Bacterial physiology

Dr. Mohammed Radhi

Microbial Growth

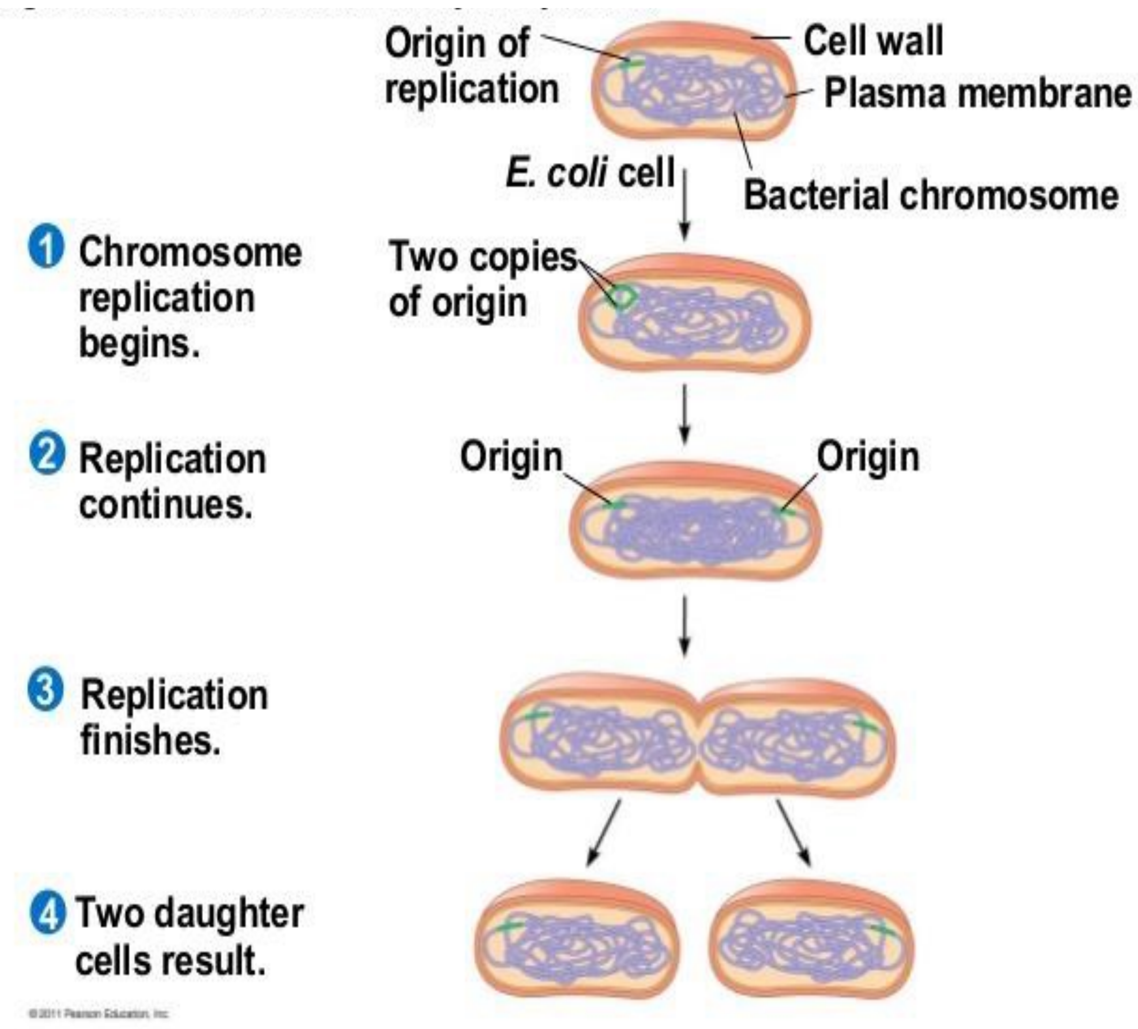
- When microbes are provided with nutrients and the required environmental factors, they become metabolically active and grow.

- Growth takes place on two levels.

-Cell synthesizes new cell components and increases its size.

-The number of cells in the population increases.

- The size of population is increased due to the bacterial cell multiplication by cell division. This has tremendous importance in microbial control, infectious disease, and biotechnology.
- The division of a bacterial cell occurs mainly through binary, or transverse, fission. During binary fission, the parent cell enlarges, duplicates its chromosome, and forms a central transverse septum that divides the cell into two daughter cells. This process is repeated at intervals by each new daughter cell in turn; and with each successive round of division, the population increases.



