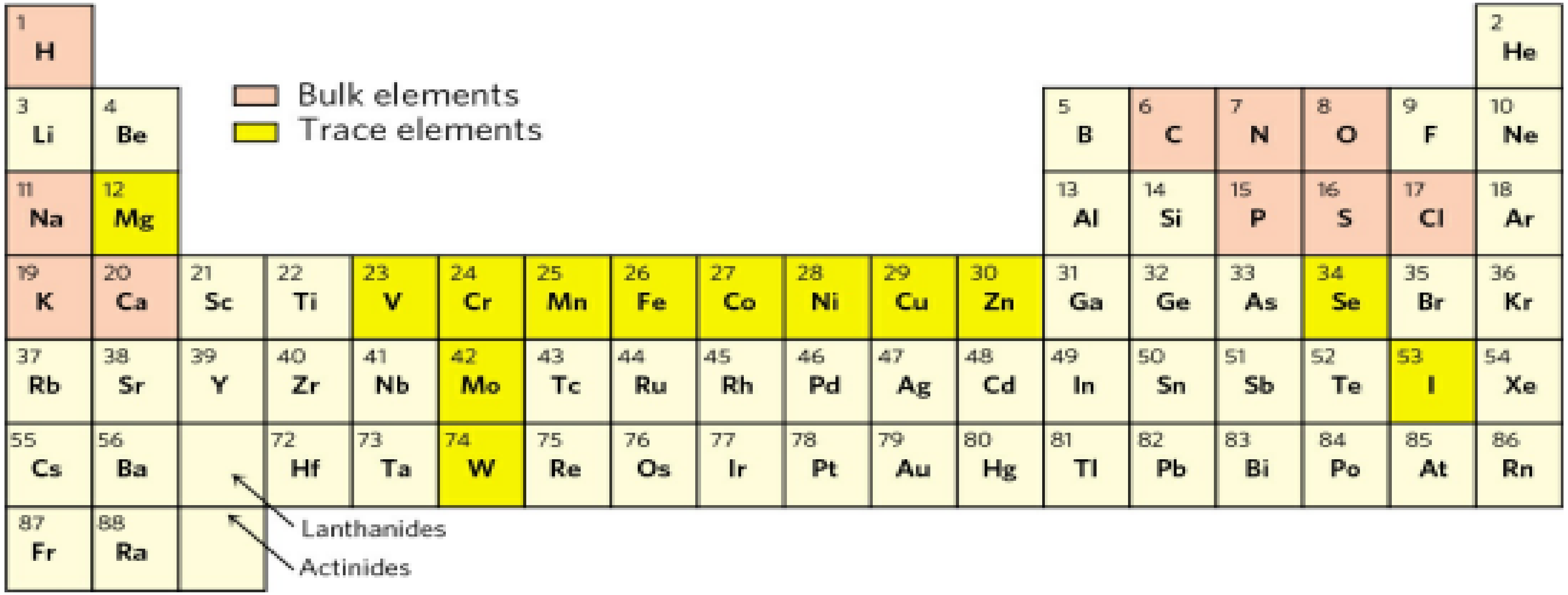
Elements essential to animal life and health:



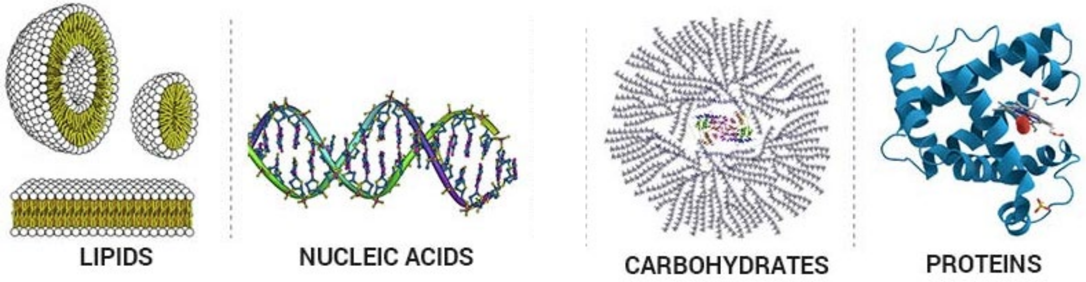
Red: structural components of cells

Yellow: Trace elements, required in less quantity. Fe, Cu and Zn are required in much less quantity

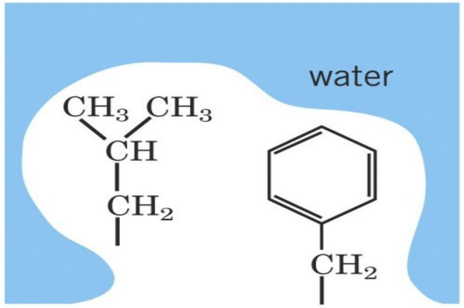
Macromolecules are the Major Constituents of Cells

Molecular components of an E. coli cell

	Percentage of total weight of cell	*Approximate number of different molecular species*
Water	70	1
Proteins	15	3,000
Nucleic acids		
DNA	1	1
RNA	6	>3,000
Polysaccharides	3	5
Lipids	2	20
Monomeric subunits and intermediates	2	500
Inorganic ions	1	20



Four types of Noncovalent (weak) interactions among Biomolecules

Hydrogen bonds	
Between neutral groups	$>C{=}O \cdots H{-}O{-}$
Between peptide bonds	$>C{=}O \cdots H{-}N<$
Ionic interactions	
Attraction	$-{}^{+}NH_3 \rightarrow\leftarrow {}^{-}O-\overset{O}{\overset{\Vert}{C}}-$
Repulsion	$-{}^{+}NH_3 \longleftrightarrow H_3N^{+}-$
Hydrophobic interactions	
van der Waals interactions	Any two atoms in close proximity

All the processes in living systems obeys chemical and physical laws

However, the chemistry of life is special:

1. The chemistry in living systems is majorly dependent on carbon compounds. Organisms are made mostly of carbon-based compounds. Carbon can form large, complex, diverse molecules.
Ex. Proteins, DNA, carbohydrates

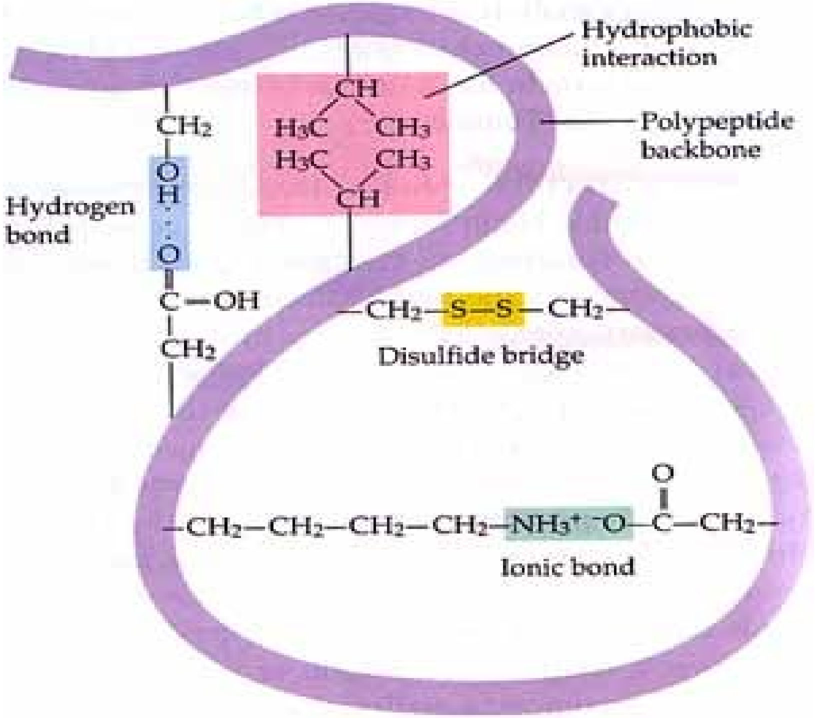
2. 70% water is present in cells, that means life depends on chemical reactions that takes place in aqueous medium

