- **WHY DO WE STUDY BACTERIAL AND VIRAL GENETICS?**

- Since the 1940s, the genetic systems of bacteria and viruses have contributed to the discovery of many important concepts in genetics.

- The study of molecular genetics initially focused almost entirely on their genes.

- Today, bacteria and viruses are still essential tools for probing the nature of genes in more complex organisms;

- Partly because they possess a number of characteristics that make them suitable for genetic studies.

- The genetic systems of bacteria and viruses are also studied because these organisms play important roles in human society.

- They have been exploited to produce a number of economically important substances, and they are of immense medical significance, causing many human diseases.

❖SUMMARY OF SOME ADVANTAGES OF USING BACTERIA AND VIRUSES IN GENETIC STUDIES

Advantages of using bacteria and viruses for genetic studies

1. Reproduction is rapid.

2. Many progeny are produced.

3. Growth in the laboratory is easy and requires little space.

4. Genomes are small (About 100-fold less that of eucaryotic cells).

5. Techniques are available for isolating and manipulating their genes.

6. They have medical importance.

7. They can be genetically engineered to produce and transfer genes of interest in large amounts.

- Genetic analysis in bacteria and viruses are different than that in eukaryotes.
- This is because bacteria and viruses have special genome organization, therefore different techniques and methods are used to analyze their genes and mutations.
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- Because they grow rapidly and also make their DNA rapidly, they are often used as host cells or vectors in recombinant DNA technology.

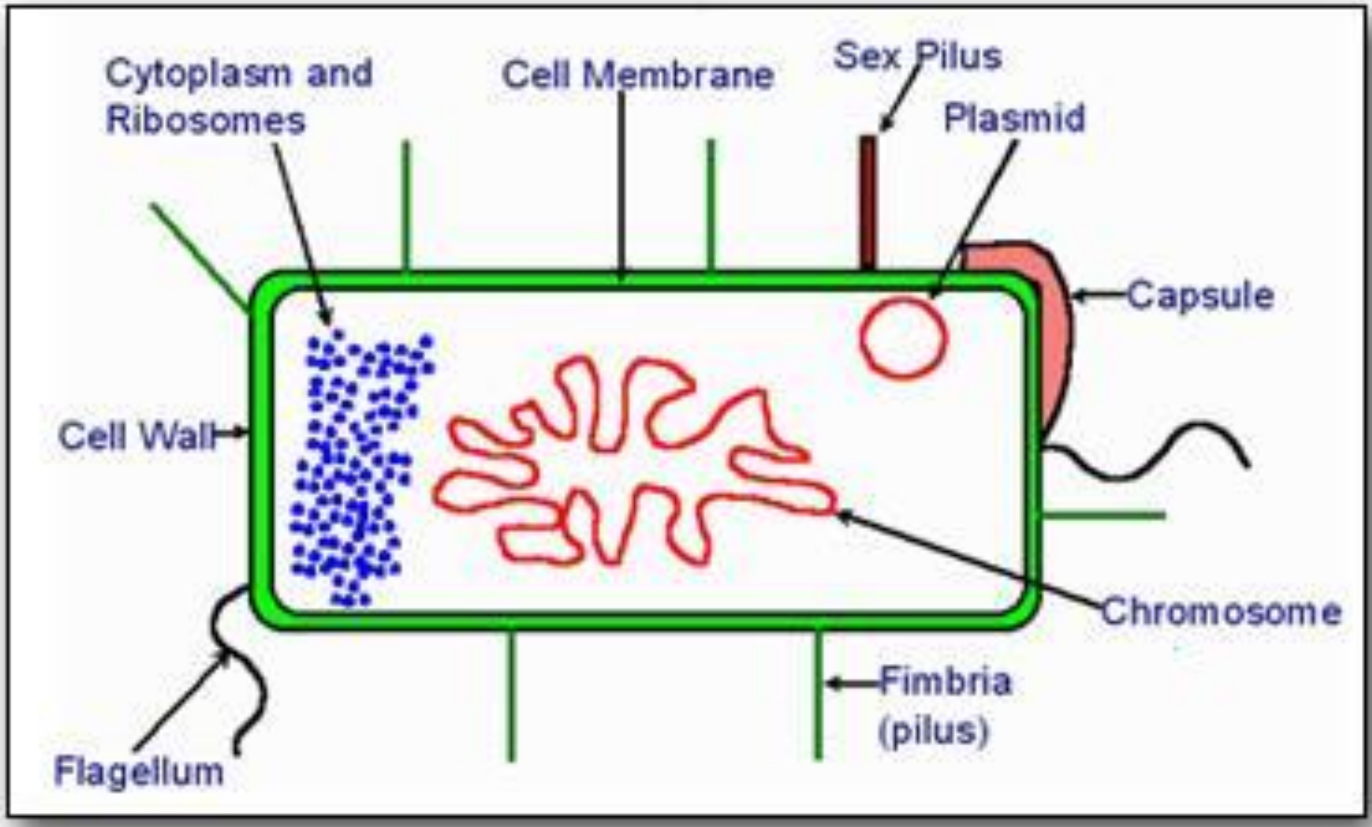
The Bacterial Chromosome

- Bacterial chromosomes are highly compacted structures and share many properties with their eukaryote counterparts, despite not being contained within a cell nucleus.

