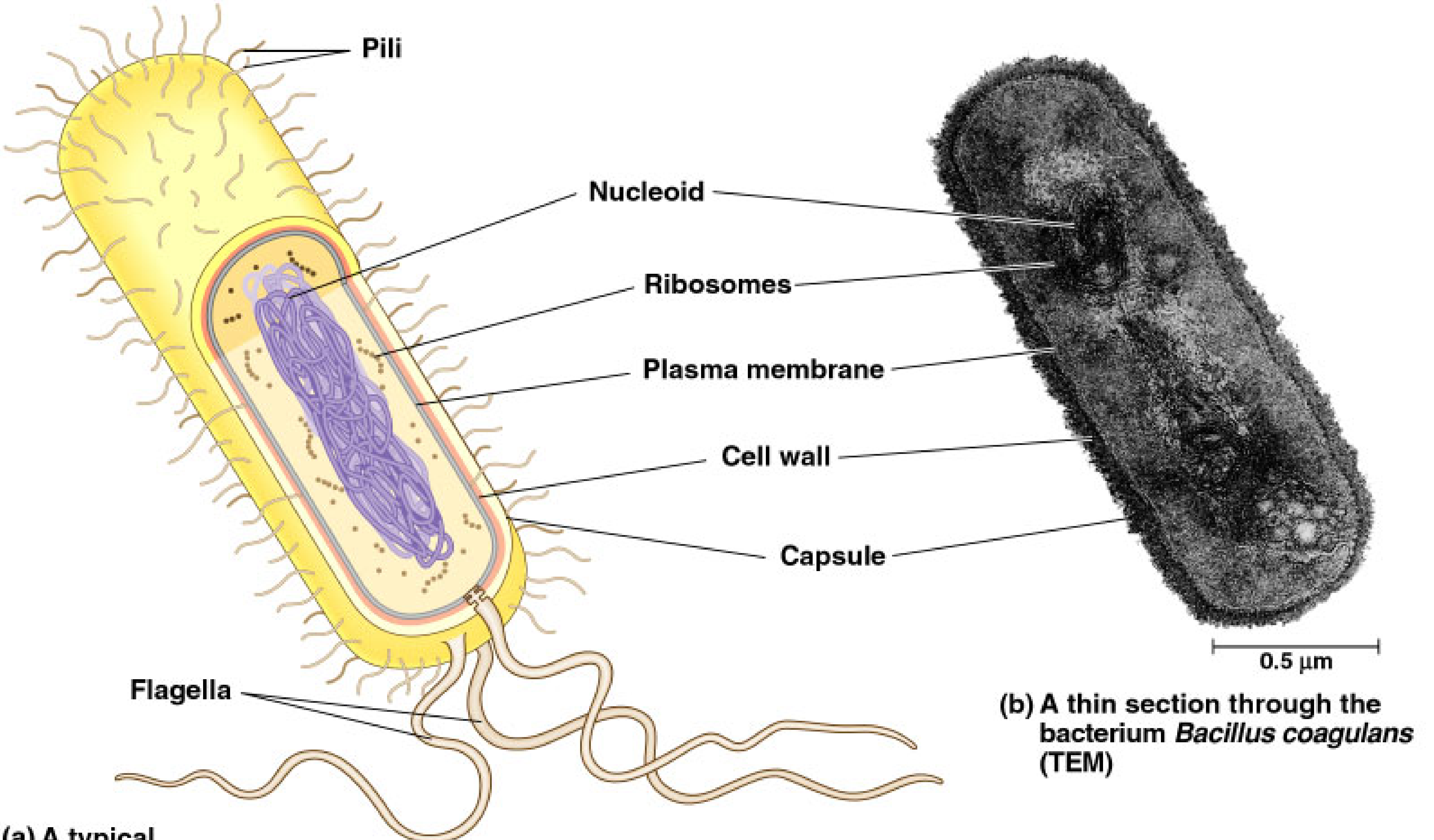
# Comparing Prokaryotic and Eukaryotic Cells

**Basic unit of living organisms is the cell; the smallest unit capable of life.**

**“Features” found in all cells:**

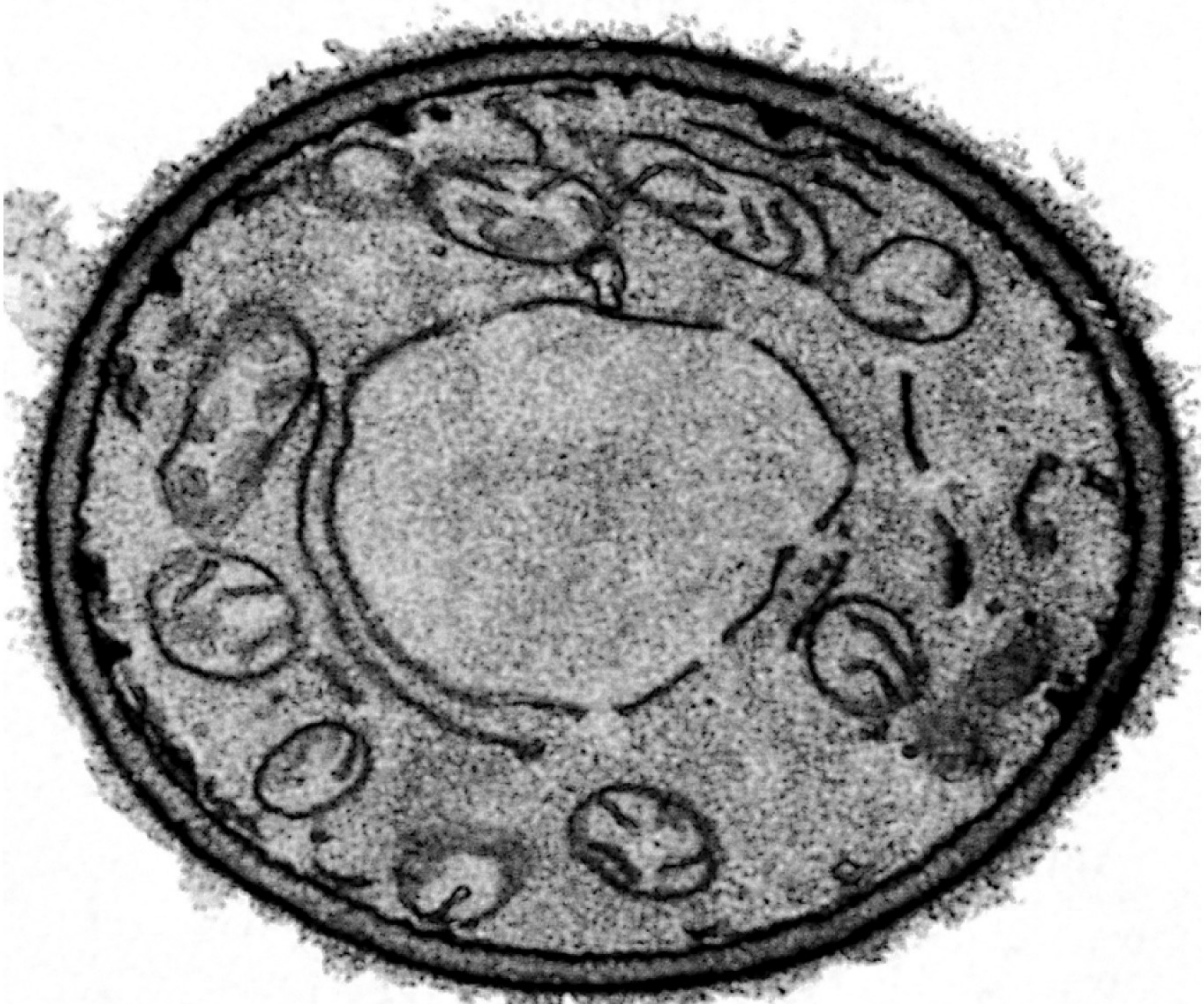
- **Ribosomes**
- **Cell Membrane**
- **Genetic Material**
- **Cytoplasm**
- **ATP Energy**
- **External Stimuli**
- **Regulate Flow**
- **Reproduce**

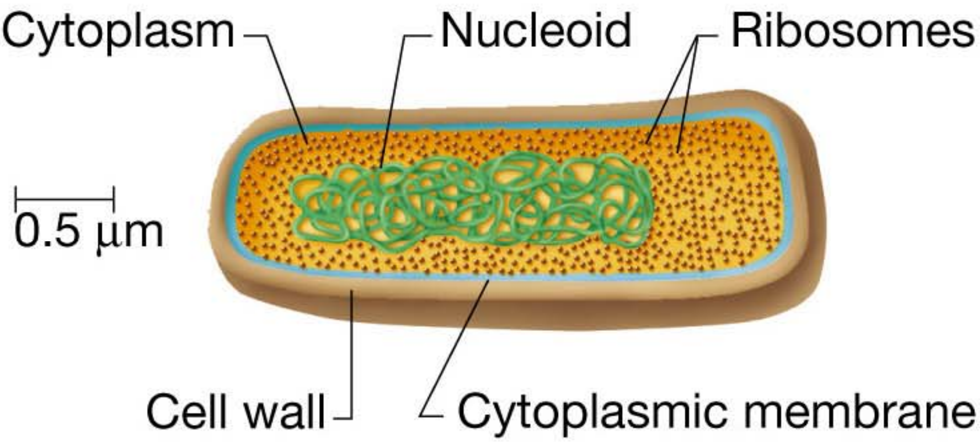
# A prokaryotic cell




**(a) A typical rod-shaped bacterium**

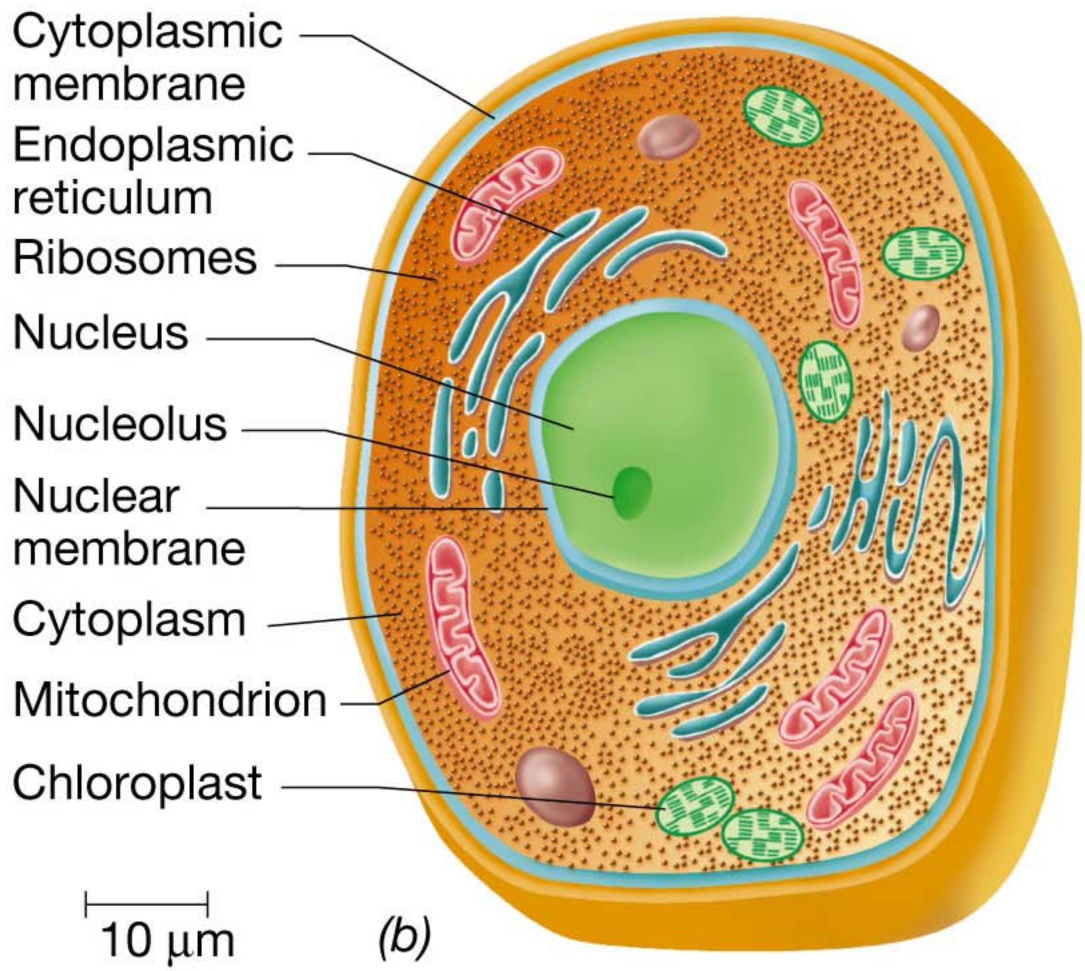
**(b) A thin section through the bacterium *Bacillus coagulans* (TEM)**





Cytoplasm
Nucleoid
Ribosomes
0.5 µm
Cell wall
Cytoplasmic membrane

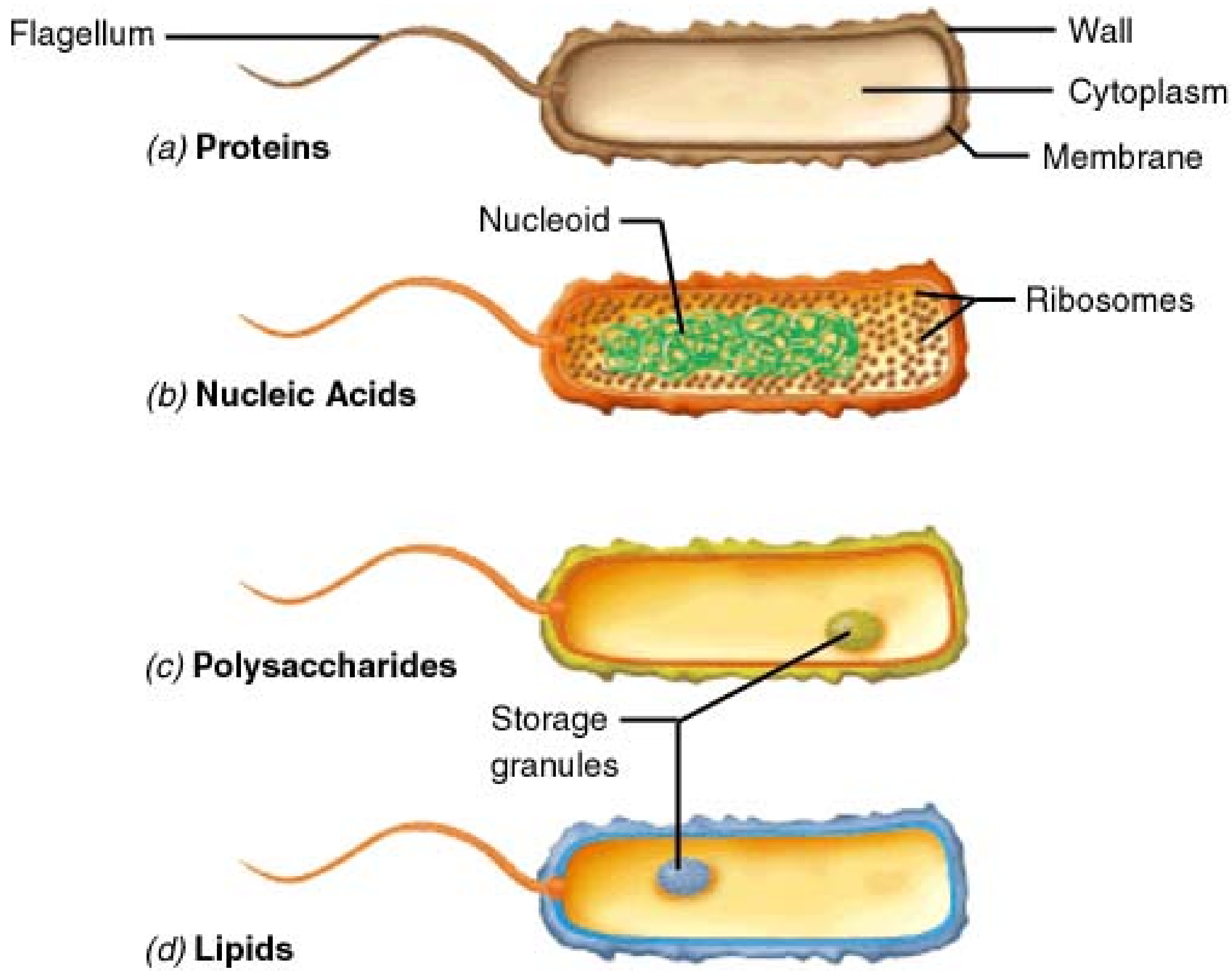
(a)



Cytoplasmic membrane
Endoplasmic reticulum
Ribosomes
Nucleus
Nucleolus
Nuclear membrane
Cytoplasm
Mitochondrion
Chloroplast
10 µm

(b)

