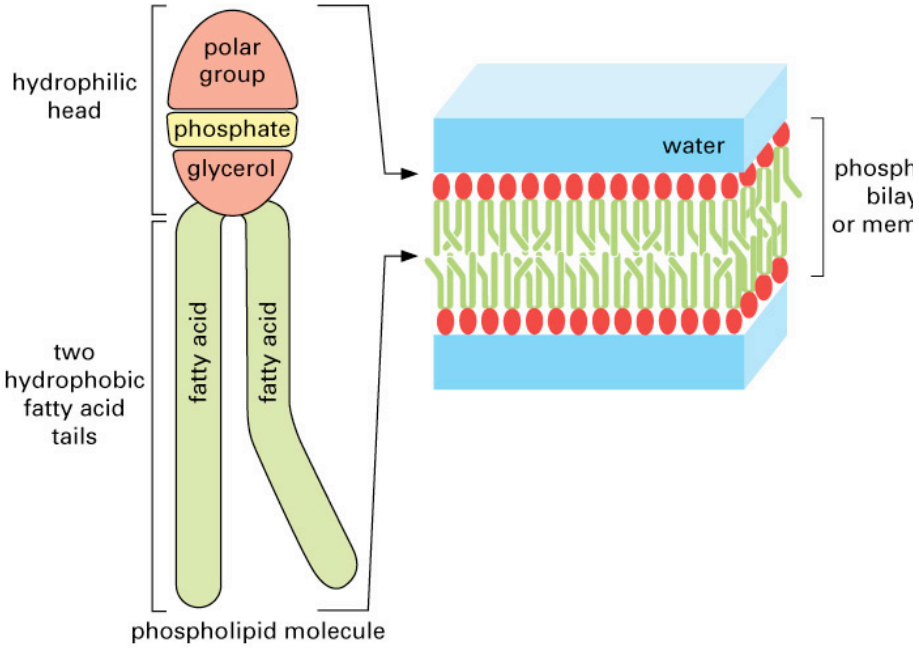
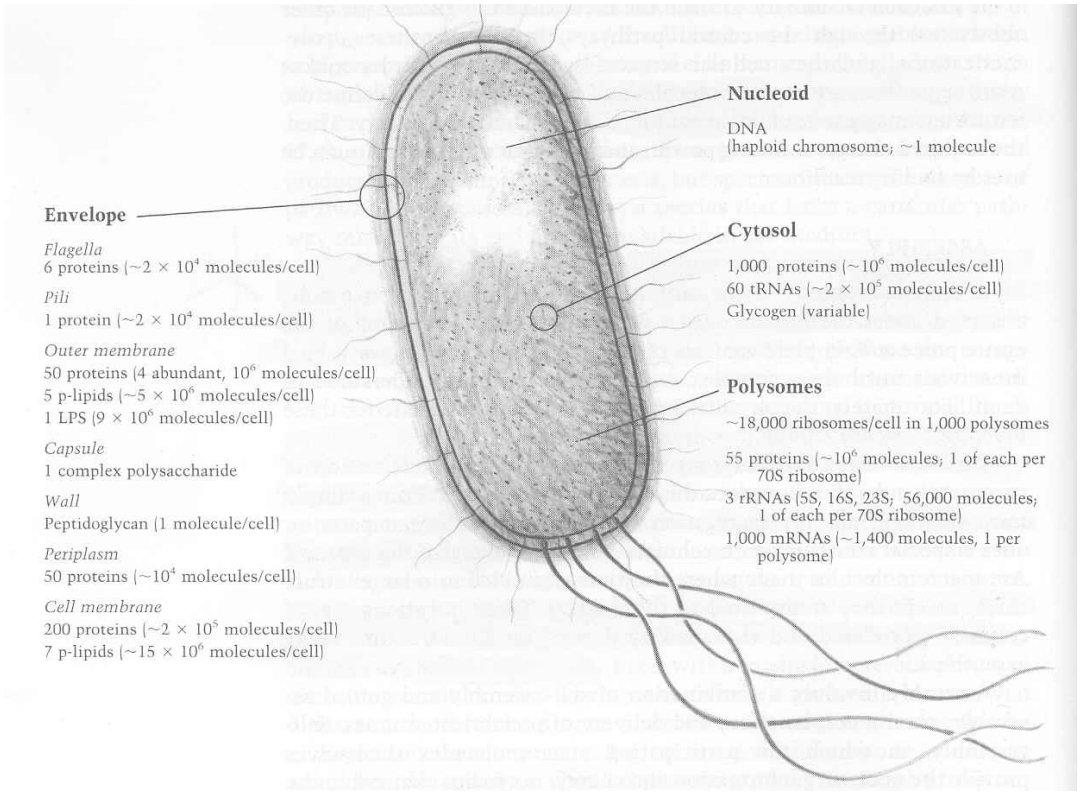
