



University of Teramo



Degree Program in Biotechnology

COURSE OF CYTOLOGY AND HISTOLOGY
Prof. Mauro

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Introduction to the Study of Cytology

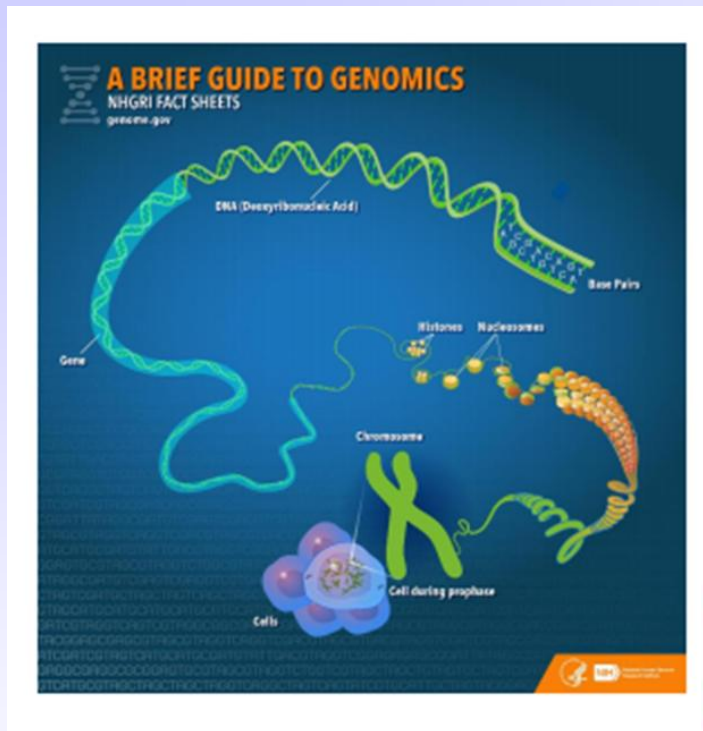


Biology (from the Greek *bios* = life and *lógos* = study → *Bios logos*, or *study of life*)

Biology is the scientific study of the **vital phenomena** of **living organisms**.

“LIVING” ORGANISM = an organism that exhibits the fundamental properties typical of life: the **ability to reproduce**, to **respond**, to **metabolize**, to **grow** (not only in volume but also through differentiation), to **change**, to perpetuate its own variations, and even to die.

Living organisms are characterized by **a genome...**



...by a metabolism...
relation of metabolic processes

Nature Biotechnology 2013

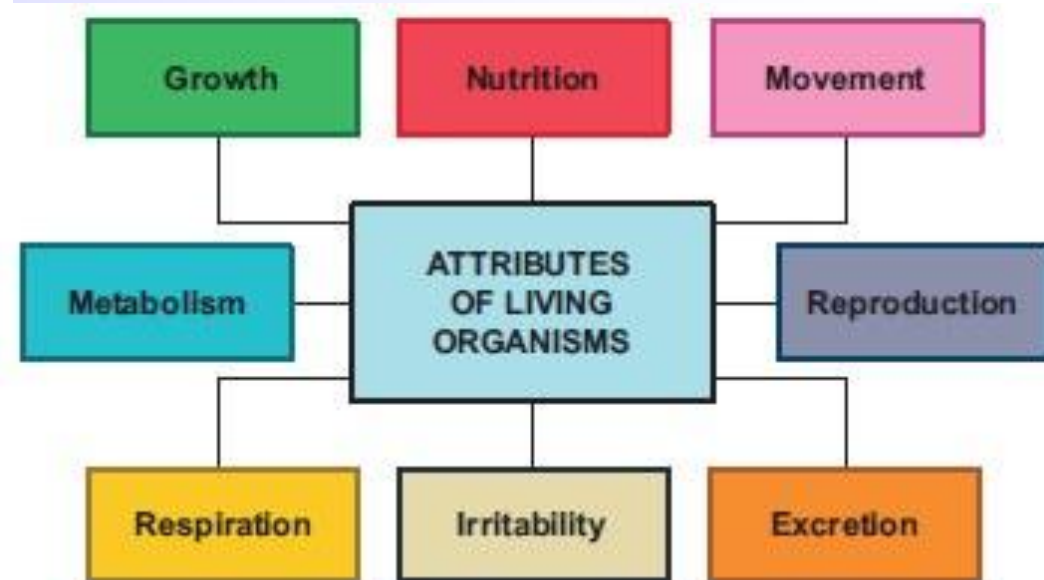
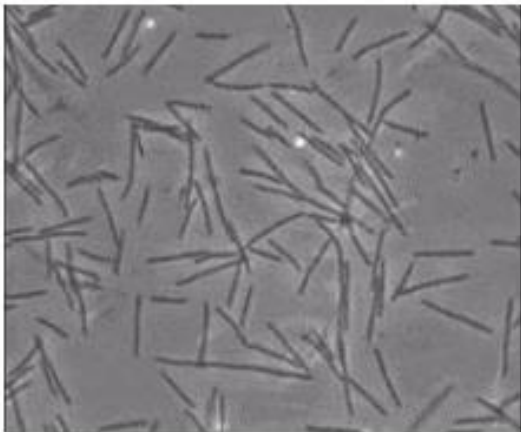
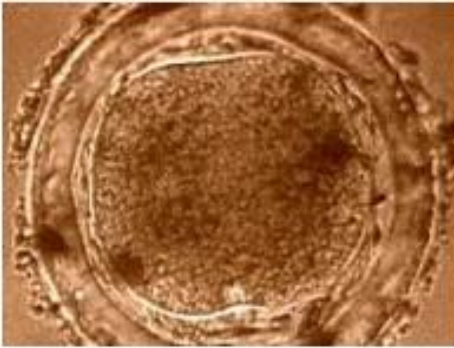
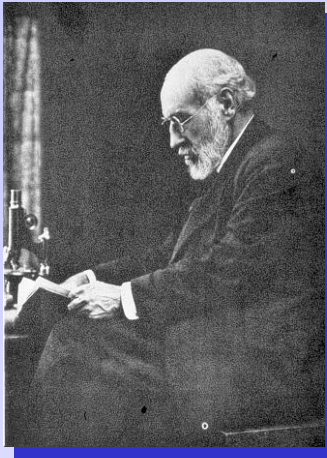


Figure 1.1: Attributes of living organisms



Natural selection is the process in which inherited traits increase survival and reproduction. Natural selection is the central mechanism of evolution.

Cell Theory



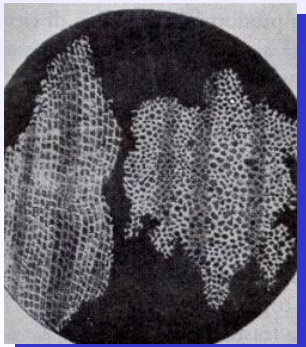
Hooke (1655)

Starting from the second half of the nineteenth century, microscopic observations led to the formulation of three fundamental general principles that constitute what is now known as the cell theory:

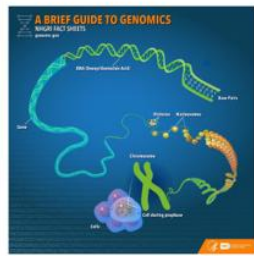
- The cell is the smallest unit that exhibits the typical properties of life.
- Cells multiply through growth and division of pre-existing cells.
- All organisms are composed of one or more cells.

Most living organisms are made up of single cells; others, such as humans, are multicellular organisms in which groups of cells perform specialized functions and are interconnected by complex communication systems.

The entire organism originates from the cell divisions of a single cell.