# Locations of macromolecules in the cell



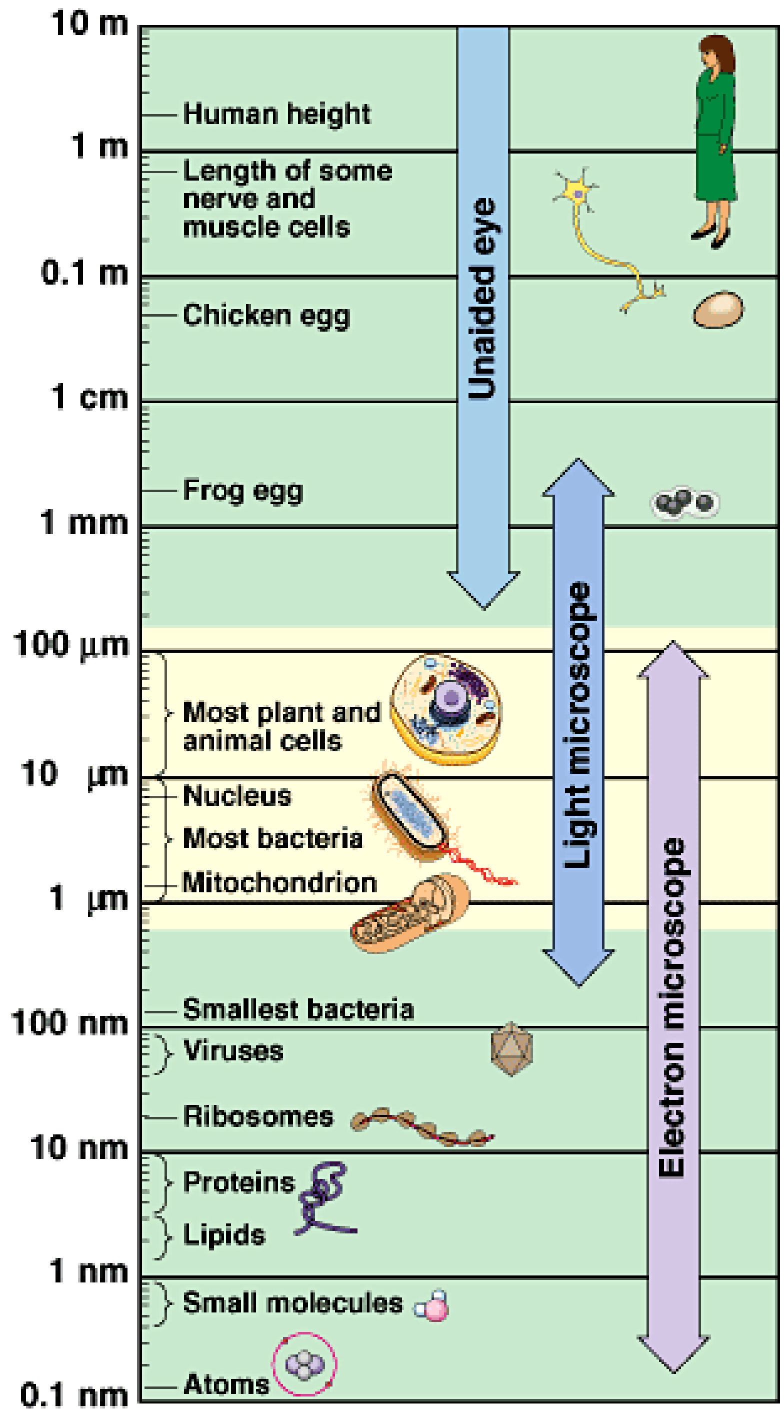

All over

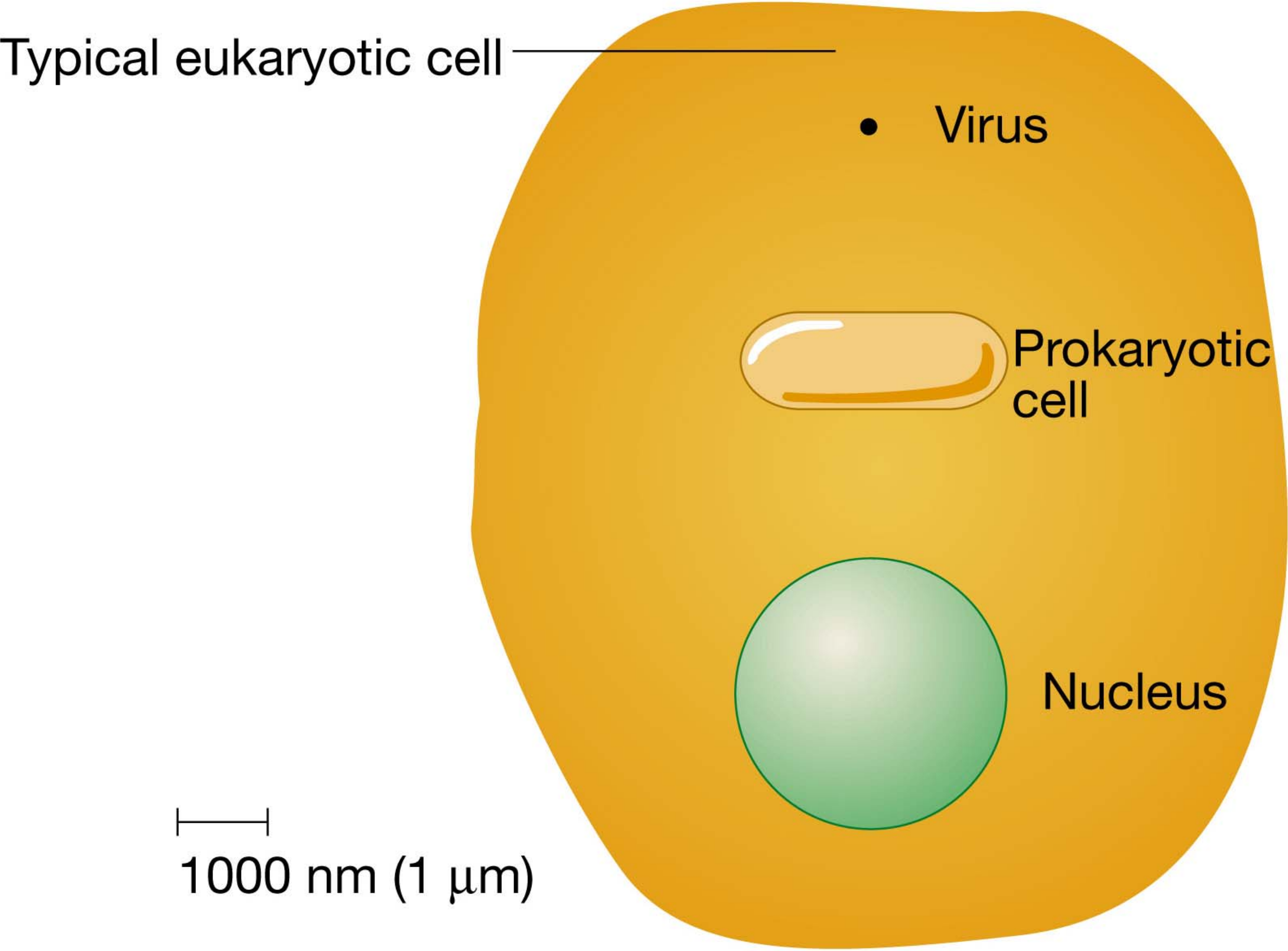
2 types
mostly

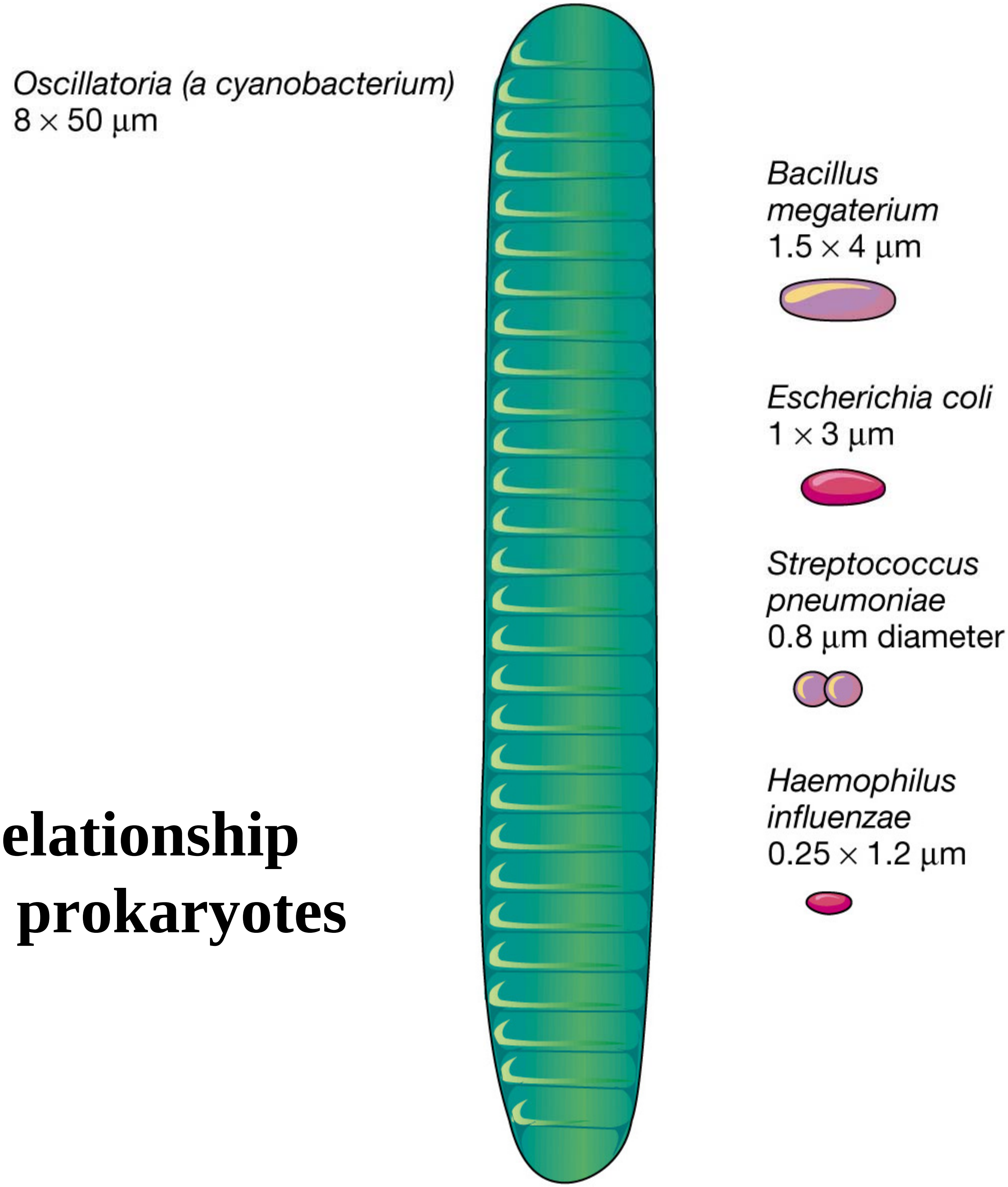
Cell Wall
mostly

Cell Wall
Cell Mem

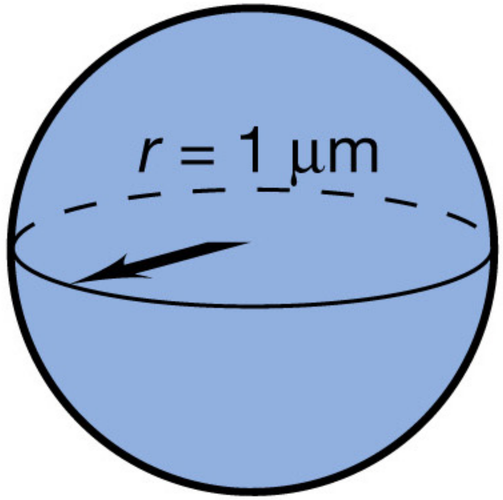
# The size range of cells




Typical eukaryotic cell
Virus
Prokaryotic cell
Nucleus
1000 nm (1 μm)