Bacterial Nutritional requirements

- Bacterial requirements for growth include oxygen, hydrogen and carbon), inorganic ions and organic nutrients.
- **Hydrogen** is usually obtained from water, and **oxygen** is obtained from atmosphere or from water where it is found in dissolved state.
- **Carbon:** according to their ability to synthesize essential metabolism (obtained carbon), bacteria can be classified into the following types:

A- Autotrophs:- These bacteria are able to synthesize their own organic food from inorganic substances. They use carbon dioxide for obtaining carbon

B- Heterotrophs:-Microbes obtain their carbon from organic compound, such as sugar, protein and lipids.

- **Inorganic ions;** Nitrogen, sulphur, phosphate, potassium and some other elements.
- **Organic nutrients**:- Organic nutrients are required in small amounts by cells because they play specific roles in biosynthesis.

Growth factors are organized into three categories:

1-purines and pyrimidines: required for synthesis of nucleic acids (DNA and RNA)

2-amino acids: required for the synthesis of proteins

3-vitamins: needed as coenzymes and functional groups of certain enzymes

Factors that modify bacterial growth

- **pH:-**
- according to their acidity requirements bacteria can be classified into:

1-Acidophiles:- Microorganisms which grow at pH (3-5).
2- Neutrophiles:- Microorganisms which grow best at neutral pH (6-8)
3- Alkaliphiles:- Microorganisms which grow best under alkaline conditions pH as high as 10.5.

Moisture:-

- Water is needed for the growth and reaction of metabolism like glycolysis and protein synthesis, various nutrient must be in a soluble form to facilitate diffusion into the cell. In the absence of the water some bacteria will form a spore for continue its survival.

Gas requirement:-

- Microorganisms fall into several groups with respect to the effect of oxygen on their growth and metabolism:
  1. **Obligate aerobes**
  - use and require oxygen as electron acceptor
  - have respiratory enzymes and lack the capacity for fermentations
  - examples: Pseudomonas, some Bacillus
  2. **Obligate anaerobes**
  - do not need or use O2 as a nutrient. In fact, O2 is a toxic substance, which either kills or inhibits their growth. Obligate anaerobic procaryotes may live by fermentation, anaerobic respiration
  - examples: Clostridium, Bacteroides

3. **Facultative organisms** •
- are organisms that can switch between aerobic and anaerobic types of metabolism. Under anaerobic conditions (no O2) they grow by fermentation or anaerobic respiration, but in the presence of O2 they switch to aerobic respiration.
- examples: all Enterobacteriaceae (*E.coli*), some Bacillus

- 4. **Aerotolerant anaerobes**
  - grow either with or without oxygen, but metabolism remains fermentative and do not use oxygen
  - examples: Enterococcus faecalis, some Lactobacillus

5-Microaerophilec

-these bacteria grow well under low oxygen concentration

-examples: *Campylobacter fetus*

Temperature:-

The temperature range at which organism grow best is called **optimum temperature.** In human parasitic organism optimum temperature ranges between 30° C and 37° C. there are three groups of bacteria as regard to the temperature:-

- 1- Psychrophilic:-

The bacteria is growing between 0° C and 25° C. they are mostly soil and water bacteria

- 2- Mesophilic:-

Some bacteria grow between 20° C and 44° C this group include bacteria producing disease.

