CHAPTER (5)

BACTERIAL GENETICS

- Genetics is the science, which **defines & analyzes heredity**
- The **unit of heredity** is the **gene →** segment of DNA that carries information for specific biochemical or physiologic property

- The **bacterial genome** is the **total set of genes present inside the bacterial cell →** **it comprises:**

❶ Bacterial chromosome	❷ Additional genes may be carried on:
Can encode up to 4000 separate genes necessary for bacterial growth & propagation	**1.** Plasmids **2.** Transposable genetic elements **3.** Bacteriophage DNA (prophage)

① The Bacterial Chromosome

- Being **prokaryote**, the **bacterial cell lacks nuclear membrane →** instead, **DNA is concentrated** in the **cytoplasm as nucleoid**

- **Nucleoid** consists of **síngle chromosome → circular, double-stranded, supercoiled DNA** molecule associated **at one point with mesosome →** this attachment plays role in **separation of two sister chromosomes following chromosomal replication**

- **The bacterial chromosome has the general chemical structure of DNA molecules:**
  - ❶ Each strand is formed of regularly alternating **phosphate and sugar (deoxy-ribose) groups**
  - ❷ A **nitrogenous base (A, G, C, or T)** is **attached** to **sugar group** & is **projecting inwards** towards the other strand
  - ❸ The **two strands are held together** by **hydrogen bonds** between **complementary bases (A-T) or (G-C)** present at the same level
  - ❹ The average **length of bacterial chromosome** is **4000-5000 Kbp**

- **Bacterial chromosome replicates** by **semi-conservative method of DNA replication →** i.e:
  The two strands are separated → each strand acts as a template to synthesize complementary strand through the action of the **polymerase enzyme**

- Bacterial chromosome follows the **same rules of gene expression** & **protein synthesis** (i.e. transcription & translation) **as higher organisms**

② Plasmids

- Plasmids are **extra-chromosomal**, **circular**, **double-stranded DNA molecules** dispersed in cytoplasm
- They are much **smaller than bacterial chromosome** (1:50) **→** (from **several to 100 Kbp**)
- Plasmids are capable of **replicating autonomously** (**independently of bacterial chromosome**) **→** thus, **multiple copies of the same plasmid may exist in the same cell →** (**plasmid copy number**)

- **According to the copy number, plasmids can be categorized into 2 groups:**

① Relaxed replicating plasmids	② Stringent plasmids
∗ Can replicate in absence of protein synthesis	∗ Require protein synthesis
∗ Usually present in 30-50 copies/cell	∗ Present in few copies (1-5 copies/cell)
∗ Relatively small in size	∗ Usually large

- Plasmids are **generally dispensable** → this indicates that **most plasmids encode properties** that are **not essential for growth, replication or survival of the host bacterium** → this is evidenced by:
  - ❶ Spontaneous **loss of plasmids during cell division**
  - ❷ **Plasmid curing:**
    → **experimental kicking off** of plasmids using **physical agents** (e.g. heat) or **chemical agents** (e.g. antibiotics)

Functions (traits) exhibited by plasmids:

① Sex pilus formation:

Some plasmids carry **fertility (F) factors** → that code for **formation of sex pilus** → which mediates the process of **conjugation** → for this reason, **such plasmids are also known** as **conjugative plasmids**

	Conjugative plasmids	Non-conjugative plasmids
Size	Large	Usually small
Copy number	1-5 → (stringent)	> 30 → (relaxed)
F factors	Present	Absent
Sex pilus formation	Yes	No
Transfer among Bacteria	By conjugation	By the help of conjugative plasmid
Host bacteria	Common in Gram -ve bacilli	Common in Gram +ve cocci

② Antibiotic resistance:

- Some plasmids carry genes for **resistance (R-factors) to one or several antimicrobial drugs**
- They often control the **formation of enzymes capable of destroying the antimicrobial drugs** → e.g. **β-lactamase enzyme** which determines resistance to penicillin & cephalosporins
- **R-factors** are usually **conjugative plasmids** that can be **transferred among bacteria by conjugation** → this results in: ❶ **Rapid spread of drug-resistance among bacterial populations**
  ❷ **Development of multiple drug-resistant bacterial strains**

③ Virulence plasmids: may **code for** exotoxins, adhesins or invasion factors

④ Bacteriocin production:

- Bacteriocins are **bactericidal substances** produced **by certain bacterial strains** & are **active against other strains** of the same or closely related species
- e.g. **colicin E_1 produced by E.coli**

⑤ Other functions: include:

❶ Nitrogen fixation ❷ Sugar fermentation ❸ Antibiotic production
❹ H_2S production ❺ Resistance to heavy metals ❻ Degradation of aromatic compounds

⑥ Act as cloning vectors in recombinant DNA technology

③ Transposable Genetic Elements

- **Extra-chromosomal, linear, single-stranded DNA → smaller than bacterial chromosome**
- These are **non-replicating DNA segments (can't replicate autonomously)**
- They are **capable of:**
  - ❶ **Inserting themselves into other DNA molecules**
  - ❷ **Mediating their own transfer from one location to another** on the same chromosome or between chromosomes & plasmids
- Transposition **occurs infrequently (once every 10^5-10^7 generations)** → often in random pattern
- The insertion of transposable element into gene usually leads to **inactivation (disruption) of that gene**
- **There are different classes of transposable genetic elements, for example:**
  - ❶ **Transposons** → which **encode specific genes** (such as **antibiotic resistance**)
  - ❷ **Pathogenicity islands (PAI)** → which give the bacterium **variety of virulence characters**
    → such as the ability to **adhere to or invade host cells**

④ Bacteriophage DNA

DNA of **temperate bacteriophage** that is **integrated in chromosome of lysogenic bacterial cell** (i.e. **prophage**) is considered as part of the genome of such bacteria (see chapter 4)

Test Yourself

1) Bacterial genetic information is carried on the following EXCEPT:

a- Ribosomes b- Chromosome c- Transposons
d- Plasmids e- Bacteriophage DNA

2) Plasmids:

a- Are single-stranded DNA molecules b- Carry optional genes (are dispensable)
c- Carry genes essential for growth d- Are always found in linear form
e- Are always present as one copy/cell

3) Plasmids differ from transposable genetic elements, as plasmids:

a- Become inserted into chromosomes b- Are self-replicating outside the chromosome
c- Move from chromosome to chromosome d- Carry genes for virulence (exotoxin production)
e- Carry genes for antibiotic resistance

4) Plasmids may code for any of the following EXCEPT:

a- Sex pilus formation b- Bacteriocin production c- Growth
d- Antibiotic resistance e- Virulence

5) Conjugative plasmids:

a- Are usually small in size b- Carry fertility (F) factor
c- Are relaxed plasmids d- Have a large copy number
e- Are common in Gram positive cocci