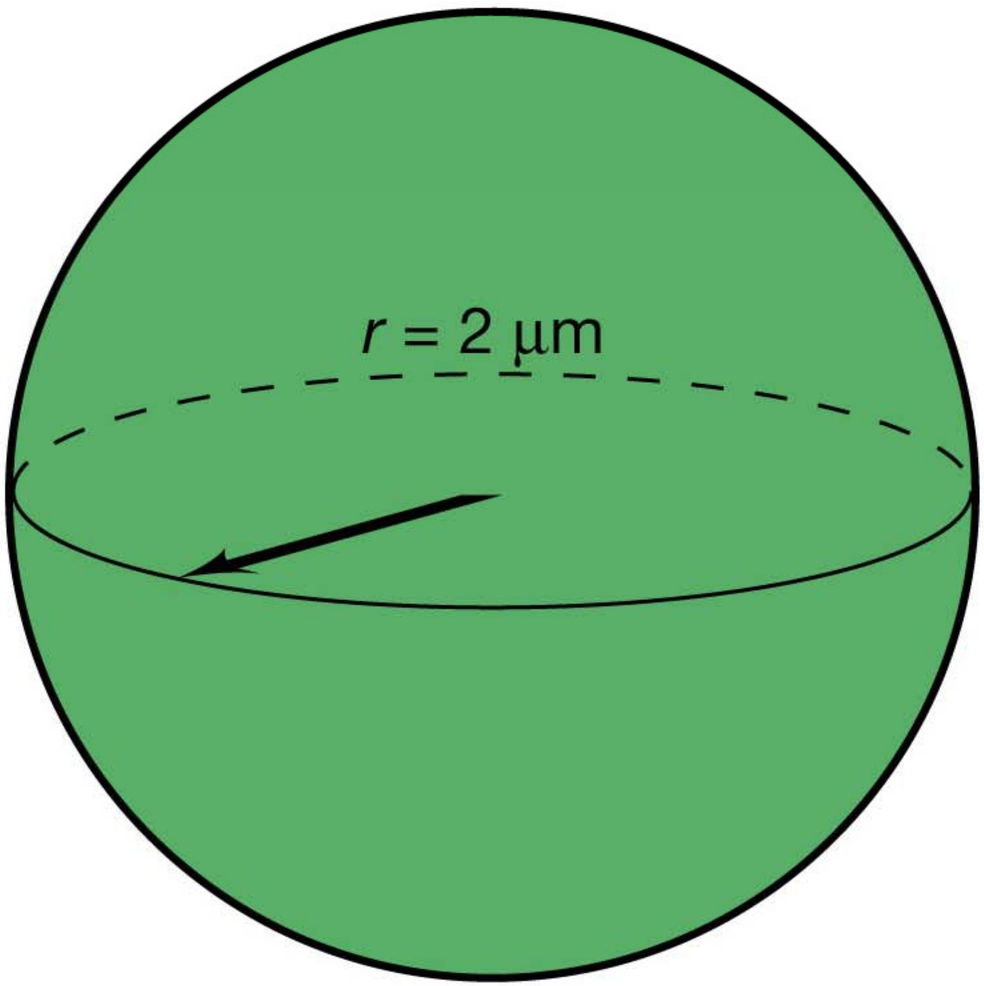

# Size relationship among prokaryotes




$$\text{Surface area } (4\pi r^2) = 12.6\ \mu m^2$$

$$\text{Volume } \left(\tfrac{4}{3}\pi r^3\right) = 4.2\ \mu m^3$$

$$\mathbf{\frac{Surface}{Volume} = 3}$$

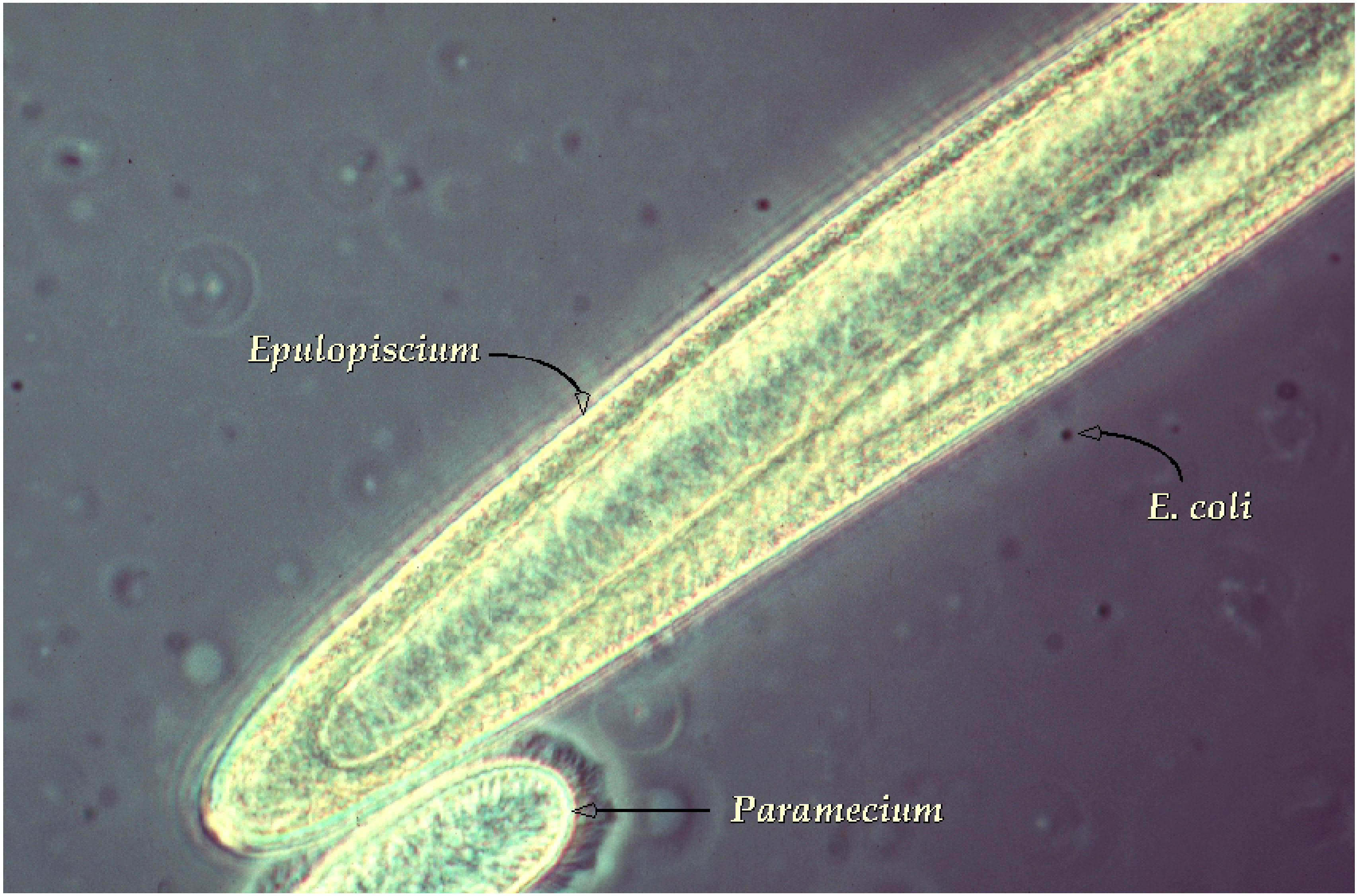



$$\text{Surface area} = 50.3\ \mu m^2$$

$$\text{Volume} = 33.5\ \mu m^3$$

$$\mathbf{\frac{Surface}{Volume} = 1.5}$$

# A Million times bigger than E. coli!



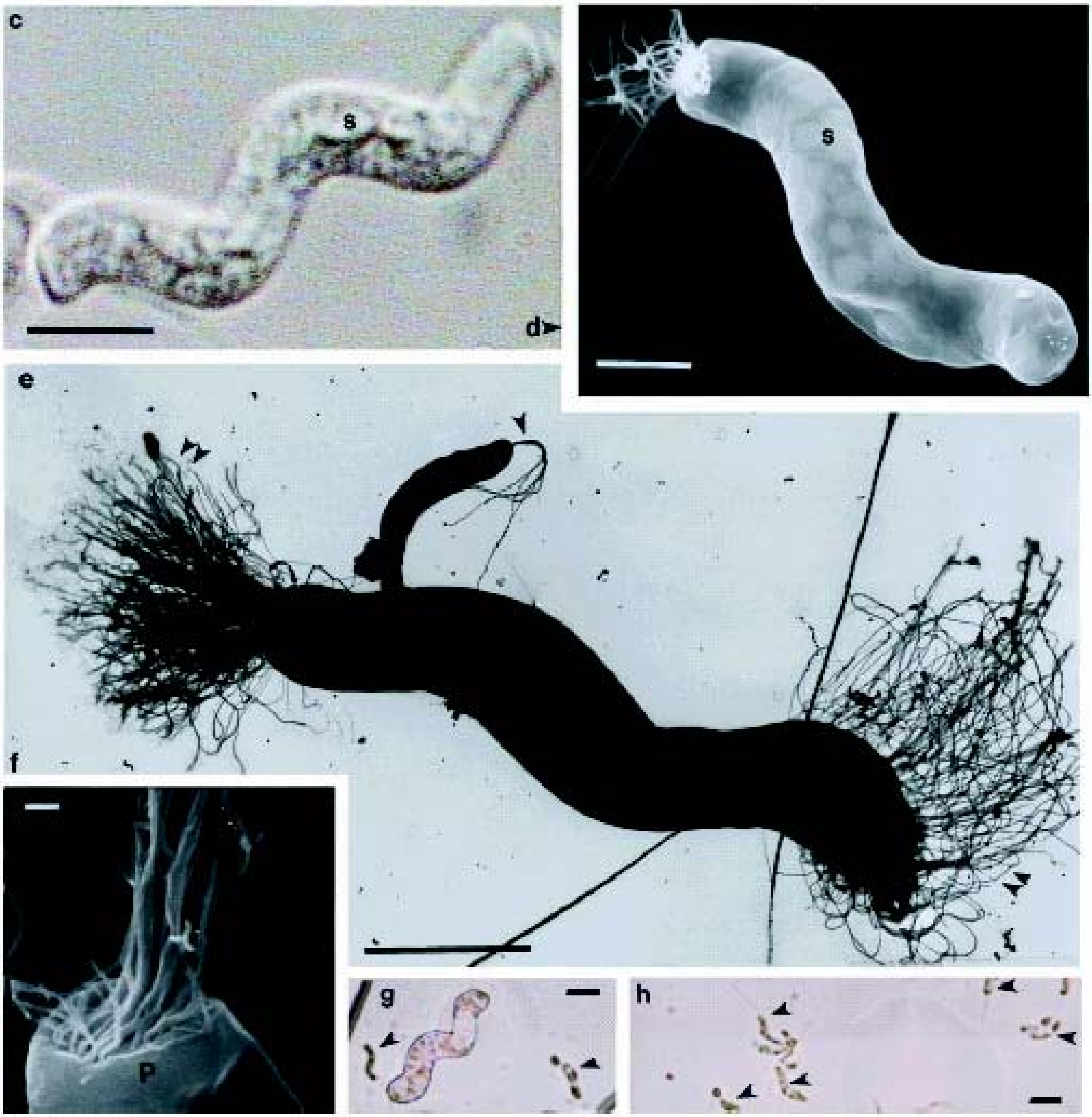



FIG. 1. (*a*) Mat surface at the Ebro Delta field site (3) showing lack of standing water. (Bar = 10 cm.) (*b*) Two spirilla cells (S, sulfur globule) shown by differential interference contrast (Nomarski). (Bar = 5 μm.) (*c*) Phase contrast microscopy of live spirillum cells. (Bar = 5 μm.) (*d*) Bipolar lophotrichous large spirillum in which only one pole has retained flagella. Sulfur globules are visible through the cell wall (scanning electron micrograph). (Bar = 5 μm.) (*e*) Negative-stain transmission electron micrograph of an entire bipolar lophotrichous large spirillum showing flagella "braids" (double arrowheads) compared with standard-sized spirilla (single arrowhead). (Bar = 5 μm.) (*f*) This scanning-electron micrograph of a cell terminus shows one vaulted end with residual flagella. The indentation coated by the polar organelle (P; see Fig. 2) is implied. (Bar = 0.5 μm.) (*g*) This Gram-stain brightfield preparation compares the two size classes, huge and standard, of Gram-negative spirilla. (Bar = 5 μm.) (*h*) Standard-sized spirillum Gram stain. The lighter spots are probably sulfur globules. (Bar = 5 μm.)

***Titanospirillum velox***

**Up to 40 μm long**

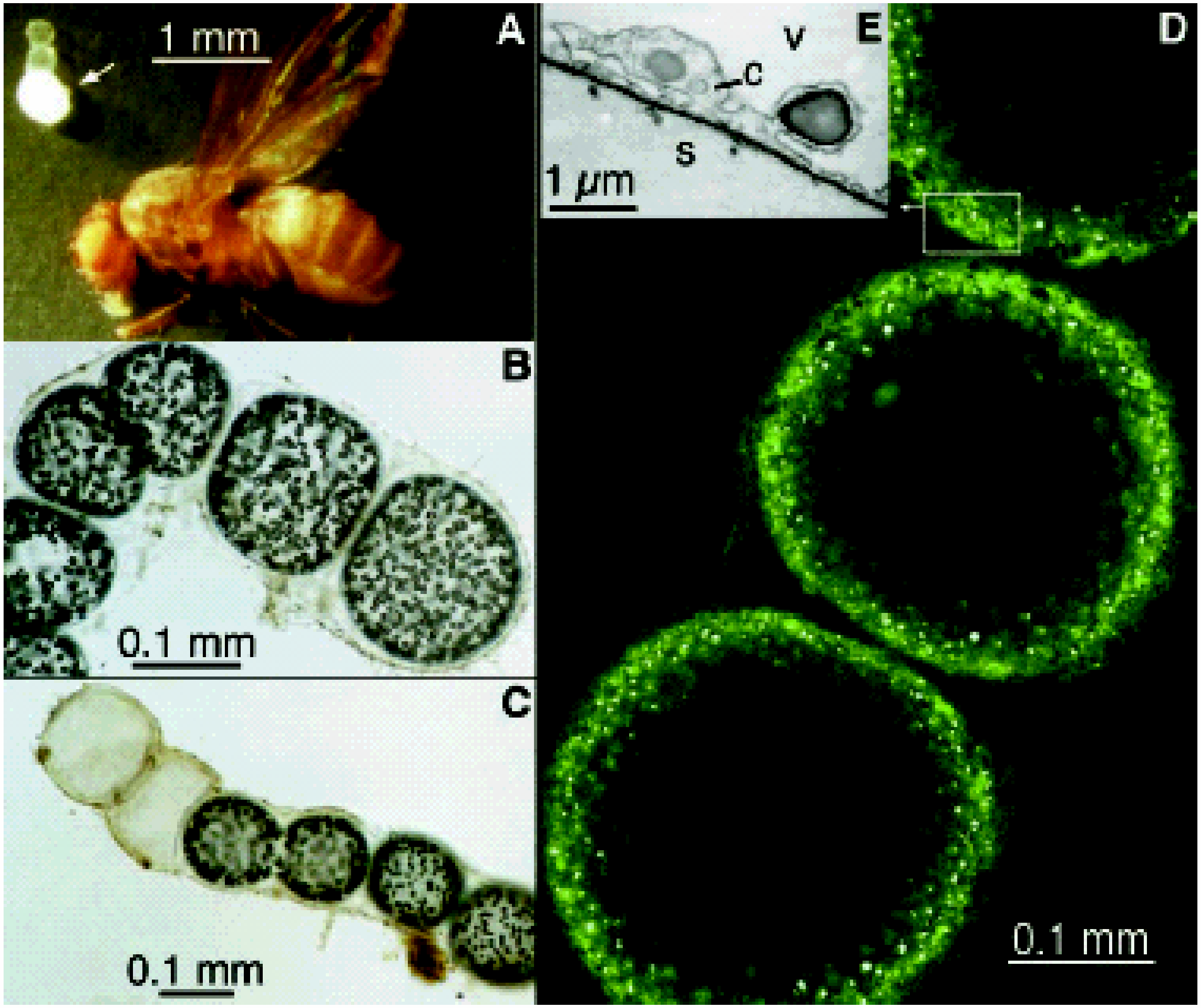
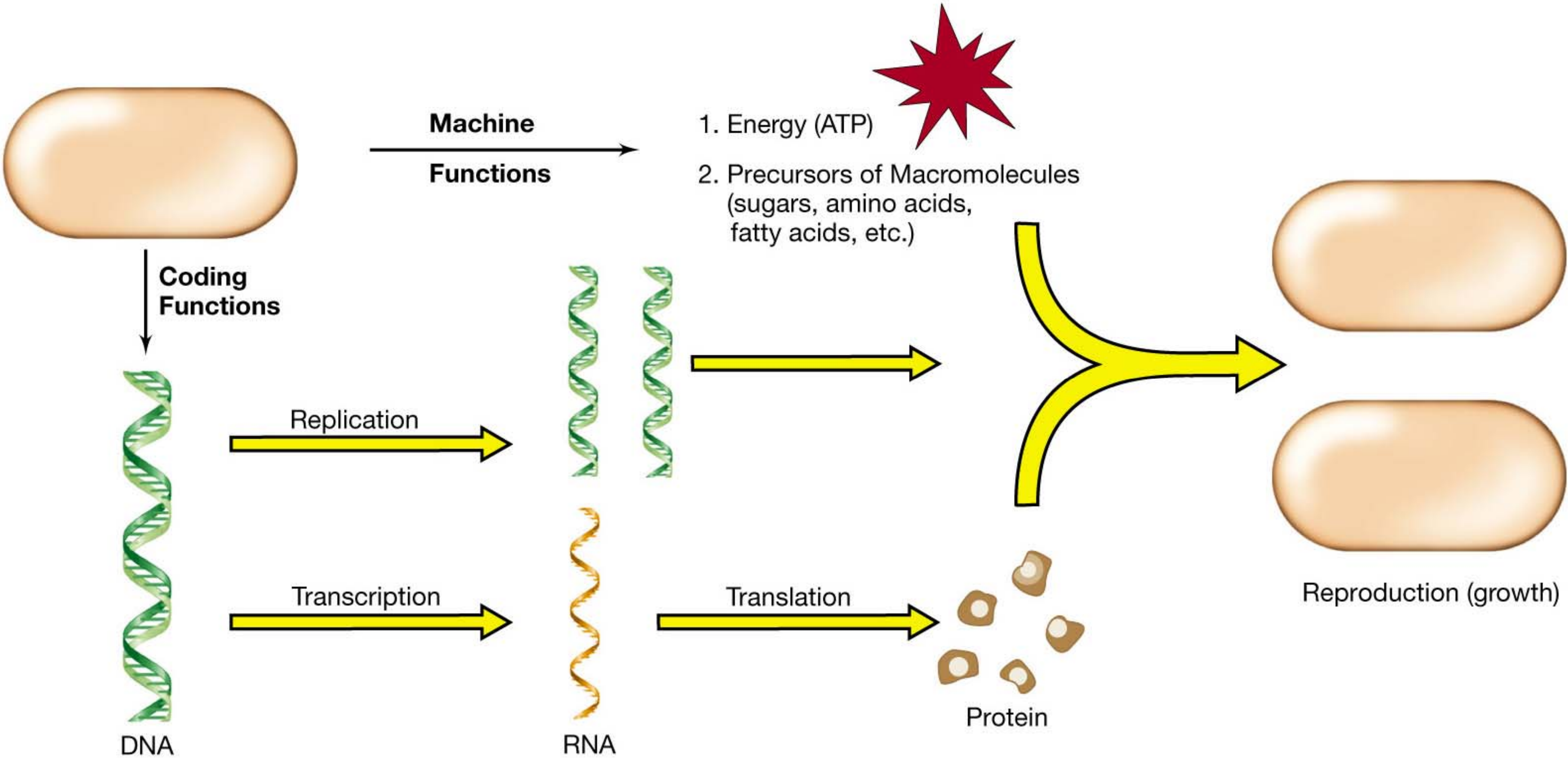



Fig. 1. *Thiomargarita namibiensis*. (A) The white arrow points to a single cell of *Thiomargarita*, 0.5 mm wide, which shines white because of internal sulfur inclusions. Above there is an empty part of the sheath, where the two neighboring cells have died. The cell was photographed next to a fruit fly (*Drosophila viriles*) of 3 mm length to give a sense of its size. (B) A typical chain of *Thiomargarita* as it appears under light microscopy. (C) At the left end of the chain there are two empty mucus sheaths, while in the middle a *Thiomargarita* cell is dividing. (D) Confocal laser scanning micrograph showing cytoplasm stained green with fluorescein isothiocyanate and the scattered light of sulfur globules (white). Most of the cells appear hollow because of the large central vacuole. (E) Transmission electron micrograph of the cell wall [enlarged area in (D)] showing the thin layer of cytoplasm (C), the vacuole (V), and the sheath (S).

***Thiomargarita namibiensis***

**Up to 500 μm wide**

# The machine/coding functions of the cell




# Central Dogma

# Comparing Prokaryotic and Eukaryotic Cells

**Basic chemical components/elements of a cell**

**CHOPKNS CaFe (its) Mg (ood)**

**TABLE 2.2** Chemical composition of a prokaryotic cell[a]

Rem: 70-85% Water

| Molecule | Percent of dry weight[b] | Molecules per cell | Different kinds |
|---|---|---|---|
| Total macromolecules | 96 | 24,610,000 | ~2500 |
| Protein | 55 | 2,350,000 | ~1850 |
| Polysaccharide | 5 | 4,300 | 2[c] |
| Lipid | 9.1 | 22,000,000 | 4[d] |
| Lipopolysaccharide | 3.4 | 1,430,000 | 1 |
| DNA | 3.1 | 2.1 | 1 |
| RNA | 20.5 | 255,500 | ~660 |
| Total monomers | 3.0 | | ~350 |
| Amino acids and precursors | 0.5 | | ~100 |
| Sugars and precursors | 2 | | ~50 |
| Nucleotides and precursors | 0.5 | | ~200 |
| Inorganic ions | 1 | | 18 |
| Total | 100% | | |

*a* Data from Neidhardt, F. C., et al. (eds.), 1996. *Escherichia coli* and *Salmonella typhimurium—Cellular and Molecular Biology*, 2nd edition. American Society for Microbiology, Washington, DC.

*b* Dry weight of an actively growing cell of *E. coli* ≅ $2.8 \times 10^{-13}$ g; total weight (70% water) = $9.5 \times 10^{-13}$ g.

*c* Assuming peptidoglycan and glycogen to be the major polysaccharides present.

*d* There are several classes of phospholipids, each of which exists in many kinds because of variability in fatty acid composition between species and because of different growth conditions.

**Protein ~50%**
**Lipid ~10%**
**RNA ~20%**
**DNA ~ 3-4%**

→ **Cell Wall 10–20%**

**Take Home Message:**

**Proteins are #1 by weight**

**Lipids are #1 by number**

**Peptidoglycan is 1 jumbo molecule**

# Comparing Prokaryotic and Eukaryotic Cells

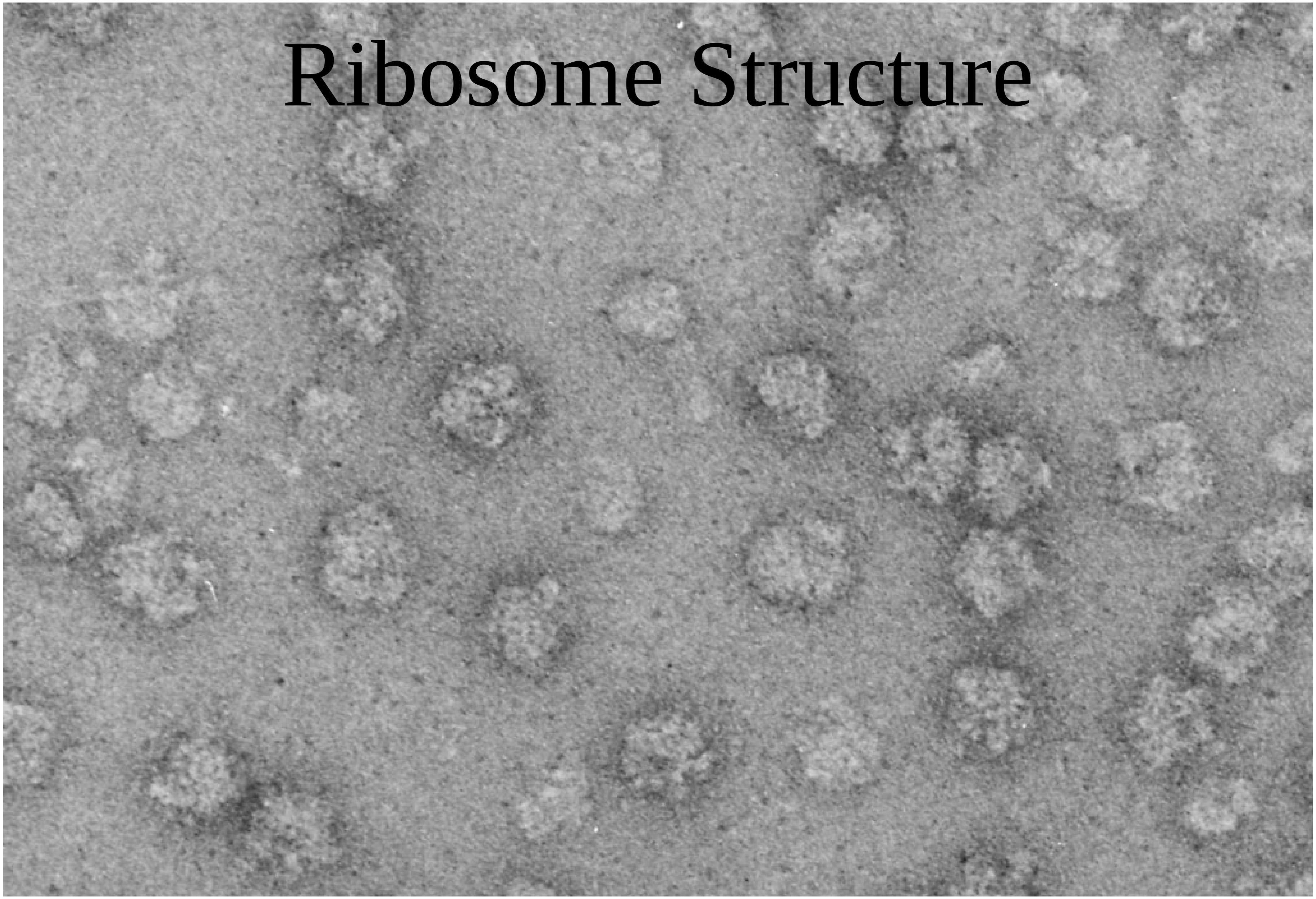
**Classification of prokaryotic cellular features:**
**Invariant (or common to all)**