3- Thermophilic:-

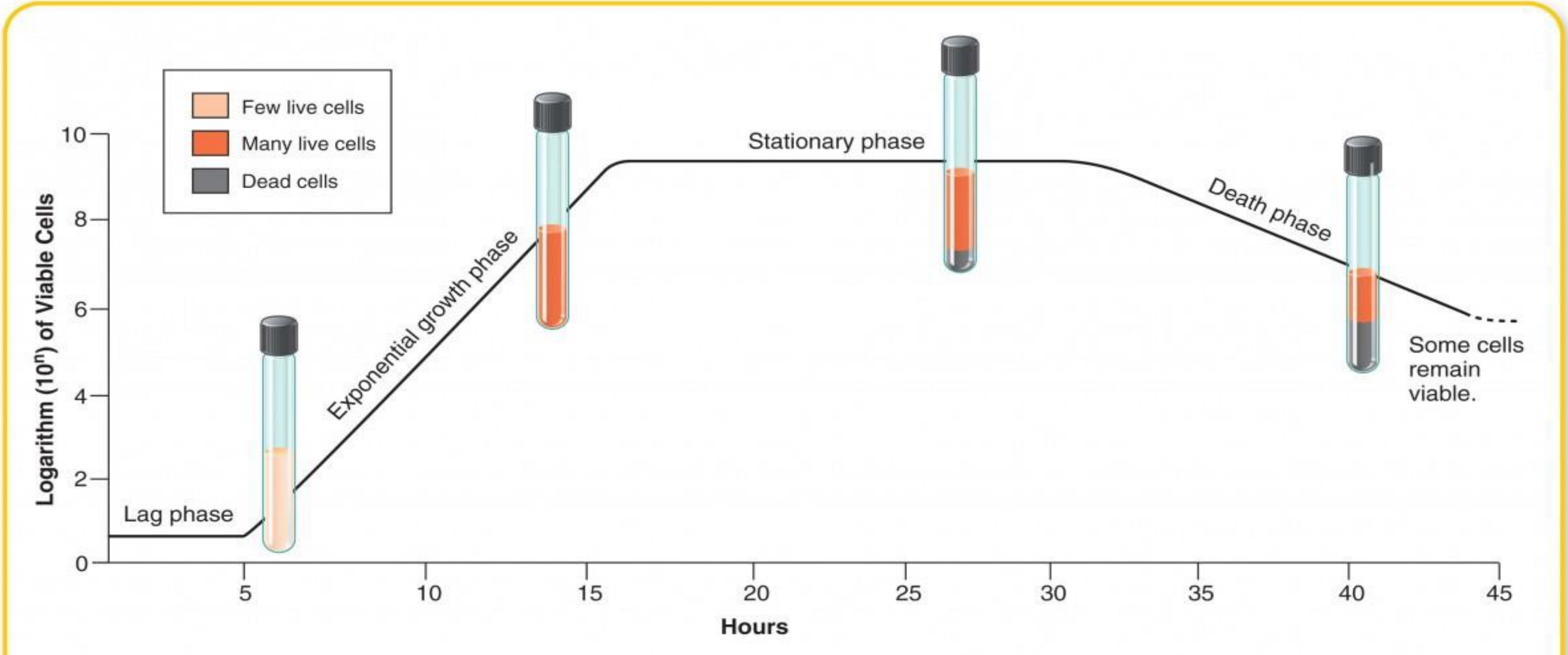
- The bacteria can grow between 50 and 80° C this bacteria will survive after pasteurization processes of milk.

The Rate of Population Growth

- The time required for a complete fission cycle—from parent cell to two new daughter cells—is called the **generation**, or **doubling time**. In bacteria, each new fission cycle or generation increases the population by a factor of 2, or doubles it.
- The length of the generation time is a measure of the growth rate of an organism. The average bacterial generation time is 30 to 60 minutes under optimum conditions.
- The shortest generation times average 5 to 10 minutes, and longer generation times require days.
- Some bacterial species, for example, *Mycobacterium leprae* (the cause of Hansen's disease), has a generation time of 10 to 30 days.
- Most pathogenic bacteria have relatively short doubling times. *Salmonella enteritidis* and *Staphylococcus aureus*, bacteria that cause food-borne illness, double in 20 to 30 minutes.

Stages in the Normal Growth Curve

- Data from an entire growth period of 3 to 4 days typically produce a curve with a series of phases termed the lag phase, the exponential growth (log) phase, the stationary phase, and the death phase .



Total cells in population, live and dead, at each phase.

The death phase

The decline in the growth rate is caused by several factors.