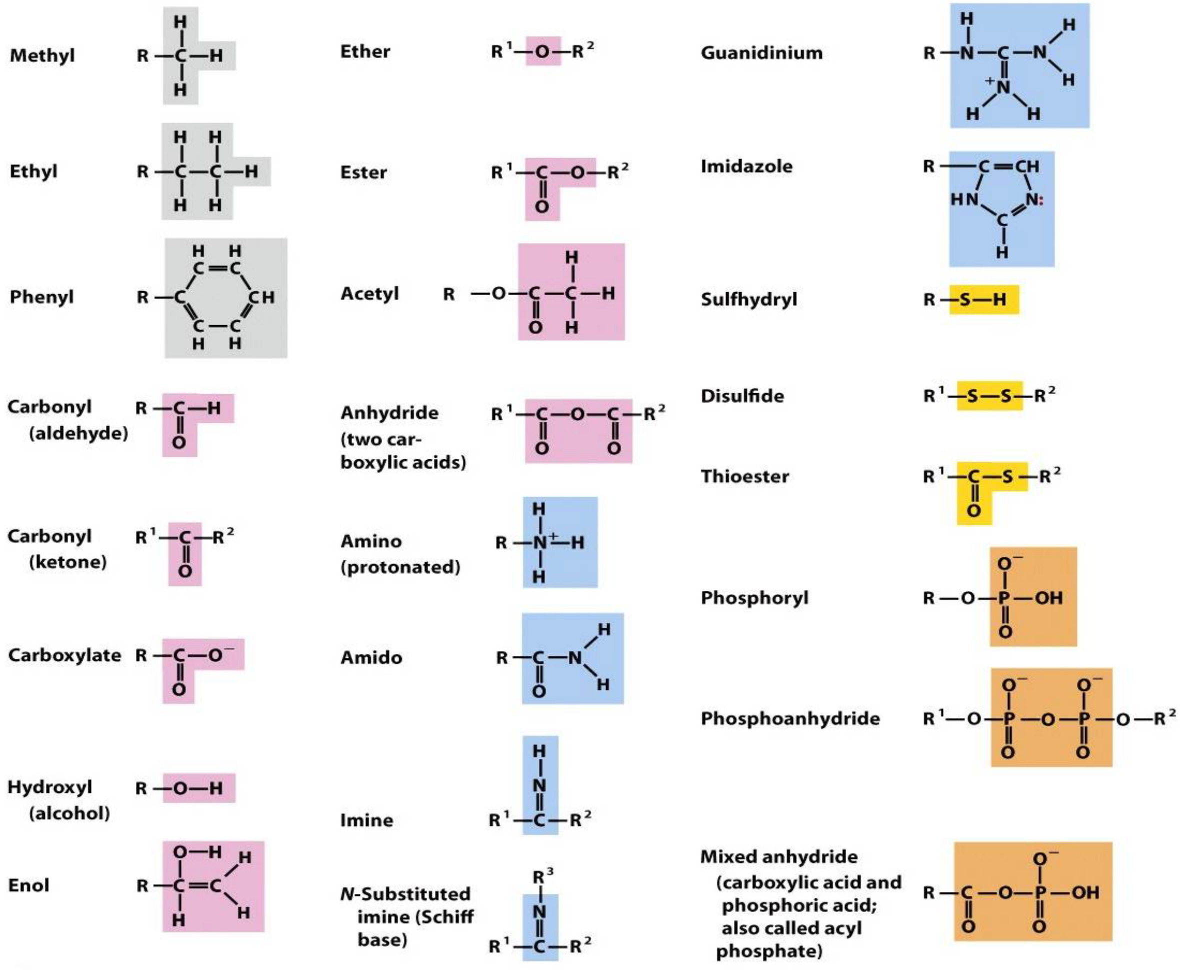
3. Cellular chemistry is enormously complex than any other known chemical system. Most of the carbon atoms in cells are incorporated into polymeric molecules.

polymer	**category of biomolecules**	**monomer**
polysaccharide	**carbohydrates**	monosaccharides
polypeptides	proteins	amino acids
polynucleic acids	RNA & DNA	nucleotides

A few chemical groups are key to the functioning of biological molecules

Properties of biological molecules depend on carbon skeleton and the molecular components attached





A molecule with multiple functional groups

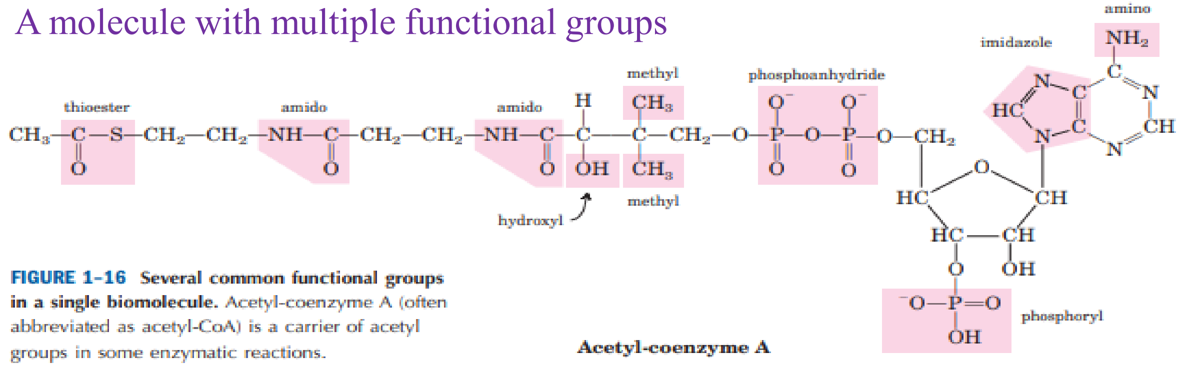
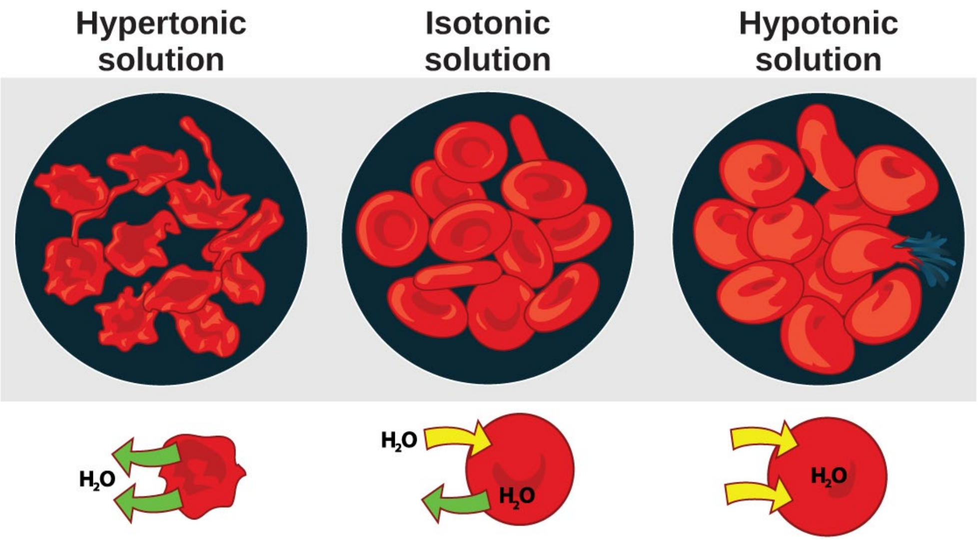
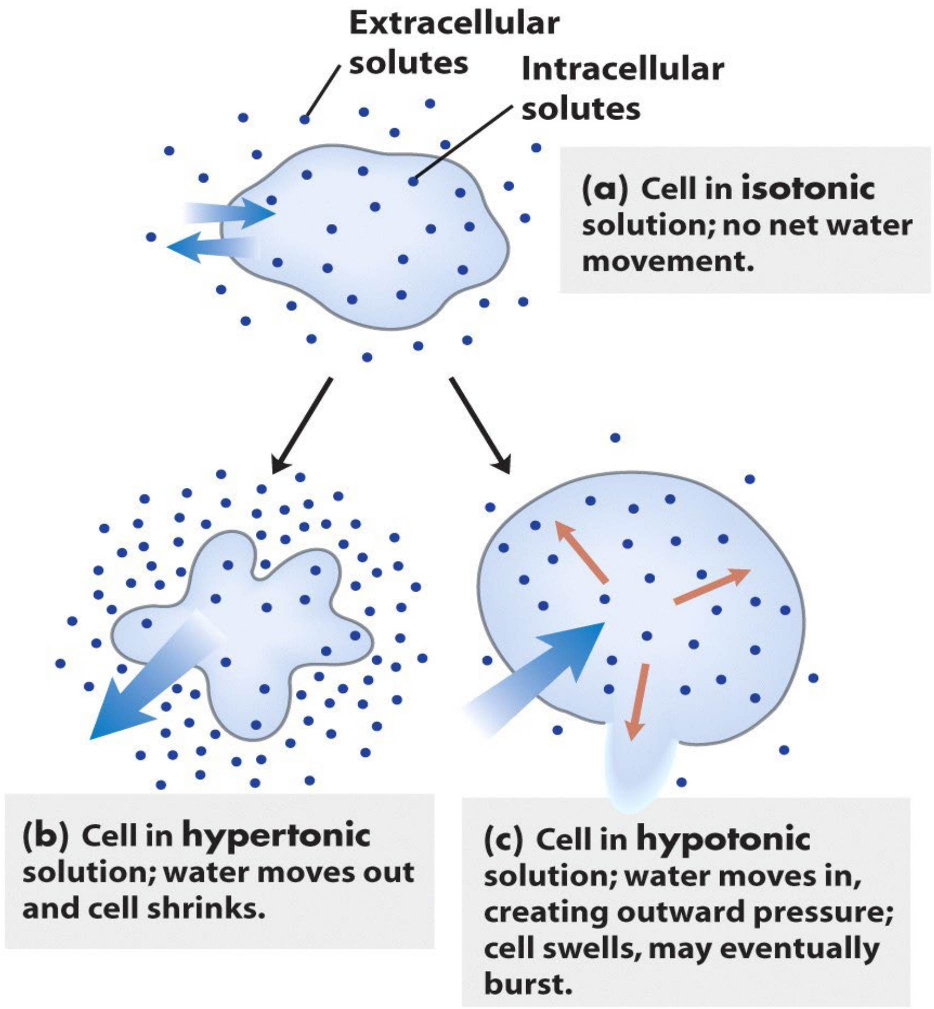