➡ • **Ribosomes: Sites for protein synthesis – aka the grand translators**

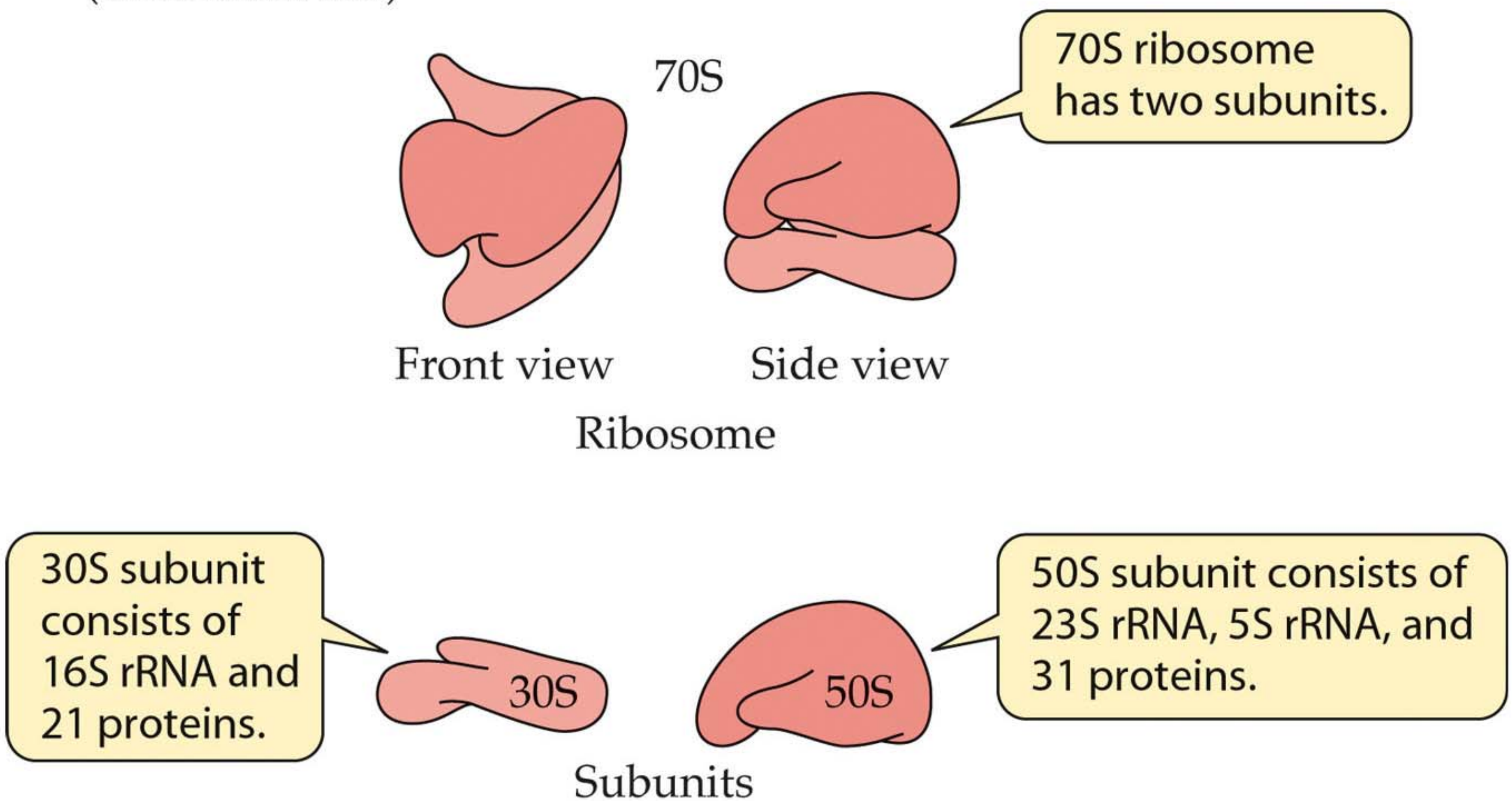
• **Cell Membranes: The barrier between order and chaos**

• **Nucleoid Region: Curator of the Information**

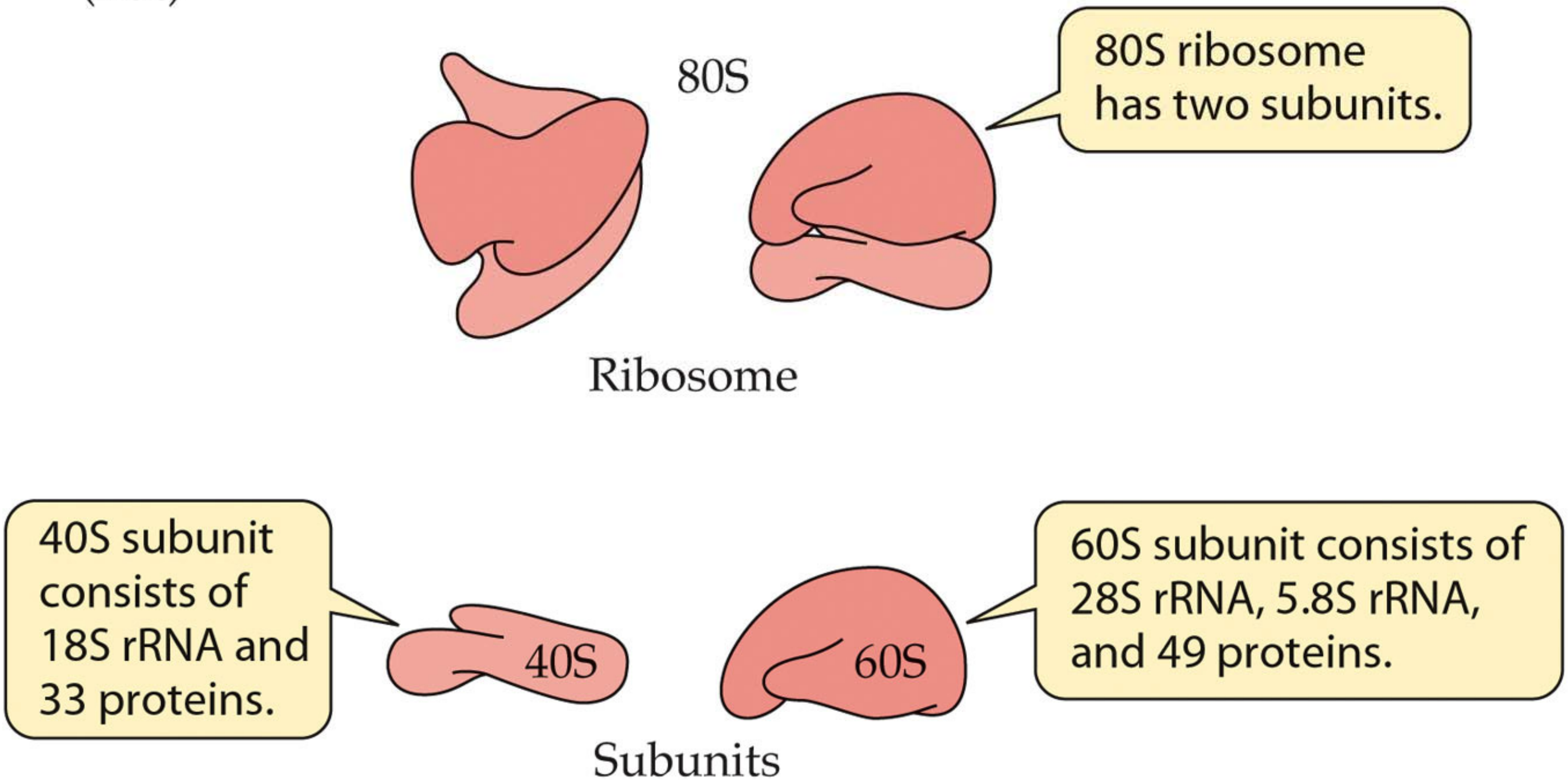
# Ribosome Structure



(B) Prokaryotic ribosome
(*Escherichia coli*)



(C) Eukaryotic ribosome (Rat)

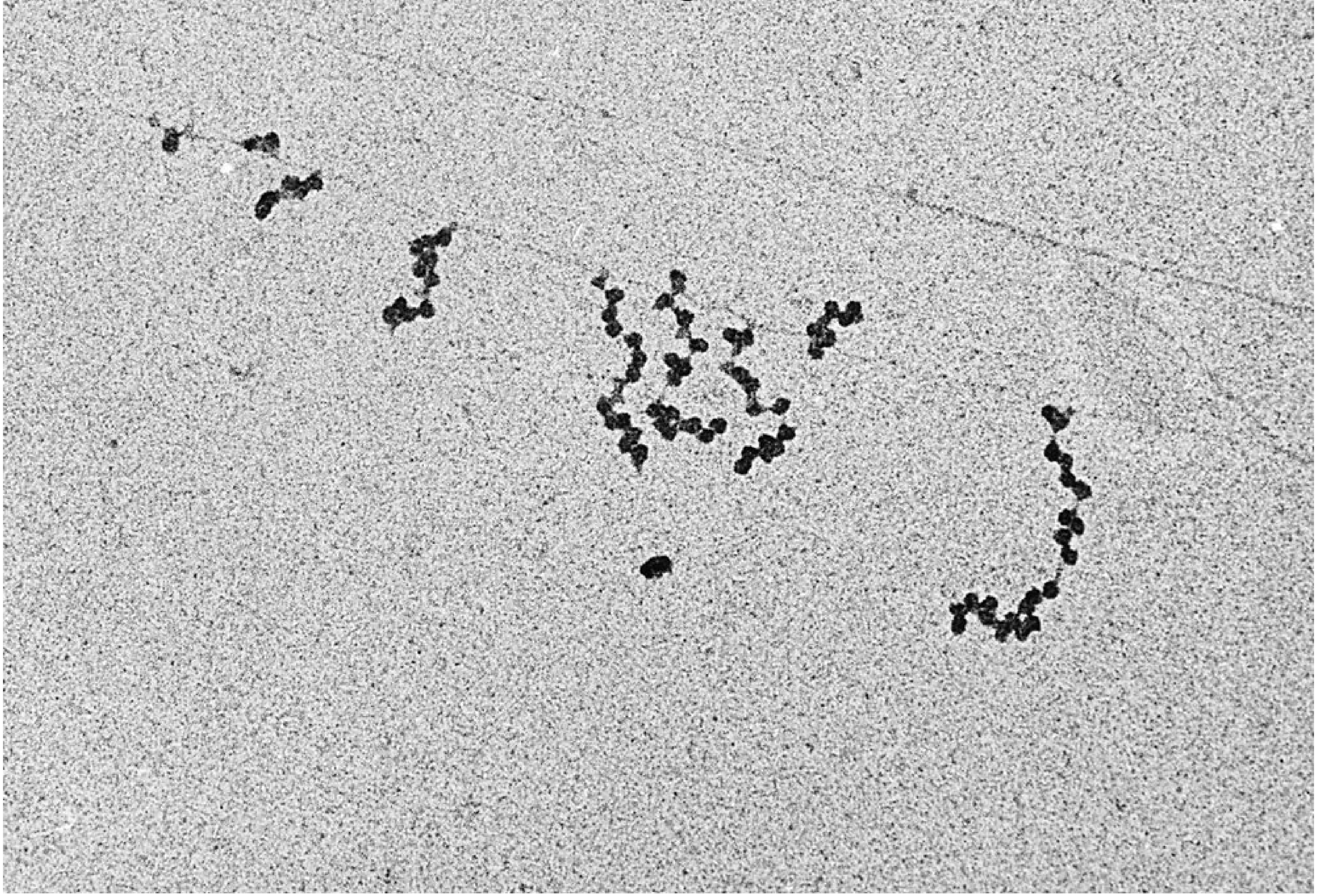


## TABLE 7.4 Ribosome structure[a]

| Property | Prokaryote | Eukaryote |
|---|---|---|
| Overall size | 70S | 80S |
| Small subunit | 30S | 40S |
| Number of proteins | ~21 | ~30 |
| RNA size (number of bases) | 16S (1500) | 18S (2300) |
| Large subunit | 50S | 60S |
| Number of proteins | ~34 | ~50 |
| RNA size (number of bases) | 23S (2900)<br>5S (120) | 28S (4200)<br>5.8S (160)<br>5S (120) |

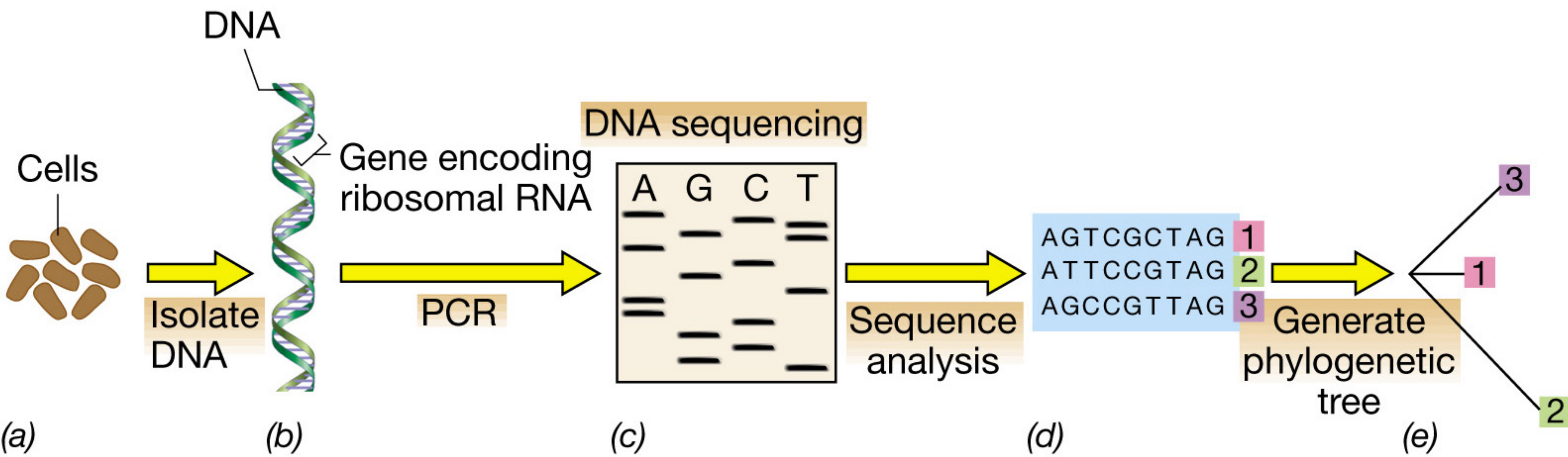
**S= Svedberg; a sedimentation coefficient that is NOT ADDITIVE!!!**

# Protein Synthesis



# Importance of a Molecular Biological Approach

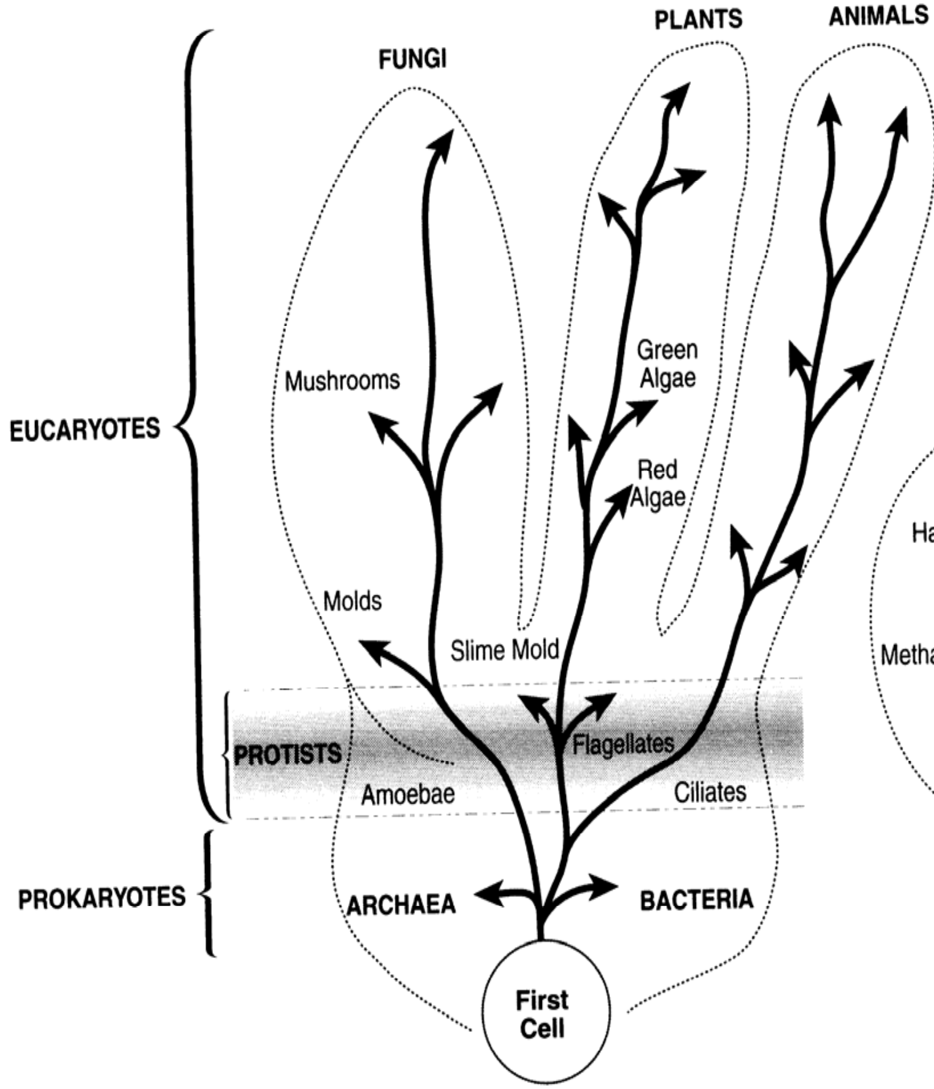
- **Traditional culturing** techniques isolate ~1% of the total bacteria in marine ecosystems, thereby severely underestimating diversity and community structure.
- Because nutrient-rich **culture media** have been historically used during enrichment procedures, bacteria which may be dominant in natural communities are selected against in favor of copiotrophic (weedy) bacteria.
- **SSU rRNAs** and their respective genes are excellent descriptors of microbial taxa based on phylogeny.