Living organisms are characterized by **a genome...**



...by a metabolism...
relation of metabolic processes

Nature Biotechnology 2013

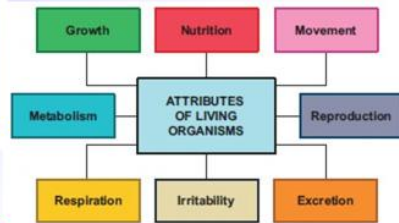
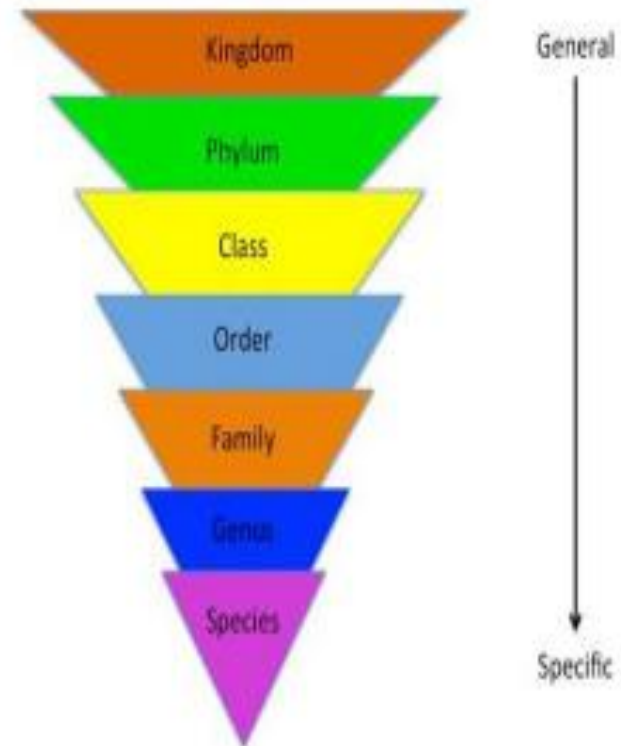
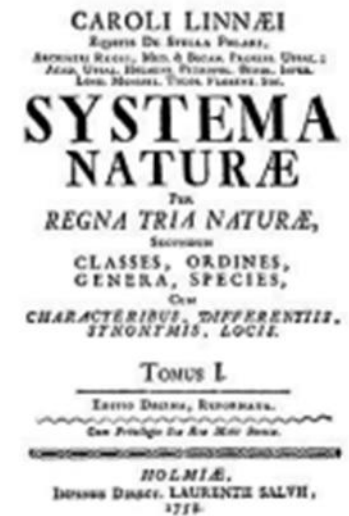
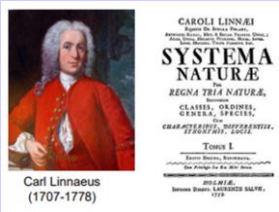


Figure 1.1: Attributes of living organisms

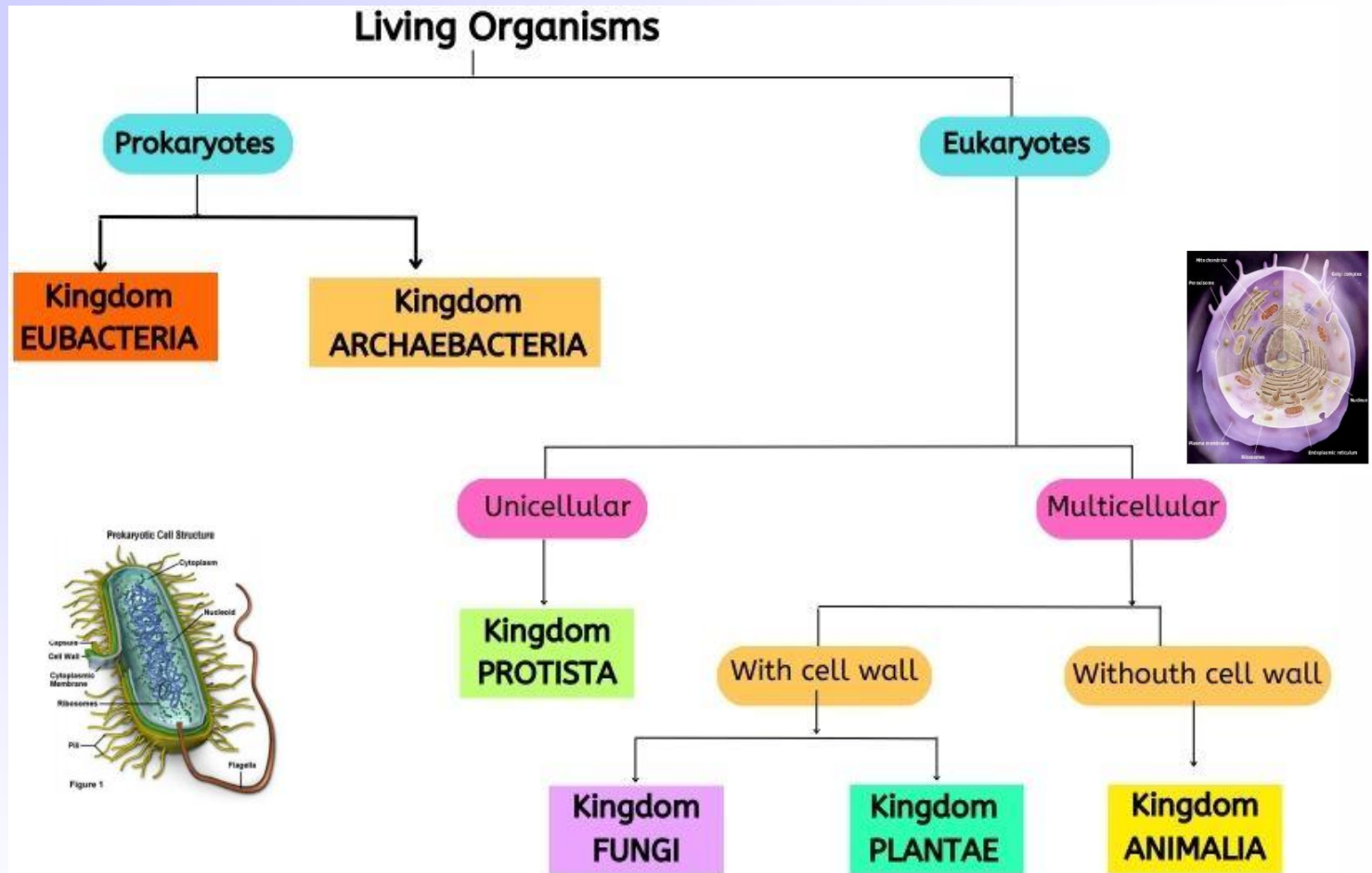


Carl Linnaeus
(1707-1778)