FIGURE 1-16 Several common functional groups in a single biomolecule. Acetyl-coenzyme A (often abbreviated as acetyl-CoA) is a carrier of acetyl groups in some enzymatic reactions.

Cells Response to Osmotic Pressures

- Solutions of equal osmolarity are said to be **isotonic**. Surrounded by an isotonic solution, a cell neither gains nor loses water.
- In a **hypertonic solution**, one with higher osmolarity than the cytosol, the cell shrinks as water flows out.
- In a **hypotonic solution**, with lower osmolarity than the cytosol, the cell swells as water enters.





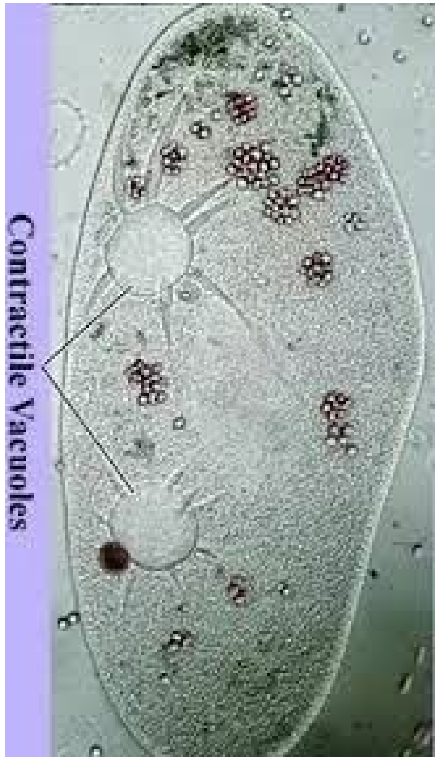
Why do organisms store fuel as polysaccharides (starch or glycogen) rather than as glucose?

For example, a gram of a polysaccharide composed of 1,000 glucose units has the same effect on osmolarity as a milligram of glucose.

Role of osmosis: a few examples

1. Contractile vacuoles regulates the quantity of water inside a cell. In freshwater environments, the concentration of solutes is hypotonic, lesser outside than inside the cell. Under these conditions, osmosis causes water to accumulate in the cell from the external environment. The contractile vacuole acts as part of a protective mechanism prevents the cell from absorbing too much water. The contractile vacuole, expels water periodically out of the cell by contracting. The amount of water expelled from the cell and the rate of contraction are related to the osmolarity of the environment. In hyperosmotic environments, less water will be expelled.

The best understood contractile vacuoles belong to the protists *Paramecium*, *Amoeba*, *Dictyostelium* and *Trypanosoma*

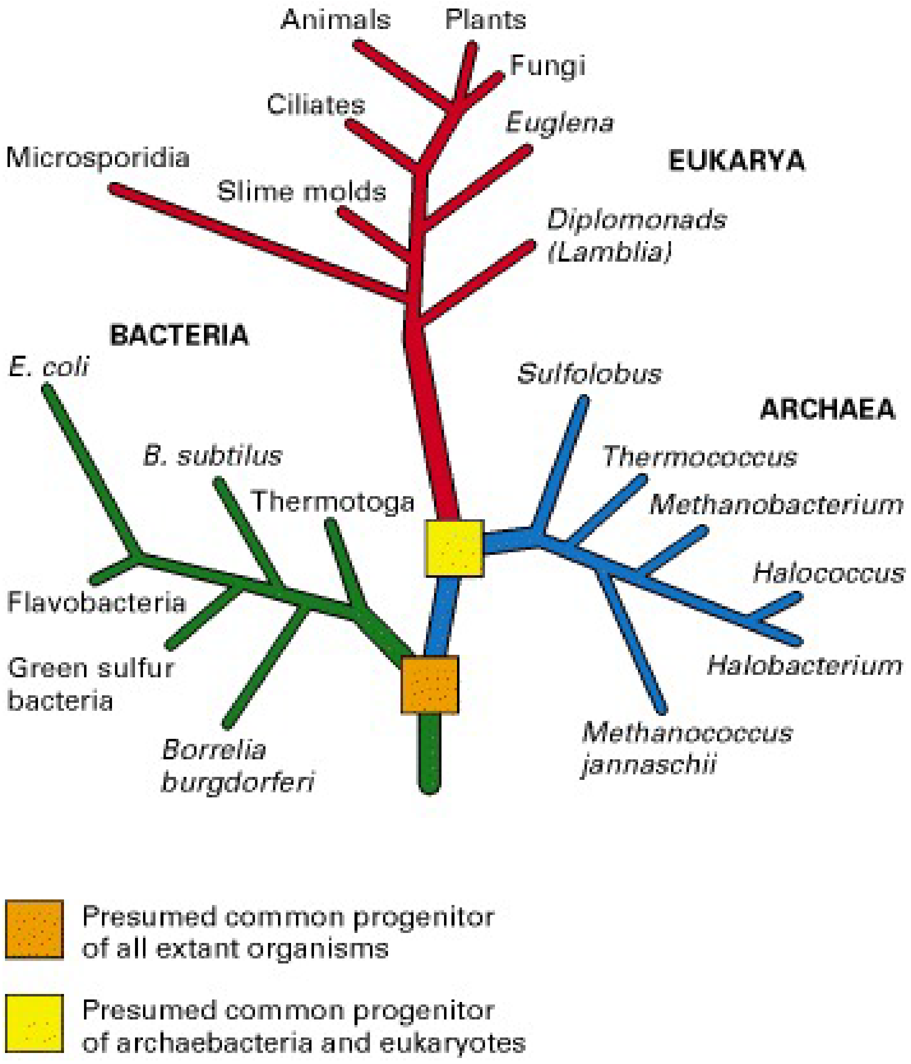


2. Role in laboratory protocols: Mitochondria, chloroplasts, and lysosomes, for example, are bounded by semipermeable membranes. In isolating these organelles from broken cells, biochemists must perform the fractionations in isotonic solutions to protect the organelles from osmotic lysis.