Cells
Isolate DNA
DNA
Gene encoding ribosomal RNA
PCR
DNA sequencing
A G C T
Sequence analysis
AGTCGCTAG 1
ATTCCGTAG 2
AGCCGTTAG 3
Generate phylogenetic tree
3
1
2
(a)
(b)
(c)
(d)
(e)

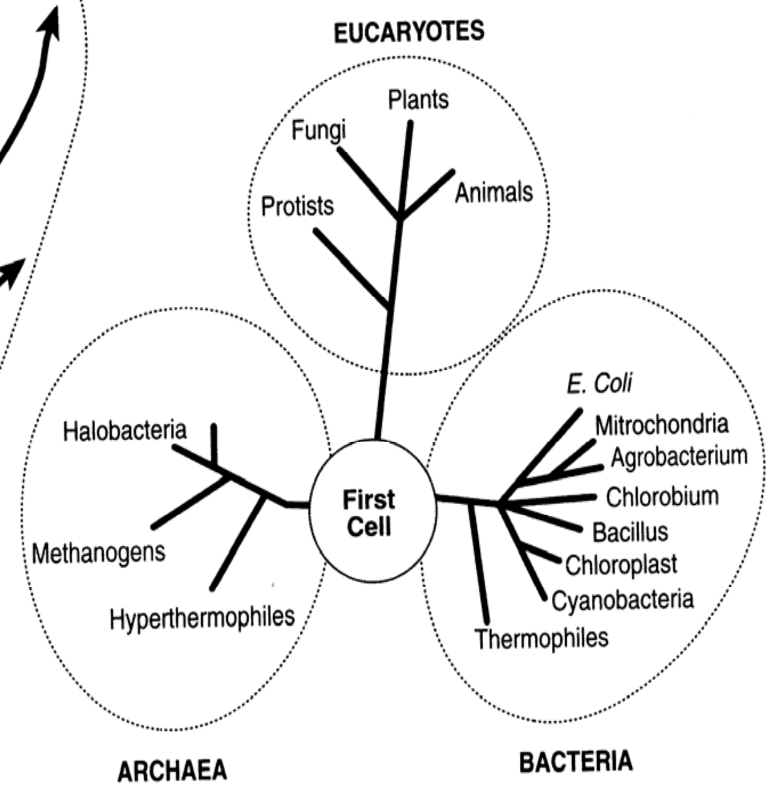
# Regarding Molecular Phylogeny

**The Root of the Problem:** Unlike zoology and botany, microbiology developed without the knowledge of phylogenetic relationships among the organisms studied.

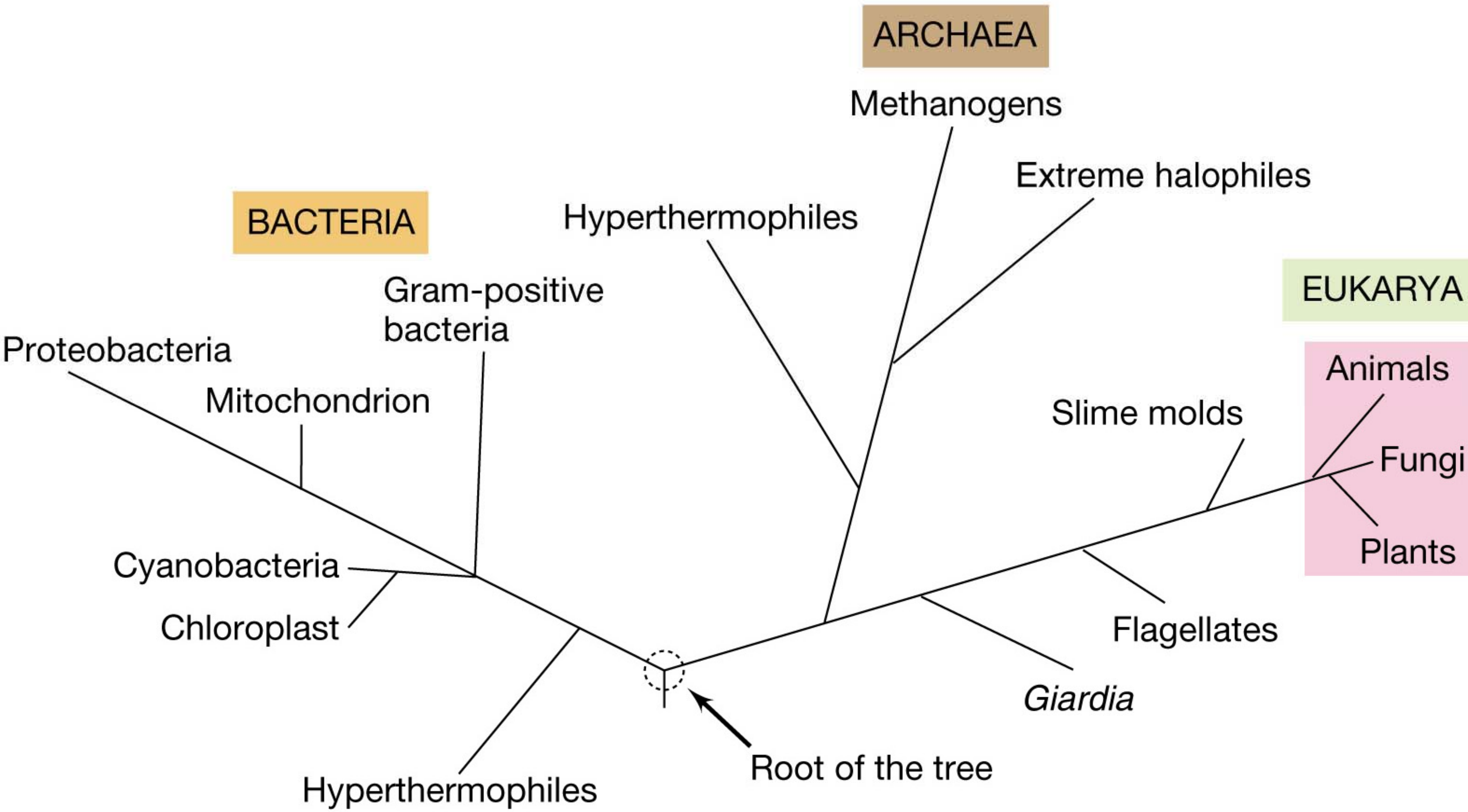
- Milestone #1: Zuckerkandl and Pauling (1965) “Semantides” (i.e., molecules as documents of evolutionary history).
- Milestone #2: Pace (1986) Applied phylogeny concept to microbial ecology's need to take a census.
- Milestone #3: Woese (1987) Applied phylogeny concept to redefine microbial systematics or the need to understand microbial genealogy.




"CLASSICAL" PHYLOGENY




MOLECULAR PHYLOGENY


ARCHAEA
Methanogens
Extreme halophiles
BACTERIA
Hyperthermophiles
EUKARYA
Gram-positive bacteria
Proteobacteria
Animals
Mitochondrion
Slime molds
Fungi
Plants
Cyanobacteria
Chloroplast
Flagellates
Giardia
Root of the tree
Hyperthermophiles

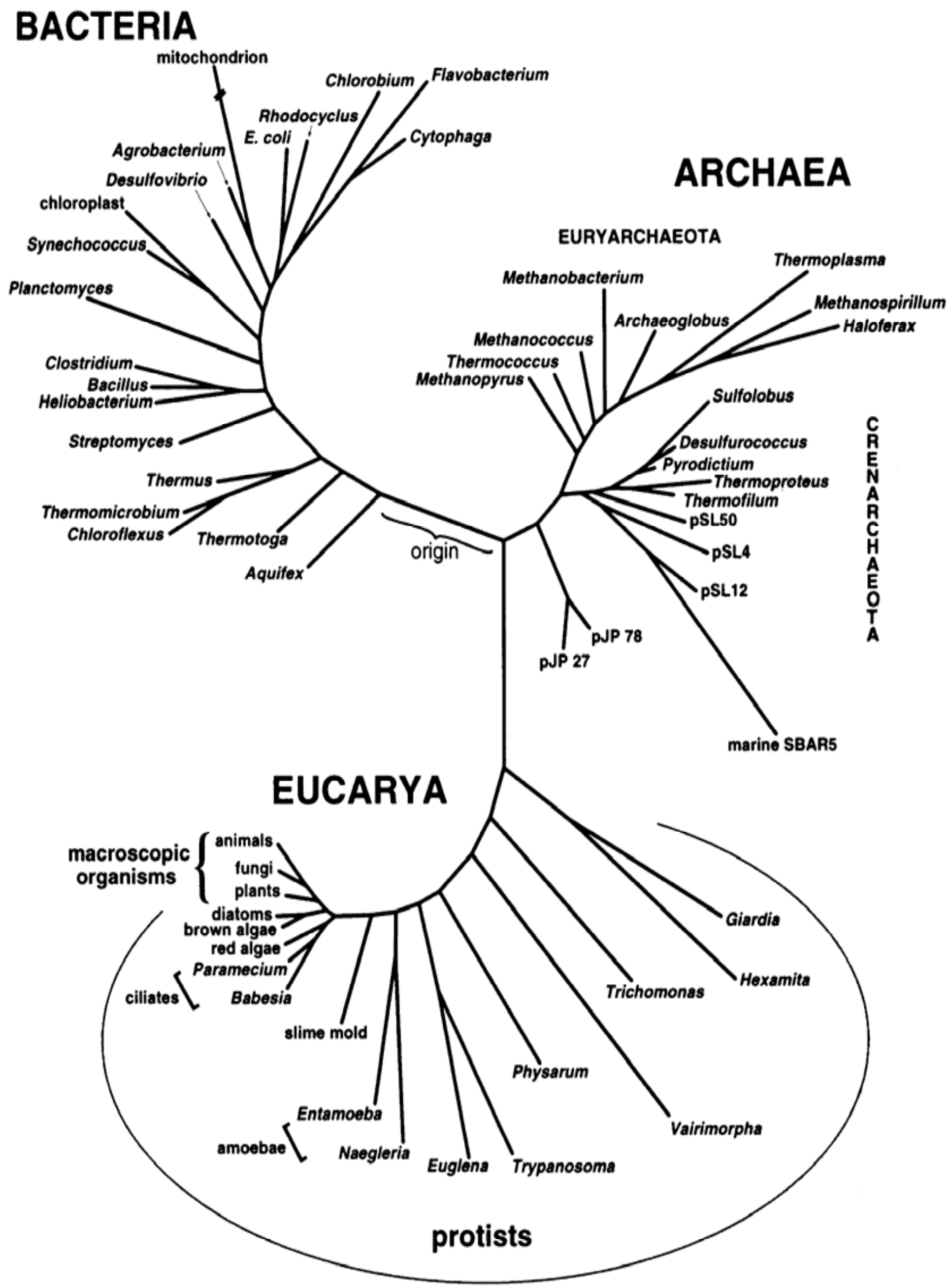



**Figure 1.** Diagrammatic "Universal" phylogenetic tree of life, based on small-subunit ribosomal RNA sequences. Based on analyses of Barns et al. (1996b), Olsen et al. (1994), and Sogin (1994).

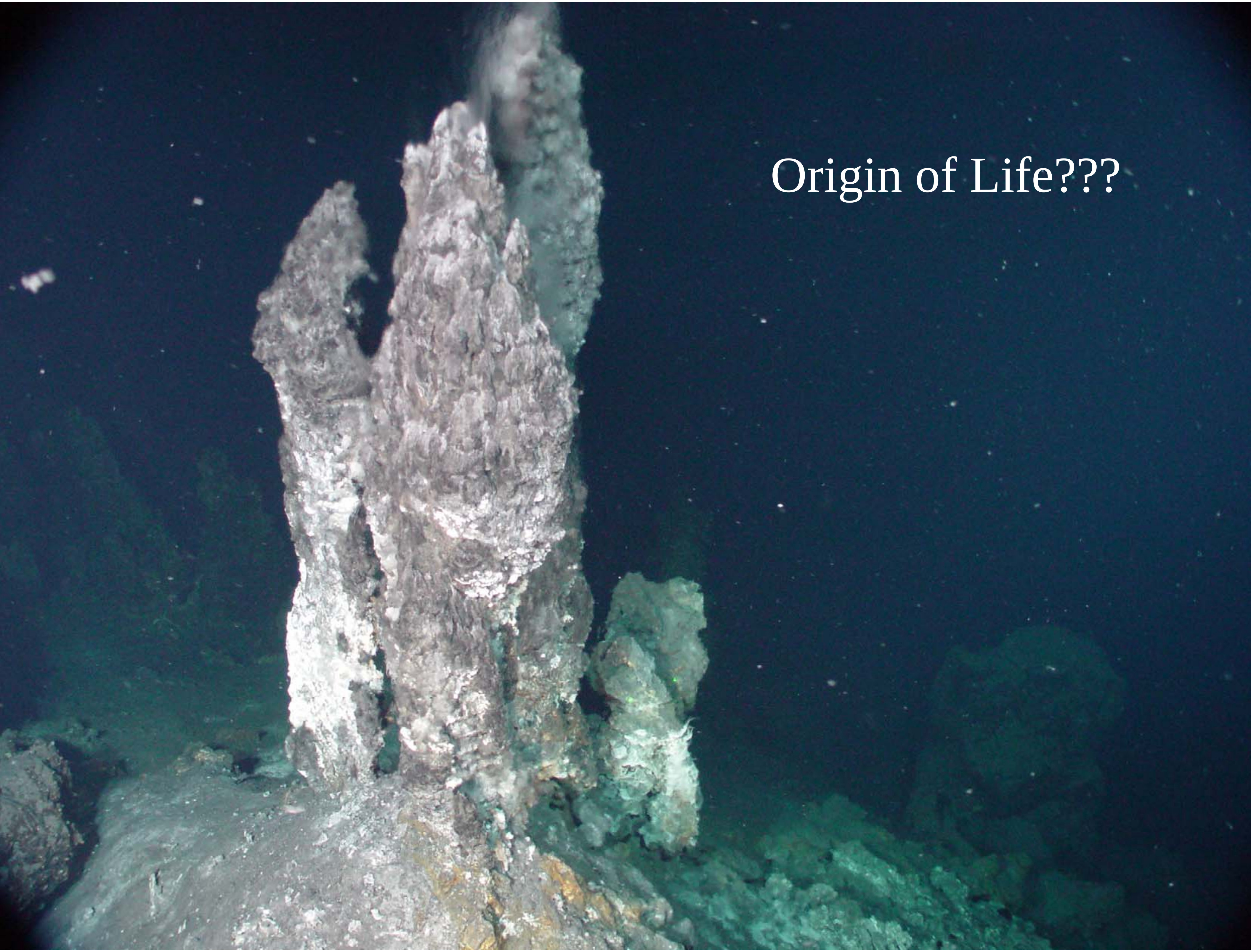
**Some Lessons from the BIG TREE: Map of the Biological Record**

Single origin for all life on Earth...

- Central Dogma intact
- ATP and PMF are universal themes
- Uniformity among chiral carbon compounds (sugars & AAs)
- Hot start origin…

General topology implies:

- Three "primary lines of evolutionary descent"
- The Eucarya *"nuclear"* lineage almost as old as the prokaryote lines
- Prokaryotes split between *Bacteria* and *Archaea*
- Shown for only a limited number of representative org's
- Mitochondria and chloroplasts proven to be of bacterial origin


Origin of Life???

