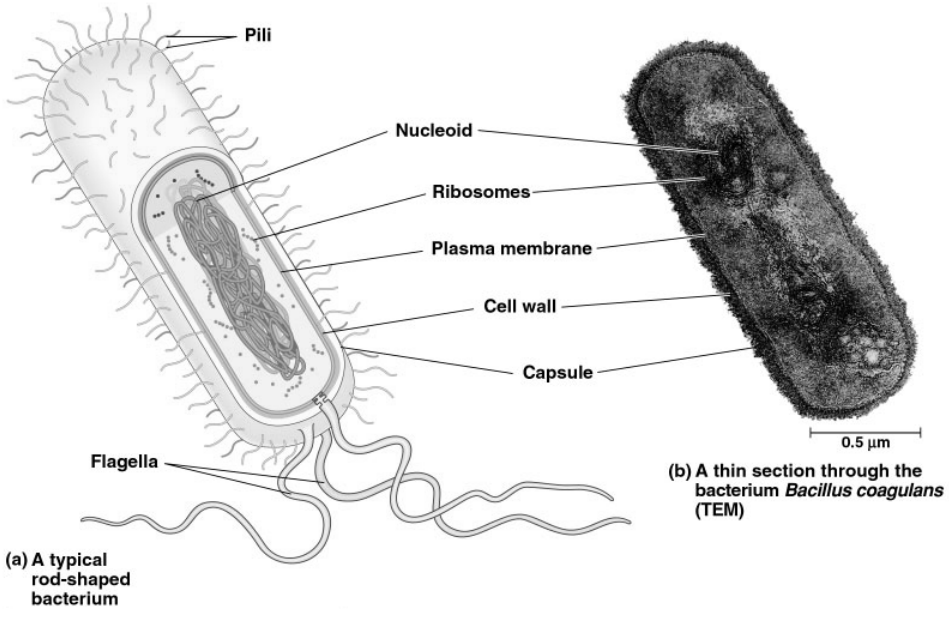
Comparing Prokaryotic and Eukaryotic Cells

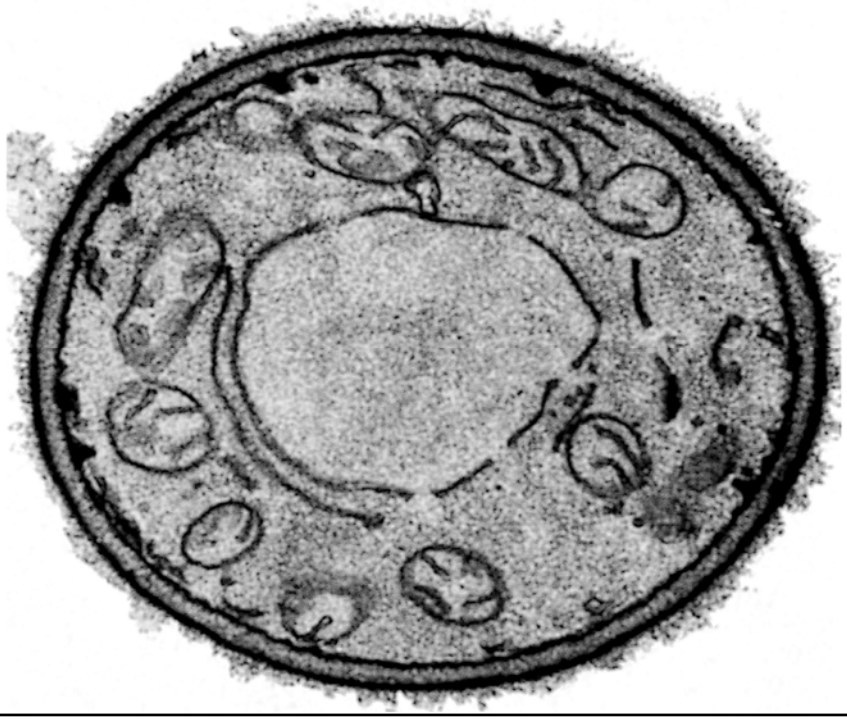
Basic unit of living organisms is the cell; the smallest unit capable of life.

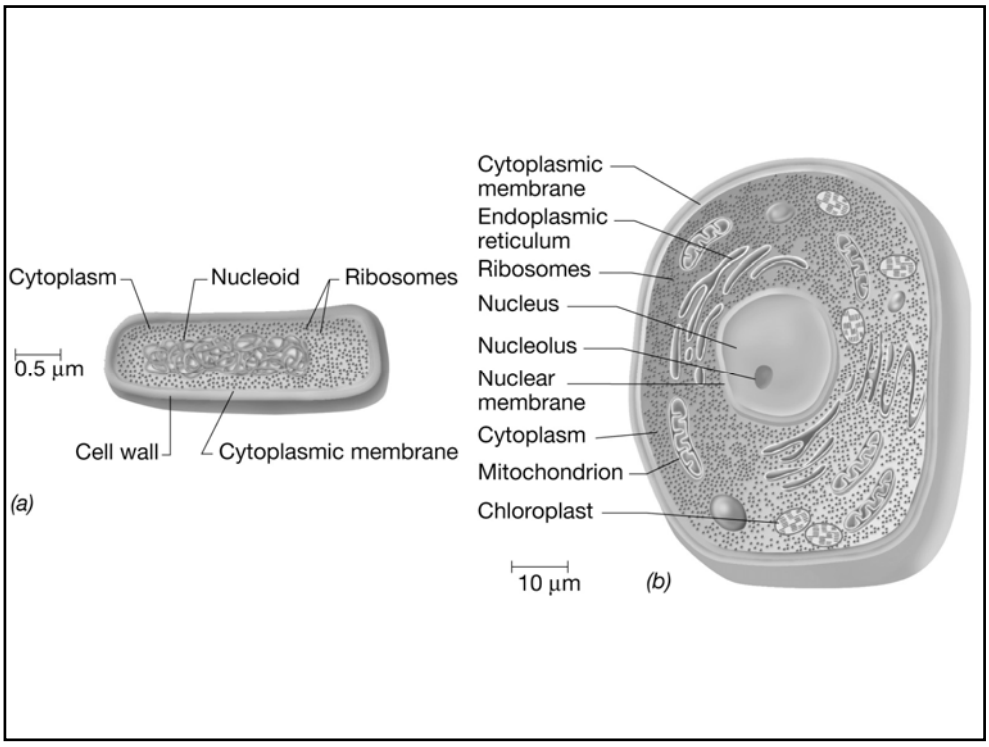
"Features" found in all cells:

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

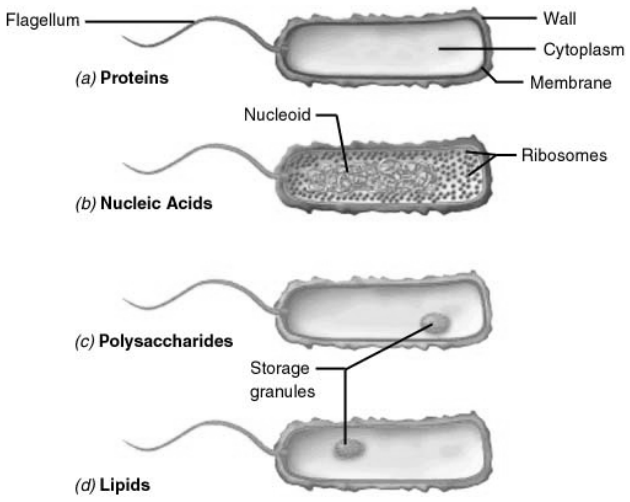
A prokaryotic cell







Locations of macromolecules in the cell



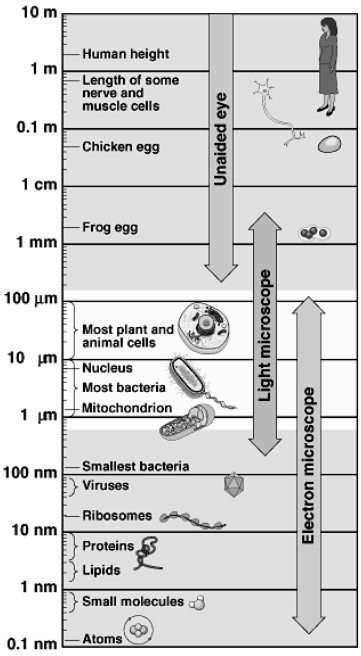
All over

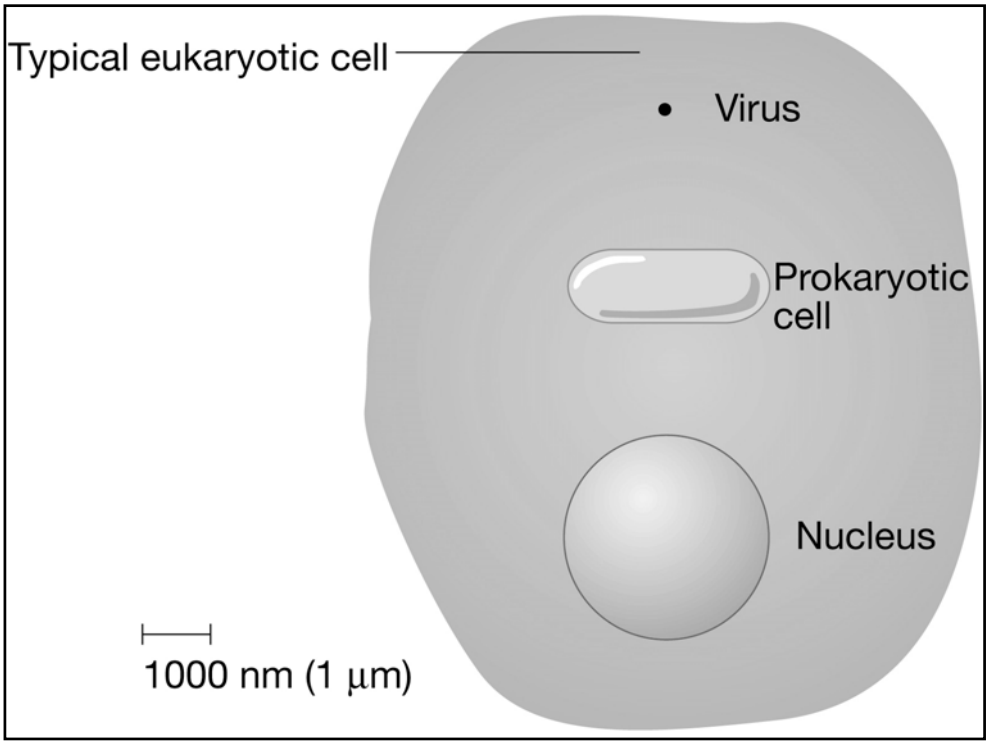
2 types mostly

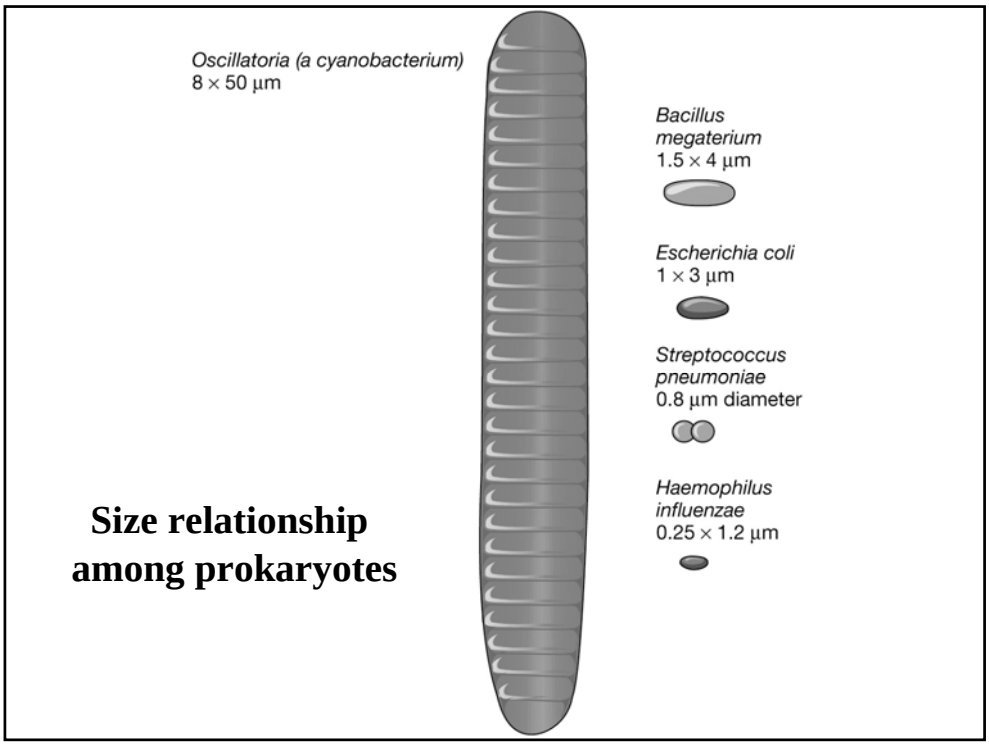
Cell Wall mostly

Cell Wall
Cell Mem

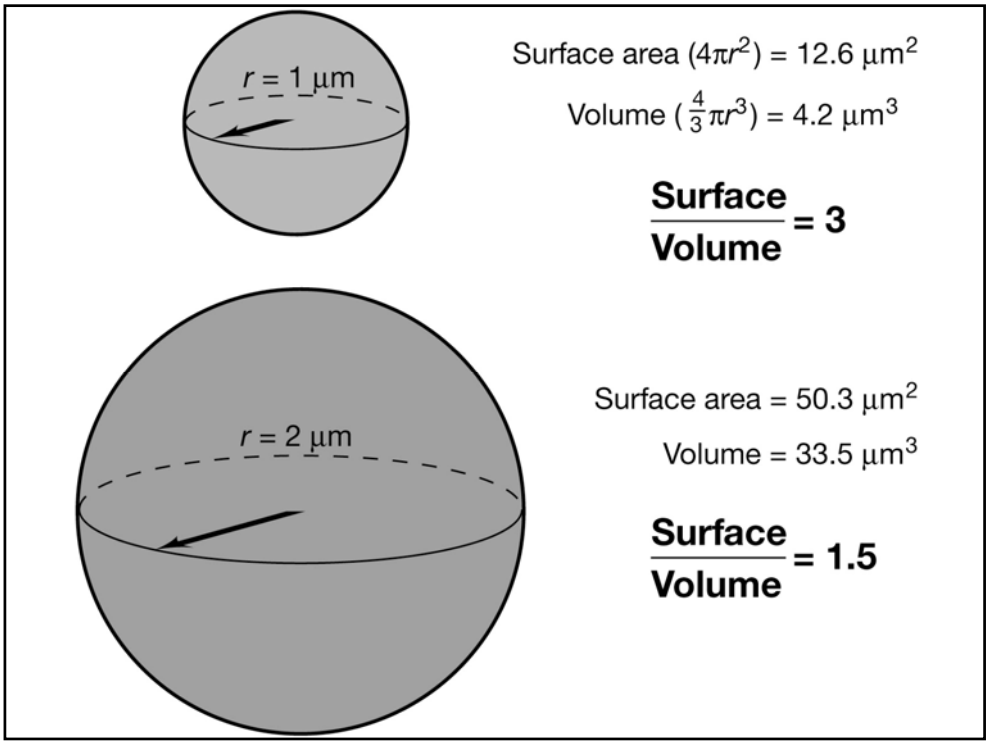
The size range of cells



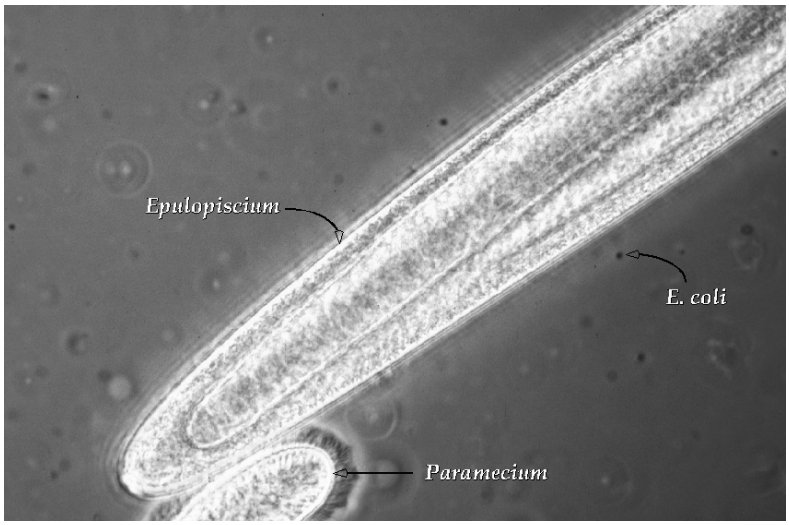




Size relationship among prokaryotes



A Million times bigger than E. coli!