- While eukaryotes have two or more chromosomes, prokaryotes such as bacteria possess a single chromosome composed of double-stranded DNA in a loop or

- The DNA is in the form of a double helix which forms a closed ring or circle with no free ends.

Bacterial Chromosome



- The bacterial chromosome must be tightly packed to fit into the small volume of the bacterial cell.

- Compacting the DNA involves supercoiling, or further twisting of the twisted chromosome.

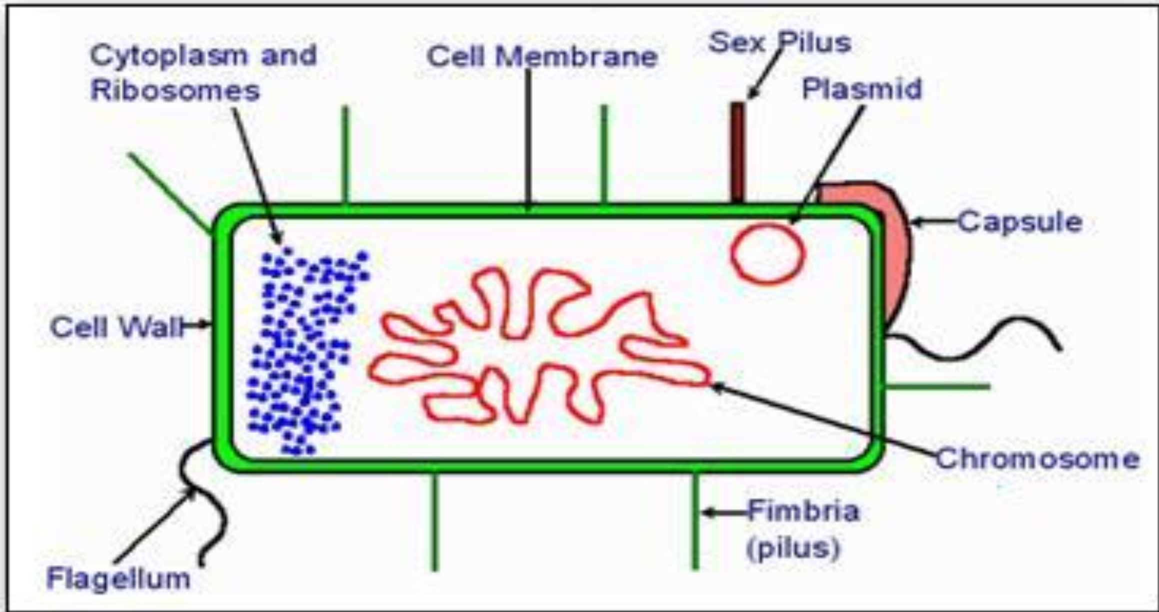
- Bacteria lack the histone proteins that are found bound to the DNA and that form the nucleosomes of eukaryotic chromosomes.

- However, it is believed that polyamines (organic molecules with multiple NH_2 or amine groups) such as spermidine, as well as some basic proteins, aid in compacting the bacterial chromosome.

- These basic proteins have a net positive charge that bind them to the negative charge of the phosphates in the DNA backbone.

- Replication of the circular chromosome begins at a single point, called OriC, and proceeds in both directions around the circle, until the two replication forks meet up.

- The bacterial chromosome lacks a protein coat and it is in direct contact with the cytoplasm, since a nuclear membrane is absent and it is called **nucleoid**.
- In addition to the nucleoid, a bacterial cell may show the presence of extra chromosomal DNA molecules called plasmids.



- Like the bacterial chromosome, plasmids are double stranded circular DNA molecules which can replicate and function independently.

- The plasmid has its own replication origin and the replication of plasmids is independent of the replication of chromosome.

- The plasmids mainly carry genes responsible for characteristics like **fertility**, **antibiotic resistance** and production of **bacteriocin** (a protein that kills closely related bacteria).

- The plasmids can be easily isolated from or introduced into the bacterial cells.

- They are small, circular DNA molecules
- Autonomous, extrachromosomal genetic elements
- Usually not essential to bacterial function but can be.

- Many of the plasmids first isolated and characterized carried genes for antibiotic resistance

- Plasmids control their own replication

- Episomes, such as the F (fertility) factor, can either exist as freely-replicating plasmids or by integrating into the chromosome.

Genetics of Viruses

- A virus particle, also known as a virion, is essentially a nucleic acid (DNA or RNA) enclosed in a protein shell or protective coat.

- Viruses are extremely small, approximately 15 - 25 nanometers in diameter.