# Comparing Prokaryotic and Eukaryotic Cells

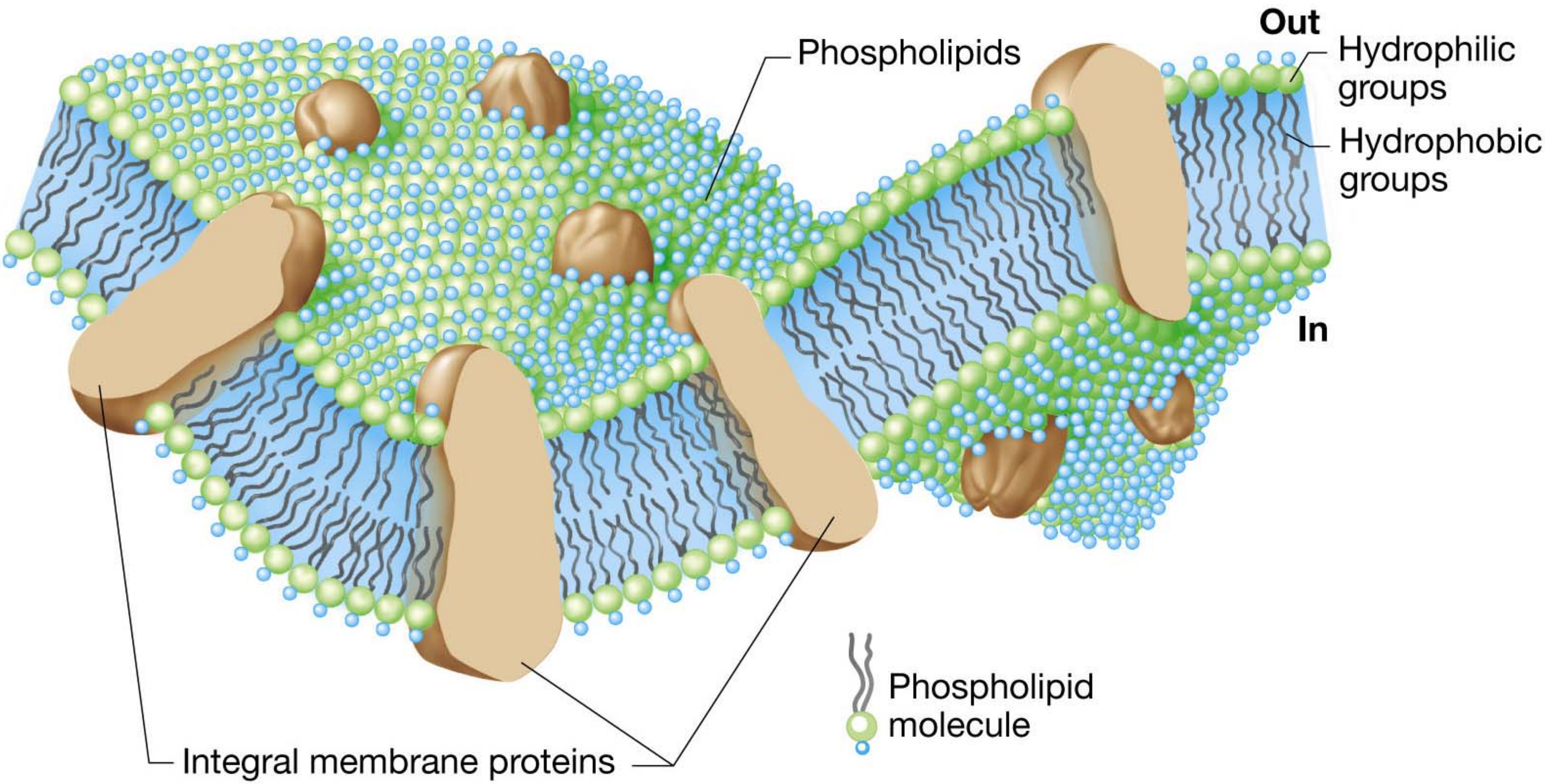
**Classification of prokaryotic cellular features:**
**Invariant (or common to all)**

- **Ribosomes: Sites for protein synthesis – aka the grand translators**

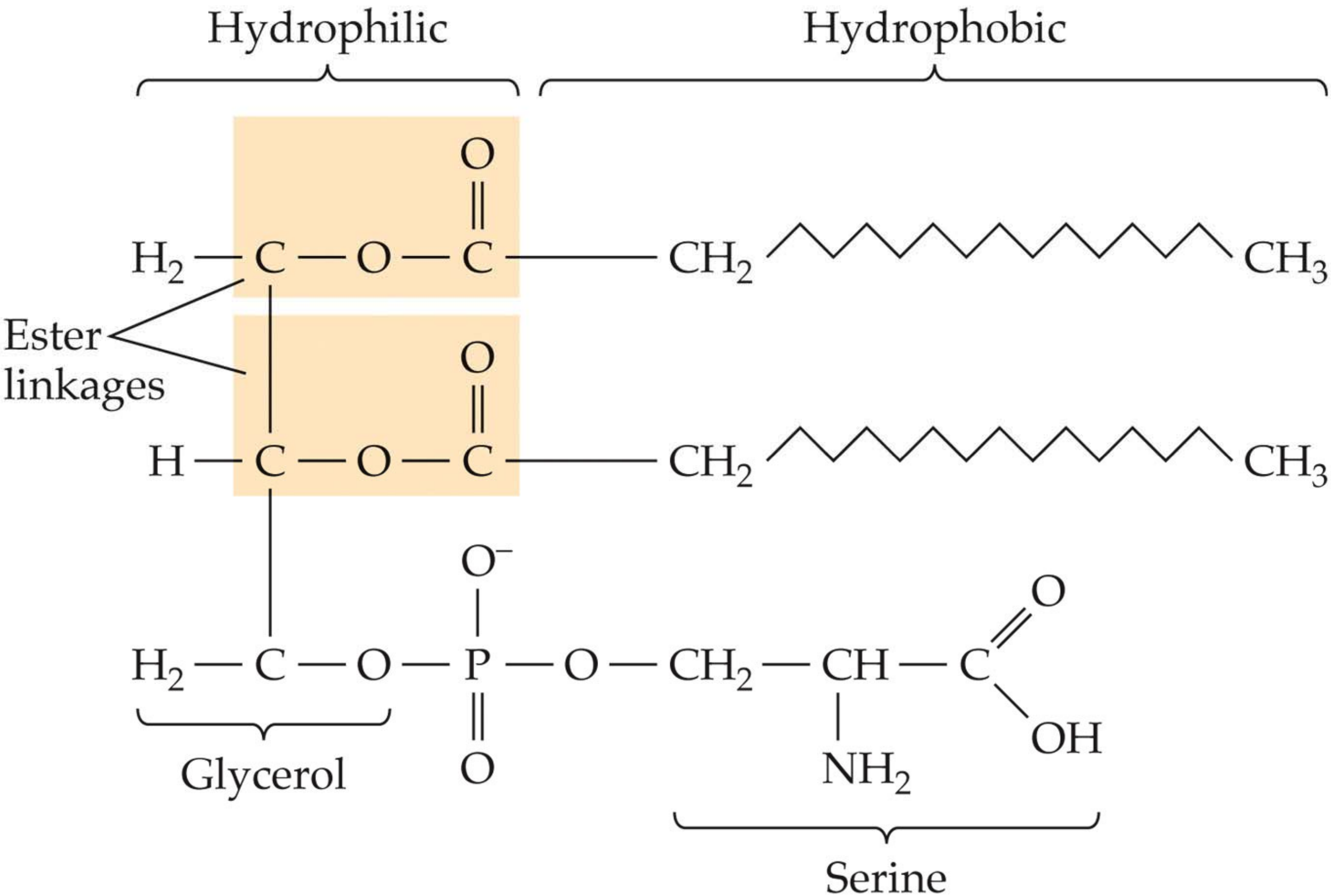
- **Cell Membranes: The barrier between order and chaos**

- **Nucleoid Region: Curator of the Information**

# The cytoplasmic membrane

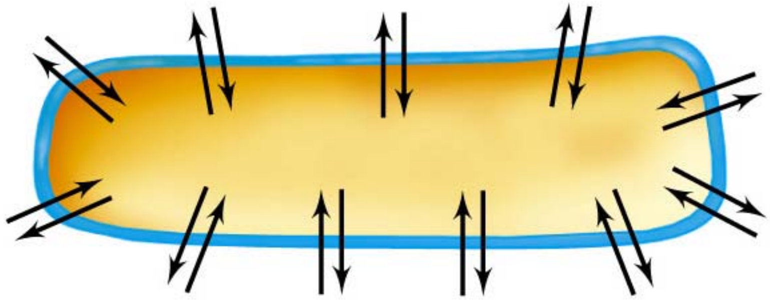



Rem: Fluid Mosaic Model

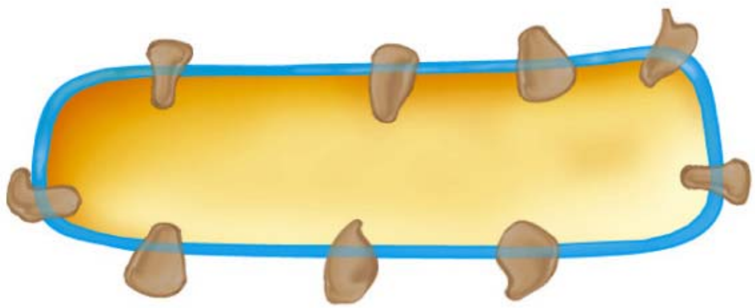



Amphipathic

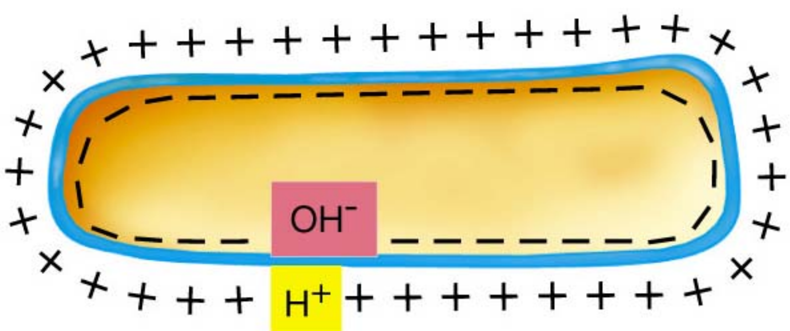
# Functions of the cytoplasmic membrane



**Permeability Barrier** — Prevents leakage and functions as a gateway for transport of nutrients into and out of the cell



**Protein Anchor** — Site of many proteins involved in transport, bioenergetics, and chemotaxis

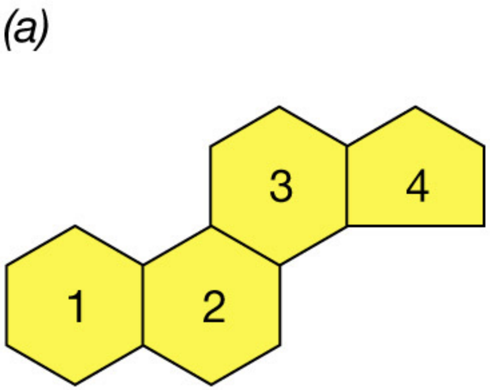


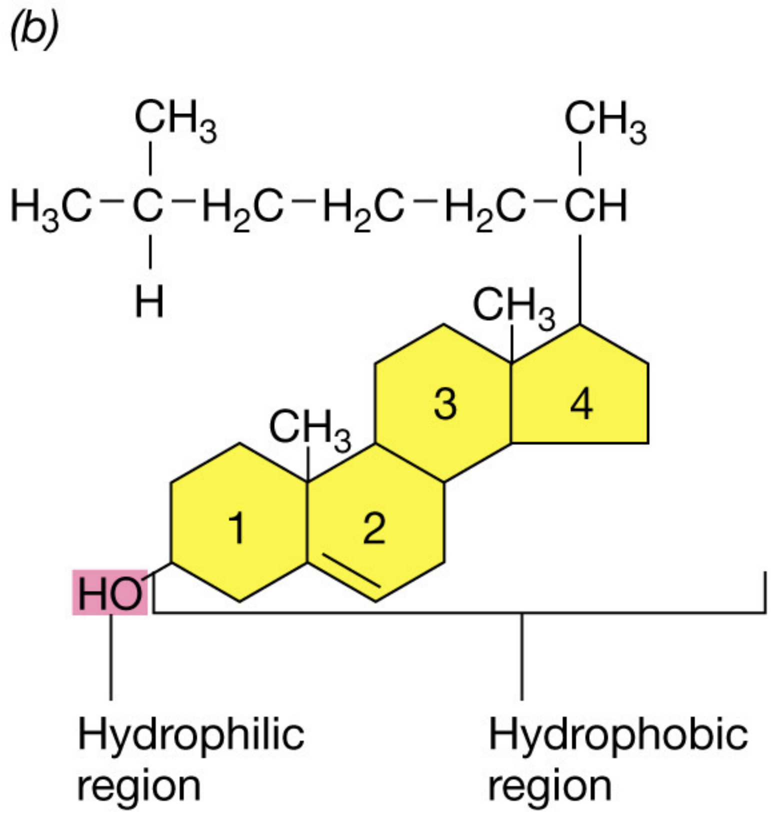

**Energy Conservation** — Site of generation and use of the proton motive force

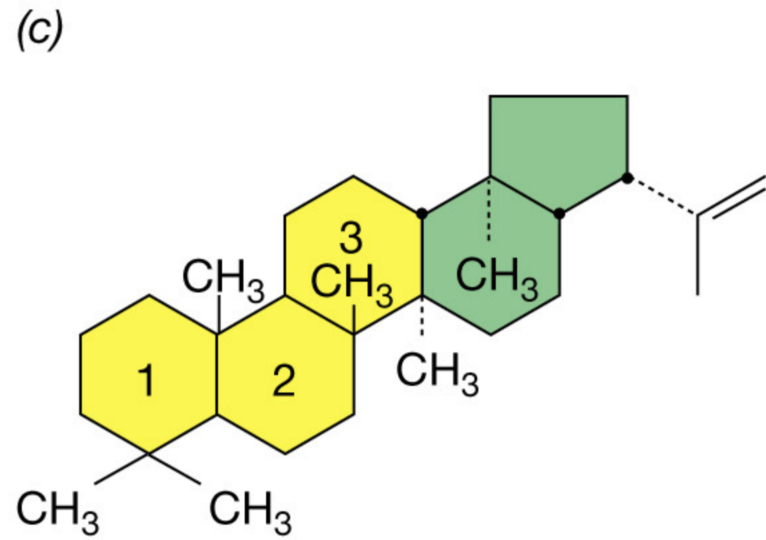
Sterol

Cholesterol

Hopanoid
(e.g., Diploptene)