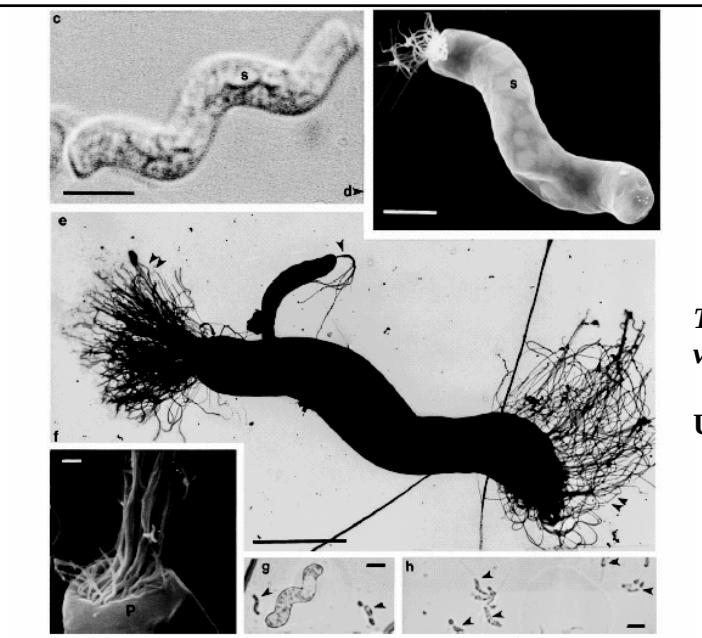


FIG. 1. (*a*) Mat surface at the Ebro Delta field site (3) showing lack of standing water. (Bar = 10 cm.) (*b*) Two spirilla cells (S, sulfur globule) shown by differential interference contrast (Nomarski). (Bar = 5 μm.) (*c*) Phase contrast microscopy of live spirillum cells. (Bar = 5 μm.) (*d*) Bipolar 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

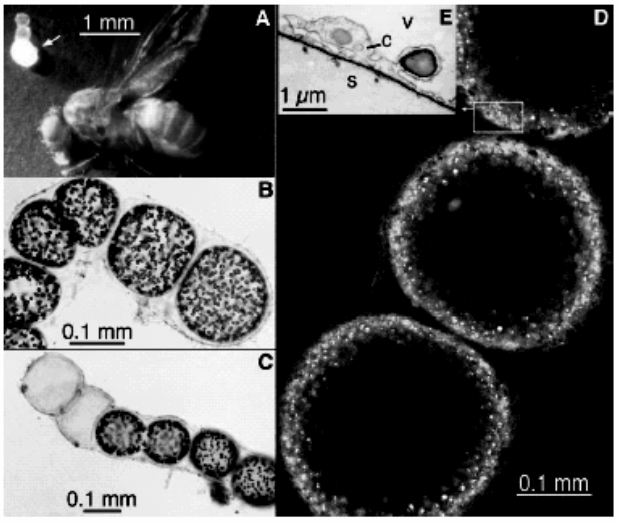
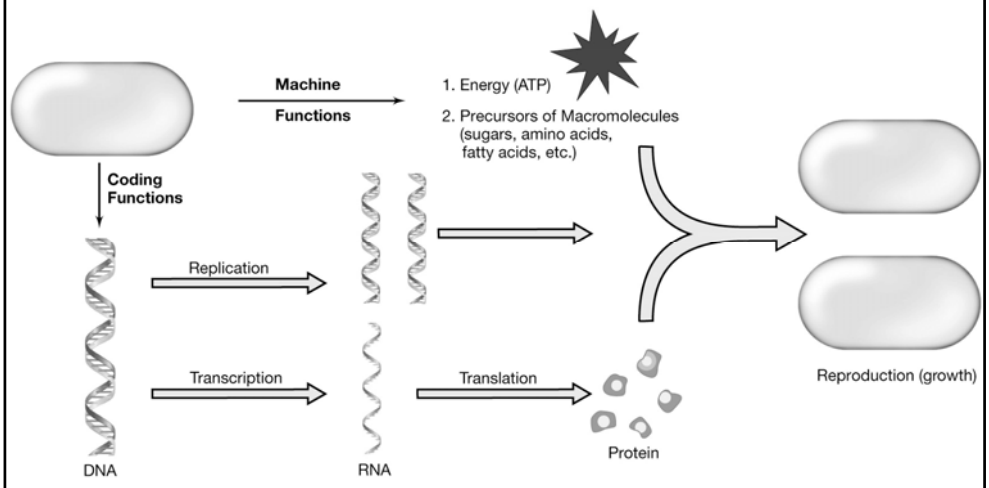


Fig. 1. *Thiomargarita namibiensis*. (A) The white arrow points to a single cell of *Thiomargarita*, 0.5 mm wide, which shines white because of internal sulfur inclusions. Above there is an empty part of the sheath, where the two neighboring cells have died. The cell was photographed next to a fruit fly (*Drosophila virilis*) 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⟩ 1
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* ≅ 2.8×10^{-13} g; total weight (70% water) = 9.5×10^{-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

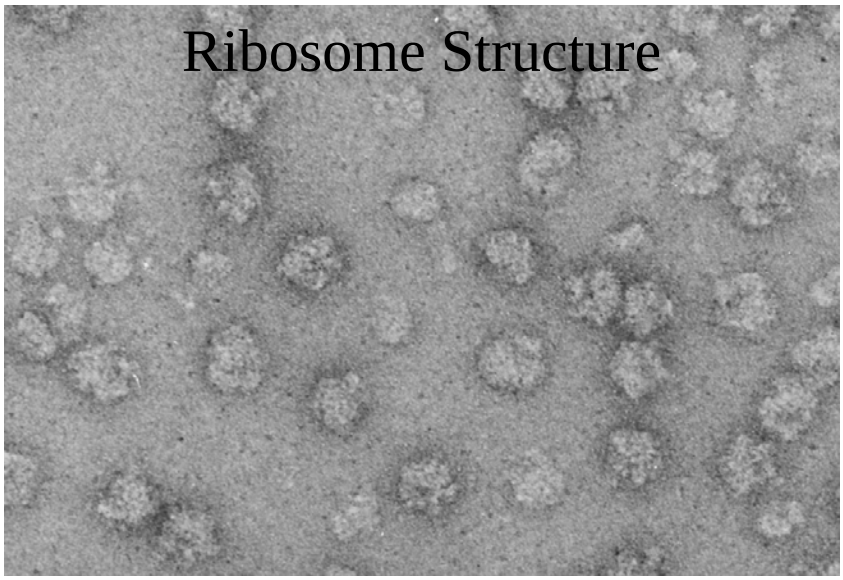
Peptidoglycan is 1 jumbo molecule

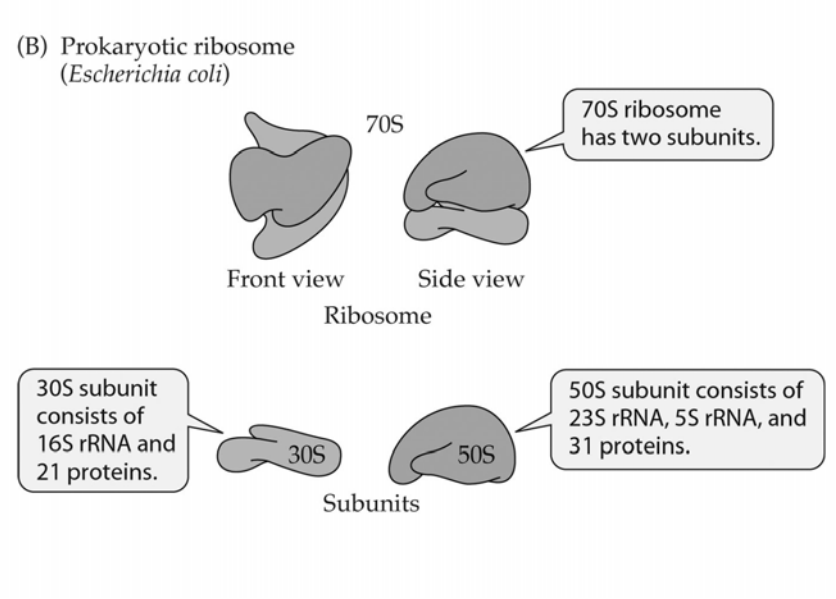
Comparing Prokaryotic and Eukaryotic Cells