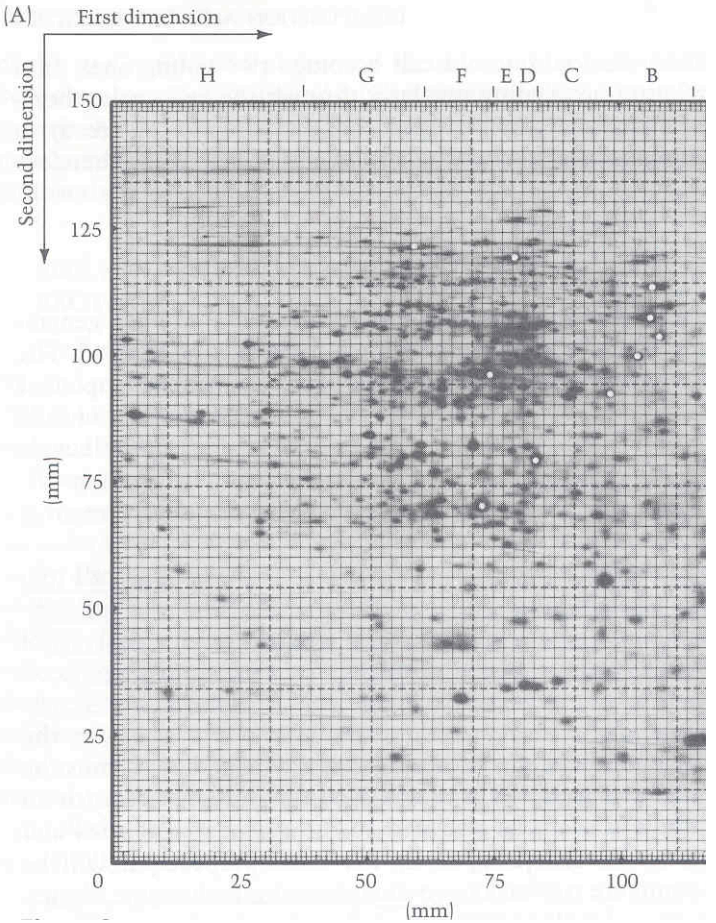