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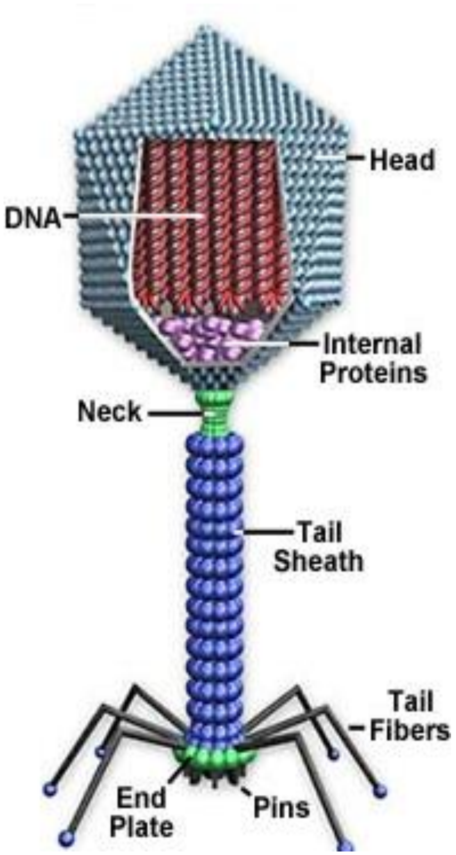
- Viral genomes are much different than prokaryotes and eukaryotes:
- \- may be **double-stranded DNA**, **single-stranded DNA**, **double-stranded RNA** or **single-stranded RNA**
- -organized as single nucleic acid molecules in linear or circular arrangements

- The type of genetic material found in a particular virus depends on the nature and function of the specific virus.

- The viral genome can consist of a very small number of genes or up to hundreds of genes depending on the type of virus.

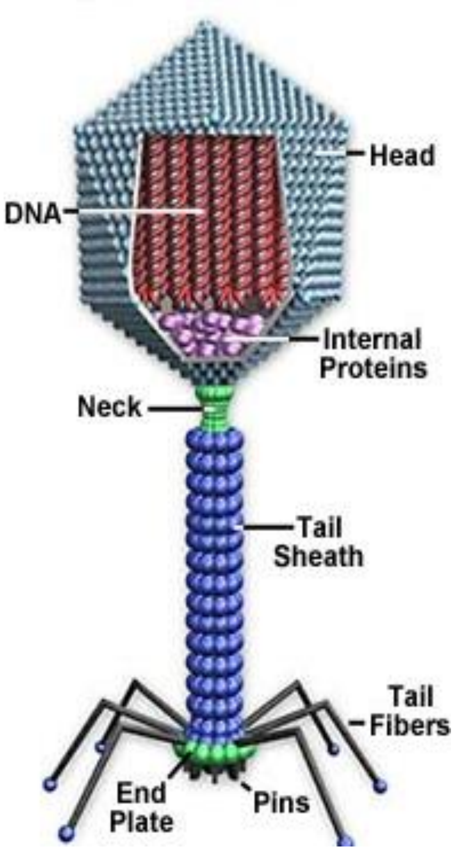
Viral Structure

- The protein coat that envelopes viral genetic material is known as a **capsid**.



- A capsid is composed of protein subunits called **capsomeres**.

- Capsids can have several shapes: Icosahedral, Helical or complex.



Functions of the Capsid

- The capsid has three functions:

(1) it protects the nucleic acid from digestion by enzymes,

(2) contains special sites on its surface that allow the virion to attach to a host cell, and

(3) provides proteins that enable the virion to penetrate the host cell membrane and, in some cases, to inject the infectious nucleic acid into the cell's cytoplasm.

- In addition to the protein coat, some viruses have specialized structures. For example, the flu virus has a membrane-like envelope around its capsid.

- **Envelope** - Many types of virus have a glycoprotein envelope surrounding the nucleocapsid.

- The envelope is composed of two lipid layers interspersed with protein molecules (lipoprotein bilayer) and may contain material from the membrane of a host cell as well as that of viral origin.

- Without a host cell, viruses cannot carry out their life-sustaining functions or reproduce.

- They cannot synthesize proteins, because they lack ribosomes and must use the ribosomes of their host cells to translate viral messenger RNA into viral proteins.

- **Nucleic Acid** - Just as in cells, the nucleic acid of each virus encodes the genetic information for the synthesis of all proteins.

- While the double-stranded DNA is responsible for this in prokaryotic and eukaryotic cells, only a few groups of viruses use DNA.

- Viruses cannot generate or store energy in the form of adenosine triphosphate (ATP), but have to derive their energy, and all other metabolic functions, from the host cell.

- They also parasitize the cell for basic building materials, such as amino acids, nucleotides, and lipids (fats).

- Viruses can reproduce only within a host cell
- They are obligate intracellular parasites –i.e. can only express genes from living cells
- Viruses have specific host range, or a limited number of host cells that they can infect

- Some have very narrow host ranges and infect single species or single tissue types of one species

  For example: The AIDS virus can only infect certain white blood cells.
  whilst the cold virus will only infect cells of the upper respiratory tract.

Viral Replication

- A single virus particle or virion in itself essentially inert.

- It lacks needed components that cells have to reproduce.