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





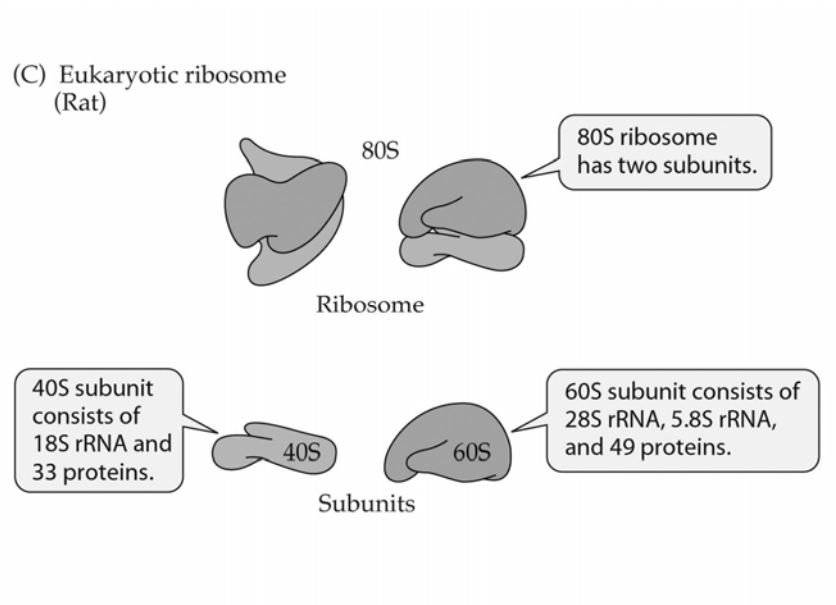
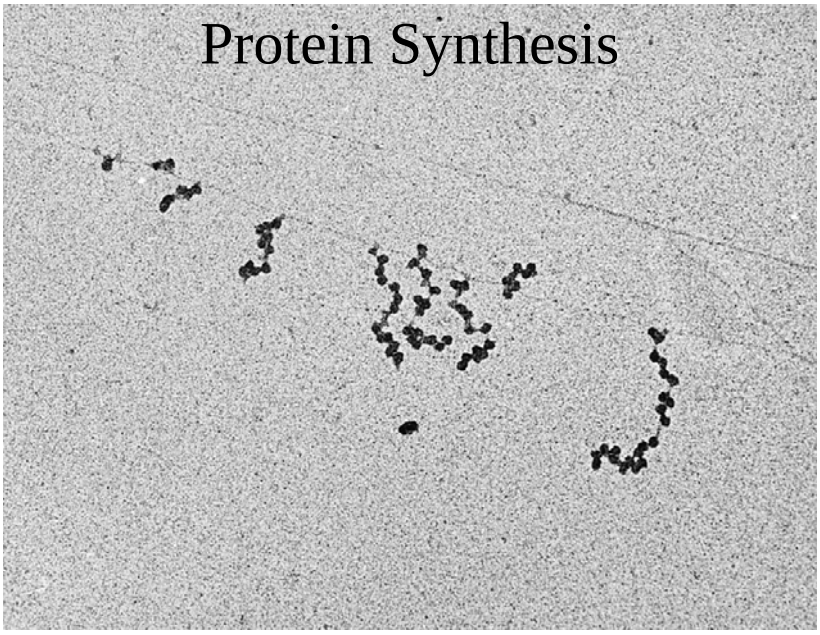


TABLE 7.4 Ribosome structure[a]

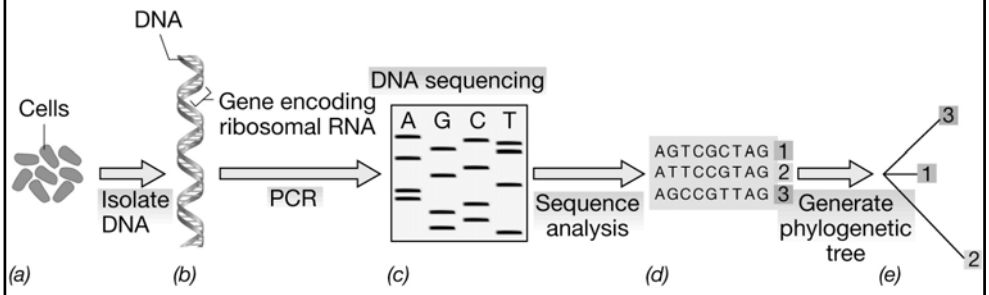
Property	Prokaryote	Eukaryote
Overall size	70S	80S
Small subunit	30S	40S
Number of proteins	~21	~30
RNA size (number of bases)	16S (1500)	18S (2300)
Large subunit	50S	60S
Number of proteins	~34	~50
RNA size (number of bases)	23S (2900) 5S (120)	28S (4200) 5.8S (160) 5S (120)

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



Importance of a Molecular Biological Approach

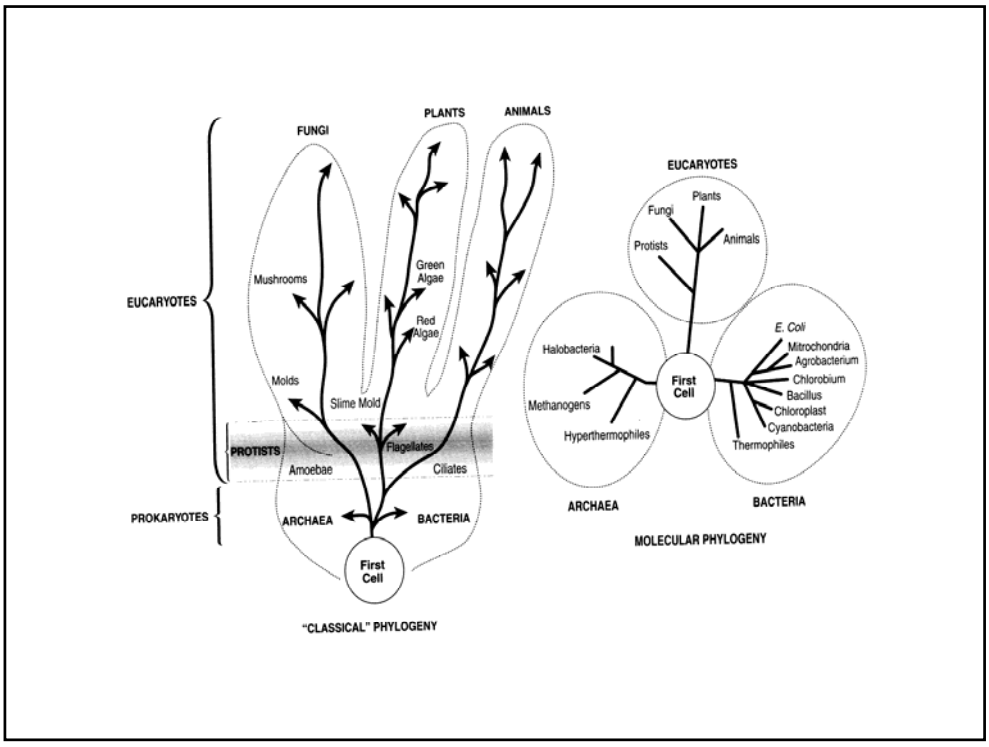
- **Traditional culturing** techniques isolate ~1% of the total bacteria in marine ecosystems, thereby severely underestimating diversity and community structure.
- Because nutrient-rich **culture media** have been historically used during enrichment procedures, bacteria which may be dominant in natural 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.

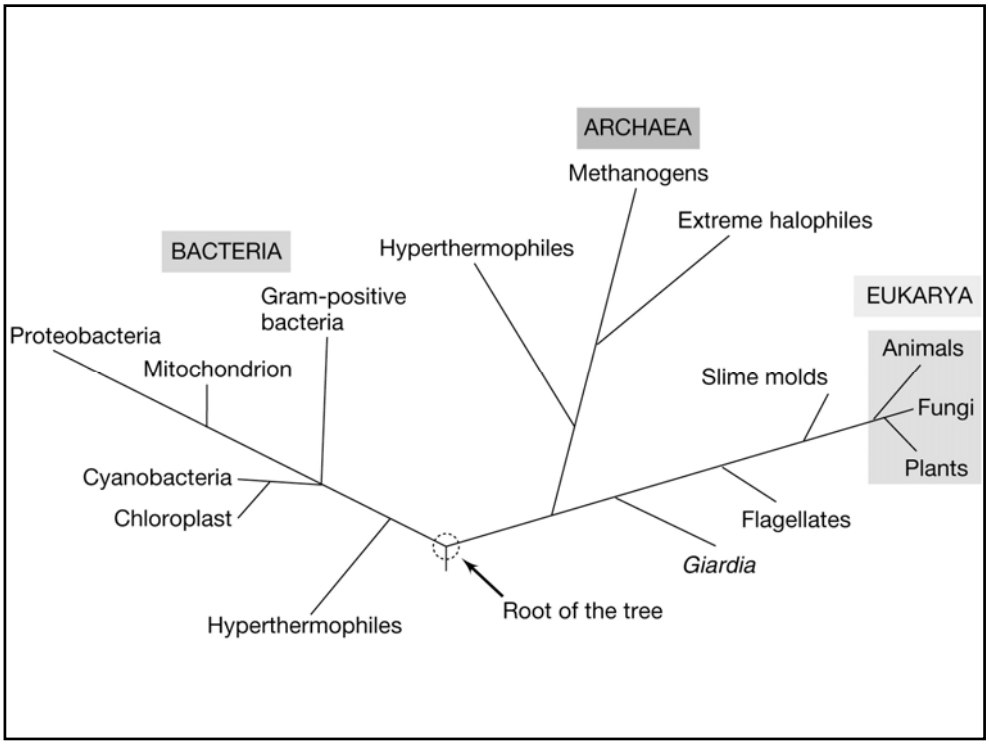


Regarding Molecular Phylogeny

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.