Figure 2-20 Essential Cell Biology, 2/e. (© 2004 Garland Science)

# A Single Molecule Census of the Cell



# A Single Molecule Census of the Cell: Part 2

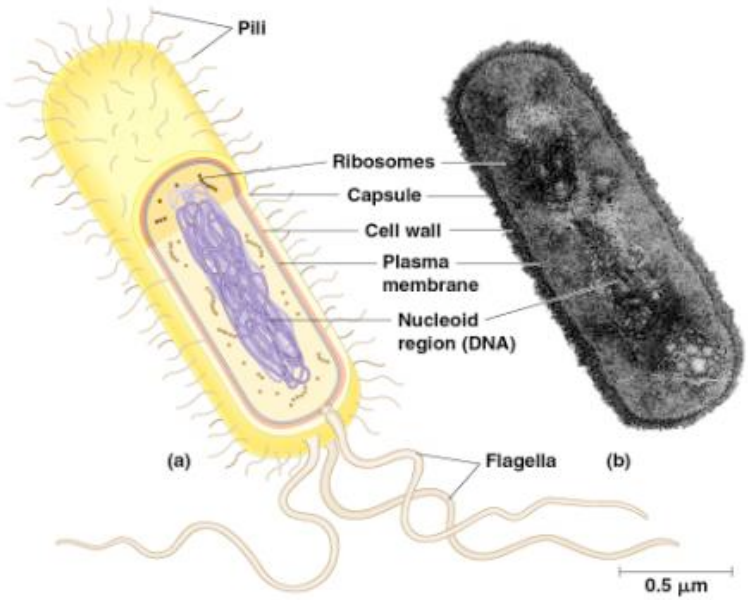


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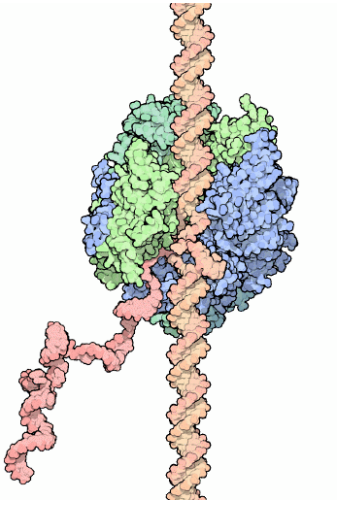
*Table 1.* Overall macromolecular composition of an average *E. coli* B/r cell[a]

| Macromolecule | Percentage of total dry weight | Weight per cell ($10^{15}$ × weight, grams) | | Molecular weight | Number of molecules per cell | D ki m |
|---|---|---|---|---|---|---|
| Protein | 55.0 | 155.0 | | $4.0 \times 10^4$ | 2,360,000 | 1, |
| RNA | 20.5 | 59.0 | | | | |
| 23S rRNA | | | 31.0 | $1.0 \times 10^6$ | 18,700 | |
| 16S rRNA | | | 16.0 | $5.0 \times 10^5$ | 18,700 | |
| 5S rRNA | | | 1.0 | $3.9 \times 10^4$ | 18,700 | |
| transfer | | | 8.6 | $2.5 \times 10^4$ | 205,000 | |
| messenger | | | 2.4 | $1.0 \times 10^6$ | 1,380 | |
| DNA | 3.1 | 9.0 | | $2.5 \times 10^9$ | 2.13 | |
| Lipid | 9.1 | 26.0 | | 705 | 22,000,000 | |
| Lipopolysaccharide | 3.4 | 10.0 | | 4346 | 1,200,000 | |
| Murein | 2.5 | 7.0 | | $(904)_n$ | 1 | |
| Glycogen | 2.5 | 7.0 | | $1.0 \times 10^6$ | 4,360 | |
| Total macromolecules | 96.1 | 273.0 | | | | |
| Soluble pool | 2.9 | 8.0 | | | | |
| building blocks | | | 7.0 | | | |
| metabolites, vitamins | | | 1.0 | | | |
| Inorganic ions | 1.0 | 3.0 | | | | |
| Total dry weight | 100.0 | 284.0 | | | | |
| Total dry weight/cell | | $2.8 \times 10^{-13}$g | | | | |
| Water (at 70% of cell) | | $6.7 \times 10^{-13}$g | | | | |
| Total weight of one cell | | $9.5 \times 10^{-13}$g | | | | |

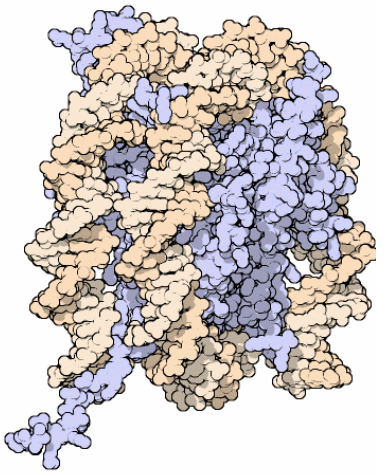
[a]In balanced growth at 37°C in glucose minimal medium, mass doubling time, *g*, of 40 minutes. The assembled from Dennis and Bremer (1974), Maaløe (1979), F. C. Neidhardt (unpublished), Roberts et a and Umbarger (1977).
[b]There are four classes of phospholipids, each of which exists in many varieties as a result of variable f residues.