3 Domains: Archaea and Bacteria, and Eukarya.

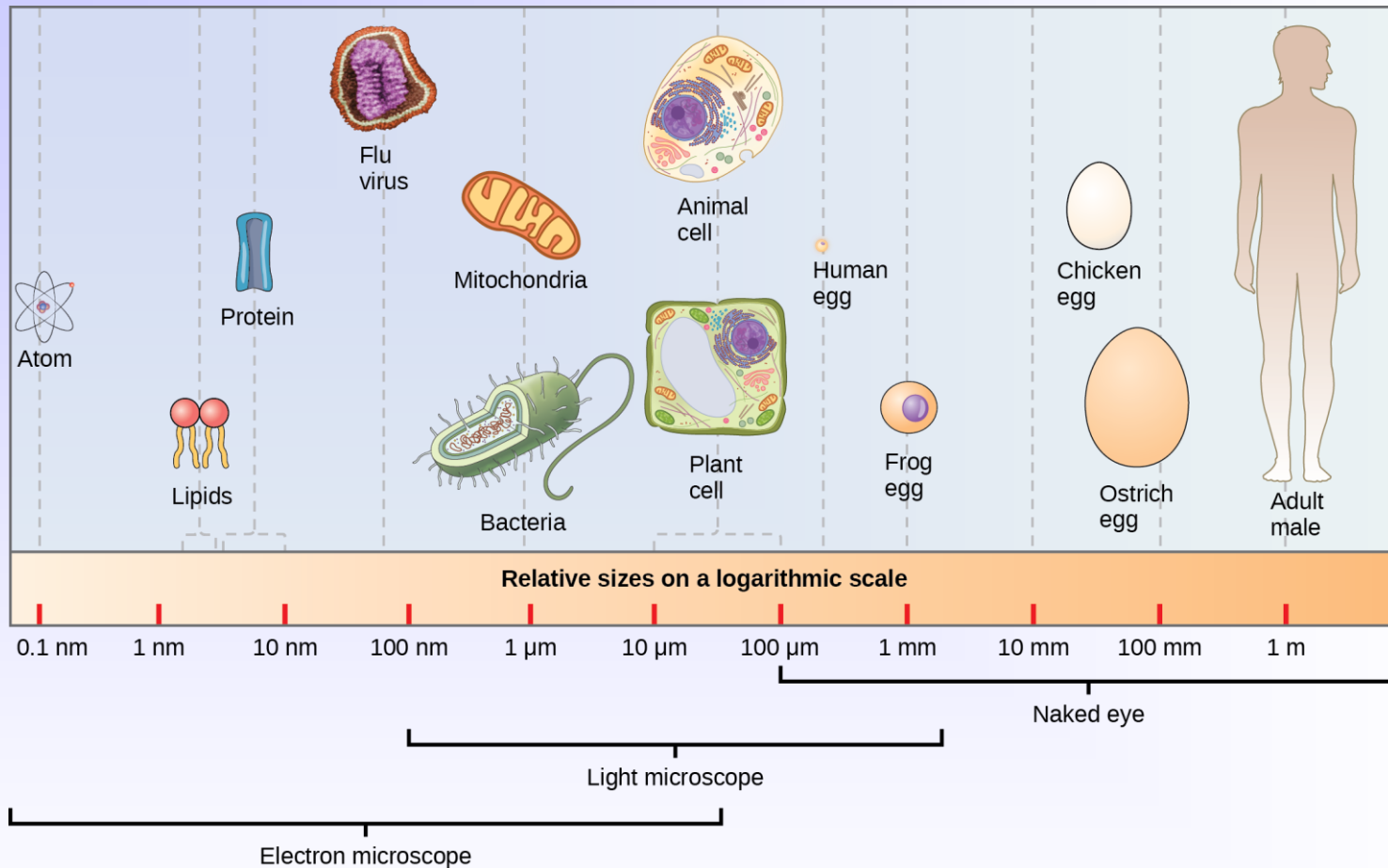


Archaea and Bacteria are PROKARYOTES—single-celled organisms without nuclei and other organelle

EUKARYA includes all animals, plants, fungi, and protists.

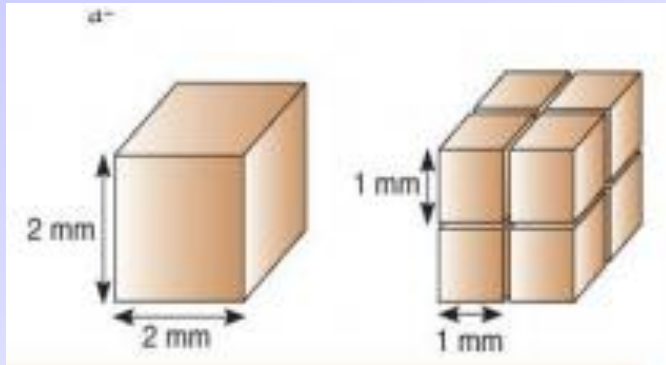
ALL VERTEBRATE ANIMALS BELONG TO THE PHYLUM CHORDATA AND THE KINGDOM ANIMALIA

Size



- The human eye can distinguish objects with a diameter down to 0.1 mm (100 μ m).
- The light microscope can distinguish objects down to a diameter of 0.1 μ m (100 nm).
- The transmission electron microscope (TEM) can distinguish objects down to 0.2 nm.

...and surface area is also very important



The surface area of a cell must be large enough compared to its volume to allow adequate exchange of materials with the environment. Although the volume of a cell increases more rapidly than its surface area, cells divide into smaller units to maintain an adequate surface-to-volume ratio.

For example, the surface/volume ratio of eight 1 mm^3 cubes is six times greater than that of a single large 2 mm^3 cube.

The surface/volume ratio (and thus the efficiency of metabolic exchanges) increases when the biological structure divides into smaller units.

Source: Solomon et al., 2012

Organization of Living Matter

1. Viruses

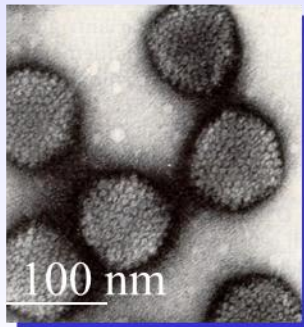
2. Bacteriophages

3. Prokaryotic Cells → bacteria, prokaryotic algae

4. Eukaryotic Cells

- **Plants** → Protophytes (unicellular), Metaphytes (multicellular)
- **Animals** → Proto

Viruses and Bacteriophages



Adenovirus, DNA virus



Influenza virus, RNA virus



They are acellular entity.

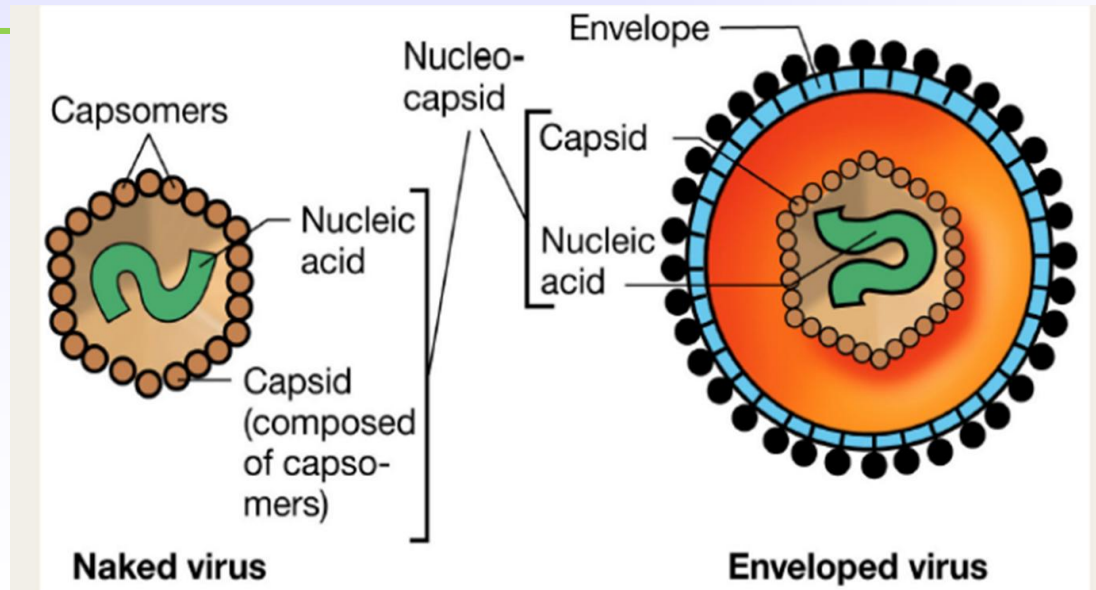
Viruses are infectious agents with both living and nonliving characteristics. In

VIRUSES – Characteristics

- Viruses are small infectious particles, visible only under the electron microscope.
- Their size ranges between 20 nm and 300 nm.