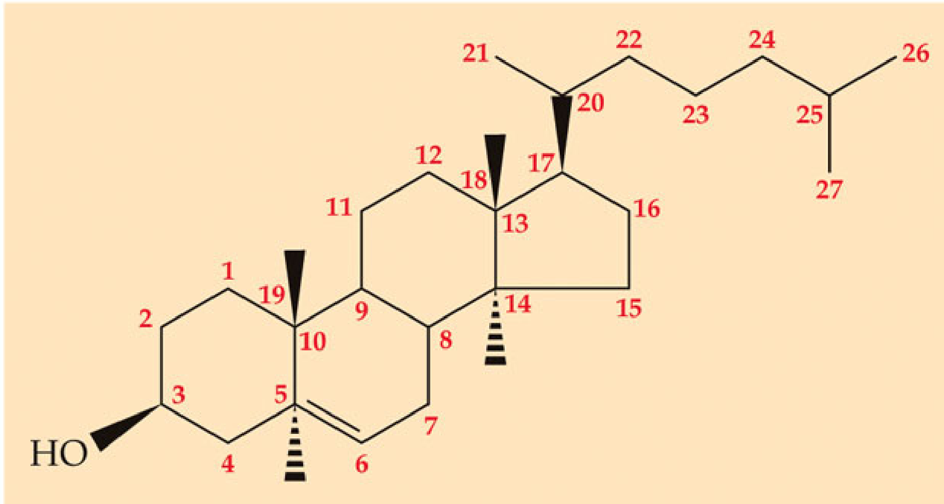

Few Bacteria

Many Bacteria

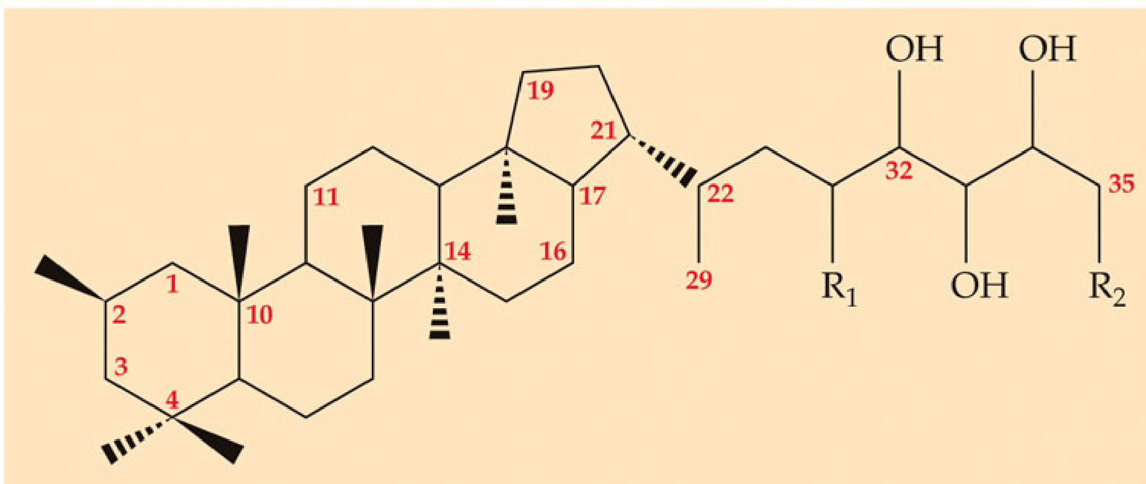
$O_2$ -

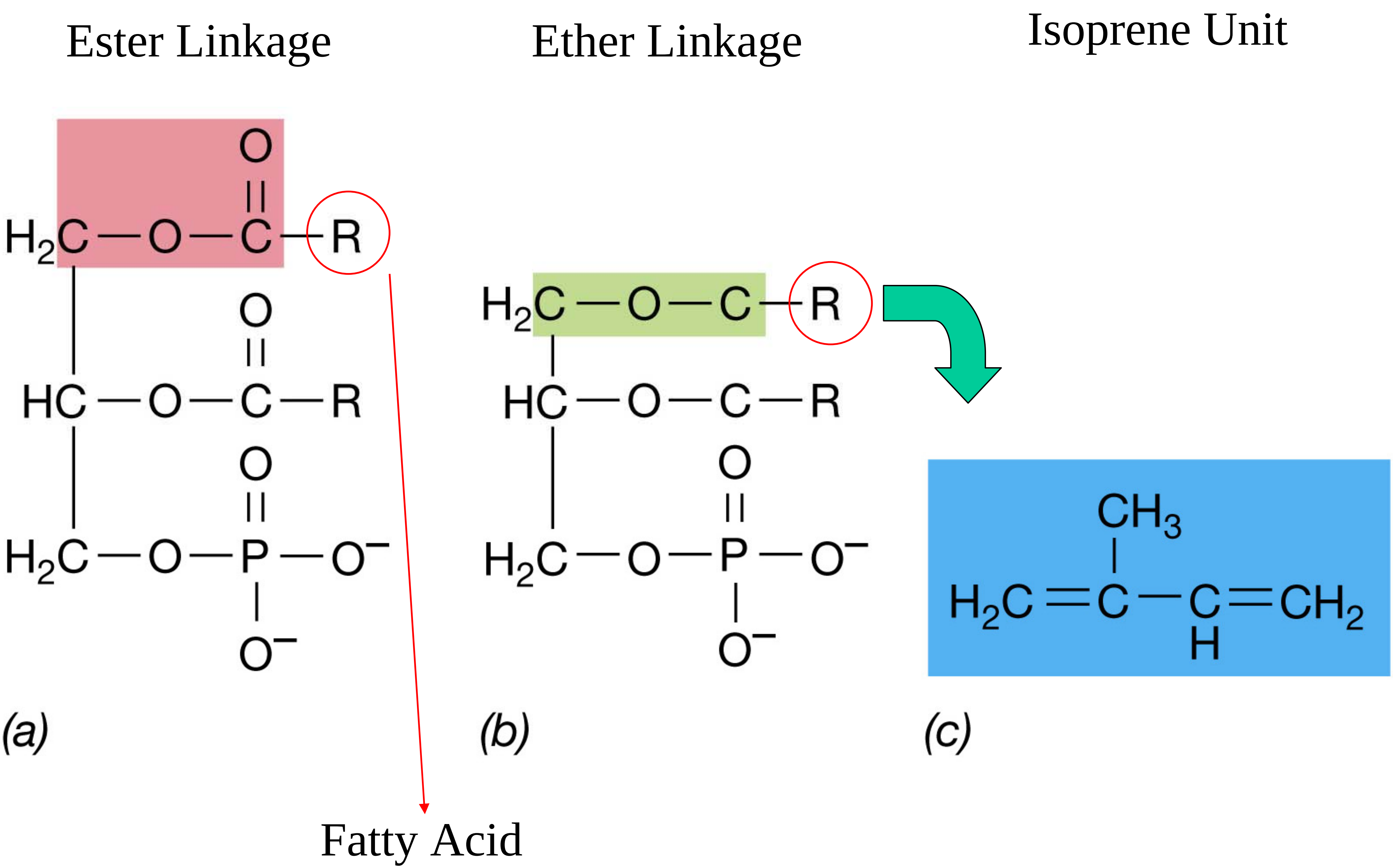
**All rigid planar molecules**

(A) Cholesterol



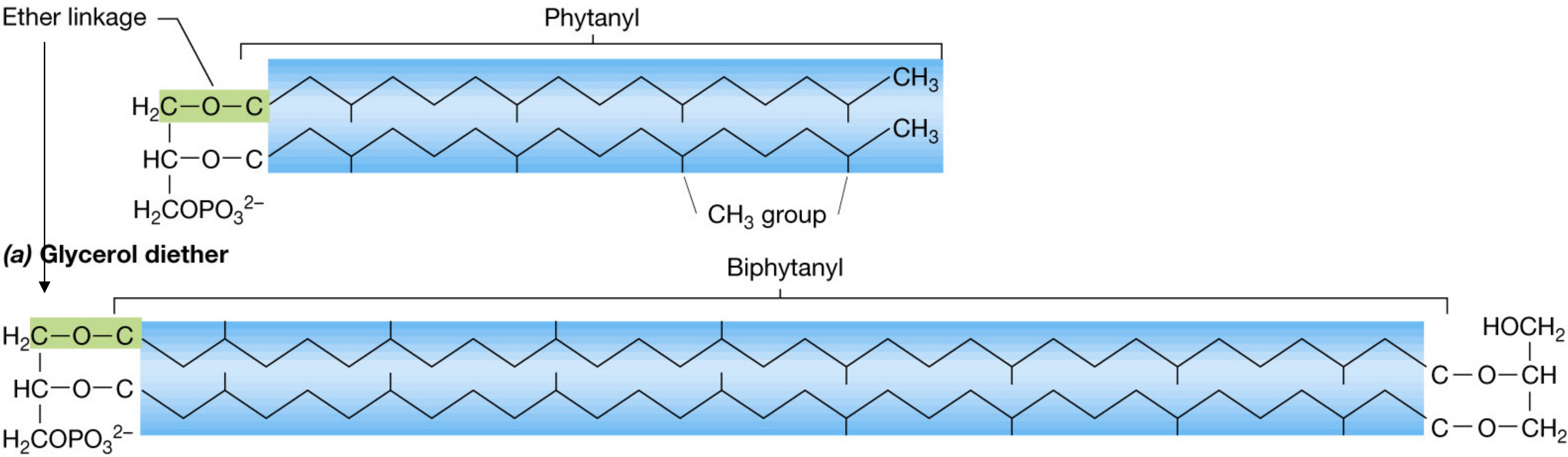

(B) A hopanoid from a cyanobacterium





Ester Linkage
Ether Linkage
Isoprene Unit
H2C—O—C—R
O
HC—O—C—R
O
H2C—O—P—O−
O
O−
(a)
H2C—O—C—R
HC—O—C—R
O
H2C—O—P—O−
O−
(b)
CH3
H2C=C—C=CH2
H
(c)
Fatty Acid

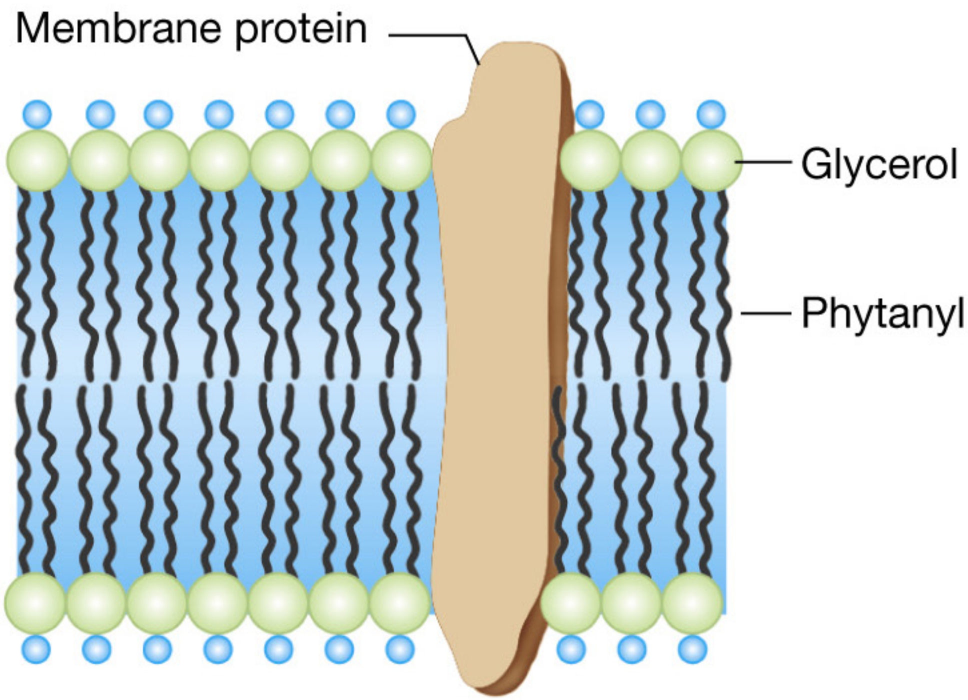
# Major lipids of *Archaea* and the structure of archaeal membranes



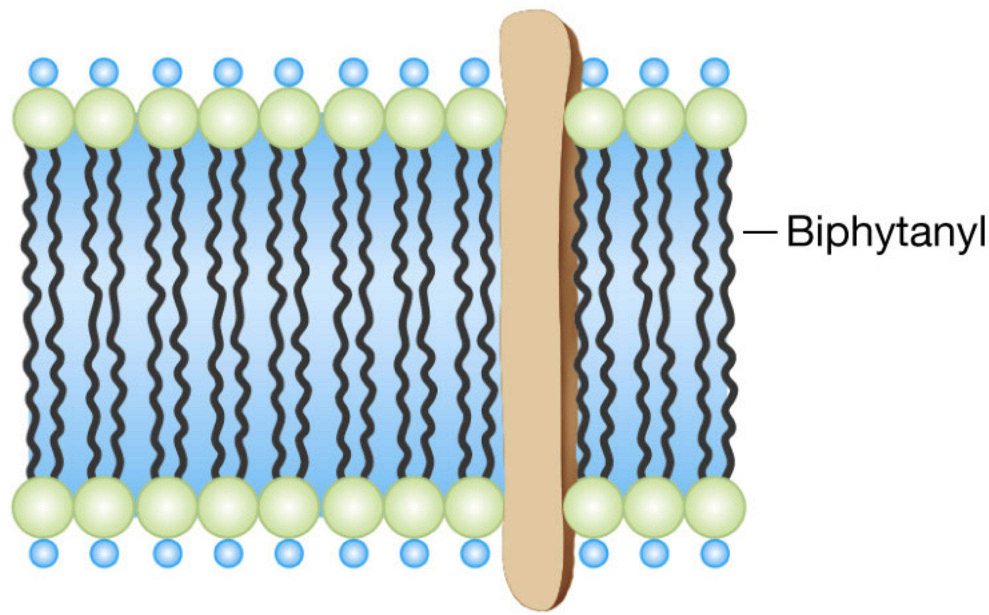

***(a)* Glycerol diether**

***(b)* Diglycerol tetraether**

# Major lipids of *Archaea* and the structure of archaeal membranes

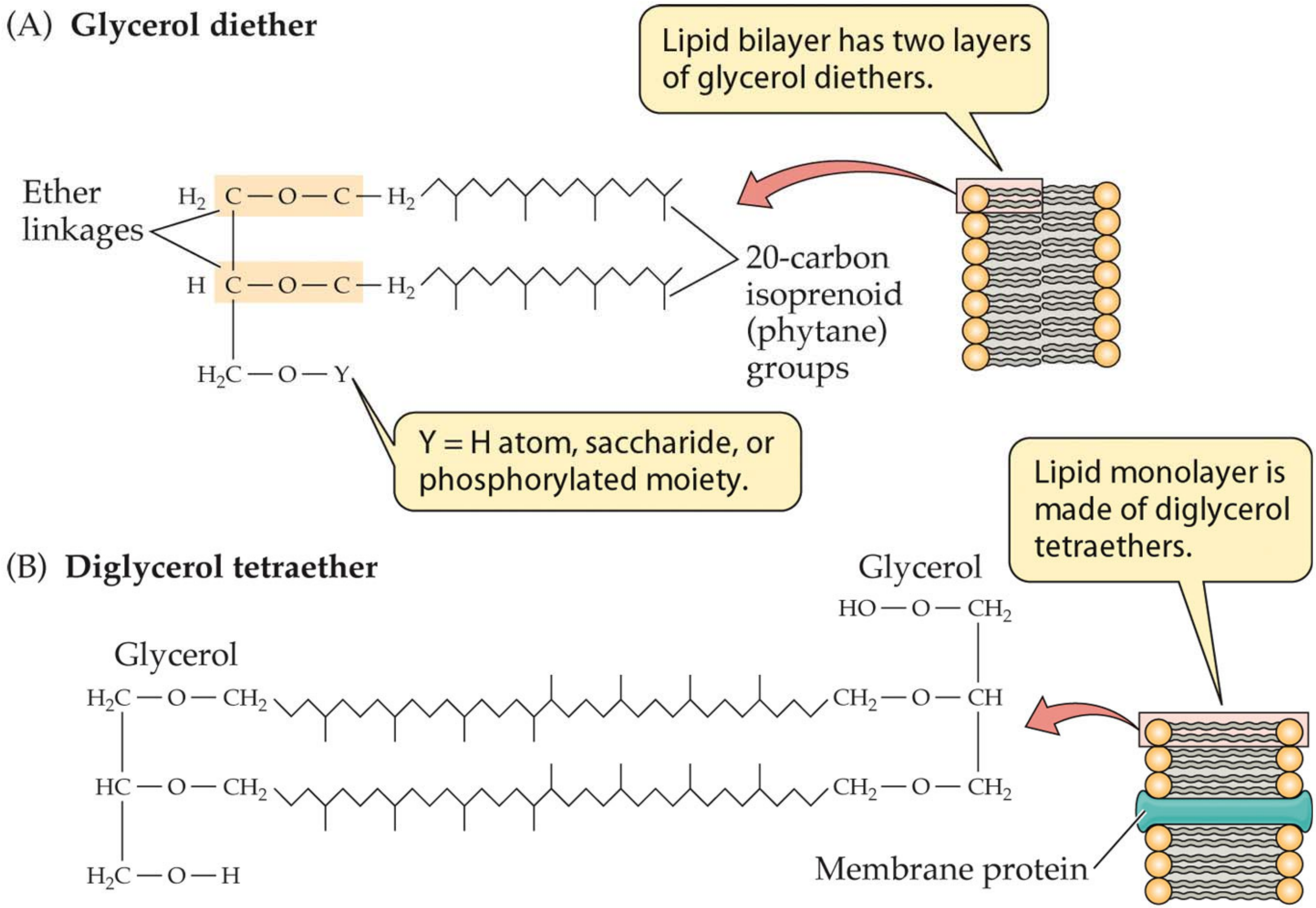



***(c)* Lipid bilayer**




***(d)* Lipid monolayer**

# Archaeal cell membrane structure



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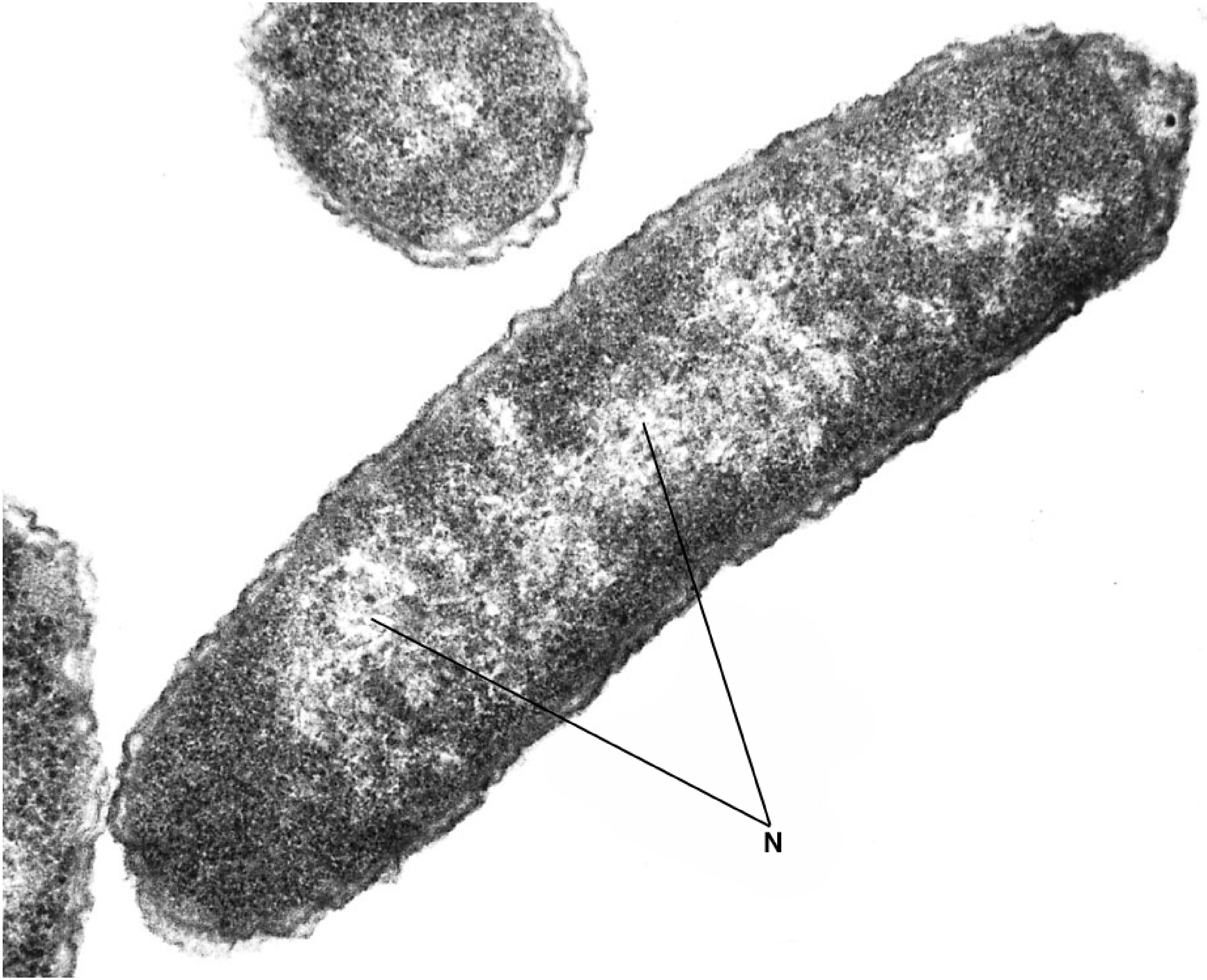
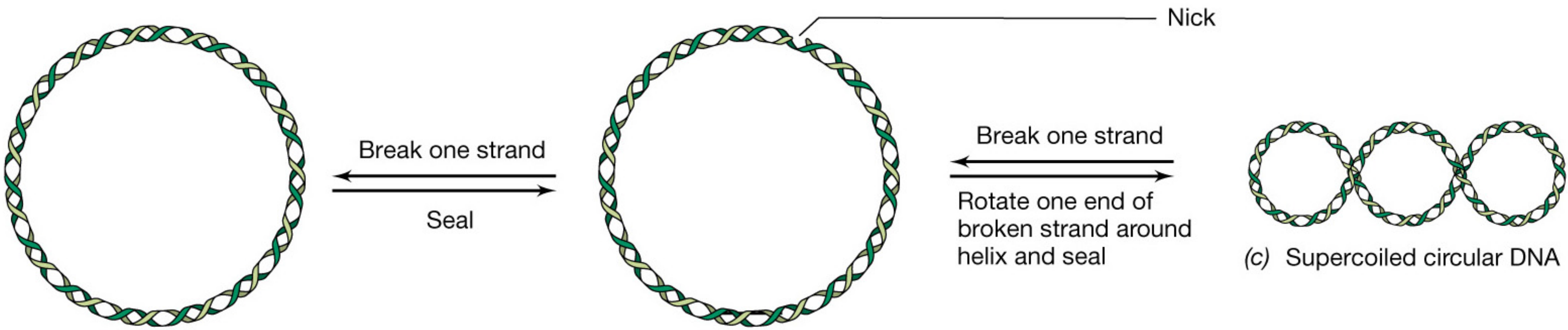
# Appearance of DNA by EM