- When a virus infects a cell, it marshals the cell's ribosomes, enzymes and much of the cellular machinery to replicate.

- Viral replication produces many progeny, that when complete, leave the host cell to infect other cells in the organism.

- The exact nature of what happens after a host is infected varies depending on the nature of the virus.

- The process for double-stranded DNA, single-stranded DNA, double-stranded RNA and single-stranded RNA viral replication will differ.

- For example, double-stranded DNA viruses typically must enter the host cell's nucleus before they can replicate.
- Single-stranded RNA viruses however, replicate mainly in the host cell's cytoplasm.

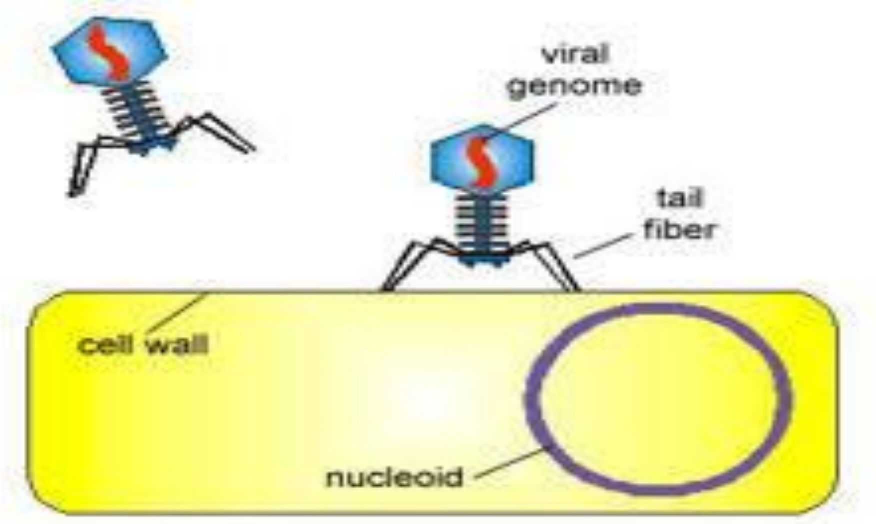
- Once a virus infects its host and the viral progeny components are produced by the host's cellular machinery, the assembly of the viral capsid is a non-enzymatic process.

- It is usually spontaneous.

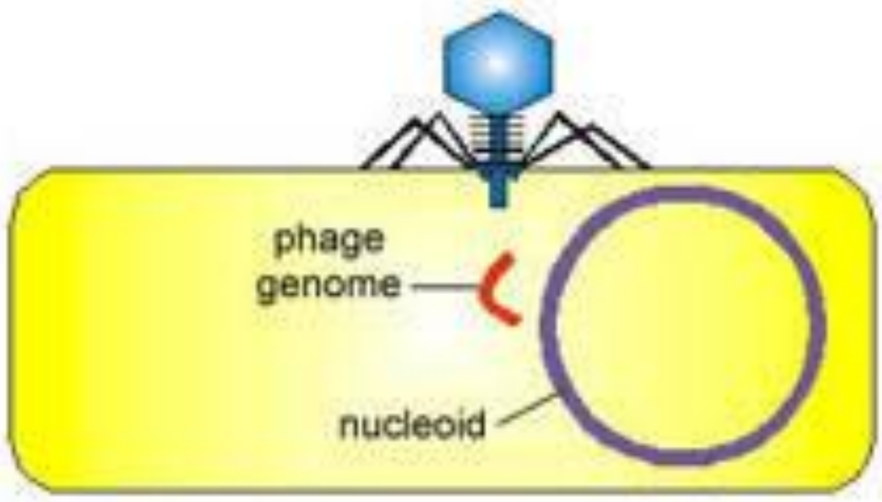
How Viruses Infect Cells

- The basic process of viral infection and virus replication occurs in 6 main steps.

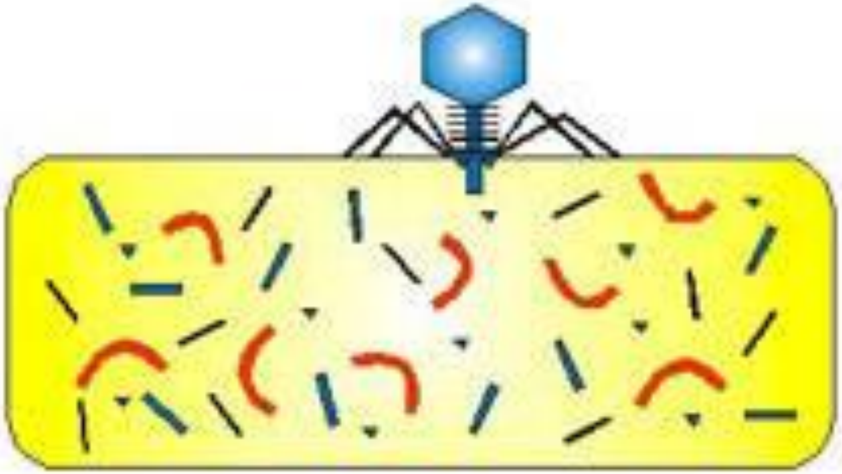
- **Adsorption/Attachment** - virus binds to the host cell.