A Virus consists of:

- **NUCLEIC ACID CORE: DNA or RNA**, but not both.
- **CAPSID** coat, composed by protein subunits called **capsomeres**, that surrounds the **core**
- **ENVELOPE (some Viruses)**, external membranous surrounding the capsid



VIRUSES – Characteristics

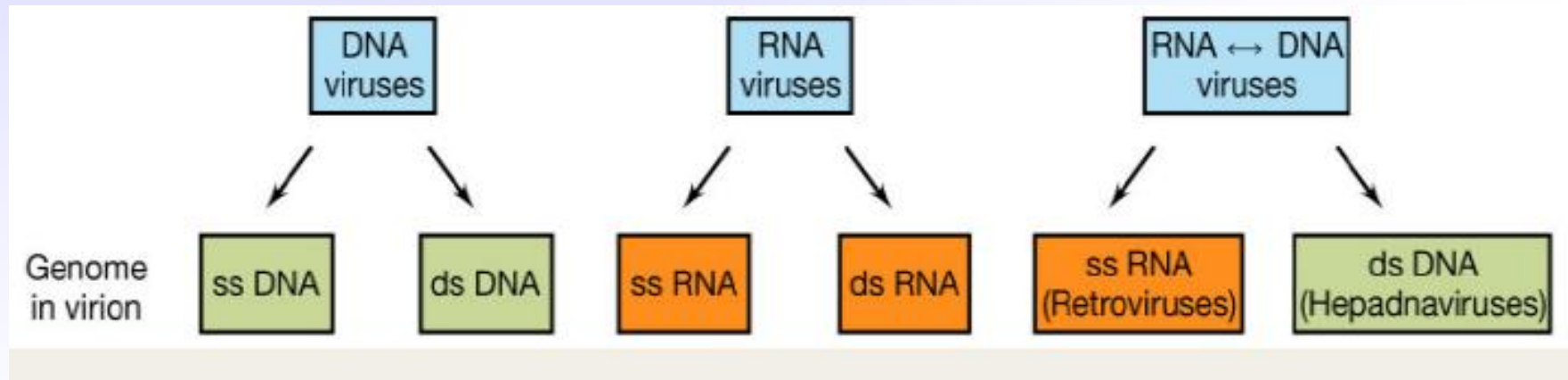
CLASSIFICATION BASED ON

- **GENOME TYPE**
- **SHAPE (MORPHOLOGY)**
- **TYPE OF PARASITIZED CELL**

VIRUSES – Characteristics

Classification of viruses based on genome type

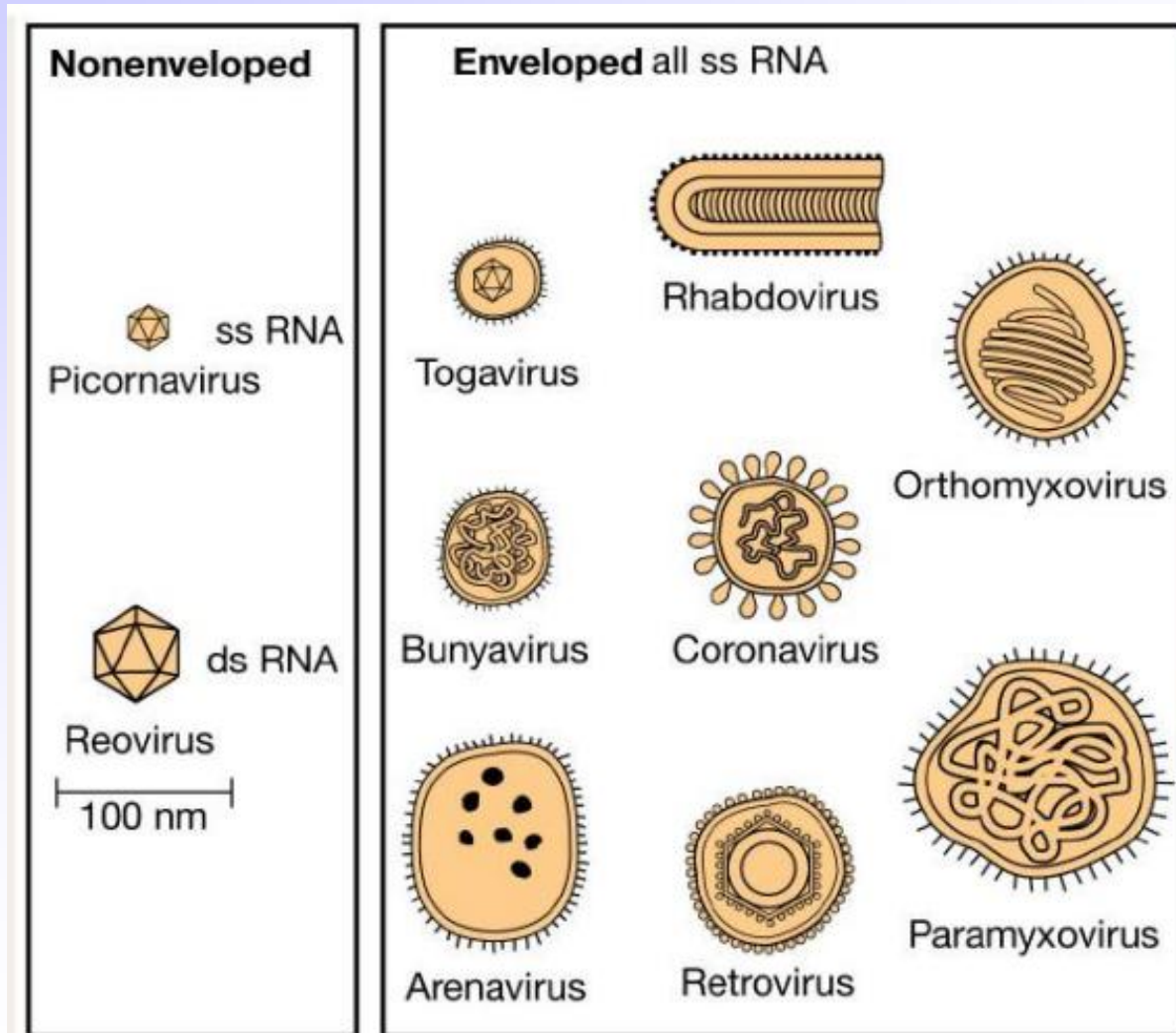
ss = single strands
ds = double strand



The largest genome: Bacteriophage G – with 6.7×10^5 bases, similar to that of intracellular bacteria.

RNA viruses

classified based on whether they are **non-enveloped** (naked) or **enveloped**.



(b) RNA viruses

VIRUSES – Characteristics

Classification based on shape (morphology):

•Helical viruses

Capsid proteins are arranged in a spiral around the nucleic acid.

Filamentous or cylindrical appearance.

May be naked or enveloped.

•**Examples:** Rabies virus (Rhabdoviridae), Tobacco mosaic virus (TMV), Paramyxoviruses (e.g., measles virus).

•Icosahedral viruses

Capsid forms a regular polyhedron with 20 triangular faces.

Compact and very stable structure.

May be naked or enveloped.

•**Examples:** Adenoviruses, Herpesviruses, Poliovirus.

•Complex viruses

Do not fit into simple geometric categories (neither helical nor icosahedral).

Often have additional structures (heads, tails, tail fibers).

•**Examples:** Bacteriophages (e.g., T4 phage), Poxviruses (e.g., smallpox virus).

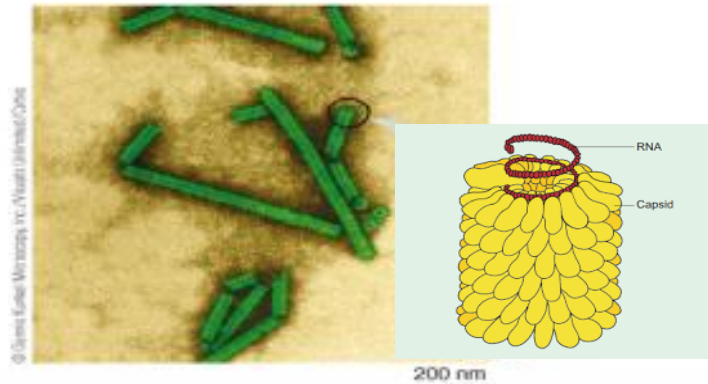
•Enveloped spherical viruses

Surrounded by a lipid envelope derived from the host cell membrane.

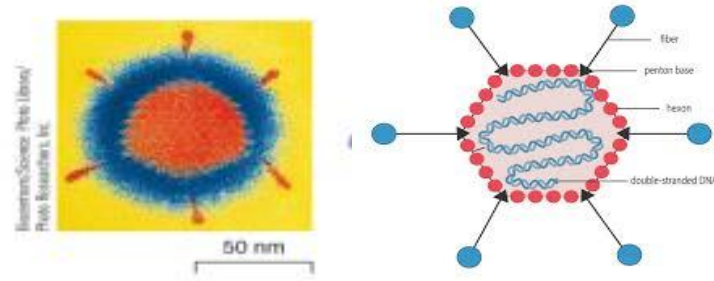
Appear spherical, but their internal symmetry can be helical or icosahedral.