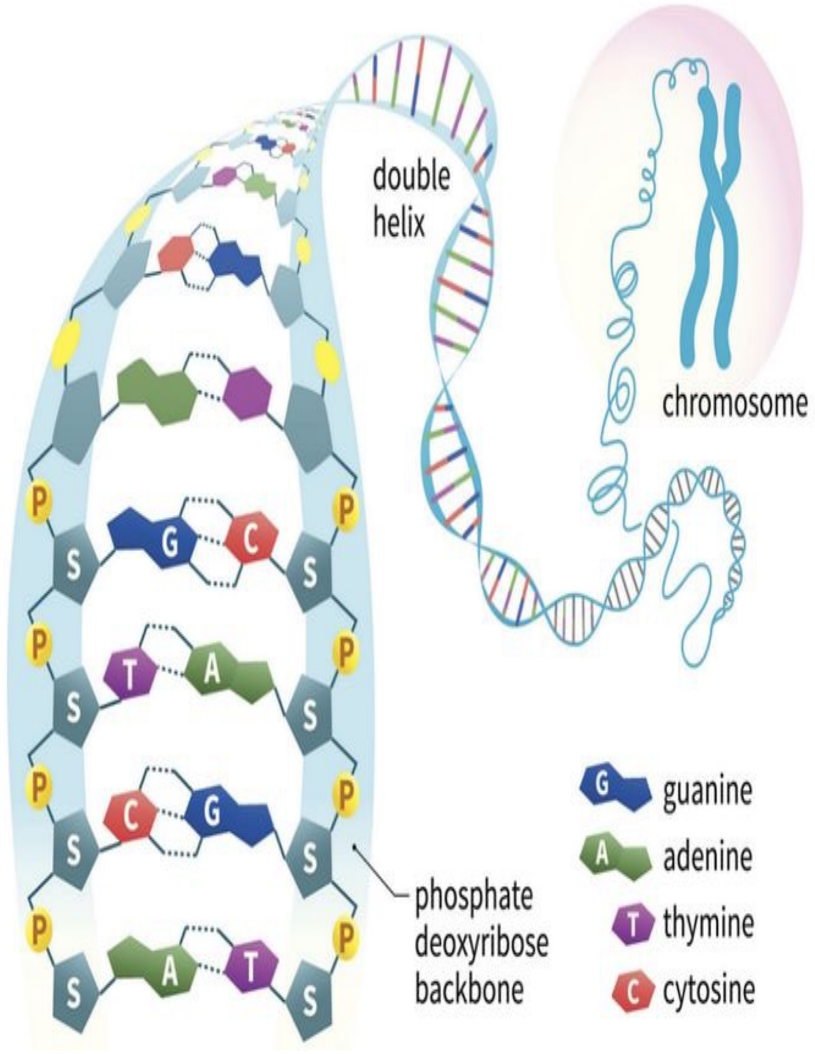
- 1-Depletion of nutrients and oxygen.
- 2-Increased cell density often causes an accumulation of organic acids and other toxic biochemicals.

Cells begin to die at an exponential rate and most are unable to multiply. The curve now dips downward as the death phase begins. The speed with which death occurs depends on the relative resistance of the species and how toxic the conditions are, but it is usually slower than the exponential growth phase.

Bacterial genetics

- Genetics is the study of the inheritance and variation. All bacterial characteristics are encoded in DNA. DNA or **Deoxyribonucleic acid** is a molecule composed of two chains (made of nucleotides) that coil around each other to form a double helix carrying all the genetic instructions that used in the growth, development, functioning and reproduction of all known living organisms and many viruses. DNA and ribonucleic acid (RNA) are nucleic acids; alongside proteins, lipids and complex carbohydrates (polysaccharides), which all are the four major types of macromolecules that are essential for all known forms of life.
- The two DNA strands are also known as polynucleotides since they are composed of simpler monomeric units called nucleotides.

- Each DNA nucleotide is composed of one of four nitrogen-containing nucleobases (cytosine[C], guanine [G], adenine [A] or thymine [T]), a sugar called deoxyribose, and a phosphate group.
- The nucleotides are joined to one another in a chain by covalent bonds between the sugar of one nucleotide and the phosphate of the next, resulting in an alternating sugar-phosphate backbone. The nitrogenous bases of the two separate polynucleotide strands are bound together, according to base pairing rules (A with T and C with G), with hydrogen bonds to make double-stranded DNA.



- The DNA of most bacteria is contained in a single circular molecule, called the bacterial chromosome. The chromosome, along with several proteins and RNA molecules, forms an irregularly shaped structure called the nucleoid. This sits in the cytoplasm of the bacterial cell.