# PDB Structures and PDB Files

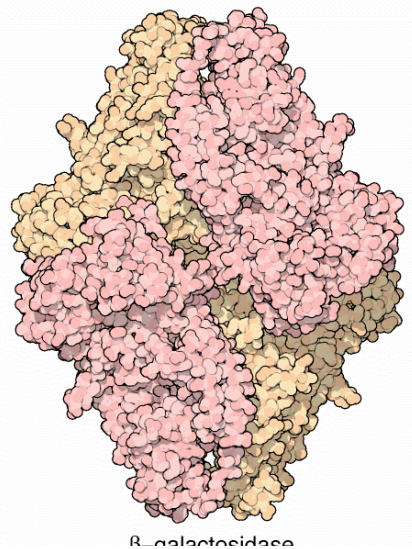
- *The Outcome from Structural Biology: Boat loads of atomic coordinates.*
- *"A science is built up of facts as a house is built up of bricks, but a mere accumulation of facts is no more a science than a pile of bricks is a house." – Poincare*
- *See http://www.rcsb.org/pdb/*
- *All cartoons due to David Goodsell, Scripps*



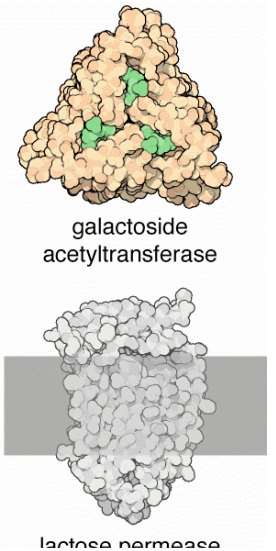
*RNA polymerase*



*Nucleosome*



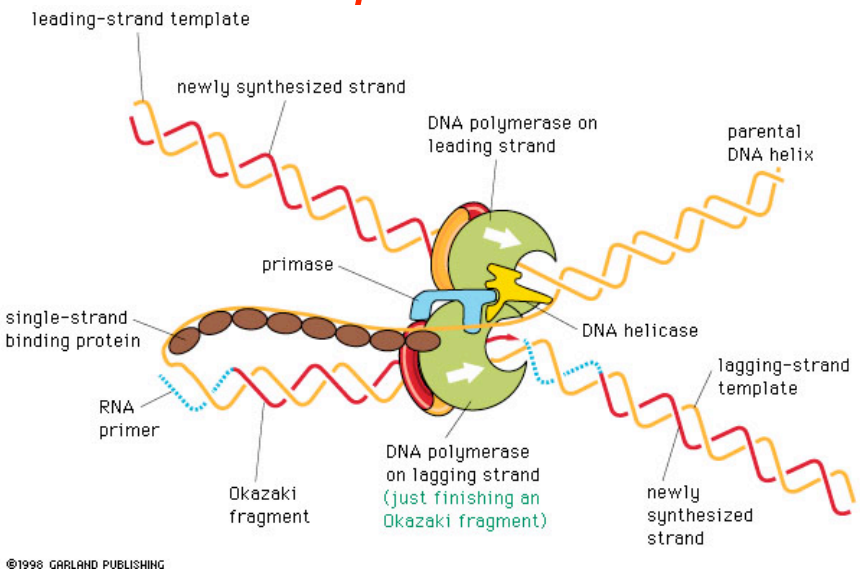
β-galactosidase



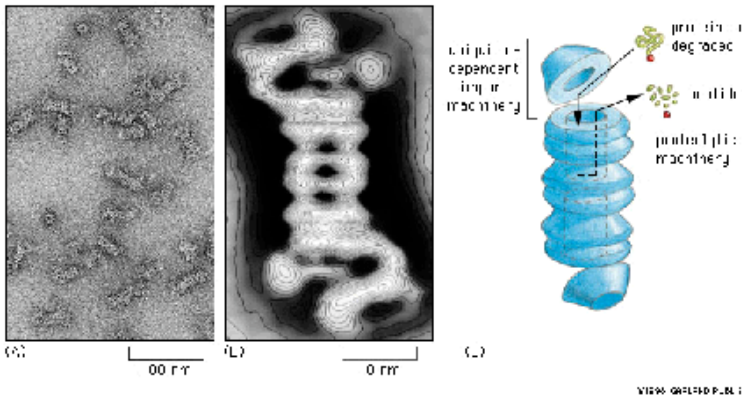
# Somes: The Biologists Ons Macromolecular Assemblies

- *Physicists characterize collective excitations as ONS (phonons, magnons, excitons, etc…)*
- *Biologists also consider collective phenomena in the form of interacting macromolecular complexes.*