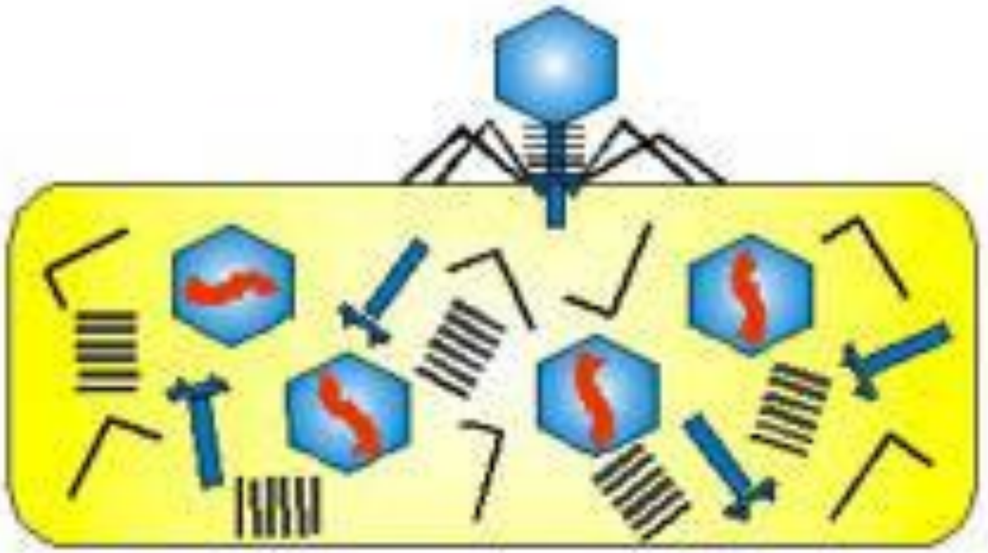
- **Penetration** - virus injects its genome into host cell. At this point, the virus can no longer be recovered from the intact cell.



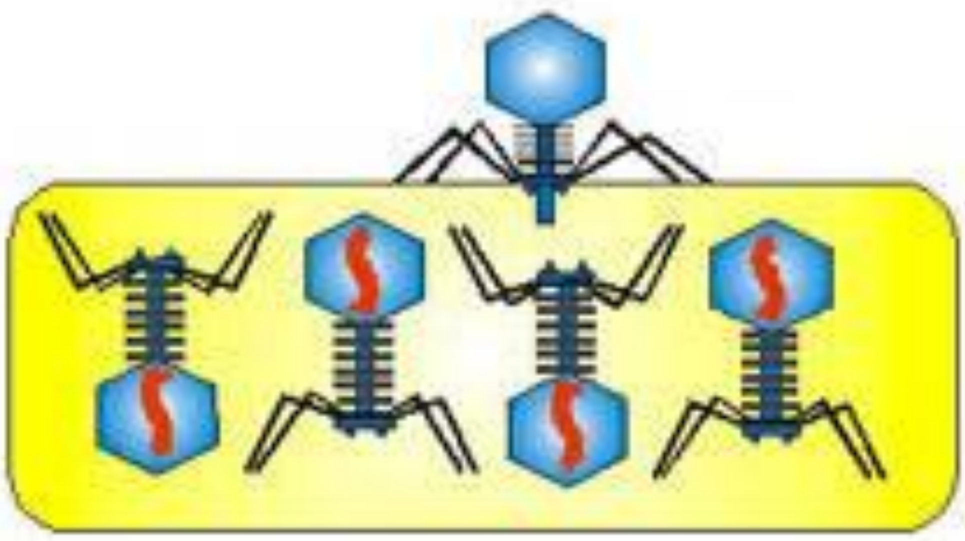
- **Replication or Synthesis** – The viral genome replicates using the host's cellular machinery.