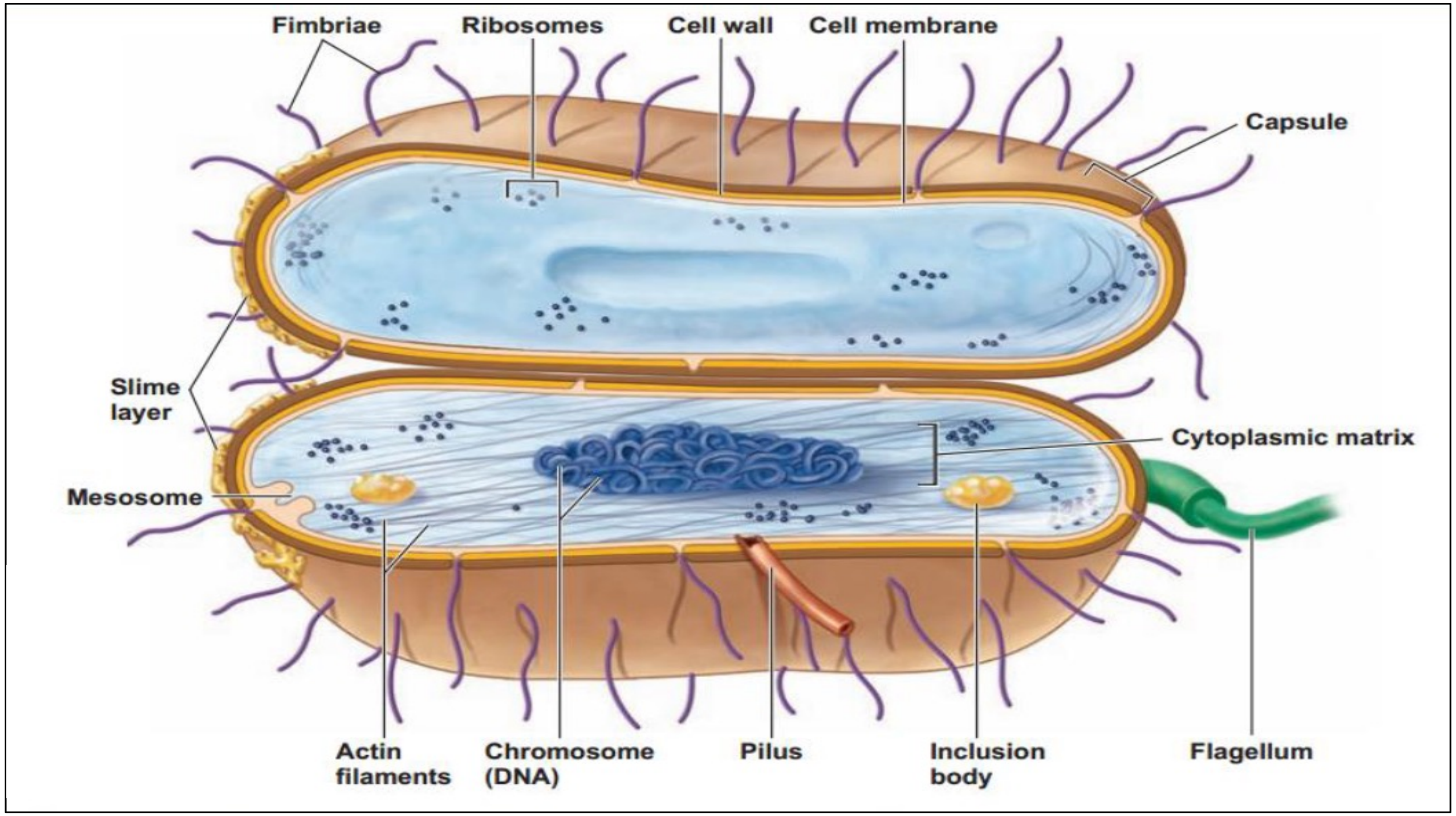
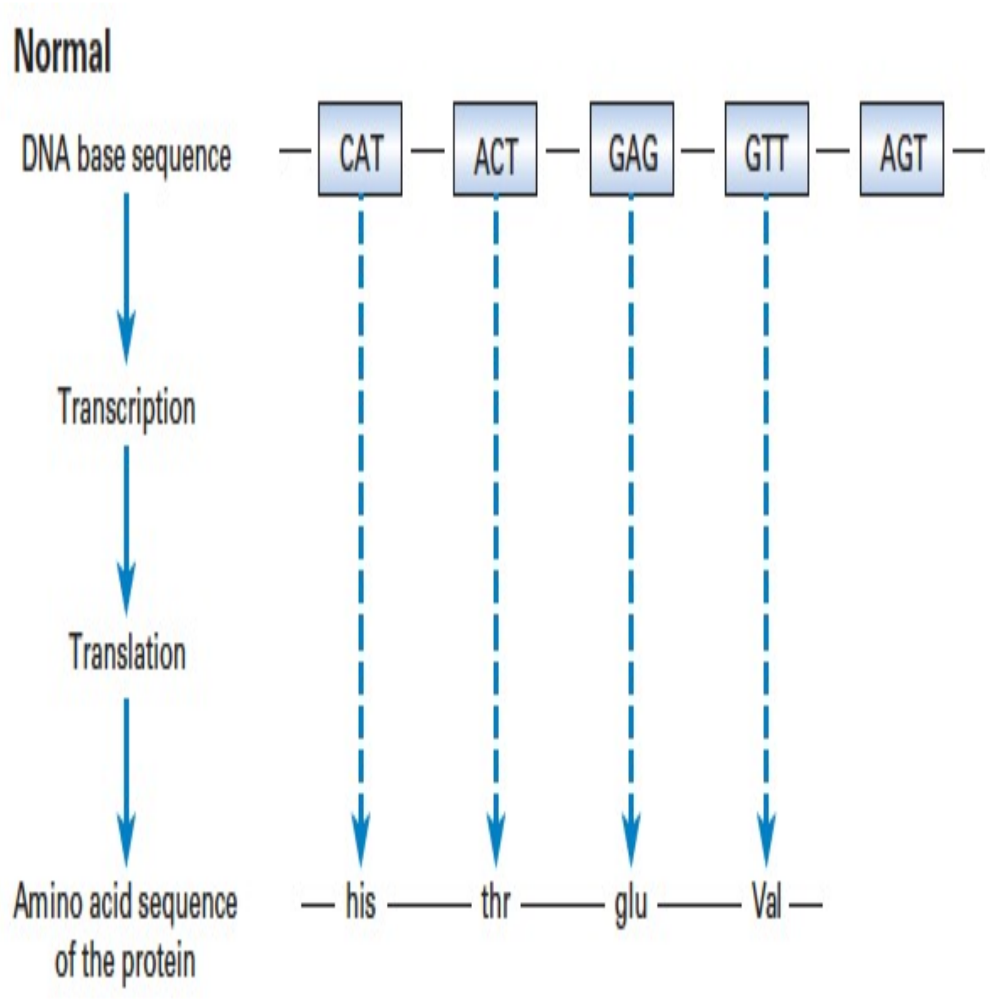