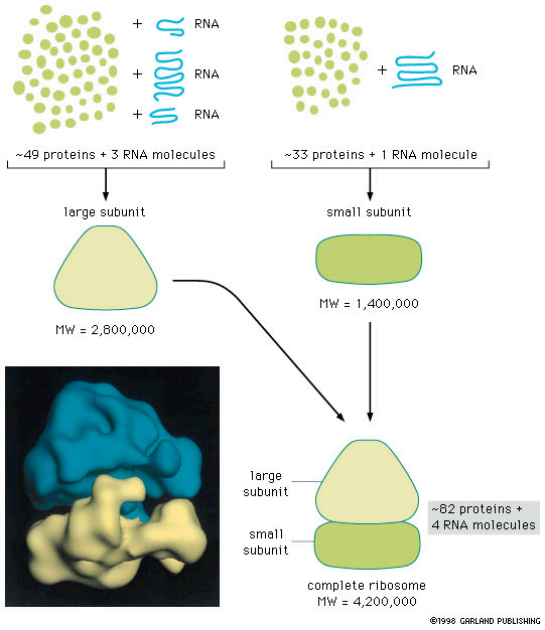
## Replisome




## Proteosome

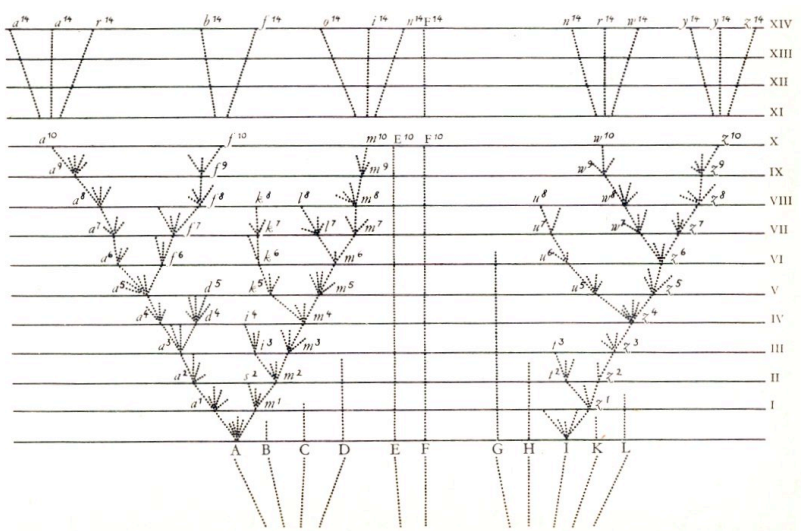


## Ribosome

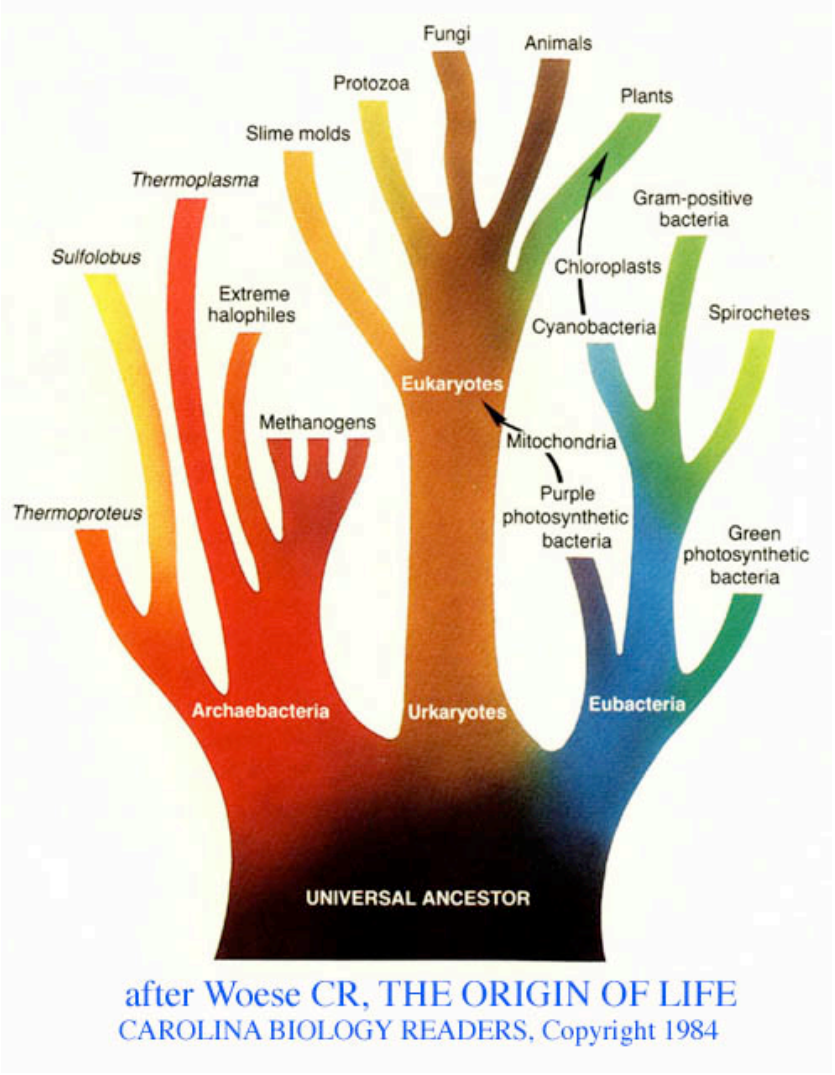


# Ribosomes and the Tree of Life

- *One of the great themes of all of biology: the unity of biochemistry. Evident especially with the processes of the central dogma, but also as concerns metabolism.*