FUNGI
PLANTS
ANIMALS
EUCARYOTES
Mushrooms
Green Algae
Red Algae
Molds
Slime Mold
PROTISTS
Flagellates
Amoebae
Ciliates
PROKARYOTES
ARCHAEA
BACTERIA
First Cell
"CLASSICAL" PHYLOGENY
EUCARYOTES
Plants
Fungi
Protists
Animals
E. Coli
Mitrochondria
Agrobacterium
Chlorobium
Bacillus
Chloroplast
Cyanobacteria
Halobacteria
Methanogens
Hyperthermophiles
First Cell
Thermophiles
ARCHAEA
BACTERIA
MOLECULAR PHYLOGENY


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

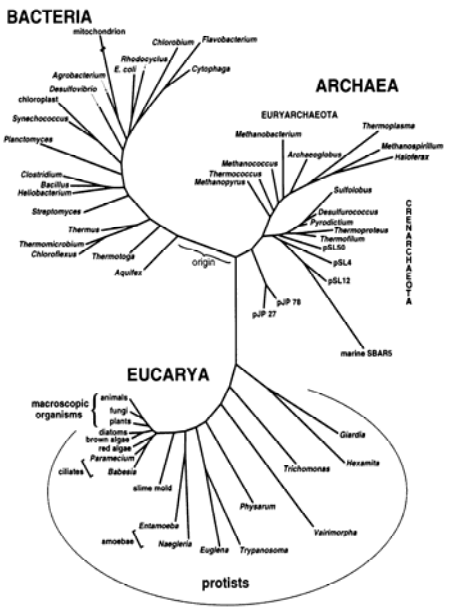


Figure 1. Diagrammatic "Universal" phylogenetic tree of life, based on small-subunit ribosomal RNA sequences. Based on analyses of Barns et al. (1996b), Olsen et al. (1994), and Sogin (1994).

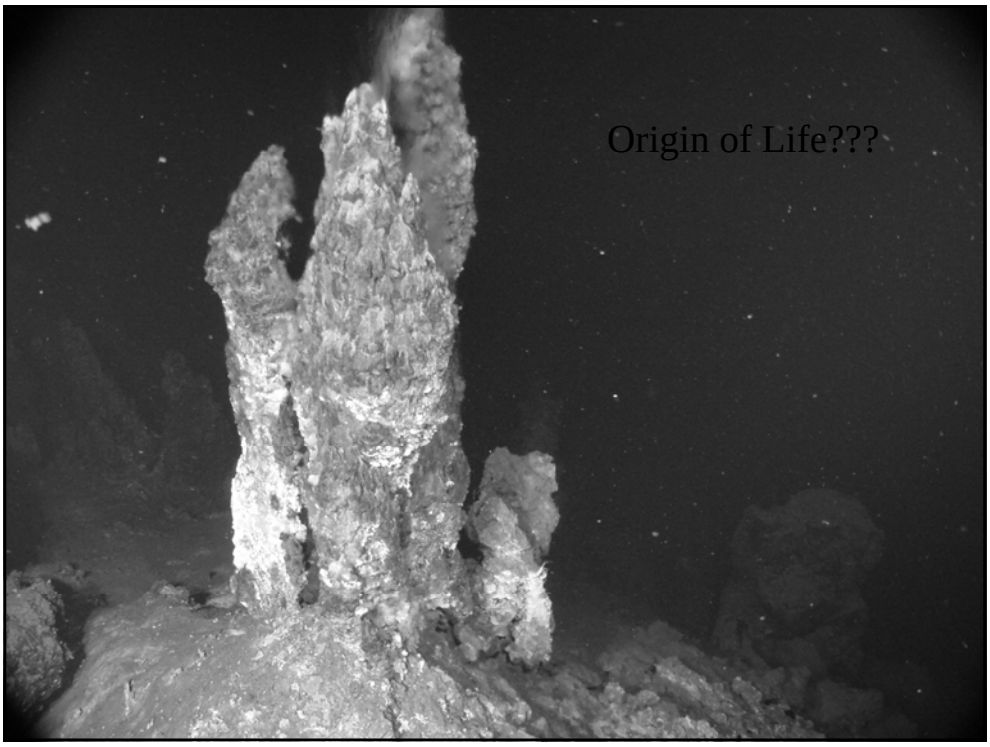
Some Lessons from the BIG TREE: Map of the Biological Record

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



Comparing Prokaryotic and Eukaryotic Cells

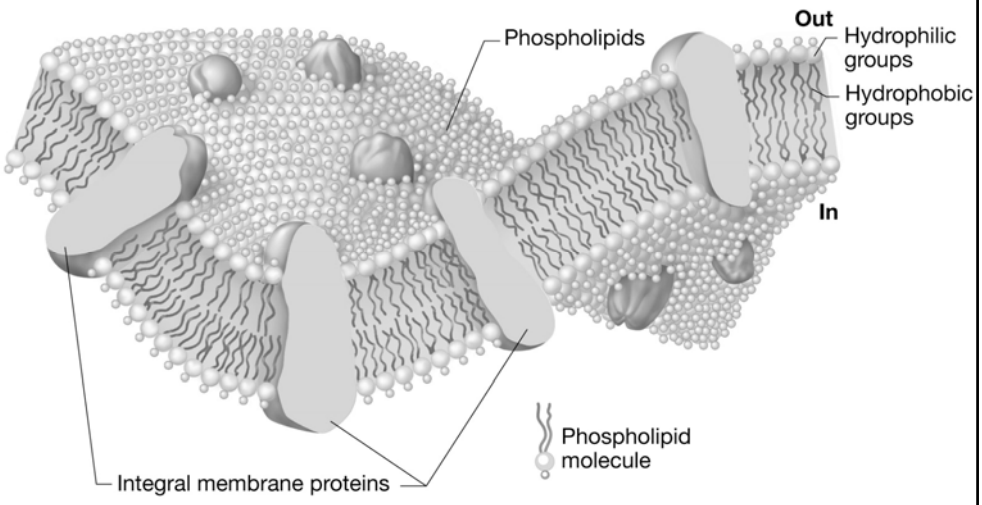
Classification of prokaryotic cellular features:
Invariant (or common to all)

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

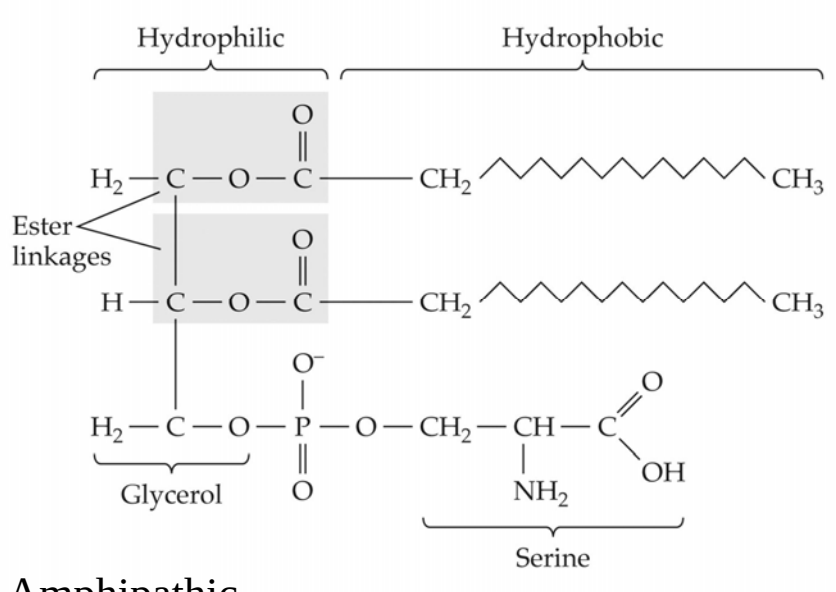
⇨ • **Cell Membranes: The barrier between order and chaos**