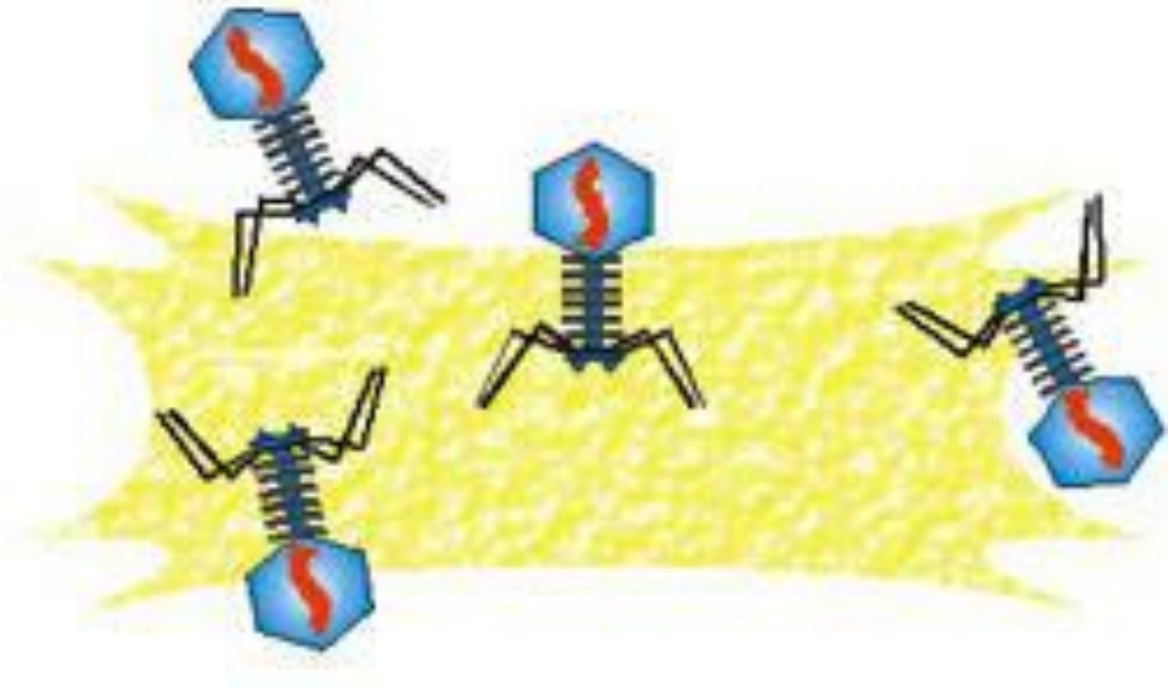
- **Assembly** - viral components and enzymes are produced and begin to assemble.



- **Maturation** - viral components assemble and viruses fully develop.

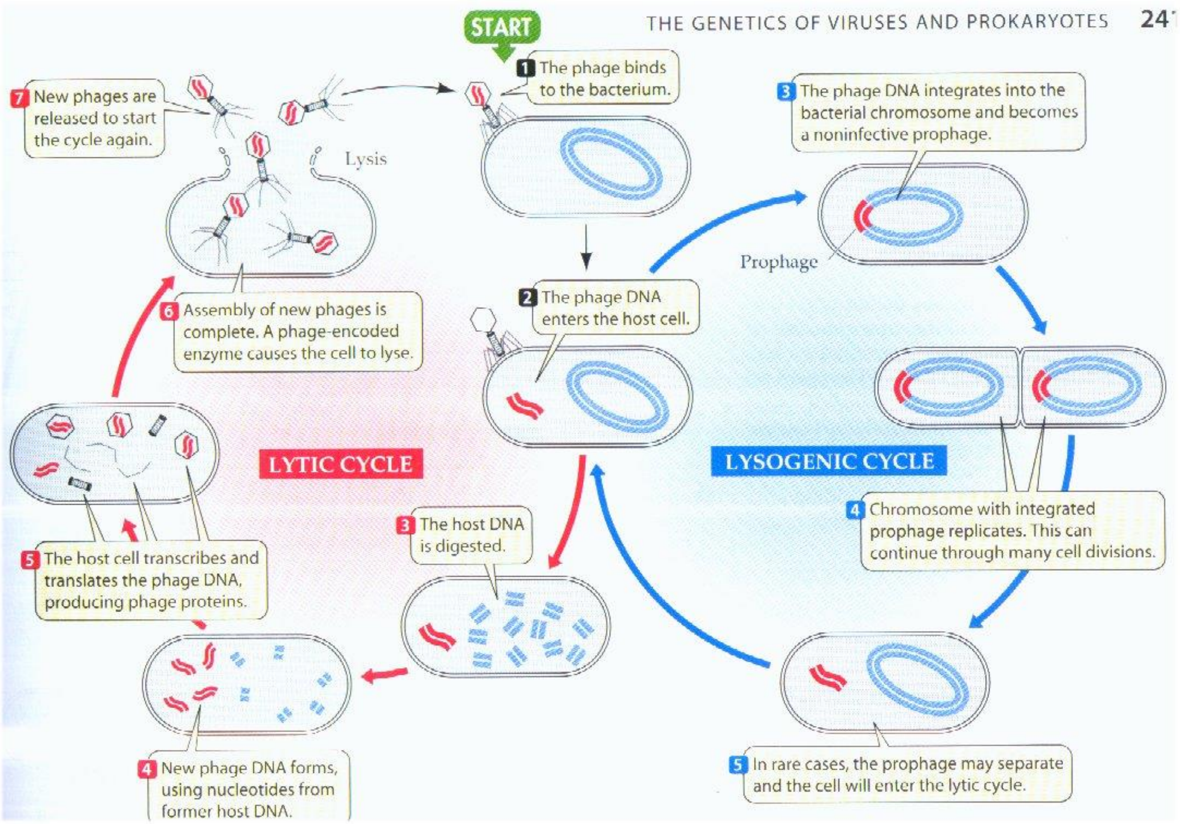


- **Release** - newly produced viruses are release from the host cell. The virus releases enzymes to break the cell wall and the cell wall bursts.