- *A beautiful use of this idea by Carl Woese - molecular analysis of the tree of life.*



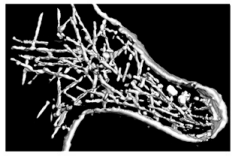
*Only figure in Darwin's ``Origin''*



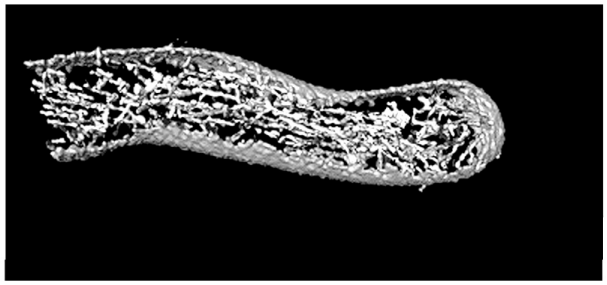

after Woese CR, THE ORIGIN OF LIFE
CAROLINA BIOLOGY READERS, Copyright 1984

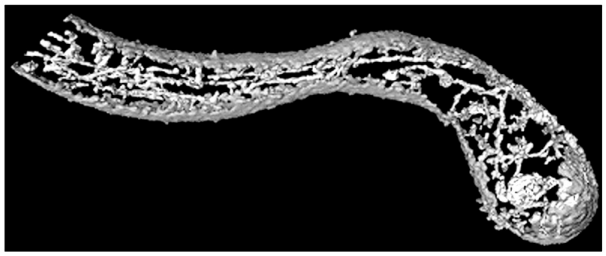
# Experimental Transformation of Biology: Structures from Cryo EM