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

The cytoplasmic membrane

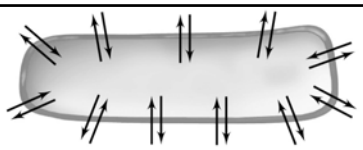


Rem: Fluid Mosaic Model

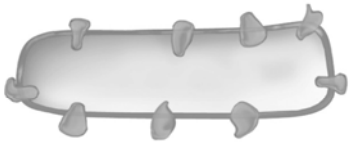


Amphipathic

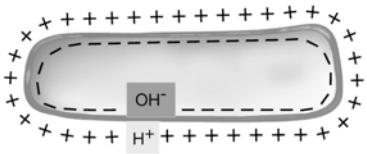
Functions of the cytoplasmic membrane



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

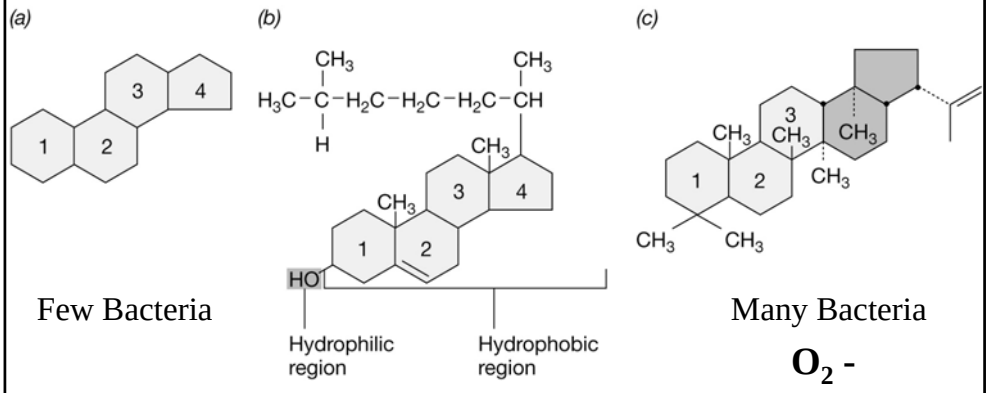


Energy Conservation — Site of generation and use of the proton motive force

Sterol

Cholesterol

Hopanoid
(e.g., Diploptene)



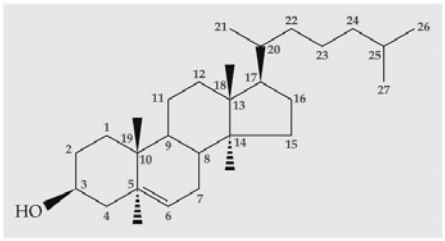
Few Bacteria

Many Bacteria

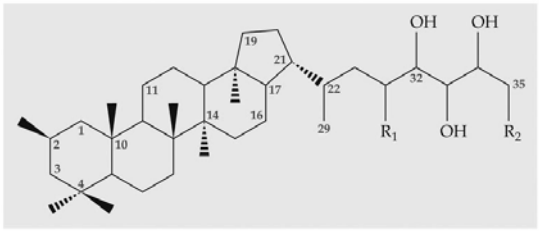
O_2 -

All rigid planar molecules

(A) Cholesterol



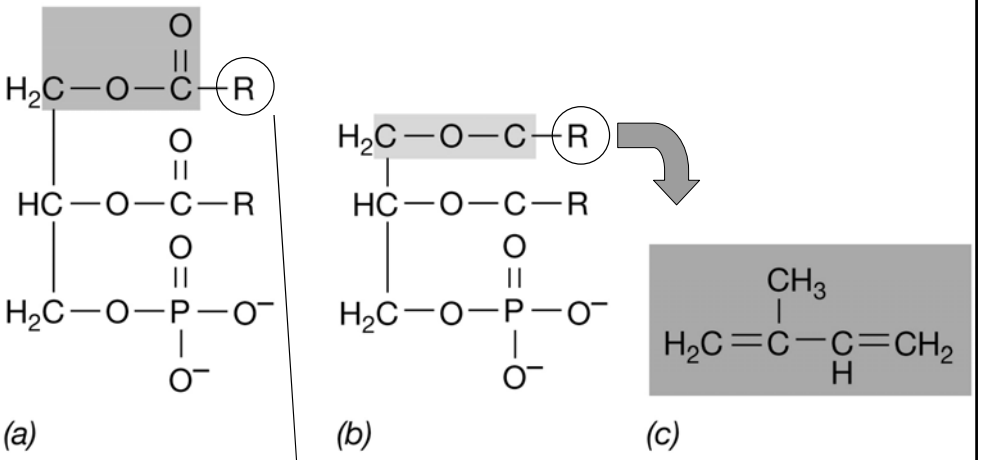
(B) A hopanoid from a cyanobacterium



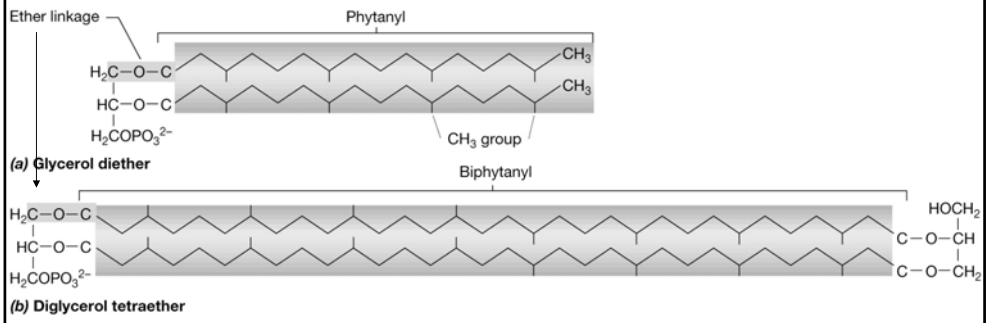
Ester Linkage

Ether Linkage

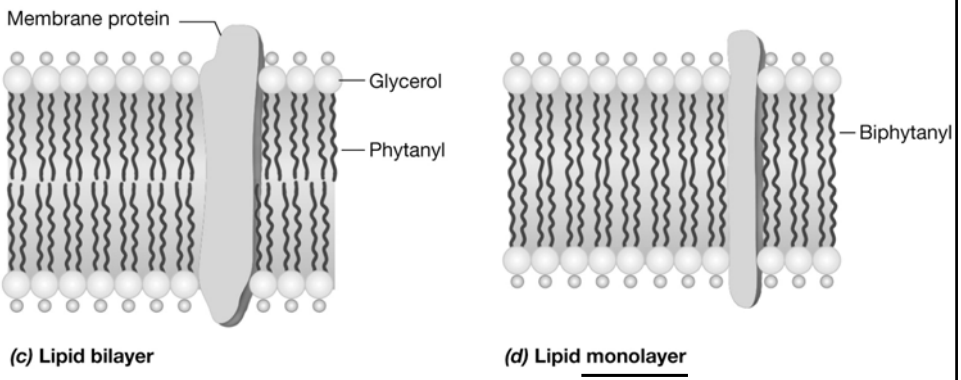
Isoprene Unit



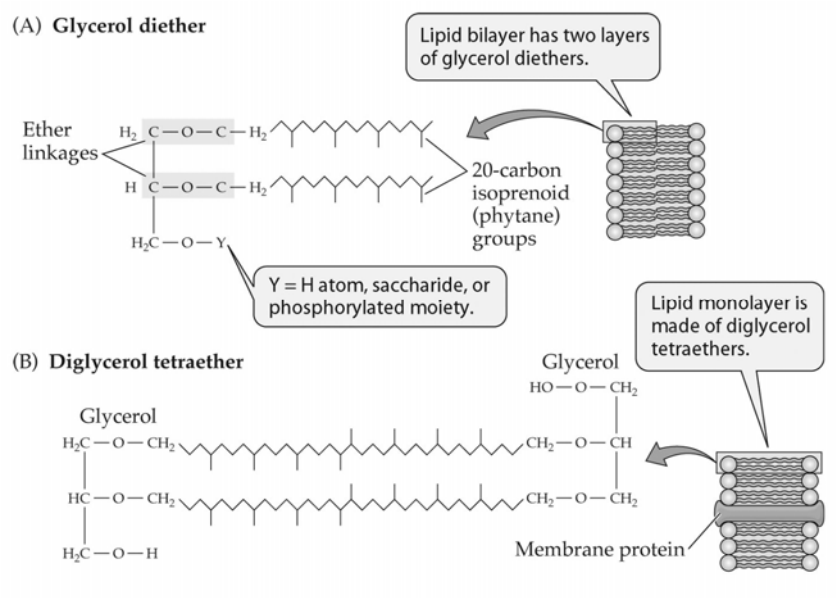
Major lipids of *Archaea* and the structure of archaeal membranes