3. Plants for nutrition and turgidity:

Carnivorous plants, such as the Venus flytrap (*Dionaea muscipula*), depend on an animal diet when grown in nutrient-poor soils.

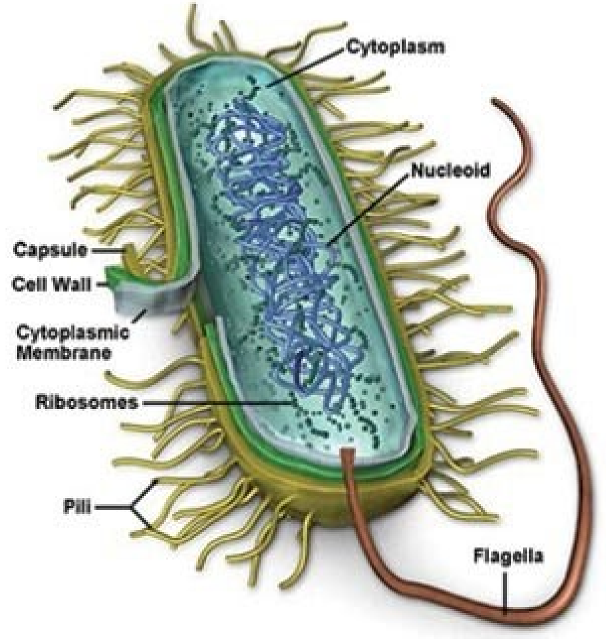
The three kingdoms of organisms

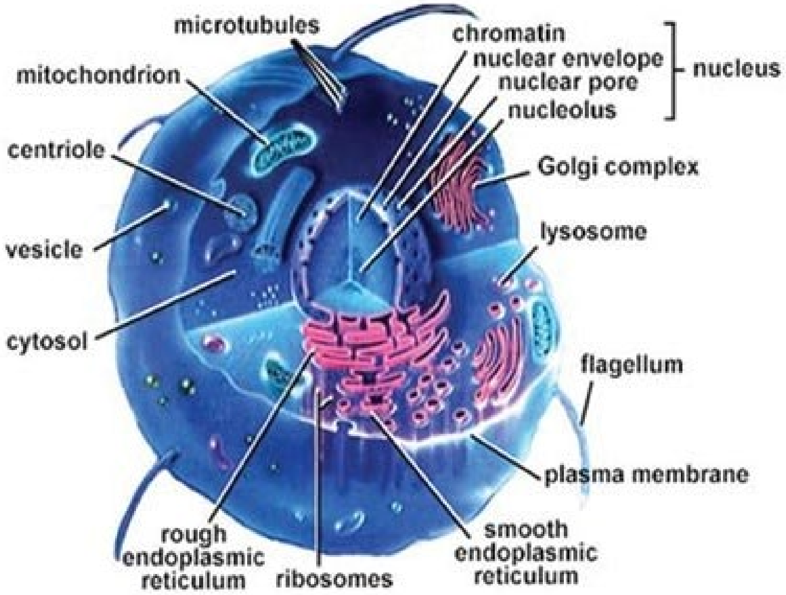


- The biological universe consists of two types of cells — *prokaryotic cells,* which lack a defined nucleus and have a simplified internal organization, and *eukaryotic cells,* have a more complicated internal structure including a defined, membrane-limited nucleus.
- Detailed analysis of the DNA from a variety of prokaryotic organisms in recent years has revealed two distinct types: bacteria (often called “true” bacteria or eubacteria) and archaea (also called *archaebacteria* or *archaeans*). The archaea are in some respects more similar to eukaryotic organisms than to the true bacteria.

Important differences between eukaryotic and prokaryotic cells

	Prokaryote	Eukaryote
1.	Single chromosome	Many chromosome
2.	Genome condensed in Nucleoid	Condensed in membrane bound nucleus
3.	No nucleus, hence transcription and translation occur simultaneously	Transcription in nucleus and translation in cytoplasm
4.	One copy of each gene	Most eukaryote contain two copies of each gene
5.	Contain extrachromosomal plasmids	Normally do not contain extrachromosomal plasmids





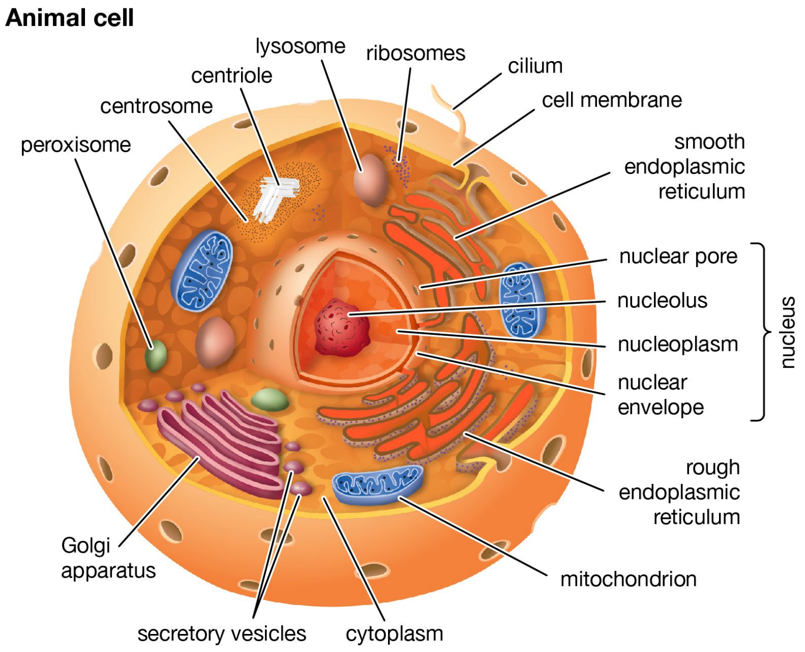
Major components of living cells

* What are the major organelles and their functions?

* How do cell divide?

* How do small and large molecules pass through the membrane barrier?

* How do cells communicate with each other and extracellular signals recognized & processed by the cell?



Nucleus:
- contains DNA genome
- site of DNA and RNA synthesis

Cytoplasm:
- comprises ~50% of cell volume
- site of protein synthesis and metabolism

- Ribosomes

- Chloroplast

- Endoplasmic Reticulum (ER): made up of smooth and rough ER, site of entry into the secretion pathway, major site of lipid biosynthesis, comprises > 50% of total cell membrane

- Golgi Complex: disc-like compartments of the secretion pathway

- Mitochondria: most of the ATP production in eukaryotic cells, enclosed within a double membrane