Figure 8. 3D structure of the bacterial cell.

Genes

- The genetic code of bacteria is contained in a series of units called genes. As the normal bacterial chromosome has one copy of each gene, bacteria are called **haploid** organisms (higher organisms which contain two copies of the gene called diploid).
- A gene is a chain of purine (A&G) and pyrimidine (T&C) nucleotides. the genetic information is encoded in triple nucleotide groups or codons. Each codon codes for specific amino acid or regulatory sequence, e.g. starts and stope codons. In this way the structural genes determine the sequence of amino acids that form the protein, which is the gene product.



Genetic variation in bacteria

Genetic variation can occur as a result of mutation or gene transfer.

A- Mutation

- Mutation is a change in the base sequence of DNA, as a consequence of which different amino acids are incorporated into a protein, resulting in an altered phenotypes. There are three types of DNA mutations.

1- Base substitution : this occurs during DNA replication when one base is inserted in place of another. And it has two types

-Missense mutation: when the base substitution results in a codon that instructs a different amino acid to be inserted.

-nonsense mutation: when the gene mutation stops its protein synthesis.

2- Frame shift mutation: which occur when one or more base pair are added or deleted that resulted in production of inactive protein because of the production of wrong amino acids.

- Insertion : the insertion of additional pieces of DNA.

B-Gene transfer

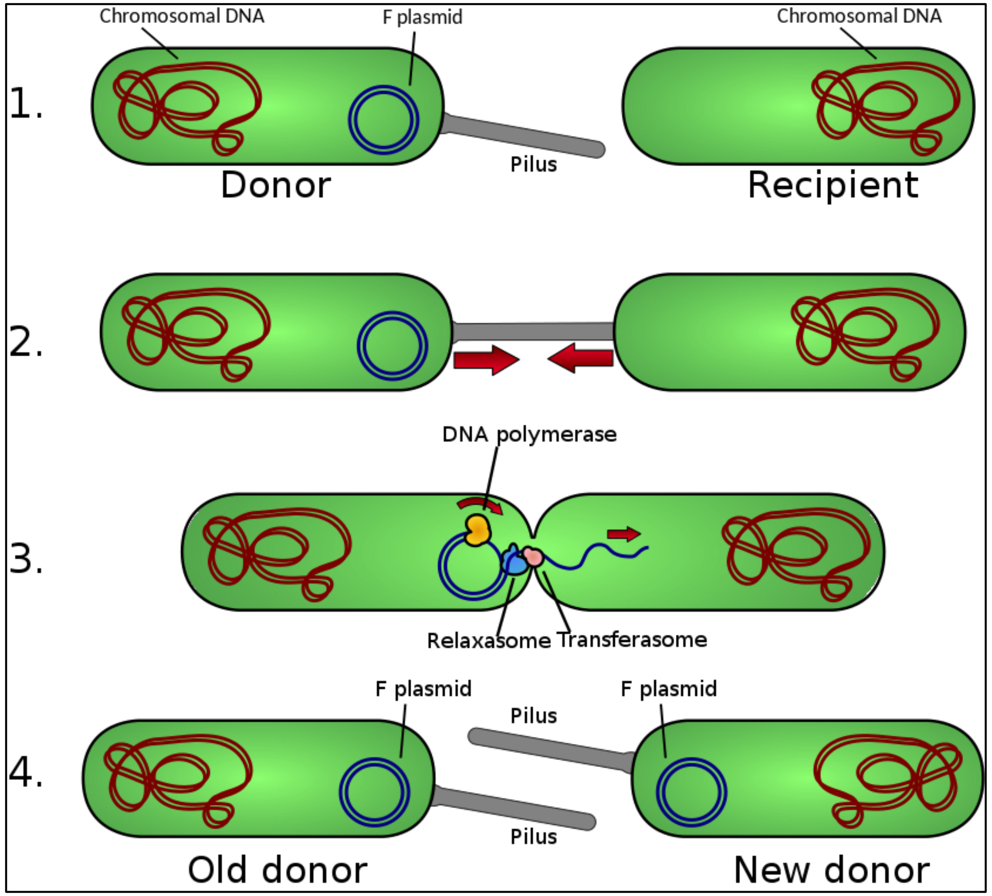
the transfer of genetic information can occur by:

- Conjugation
- Transduction
- Transformation
- Transposition

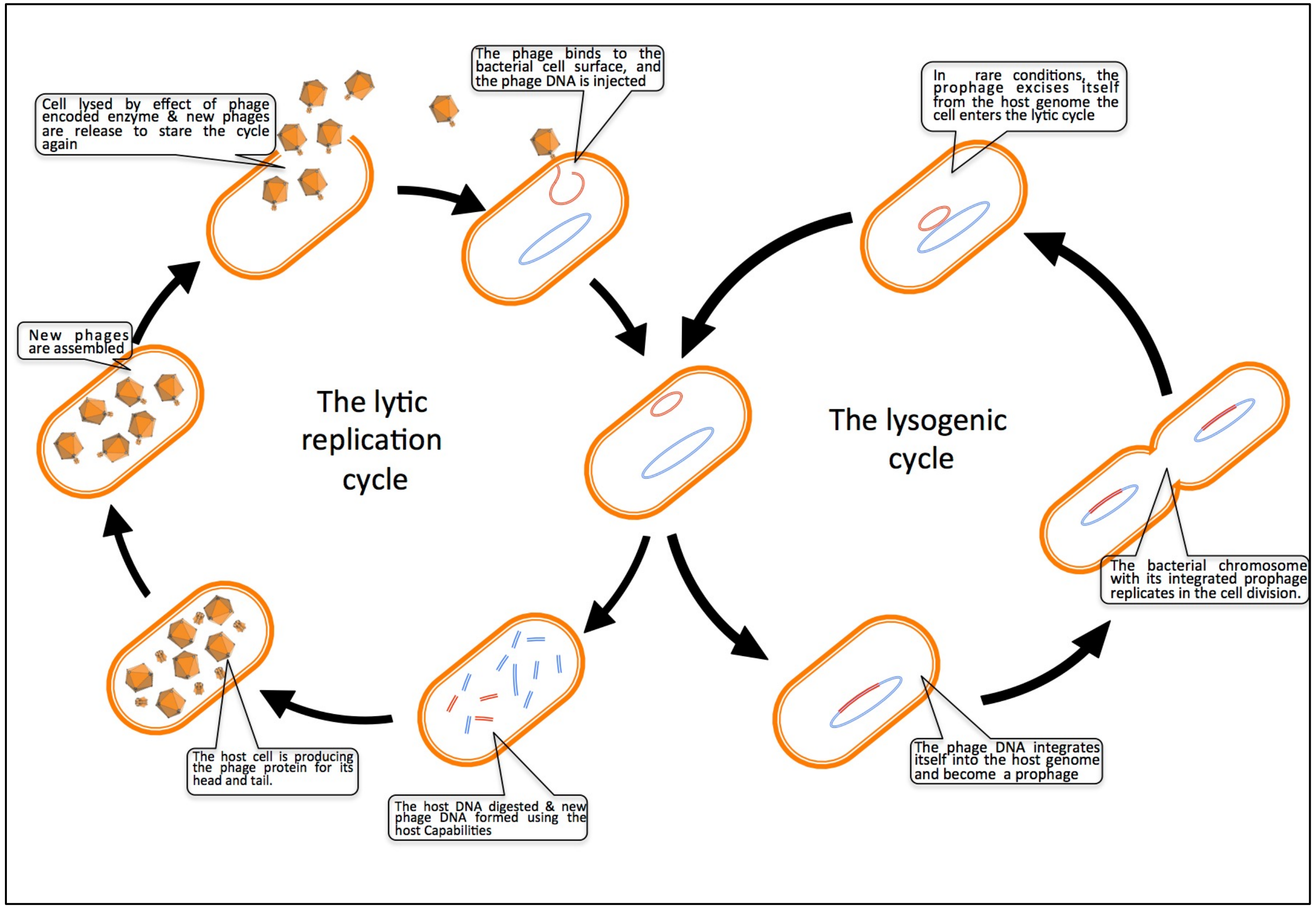
Conjugation

- Bacterial conjugation is the transfer of genetic material between bacterial cells by direct cell-to-cell contact (mating of two cells) or by a bridge-like connection between two cells. This takes place through pilus (Pili in plural).
- It is one of horizontal gene transfer mechanisms. During conjugation the *donor* cell provides a conjugative or mobilizable genetic element that is most often a plasmid or transposon. Most conjugative plasmids have systems ensuring that the *recipient* cell does not already contain a similar element.
- The genetic information transferred is often beneficial to the recipient. Benefits may include antibiotic resistance, xenobiotic tolerance or the ability to use new metabolites. The mating process is controlled by an F (fertility) plasmid ,carrying genes for the proteins required for mating including pilin, which forms pilus.

- Donor cell [cell carrying F factor or (F+)] produces pilus.
- Pilus attaches to recipient cell and brings the two cells together.
- The mobile plasmid is cleaved enzymatically and a single strand of DNA is then transferred to the recipient cell.
- Both cells synthesize a complementary strand to produce a double stranded circular plasmid and are able to reproduce pili; both cells are now viable donor for the F-factor.

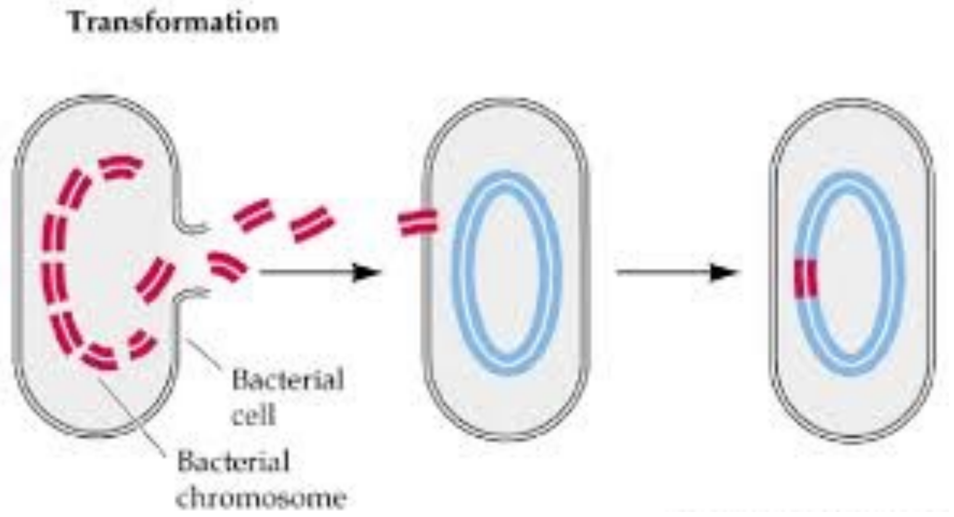


Transduction



Transformation

- This is the transfer of exogenous of bacterial DNA from one cell to another. It occurs in nature when dying bacteria release their DNA, which is than taken up by recipient cells and recombined with the recipient cell’s DNA.



Transposition

- This occurs when transposable element moves from one DNA site to another within the same genome of the same organism.
- The simplest transposable elements, called; insertion sequences, are less than 2 kilobases in length and encodes enzymes (transposase) required for “DNA jumping” from one site to another.

DNA recombination

- The transferred DNA from the donor cell to the recipient cell is integrated into the host genome by a process called DNA recombination. There are two types of DNA recombination depends on DNA homology between the two recombinant molecules:
- Homologous recombination
- Nonhomologous recombination.

Plasmids

- A **plasmid** is a small DNA molecule within a cell that is physically separated from a chromosomal DNA and can replicate independently. They are most commonly found as small circular, double-stranded DNA molecules in bacteria; however, plasmids are sometimes present in archaea and eukaryotic organisms. In nature, plasmids often carry genes that may benefit the survival of the organism, for example antibiotic resistance.

- While the chromosomes are big and contain all the essential genetic information for living under normal conditions, plasmids usually are very small and contain only additional genes that may be useful to the organism under certain situations or particular conditions. Artificial plasmids are widely used as vectors in molecular cloning, serving to drive the replication of recombinant DNA sequences within host organisms. In the laboratory, plasmids may be introduced into a cell via transformation.