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



Archaeal cell membrane structure



Comparing Prokaryotic and Eukaryotic Cells

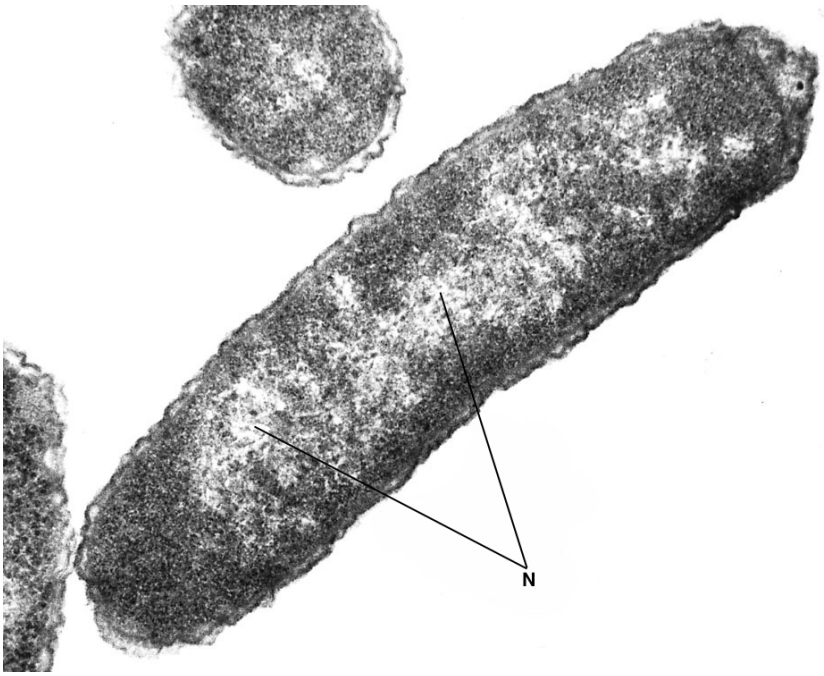
Classification of prokaryotic cellular features:
Invariant (or common to all)

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

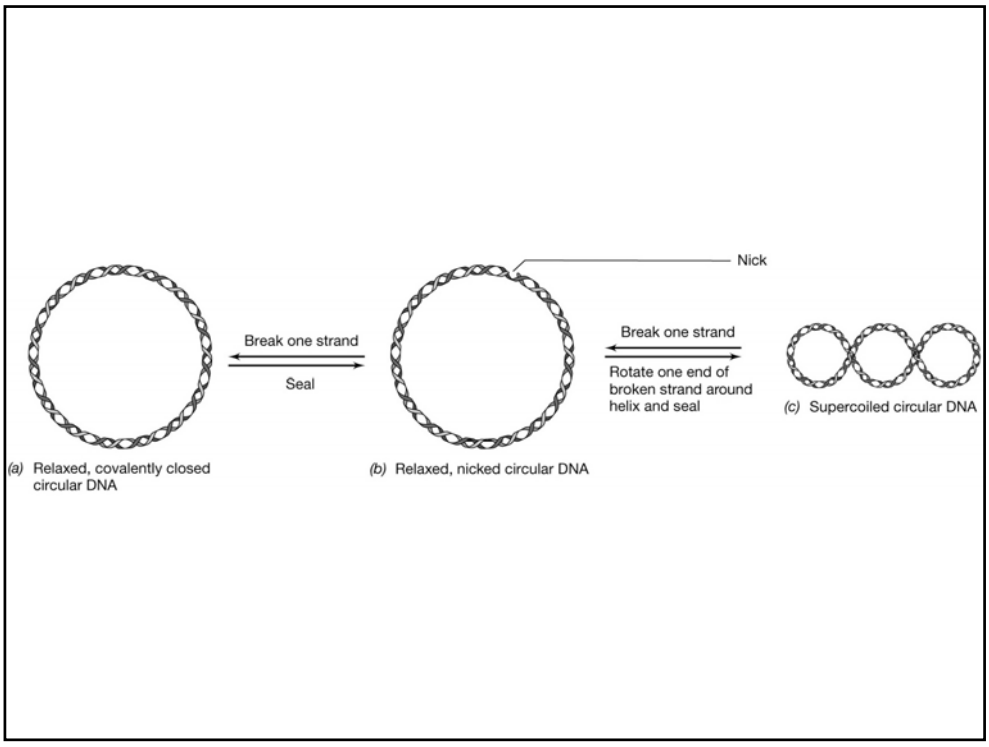
- **Cell Membranes: The barrier between order and chaos**

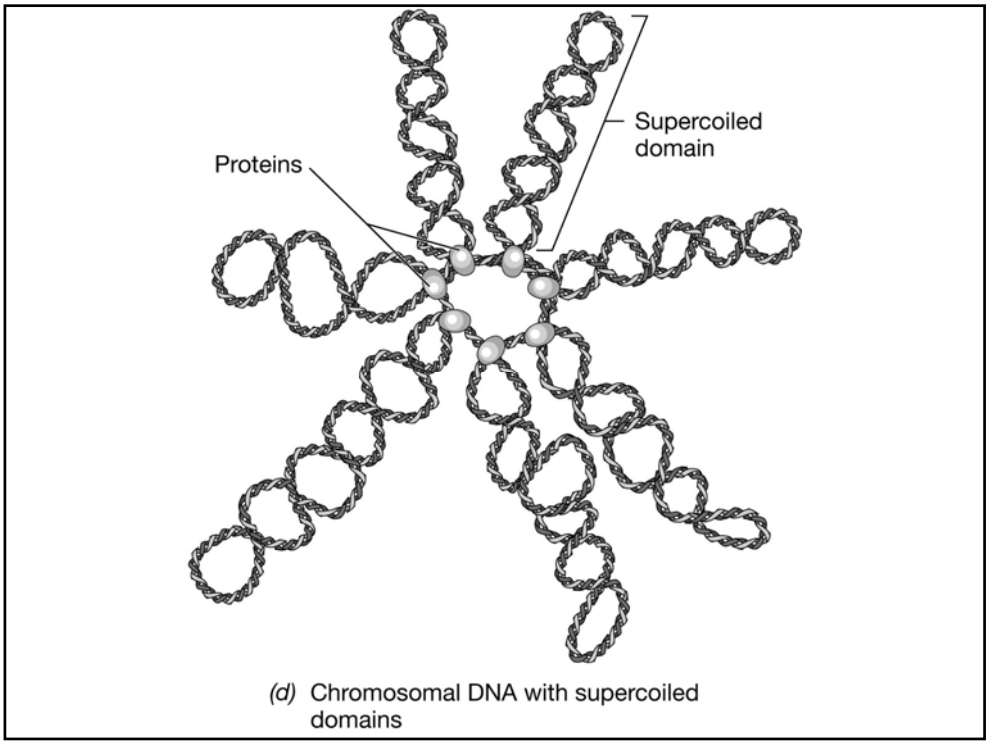
➡ • **Nucleoid Region: Curator of the Information**