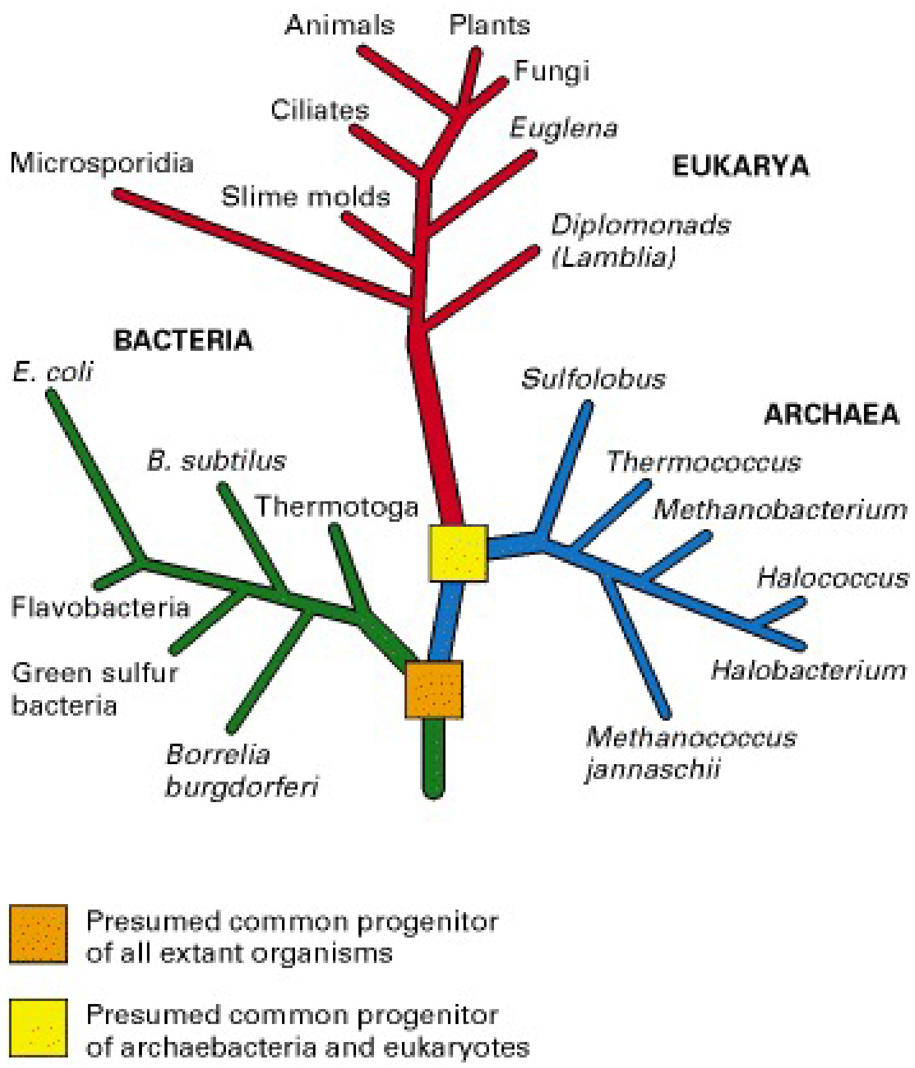
- Lysosomes: contains a variety of digestive or degradative enzymes, responsible for degradation of cellular macromolecules, (autophagy)

- Endosomes: compartments that serve as an intermediate destination for endocytosed material

- Peroxisomes: carry out a variety of oxidative reactions

- Vacuoles

The three kingdoms of organisms



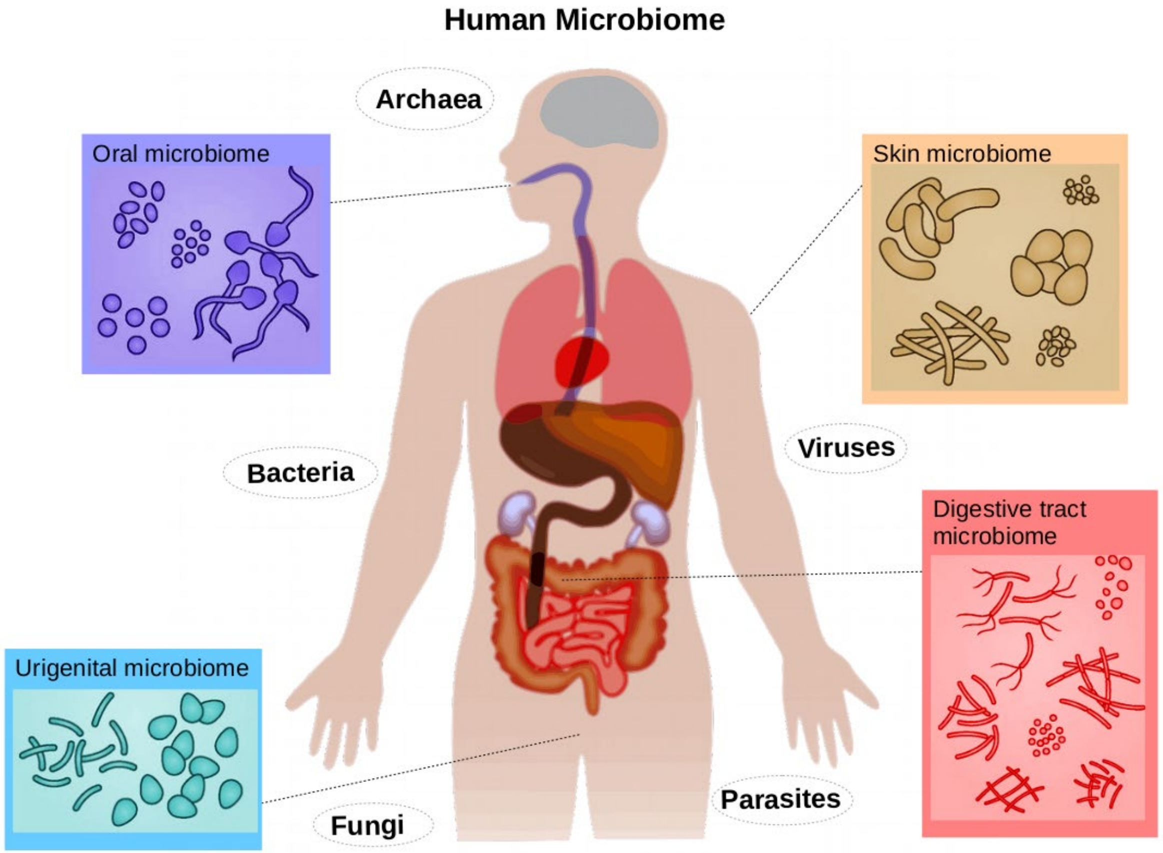
- The biological universe consists of two types of cells — *prokaryotic cells,* which lack a defined nucleus and have a simplified internal organization, and *eukaryotic cells,* which have a more complicated internal structure including a defined, membrane-limited nucleus.
- Detailed analysis of the DNA from a variety of prokaryotic organisms in recent years has revealed two distinct types: bacteria (often called "true" bacteria or eubacteria) and archaea (also called *archaebacteria* or *archaeans*).

  The archaea are in some respects more similar to eukaryotic organisms than to the true bacteria.

Prokaryotic microorganisms are found everywhere; soil, water, air, animals and plants

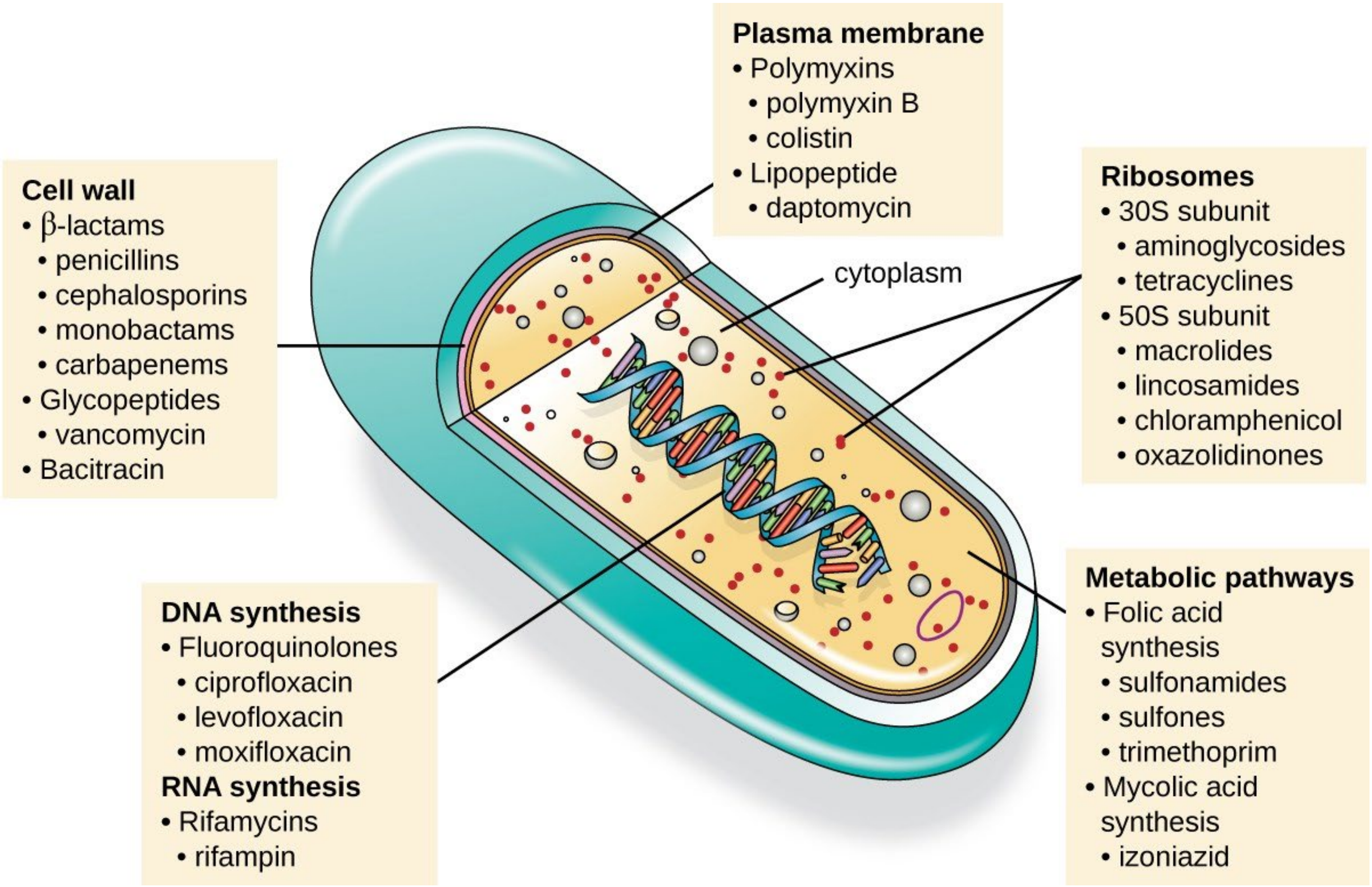
Most types of bacteria are not harmful; many are even helpful. They make up your microbiome, which keeps your gut healthy. Other bacteria, called pathogens, can cause infections that require treatment. We use antibiotics to treat many of these infections.