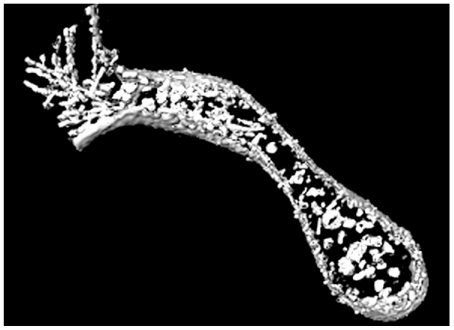
***Filopodia in motile cells***



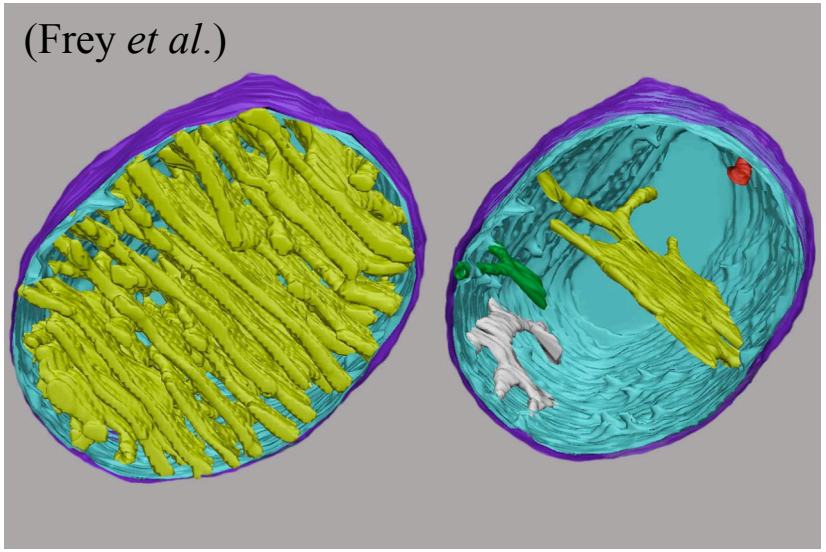
(Medalia *et al*.)



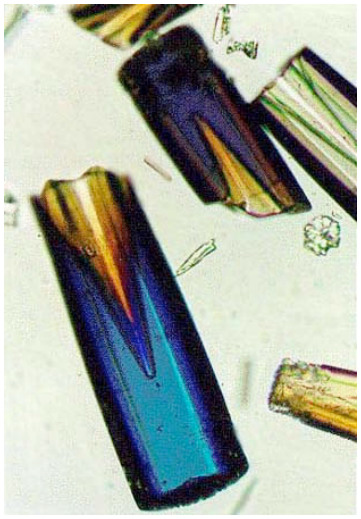




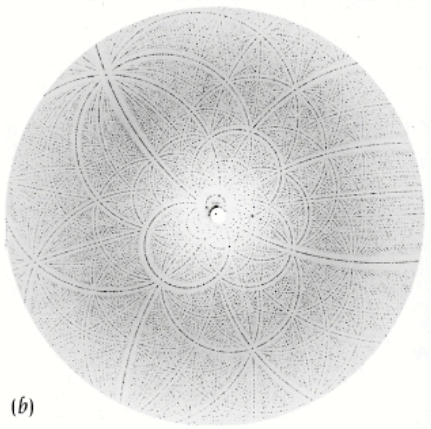
***Mitochondria***



# Experimental Transformation of Biology: X-Ray Crystallography of Proteins



(a)



(b)

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