•**Examples:** Influenza virus, HIV, Coronaviruses.

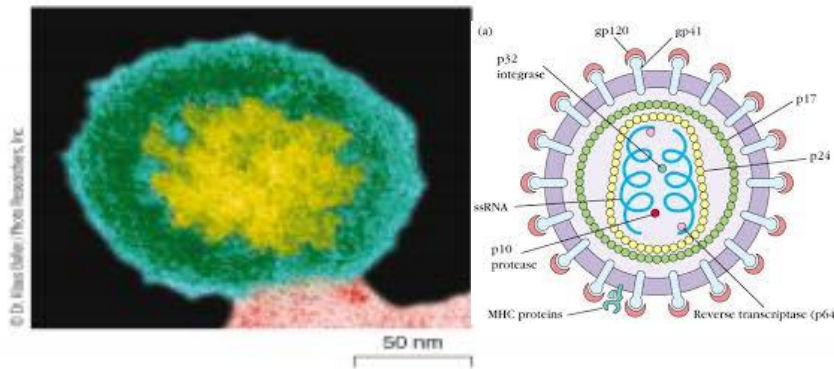
Examples of Viruses Structure



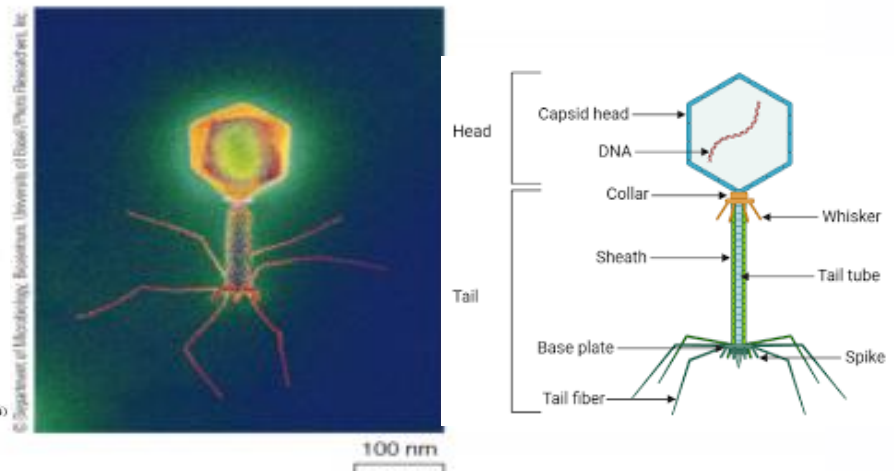
(a) Color TEM photograph of **tobacco mosaic virus**. It is a helical virus with a cylindrical capsid protein arrangement.



(b) Color TEM photograph of an **adenovirus**. This virus contains 252 capsomeres arranged in an icosahedral shape and projects **spikes** that allow it to recognize and infect host cells.



(c) Color TEM photograph of **HIV**, the virus that causes AIDS. The viral envelope is studded with glycoproteins that help the virus bind to host cells. Enzymes, RNA, and the protein capsid are also visible.



(d) Color TEM photograph of **bacteriophage T4**. The viral DNA is stored in the head and injected into the host bacterium through the tail. Tail fibers allow attachment to the bacterial cell wall.

VIRUSES – Viral Replication

- Viruses reproduce only inside host cells.
- They infect bacterial, animal, or plant cells in a substantially similar way.
- The two types of reproduction are the **lysogenic cycle** and **lytic cycle**
- The virus typically attaches to the surface of the cell.
- Viral nucleic acid must enter the host cell in order to synthesize viral components.
- Components are assembled and viruses are released from the cell.
- .

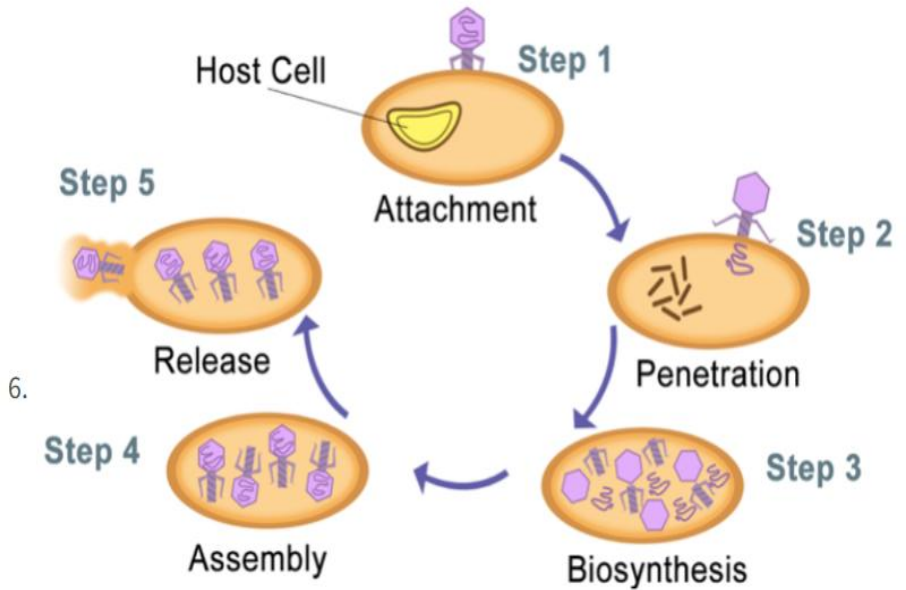


Fig 2. Viral Replication.

A-level Biology – Life Cycle and Replication of Viruses

- 1. Virus binds to host cells.** Virus binds to a host cell using its attachment proteins. Viruses can have different attachment proteins, which means that different viruses infect different types of cells. The HIV virus, for example, has attachment proteins which bind to receptors on the surface of human T-cells.
- 2. Injection of nucleic acids.** When viruses infect a host cell, they inject their nucleic acids into the host cell. Remember that viruses can have either DNA based or RNA based genomes. Once the attachment proteins of a virus attach to a host cell, the virus latches on to the cell and injects the host cell with its nucleic acids (either DNA or RNA). *This part of the viral life cycle is called the **lysogenic cycle**.*
- 3. Injection of unique viral proteins.** Certain viruses can also inject unique viral proteins into the host cell. These viral proteins help hijack the host cells machinery in order to replicate the viral genomes and to make new viral proteins. In this process, viruses can force the cell to give up using energy to make proteins and replicate DNA for the cell, and instead focus all its energy into replicating the viral genome and making viral proteins. Obviously, this is not good for the cells.
- 4. Release from host cell.** Once the host cell has produced a sizeable number of viral particles, the viral particles will burst through the cell through a process called lytic release. Once they burst through the cell, the viruses will go on to infect other host cells.
- 5. The host cell dies.** Meanwhile, the original host cell is now dead because of a gaping hole in its cell membrane. *This part of the reproduction cycle is called the **lytic cycle**.*