Bacteria occupies 1-3 percent of the human body by mass



How can we protect us from harmful microorganisms?

We use Antibiotics and vaccines to protect us from infectious diseases



Challenges?

Delivery

Specificity

Stability

Metabolism………

Diphtheria Toxin Blocks Protein Synthesis in Eukaryotes by Inhibiting Translocation

Diphtheria is a disease resulting from bacterial infection by Corynebacterium diphtheriae.

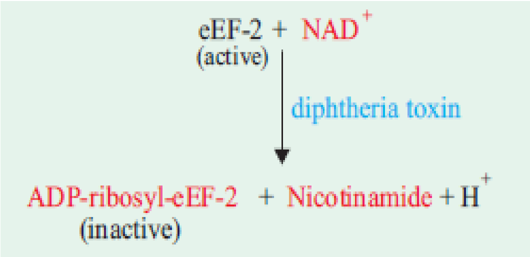
Diphtheria was a leading cause of childhood death until the late 1920s. Development of vaccine has protected humans from infection.

Although the bacterial infection is usually confined to the upper respiratory tract, the bacteria secrete a protein, called **diphtheria toxin**, that is responsible for the lethal effects.

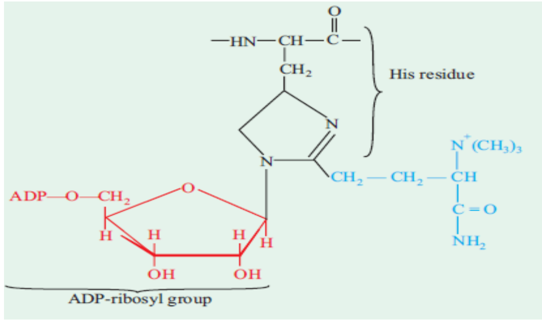
It specifically inactivates the eukaryotic enlongation factor eEF-2, thereby inhibiting eukaryotic protein synthesis.

Inside cytosol, it catalyzes the ADP-ribosylation of eEF-2 thereby inactivating this elongation factor.

Diphtheria toxin specifically **ADP-ribosylates a modified His residue on eEF-2 known as diphthamide**.

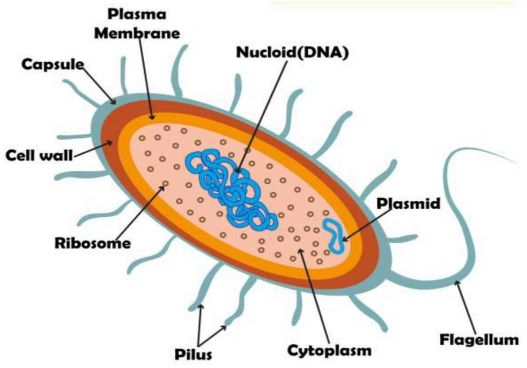


Diphthamide is a post-translationally modified histidine amino acid found in eukaryotic elongation factor 2 (eEF-2)



Prokaryotes: Bacteria

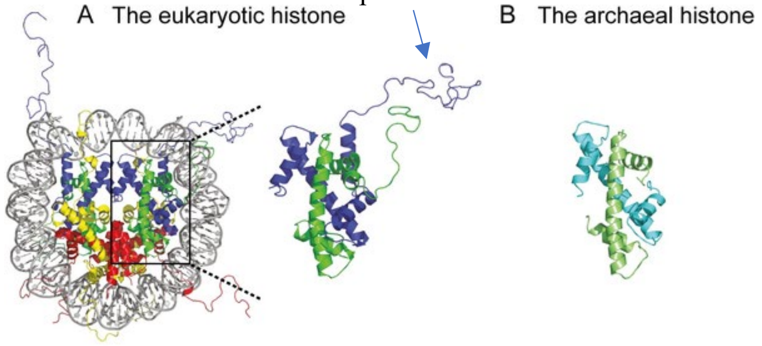
- The term **genome** refers to the sum of an organism's genetic material. The bacterial genome is composed of a single molecule of chromosomal DNA, located in a region in the cytoplasm called nucleoid.
- Nucleoid: irregularly-shaped section of a prokaryotic cell where DNA is housed.
- The bacterial chromosomal DNA is around 1000 μm long
- The length of *E. coli* bacterium is about 2 μm
- About 50% of the bacterial cell volume is occupied by nucleoid
- Long molecule of DNA to fit within the bacterium, DNA must be supercoiled to pack it roughly by 1000-fold



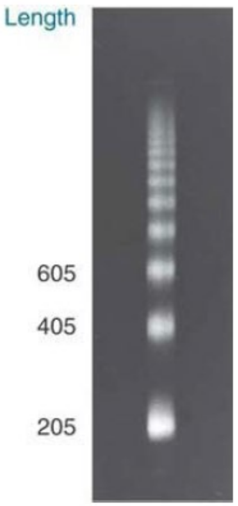
Tiny bacterial cell in the center was lysed, and all this DNA spilled out.