General Viral Life Cycle

- A virus undergoes lytic and/or lysogenic cycle to reproduce.



The Lytic cycle

- The lytic cycle is thought to be the major method of viral replication as it results in total cell lyses (that is, cell destruction of the infected bacterium).

- The viruses that undergo lytic cycle are called **virulent viruses**.

- This begins with the six stage cycle that we have discussed above.

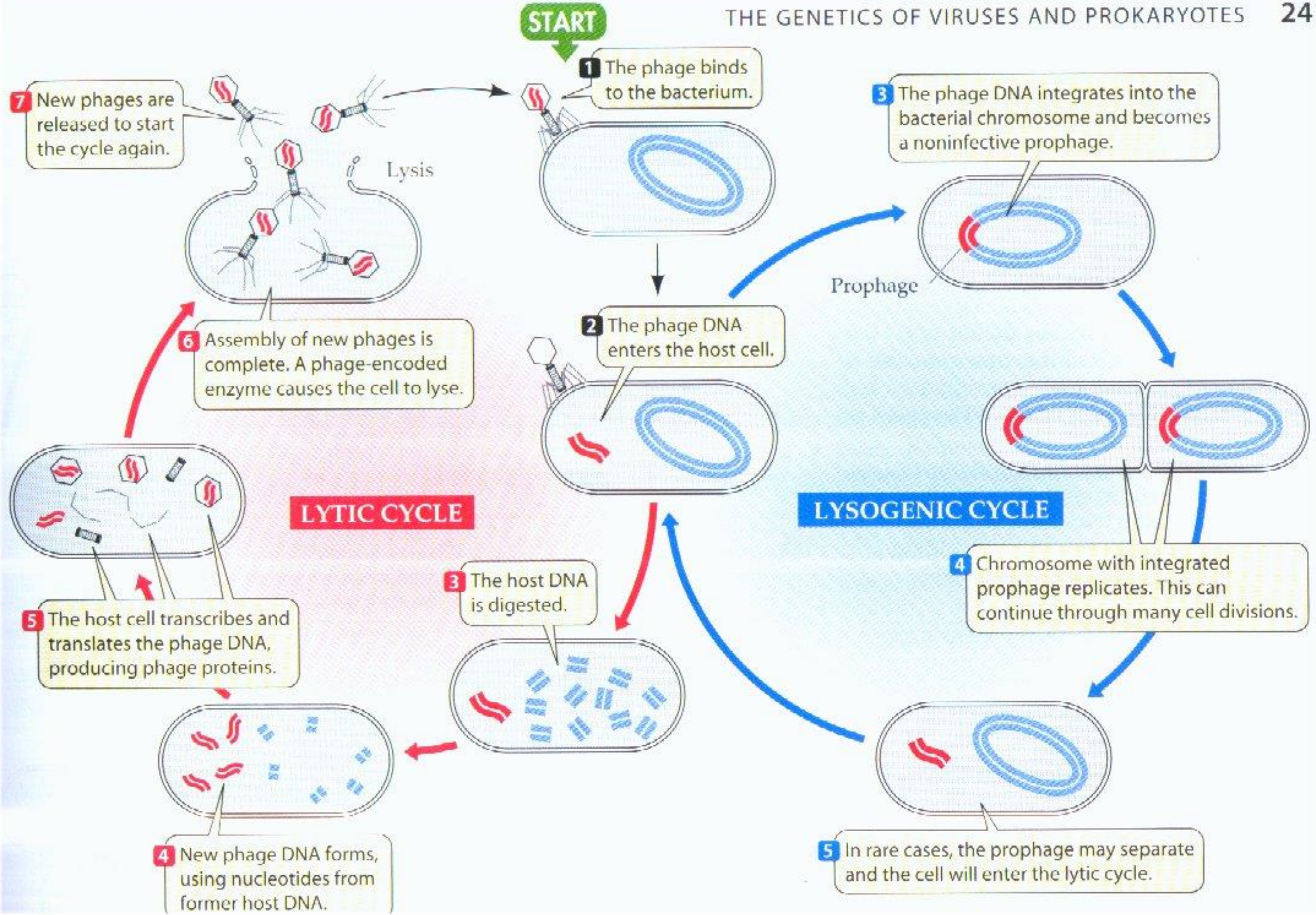
- The virus injects its nucleic acids into the host cell that form a circle in the center of the cycle.

- The host cell is then “tricked” or “directed” into replicating the viral nucleic acid instead of its own nucleic acids.

- This viral DNA then begins organizing itself into a viral cell inside the host cell.

- When the number of viruses in the host cell increases, it causes the cell membrane to split or lyse under the pressure from so many cells.

- Thus, the viruses are released from the host body and ready to infect another cell
- A host cell releases about 100 to 200 viruses approximately.
- These viruses cause cell lyses, thus giving rise to the name **lytic cycle**.