Prokaryotic cells

Prokaryotic Cell Structure

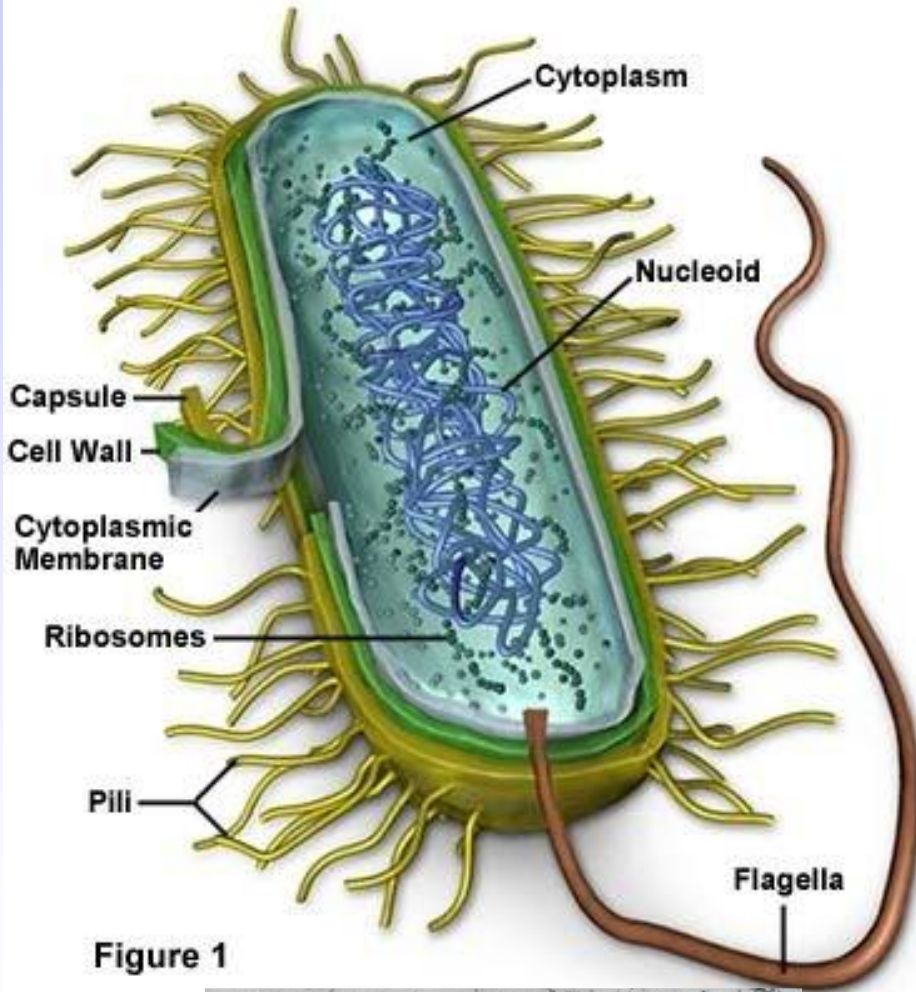
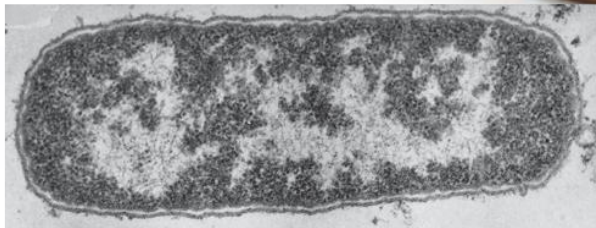
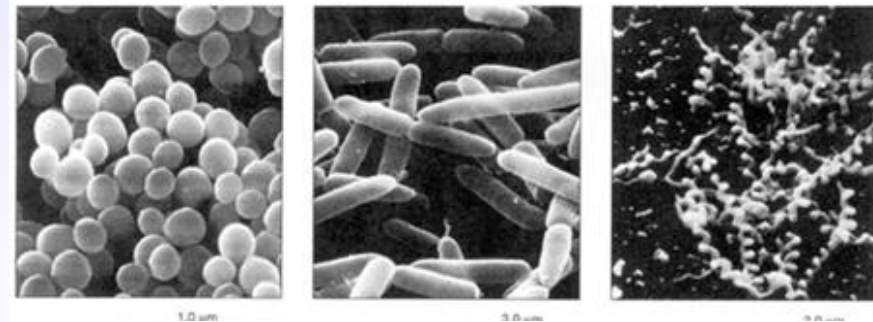


Figure 1



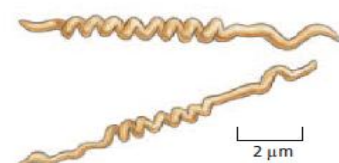
Prokaryotes **do not have a nucleus** like eukaryotes do. Their DNA is not membrane-bound, just free in the cytoplasm.



spherical cells,
e.g., *Streptococcus*



rod-shaped cells,
e.g., *Escherichia coli*,
Salmonella

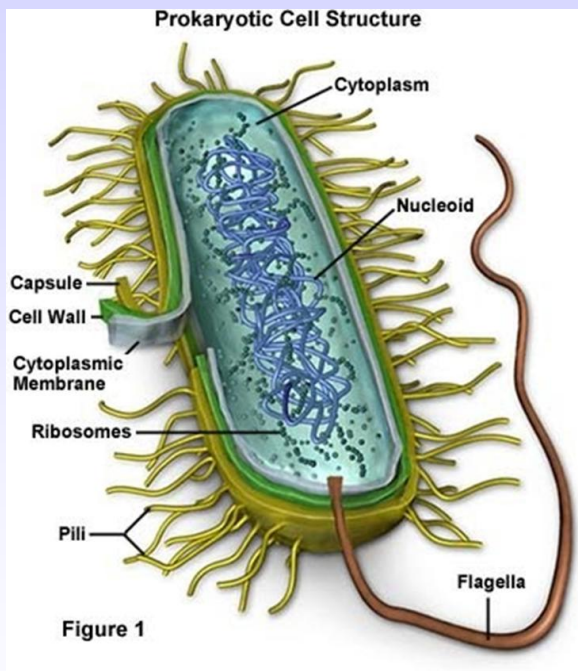


spiral cells,
e.g., *Treponema pallidum*

Prokaryotic cells

Prokaryotic cells, lack a nucleus and membrane-bound organelles, instead possessing a single circular chromosome and ribosomes in the cytoplasm. Key structures include the cell wall, plasma membrane, and sometimes a capsule for protection. Appendages like [flagella](#) and [pili](#) aid in movement and gene exchange, while internal [plasmids](#) hold extra genetic information. Prokaryotes reproduce asexually, primarily through binary fission.

Key Components and Functions



- **[Nucleoid](#):** Instead of a nucleus, prokaryotes have a nucleoid region where their single, circular chromosome is located.
- **[Ribosomes](#):** These organelles are responsible for protein synthesis and are found in the cytoplasm of prokaryotic cells.
- **[Cytoplasm](#):** A jelly-like substance that fills the cell, containing the ribosomes, genetic material, and other molecules.
- **[Plasma Membrane](#):** Encloses the cell's interior, controlling the movement of substances in and out.
- **[Cell Wall](#):** A rigid layer outside the plasma membrane that provides structural support and protection.
- **[Capsule](#):** An outer layer, found in some prokaryotes, that offers additional protection and helps the cell adhere to surfaces.
- **[Flagella](#):** Whip-like appendages that enable the cell to move.
- **[Pili](#) and [Fimbriae](#):** Hair-like structures; fimbriae help the cell attach to surfaces, while pili are involved in the exchange of genetic material (DNA) between cells.
- **[Plasmids](#):** Small, circular, extra-chromosomal DNA molecules that can carry additional genes, such as those for antibiotic resistance.

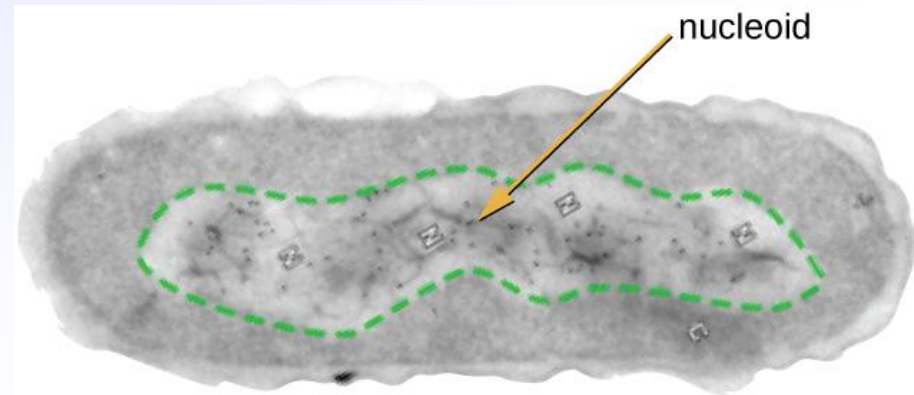
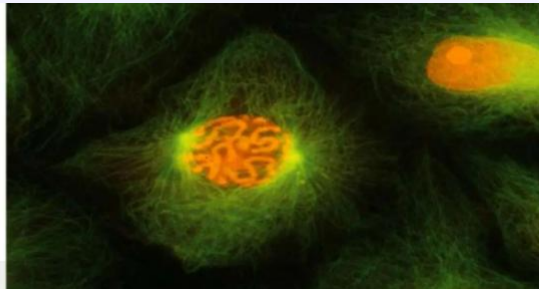
Prokaryotic cells

Asexual Reproduction and Genetic Exchange

- **Binary Fission:** The primary method of asexual reproduction, where one cell divides into two genetically identical daughter cells.
- **Horizontal Gene Transfer:** Prokaryotes can exchange genetic material through processes involving structures like sex pili.