Archaea

N-terminal end of histone proteins

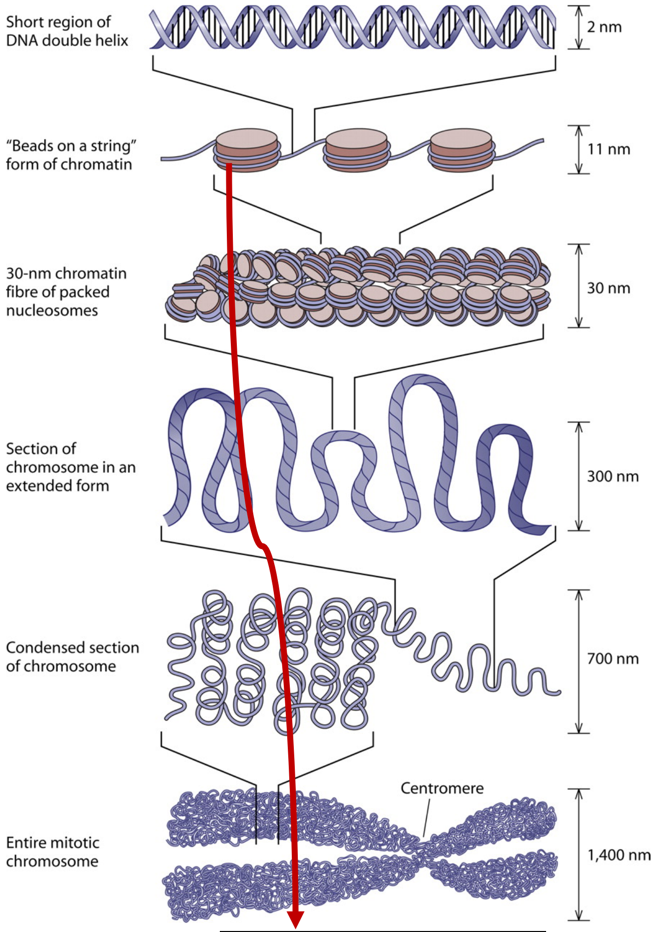


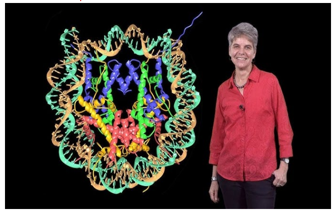
- Archaea and Bacteria do not possess membrane-bound organelles or a nucleus
- Bacteria do not contain histone proteins, but Archaea and eukaryotes contain histones
- N-terminal ends are not present in histone proteins of Archaea but present in eukaryotes
- Respiration in bacteria: glycolysis and the citric acid cycle occur in the cytoplasm and the electron transport chain occurs in the plasma membrane
- The length of DNA in a human cell is about 2.2 meters
- Archaeal nucleosomes protect ~60 bp of DNA from micrococcal nuclease digestion (MNase)
- Eukaryotic nucleosomes protect about 200 bp of DNA from MNase digestion



Electrophoresis of DNA isolated from a human cell nuclei after MNase digestion

Eukaryotes





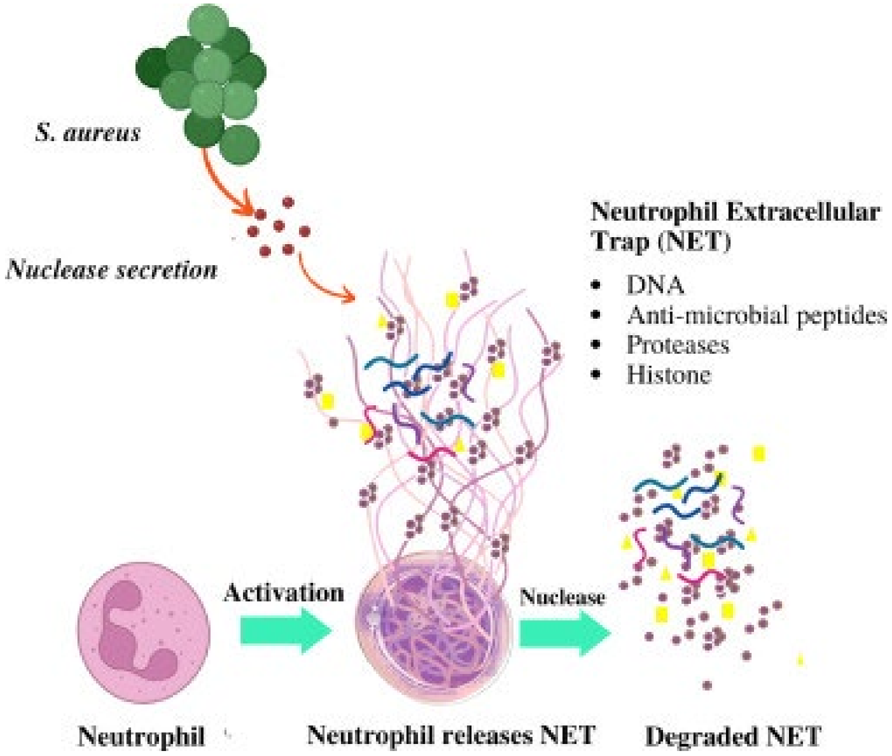
Nature **volume 389**, pages251–260 (1997)

MNase, an endonuclease enzyme cleaves the phosphodiester bonds within a polynucleotide chain

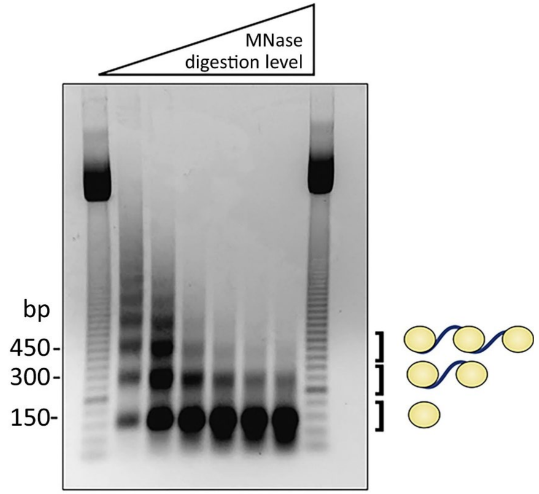
- Micrococcal nuclease is derived from Staphylococcus aureus bacteria.
- It digests DNA in regions that are not stably bound by proteins.
- DNA wrapped around the histones is protected from MNase digestion, while the linker DNA are digested. This method can be used to assess chromatin structure.

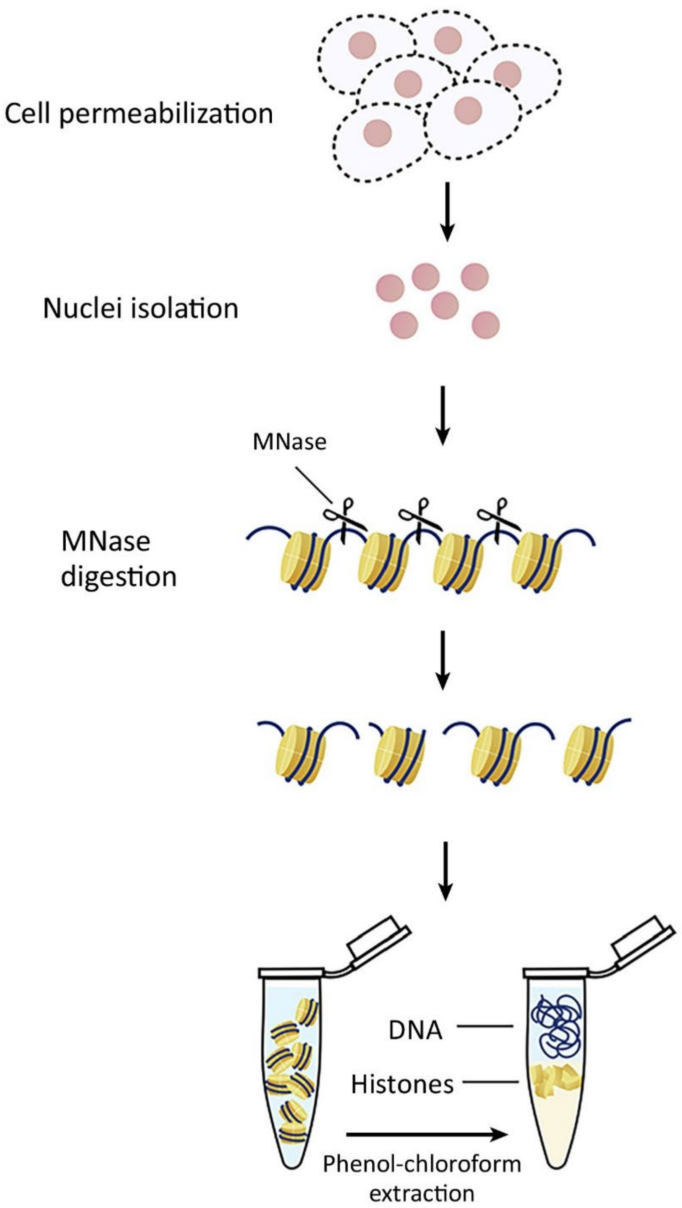
- Staphylococcus aureus (S. aureus) secretes MNase to evade the host's immune system:

• MNase cleaves the DNA backbone of neutrophil extracellular traps (NETs), which are traps produced by dying neutrophils. This allows S. aureus to escape the immune system



Electrophoresis of MNase digested DNA





nature microbiology

Article

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Histones with an unconventional DNA-binding mode in vitro are major chromatin constituents in the bacterium *Bdellovibrio bacteriovorus*