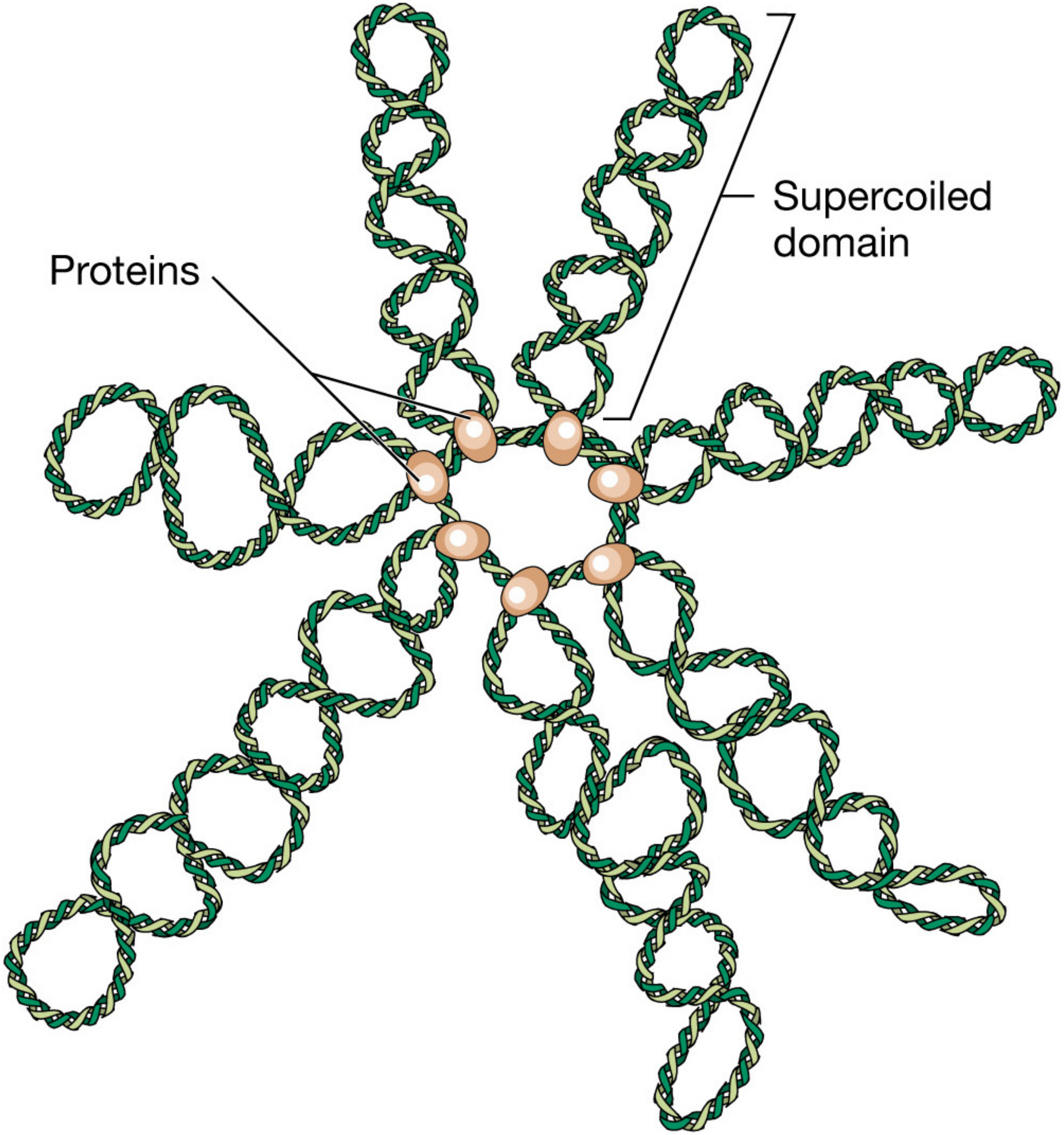
# DNA strands released from cell



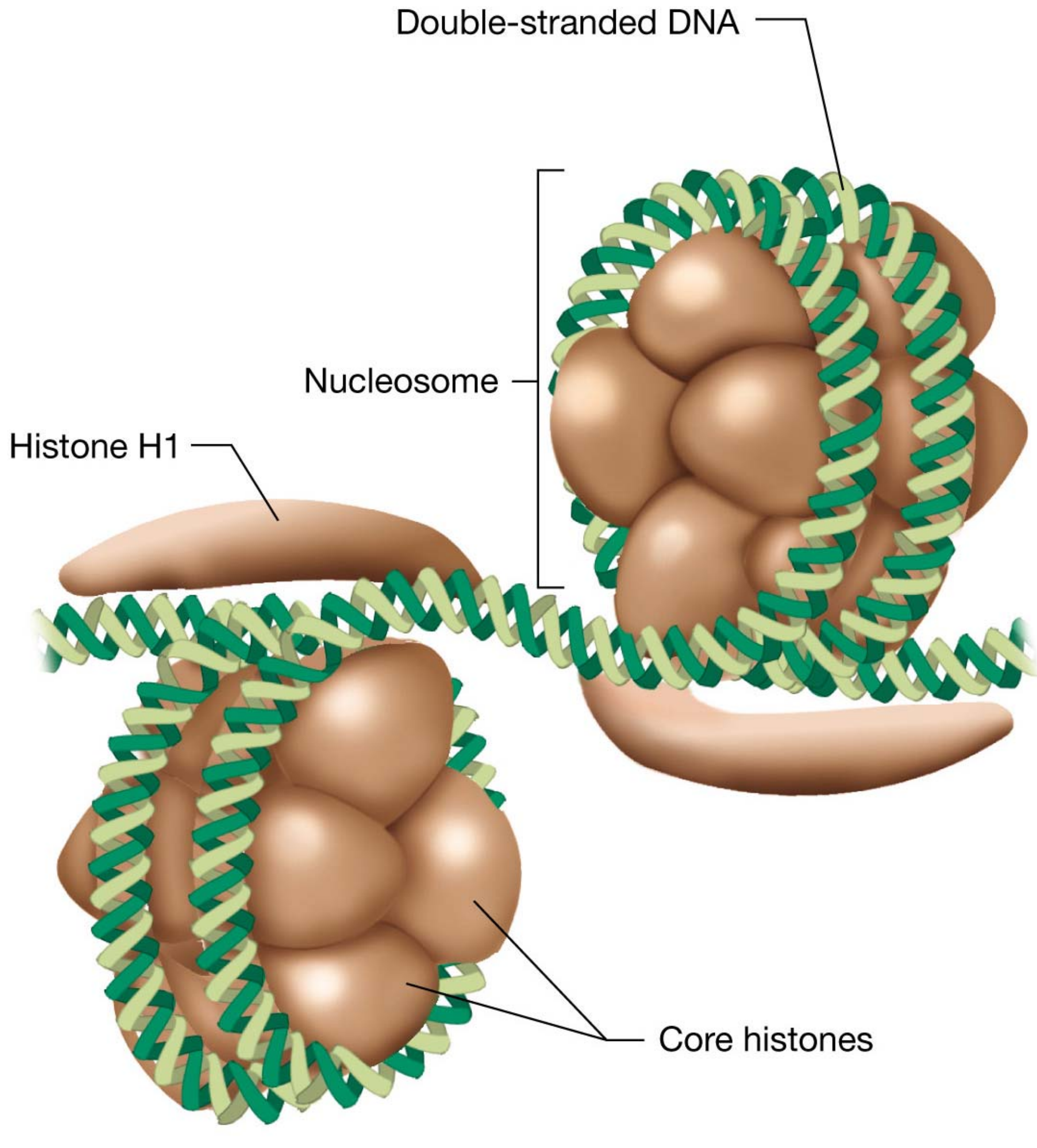

*(a)* Relaxed, covalently closed circular DNA

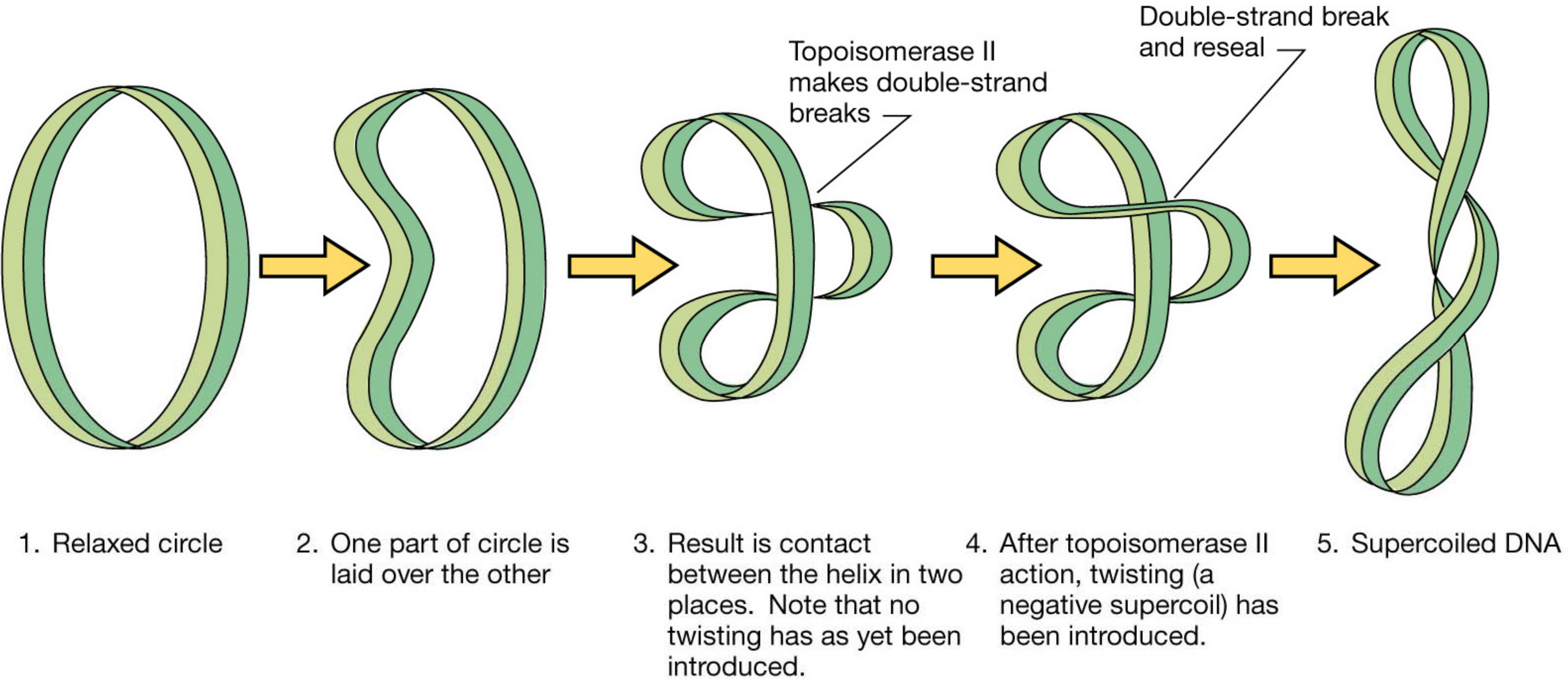
*(b)* Relaxed, nicked circular DNA

*(c)* Supercoiled circular DNA

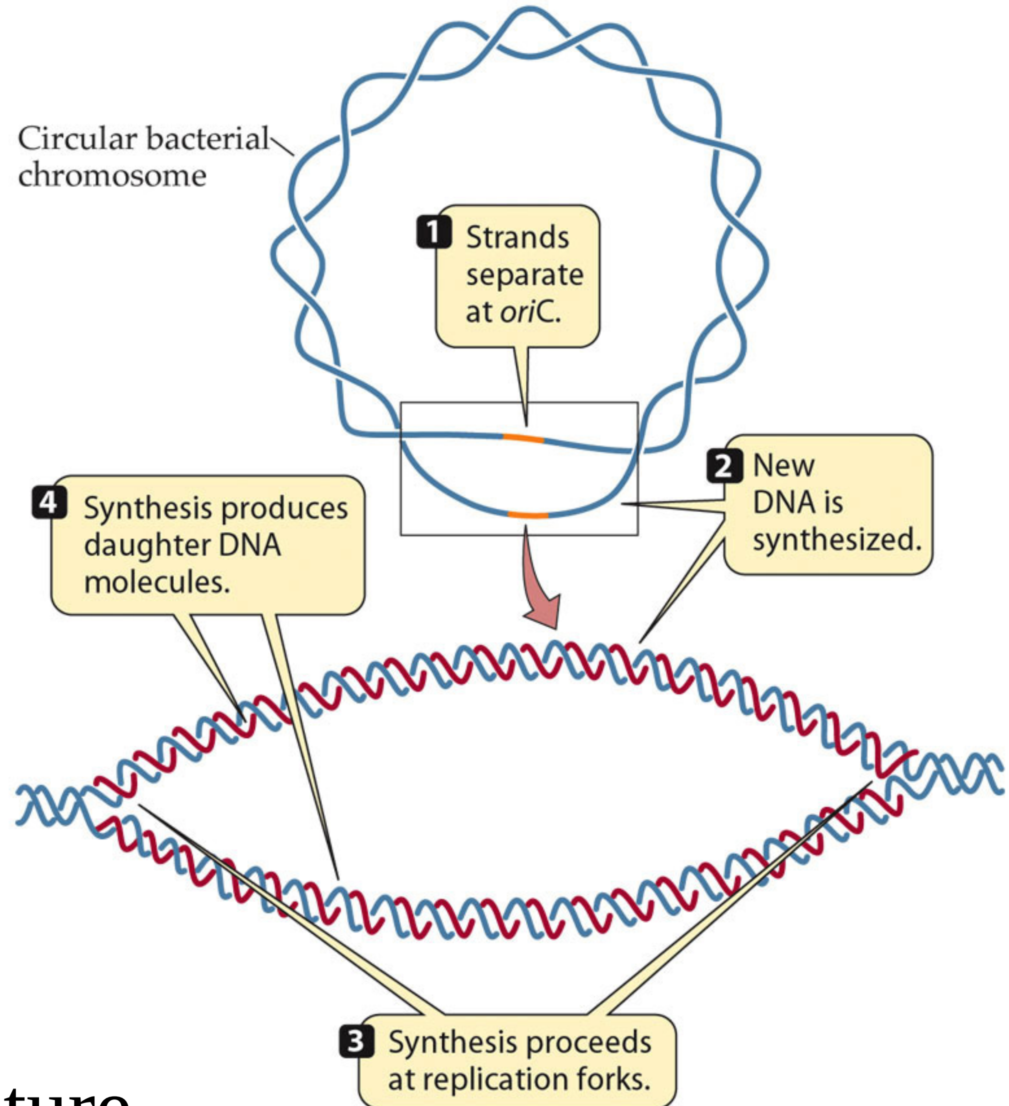



*(d)* Chromosomal DNA with supercoiled domains

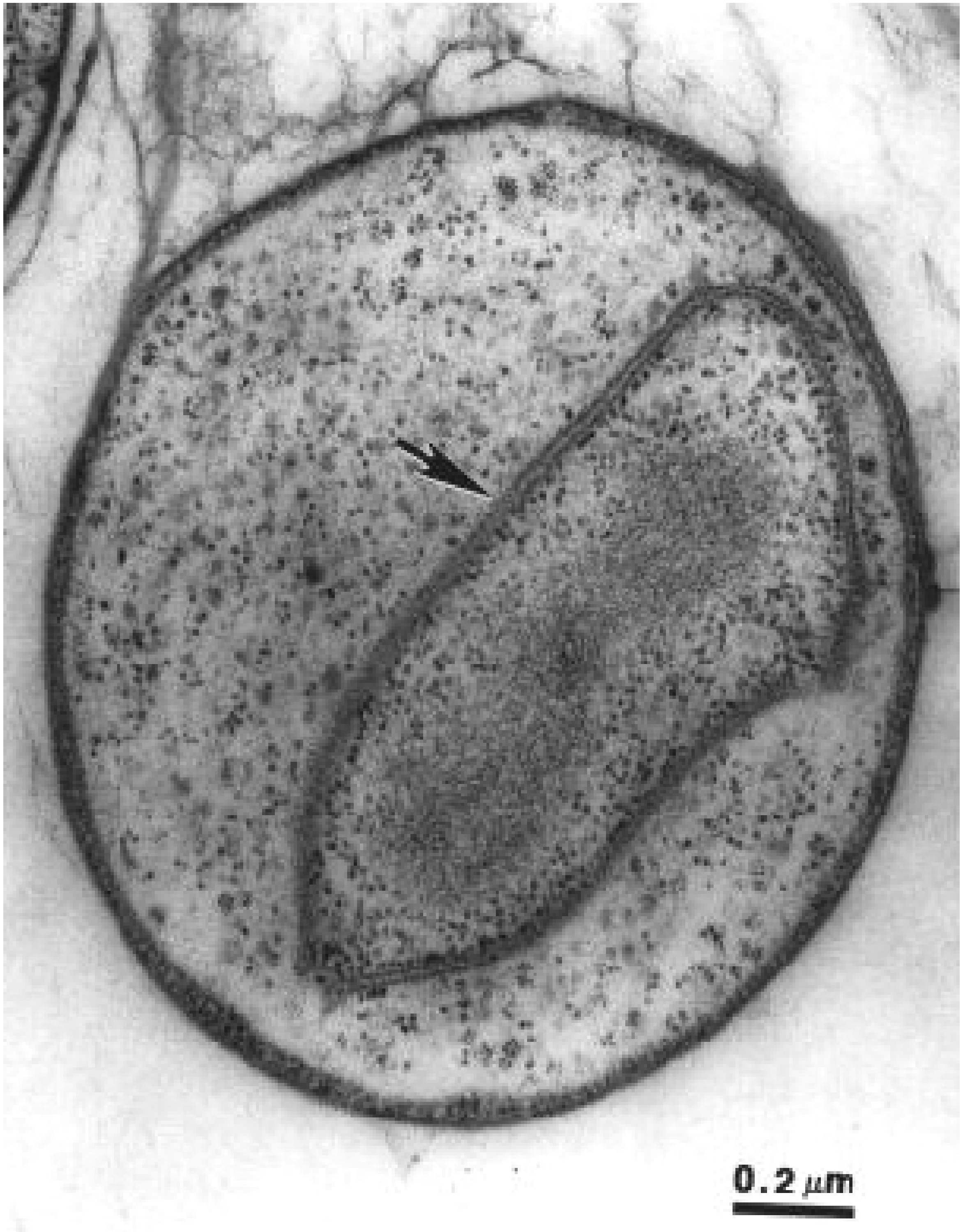

Double-stranded DNA
Nucleosome
Histone H1
Core histones


Topoisomerase II
makes double-strand
breaks
Double-strand break
and reseal
1. Relaxed circle
2. One part of circle is
laid over the other
3. Result is contact
between the helix in two
places. Note that no
twisting has as yet been
introduced.
4. After topoisomerase II
action, twisting (a
negative supercoil) has
been introduced.
5. Supercoiled DNA

# Overview of DNA replication




Theta Structure




***Gemmata obscuriglobus***

Membrane encompassed nucleoid

# Bacterial Morphologies