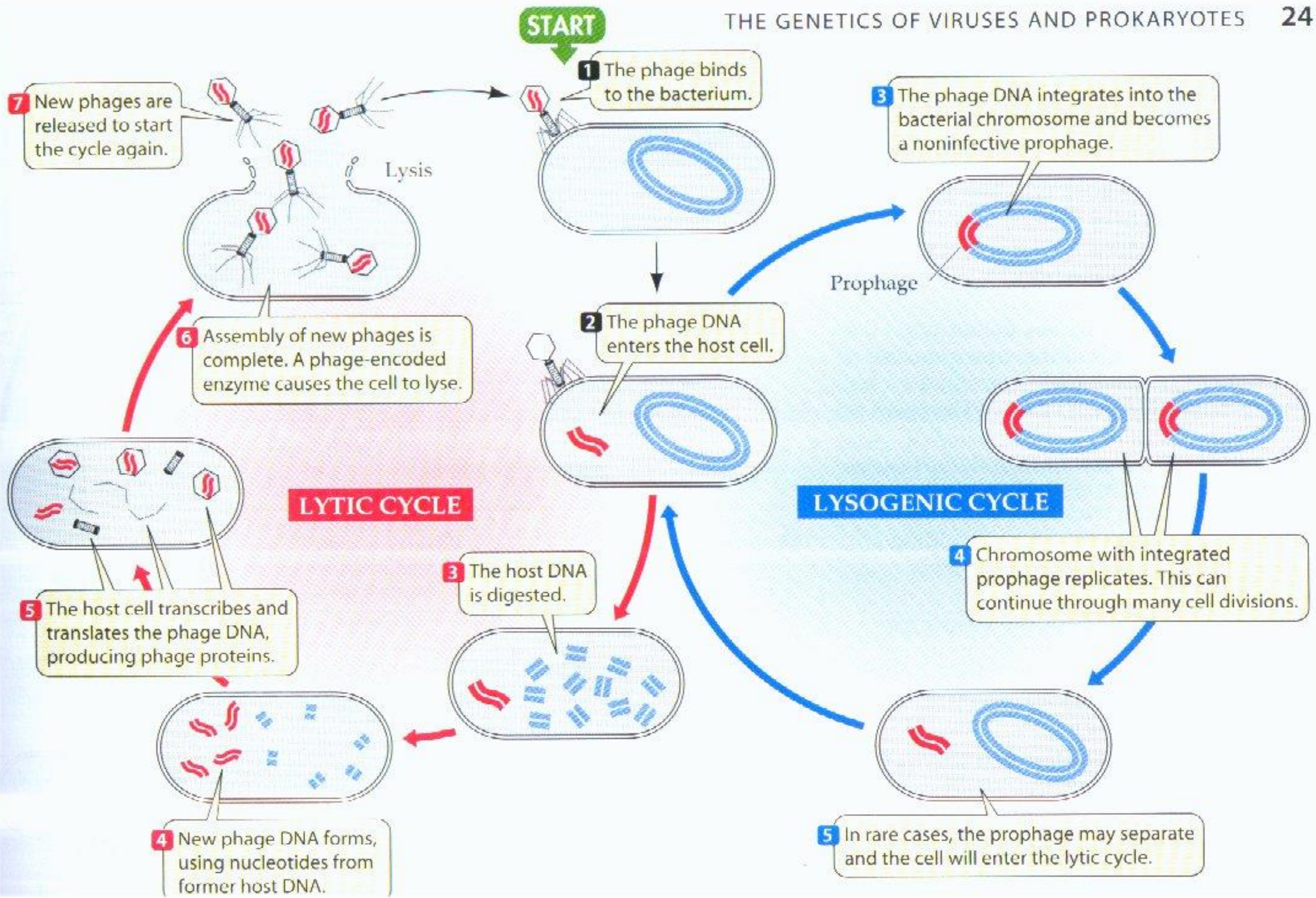

START
1 The phage binds to the bacterium.
2 The phage DNA enters the host cell.
3 The host DNA is digested.
4 New phage DNA forms, using nucleotides from former host DNA.
5 The host cell transcribes and translates the phage DNA, producing phage proteins.
6 Assembly of new phages is complete. A phage-encoded enzyme causes the cell to lyse.
7 New phages are released to start the cycle again.
Lysis
LYTIC CYCLE
LYSOGENIC CYCLE
3 The phage DNA integrates into the bacterial chromosome and becomes a noninfective prophage.
Prophage
4 Chromosome with integrated prophage replicates. This can continue through many cell divisions.
5 In rare cases, the prophage may separate and the cell will enter the lytic cycle.

The Lysogenic cycle

- Lysogenic cycle is the integration of the bacteriophage nucleic acid into the host genome.

- The new genetic material integrated into host cell is called a **prophage**.

- A prophage is transferred to the daughter cells of the host cell after each subsequent cell division.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- UV radiation, hydrogen peroxide and nitrogen mustard are chemical or physical agents that can lead to release of new phases into the environment through the lytic cycle.

- **MUTATIONS**