*Prokaryotes-
circular DNA

Eukaryotes-
linear DNA



Prokaryotic cells

Prokaryote cell reproduction

- 1) DNA replication
Starts at "origin of replication"
- 2) Origin of replication anchored to poles of cell
- 3) Cell divides
New cell wall
Identical DNA copies

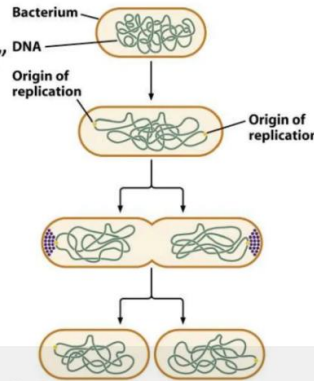
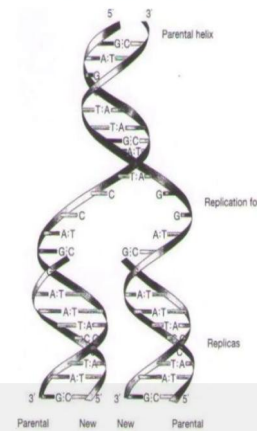


Figure 2-2a
Genetics: A Conceptual Approach, Third Edition
© 2009 W. H. Freeman and Company

DNA Replication



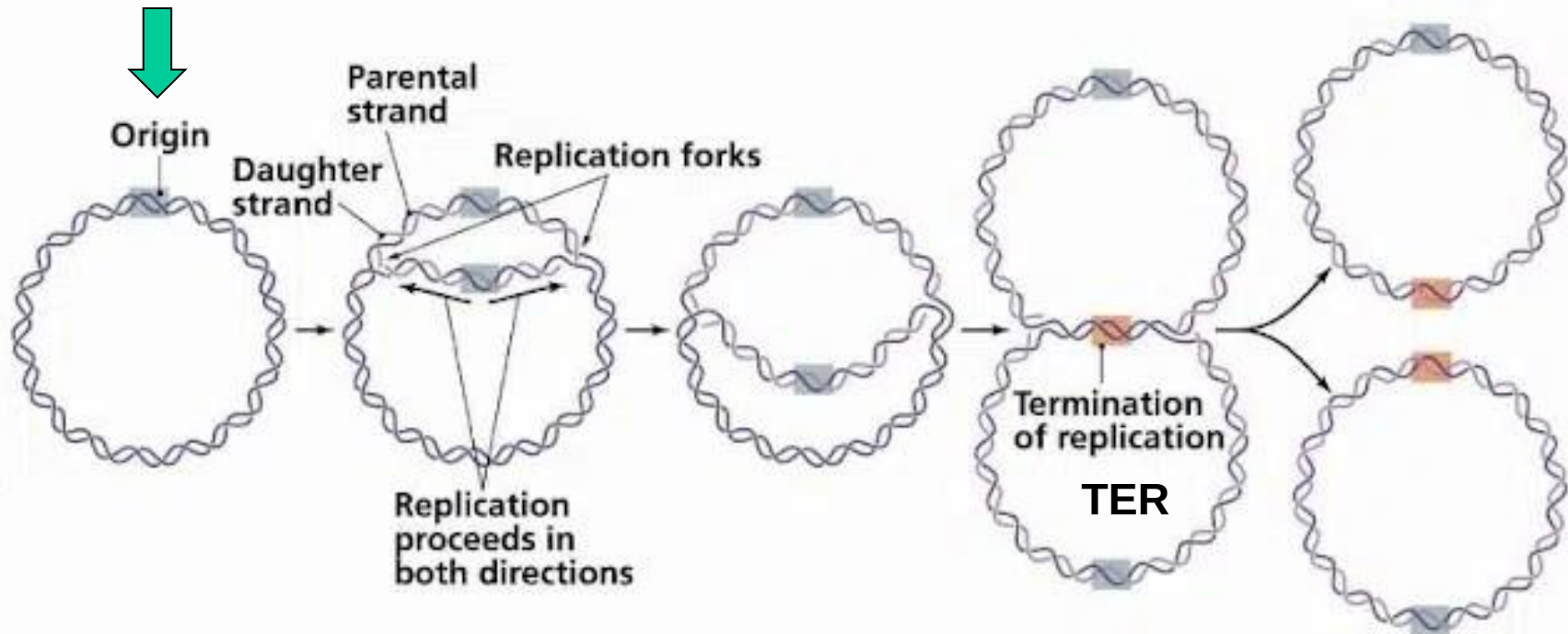
Semiconservative
Replication of DNA

The replication fork of DNA showing the synthesis of two progeny strands. Each copy contains one new and one old strand.

Bacterial chromosome is called **Replicon**

Replicon – a part of the genome that contains an origin site and is replicated as a whole unit

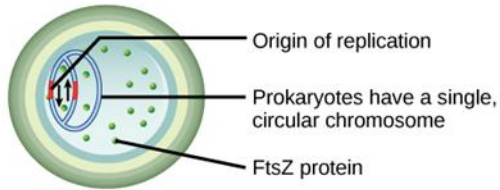
oriC locus



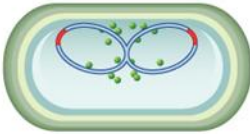
Binary Fission

Binary Fission in Prokaryotes

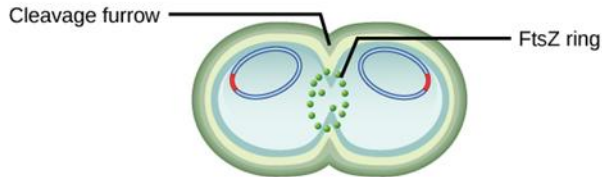
1 Replication of the circular prokaryotic chromosome begins at the origin of replication and continues in both directions at once.



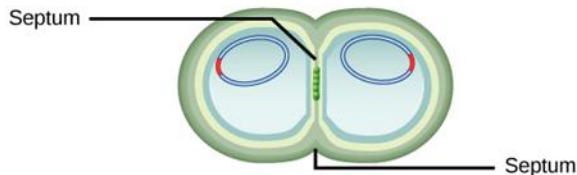
2 The cell begins to elongate. FtsZ proteins migrate toward the midpoint of the cell.



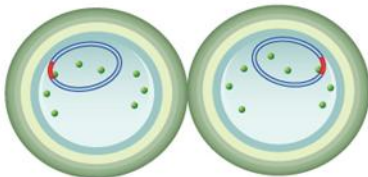
3 The duplicated chromosomes separate and continue to move away from each other toward opposite ends of the cell. FtsZ proteins form a ring around the periphery of the midpoint between the chromosomes.



4 The FtsZ ring directs the formation of a septum that divides the cell. Plasma membrane and cell wall materials accumulate.



5 After the septum is complete, the cell pinches in two, forming two daughter cells. FtsZ is dispersed throughout the cytoplasm of the new cells.



Key aspects of binary fission are:

DNA Replication: The prokaryotic cell's single, circular chromosome duplicates itself.