Bdellovibrio belongs to gram-negative category of bacteria

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Check for updates

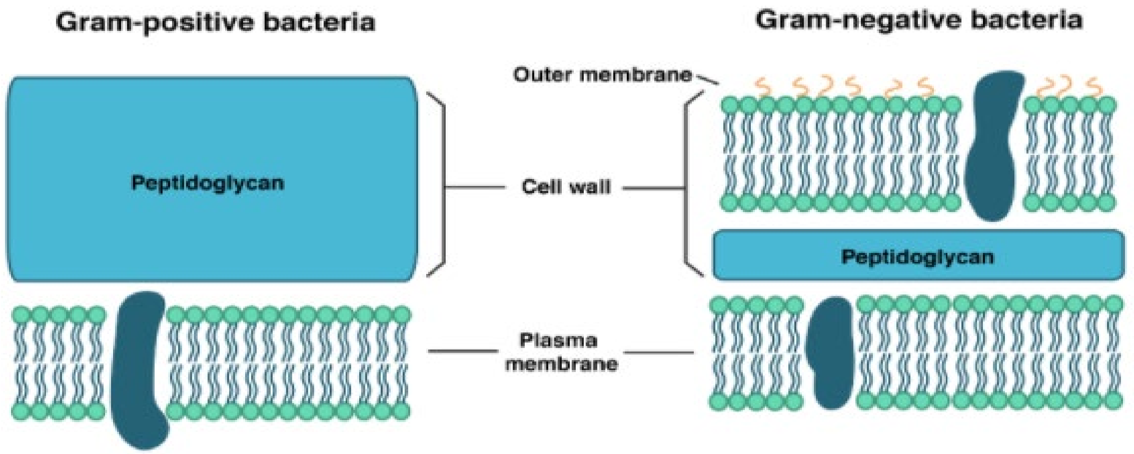
Antoine Hocher[1,2,8,9], Shawn P. Laursen[3,8], Paul Radford[4], Jess Tyson[4], Carey Lambert[4], Kathryn M. Stevens[1,2], Alex Montoya[1,2], Pavel V. Shliaha[1,2], Mathieu Picardeau[5], R. Elizabeth Sockett[4], Karolin Luger[6,7,9] & Tobias Warnecke[1,2,9]

Histone proteins bind DNA and organize the genomes of eukaryotes and most archaea, whereas bacteria rely on different nucleoid-associated proteins. Homology searches have detected putative histone-fold domains in a few bacteria, but whether these function like archaeal/eukaryotic histones is unknown. Here we report that histones are major chromatin components in the bacteria *Bdellovibrio bacteriovorus* and *Leptospira interrogans*. Patterns of sequence evolution suggest important roles for histones in additional bacterial clades. Crystal structures (<2.0 Å)

Bacterial Cell wall: Structure and Composition

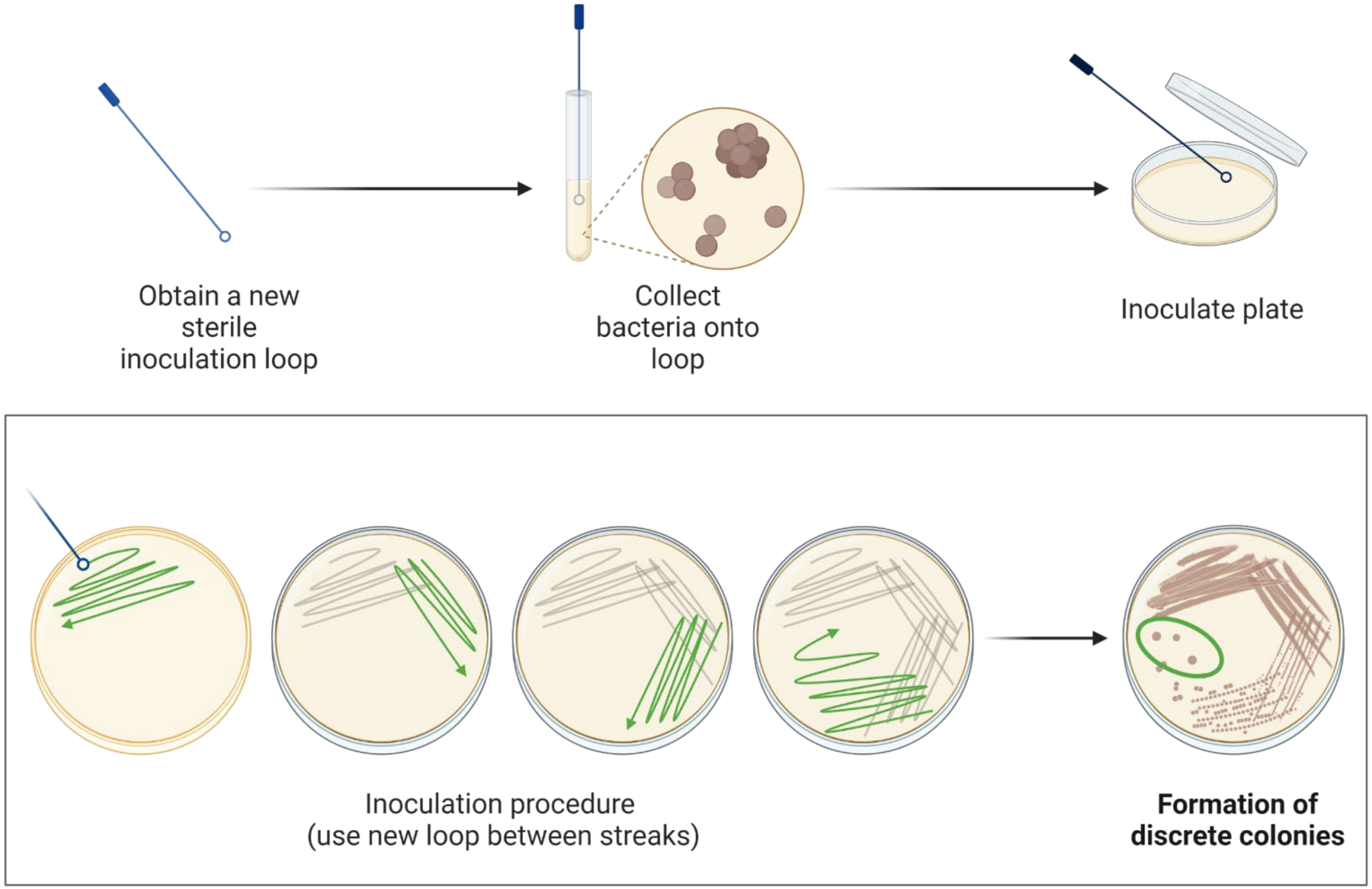
- Cell wall provides shape, rigidity and support to the cell.
- On the basis of cell wall composition, bacteria are classified into two major group;

Gram Positive and gram negative.



Parameter	Gram-positive bacteria	Gram-negative bacteria
Cell Wall	A single-layered, smooth cell wall	A double-layered, wavy cell-wall
Cell Wall thickness	The thickness of the cell wall is 20 to 80 nanometres	The thickness of the cell wall is 8 to 10 nanometres
Peptidoglycan Layer	It is a thick layer/ also can be multi-layered.	It is a thin layer/ often single-layered.
Teichoic acids	Teichoic acids are present.	Teichoic acids are not present.
Lipopolysaccharide	Lipopolysaccharide is not present.	Lipopolysaccharide is present.
Outer membrane	The outer membrane is not present.	The outer membrane is mostly present.
Lipid content	The Lipid content is very low.	The Lipid content is 20% to 30%.
Resistance to Antibiotic	These are very susceptible to antibiotics.	These are very resistant to antibiotics.

Growth of bacteria: streaking method



Gram's stain, a method of staining used to classify bacterial species into two large groups: gram-positive and gram-negative

The name is given because a bacteriologist Hans Christian Gram, who developed the technique in 1884.

Gram-positive cells have a thick layer of peptidoglycan in the cell wall that retains the primary stain, crystal violet. Gram-negative cells have a thinner peptidoglycan layer that allows the crystal violet to wash out on addition of ethanol

		Gram positive	Gram Negative
1. Primary dye	crystal violet	purple	purple
2. Decolorizer	alcohol	purple	colorless
3. Counter stain	safranin	purple	pink or red