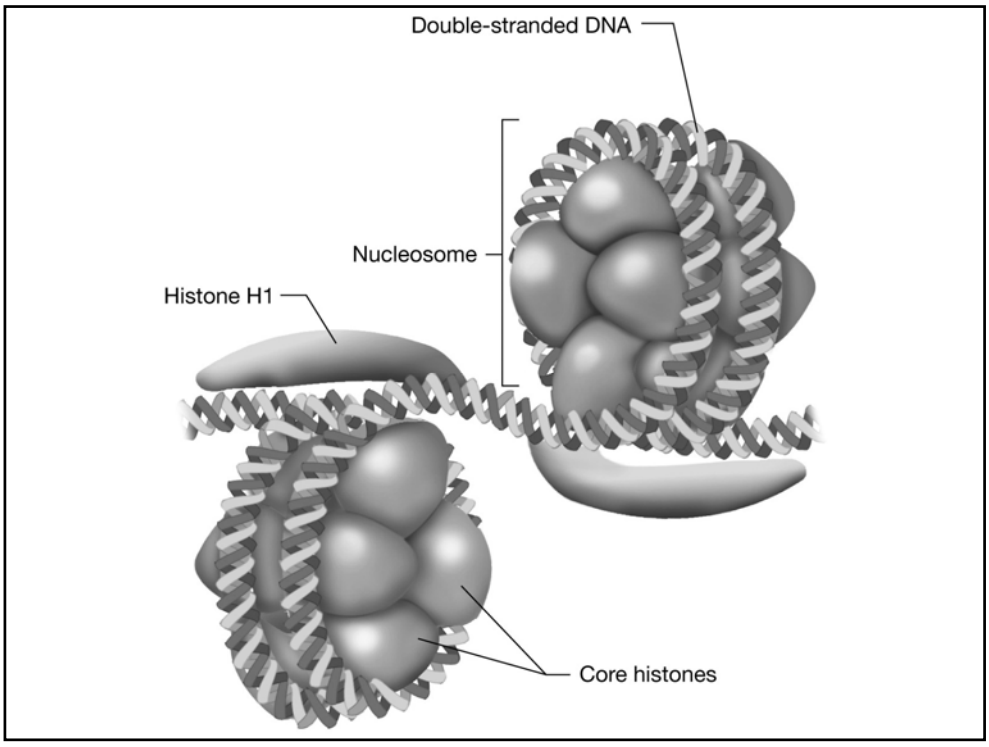
Appearance of DNA by EM

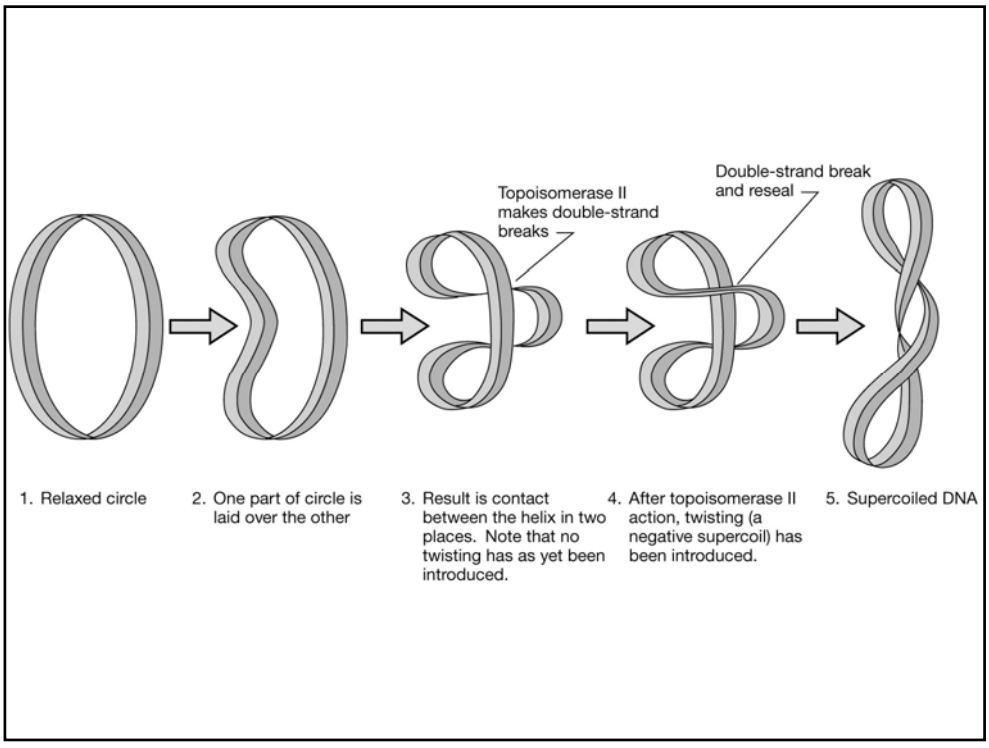


DNA strands released from cell

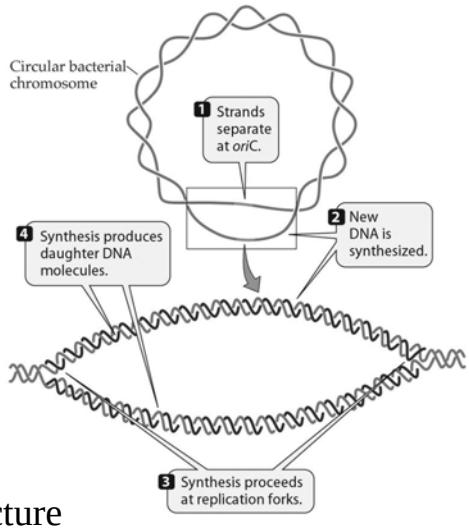

Nick
Break one strand
Seal
Break one strand
Rotate one end of broken strand around helix and seal
(a) Relaxed, covalently closed circular DNA
(b) Relaxed, nicked circular DNA
(c) Supercoiled circular DNA


Supercoiled domain
Proteins
(d) Chromosomal DNA with supercoiled domains

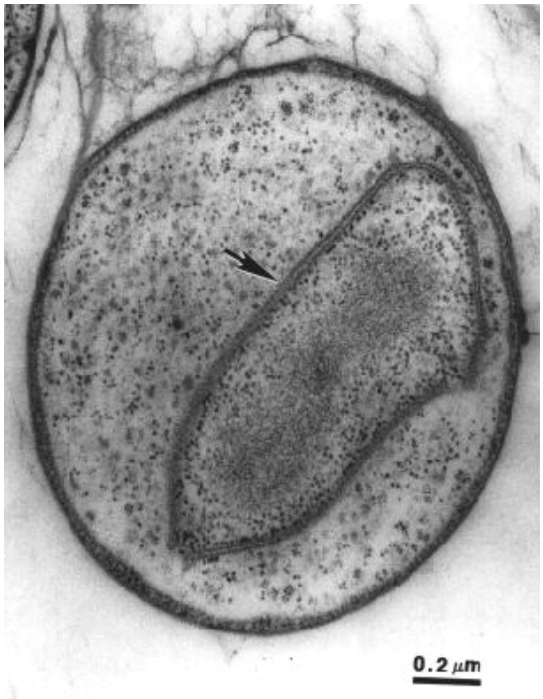

Double-stranded DNA
Nucleosome
Histone H1
Core histones


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

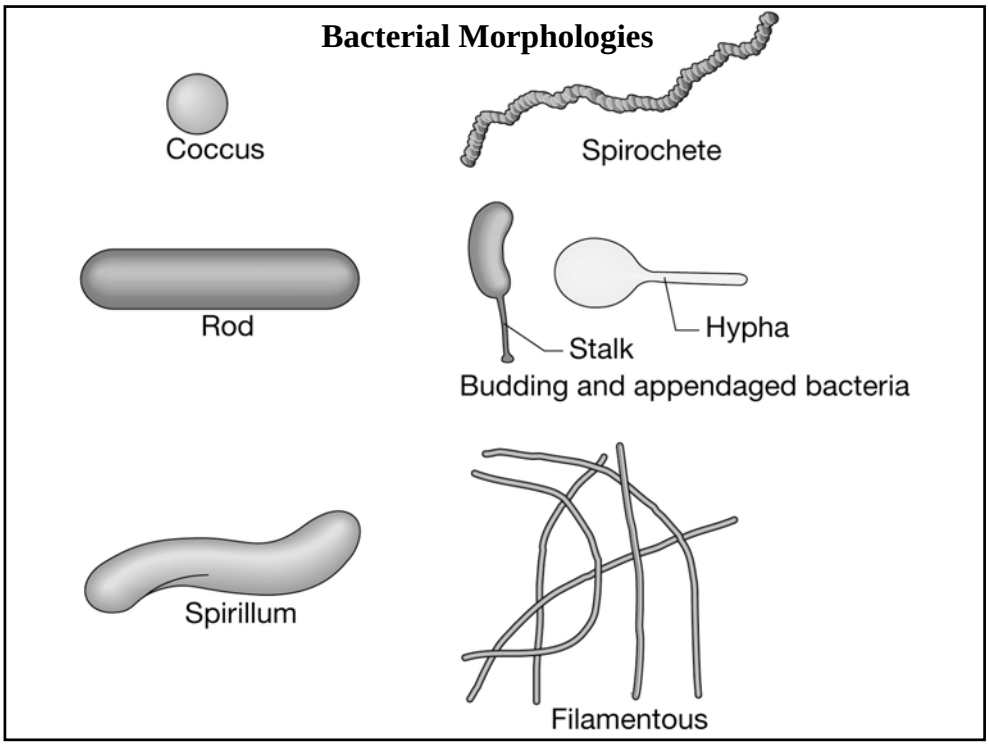


Theta Structure



Gemmata obscuriglobus

Membrane encompassed nucleoid


Bacterial Morphologies
Coccus
Spirochete
Rod
Stalk
Hypha
Budding and appendaged bacteria
Spirillum
Filamentous