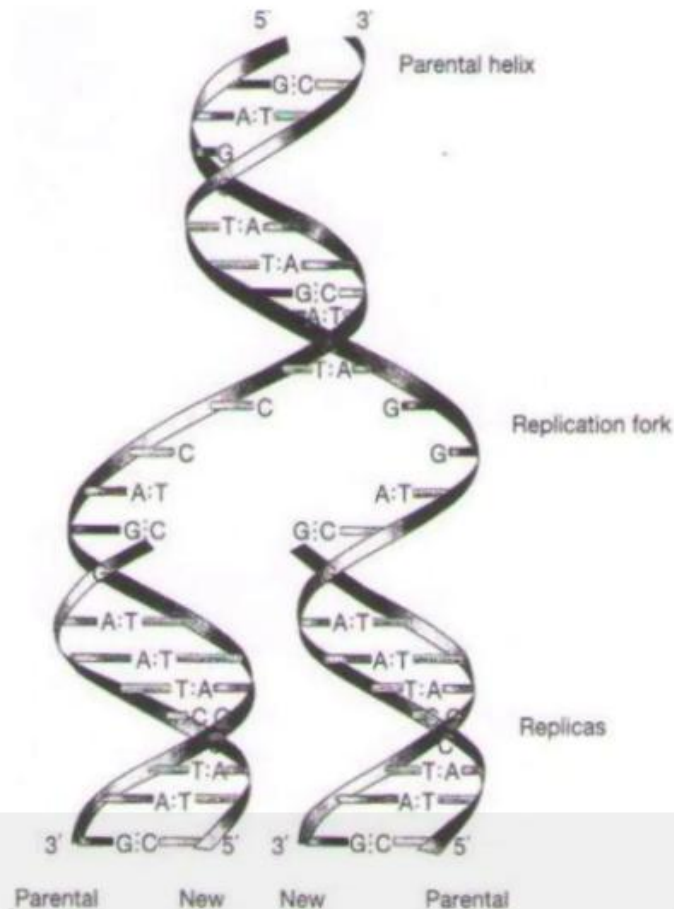
Segregation: One copy of the replicated DNA is moved to each side of the cell.

Cell Elongation: The cell grows longer, further separating the two DNA copies.

Septum Formation: A new cell wall and cell membrane begin to form in the middle of the cell, a process that involves specific proteins

Cell Division (Cytokinesis): The cell completely splits into two, each becoming a new, genetically identical daughter cell.

DNA Replication



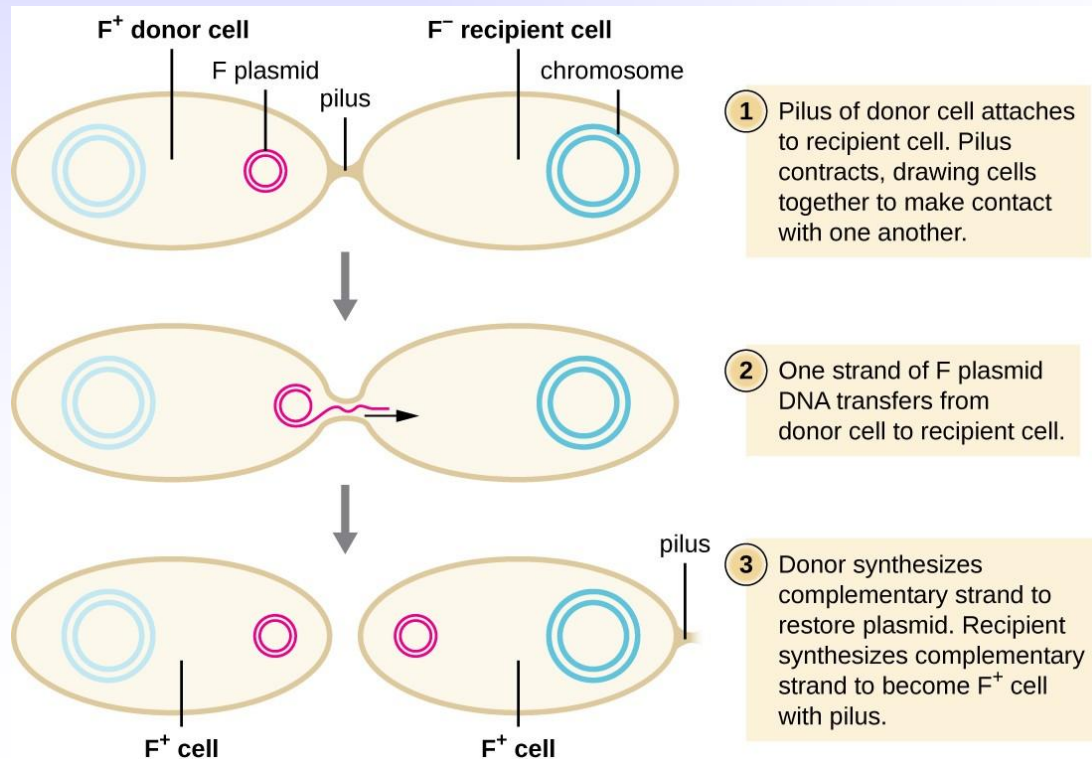
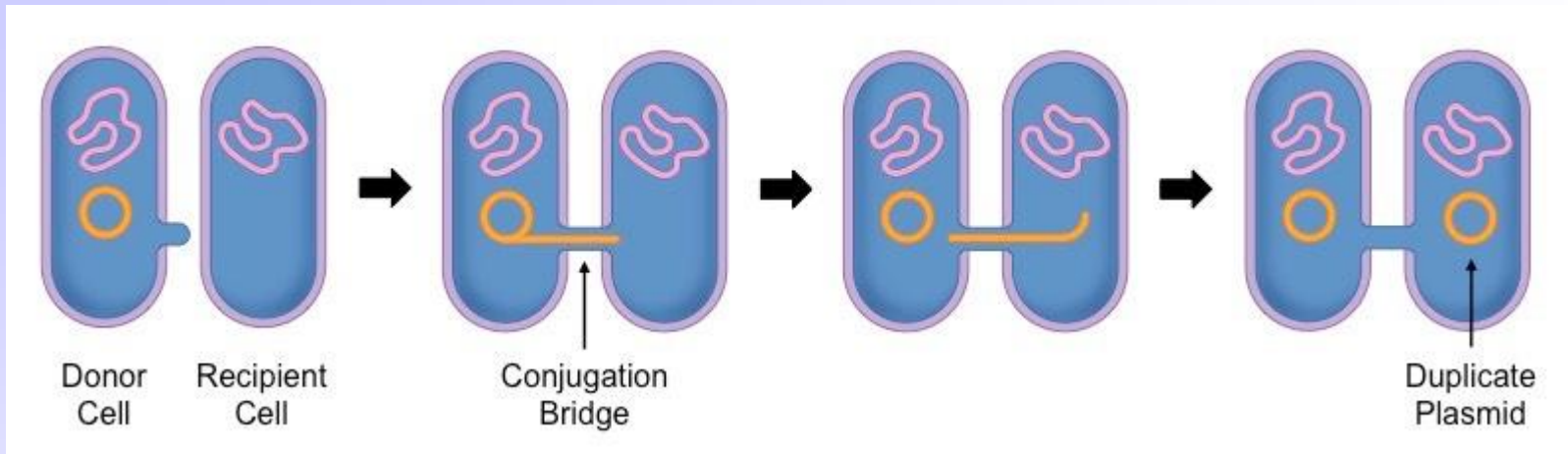
Semiconservative Replication of DNA

The replication fork of DNA showing the synthesis of two progeny strands. Each copy contains one new and one old strand.

Bacterial chromosome is called **Replicon**

Replicon – a part of the genome that contains an origin site and is replicated as a whole unit

Horizontal Gene Transfer: Conjugation



Prokaryotic cells

Feature	Prokaryotes
Size	All unicellular. Much smaller than eukaryotes. Generally 1-5µm in diameter.
Membrane-bound Organelles	No membrane bound organelles, including no nucleus, mitochondria, rough ER, smooth ER etc.
Nucleus	No nucleus but have a free floating chromosome
Plasmids	Some prokaryotes (including bacteria) have small circular DNA called plasmids. These are in addition to the bacterial chromosome.
Ribosomes	Free floating in cytoplasm, but much smaller i.e. 70s ribosomes
Cell Surface Membrane	Present. Some bacteria may have mesosomes i.e. invaginations within the cell surface membrane but these are now widely accepted as non-functional structures.
Cell Wall	Cell wall present but made out of peptidoglycan and glycoproteins (called murein)
Capsule	Certain types of bacteria can also have a protective capsule surrounding their cell walls called the lipopolysaccharide layer.
Motility (ability to move)	Many prokaryotes are motile, and have cilia and flagella to help them swim. Many bacteria also have multiple pili, which are hair-like processes that help with motility and communication with other bacteria.