

# Bacterial Genetics

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# Outline

- Genetic material –Introduction
- Gene expression
- Mutations: Definition, and types
- Gene transfer:
  - Vertical transfer
  - Horizontal transfer
    - Transformation
    - Conjugation
    - Transduction

# Bacterial Genetics

**The bacterial genome consists of:**

## **1. Chromosome**

- Single, circular DNA molecule (**haploid**, not paired like humans).
- Contains essential genes for survival.

## **2. Plasmids**

- Small, circular, extra-chromosomal DNA.
- Carry non-essential but advantageous genes: Antibiotic resistance genes
- Can be transferred between bacteria (**conjugation**).

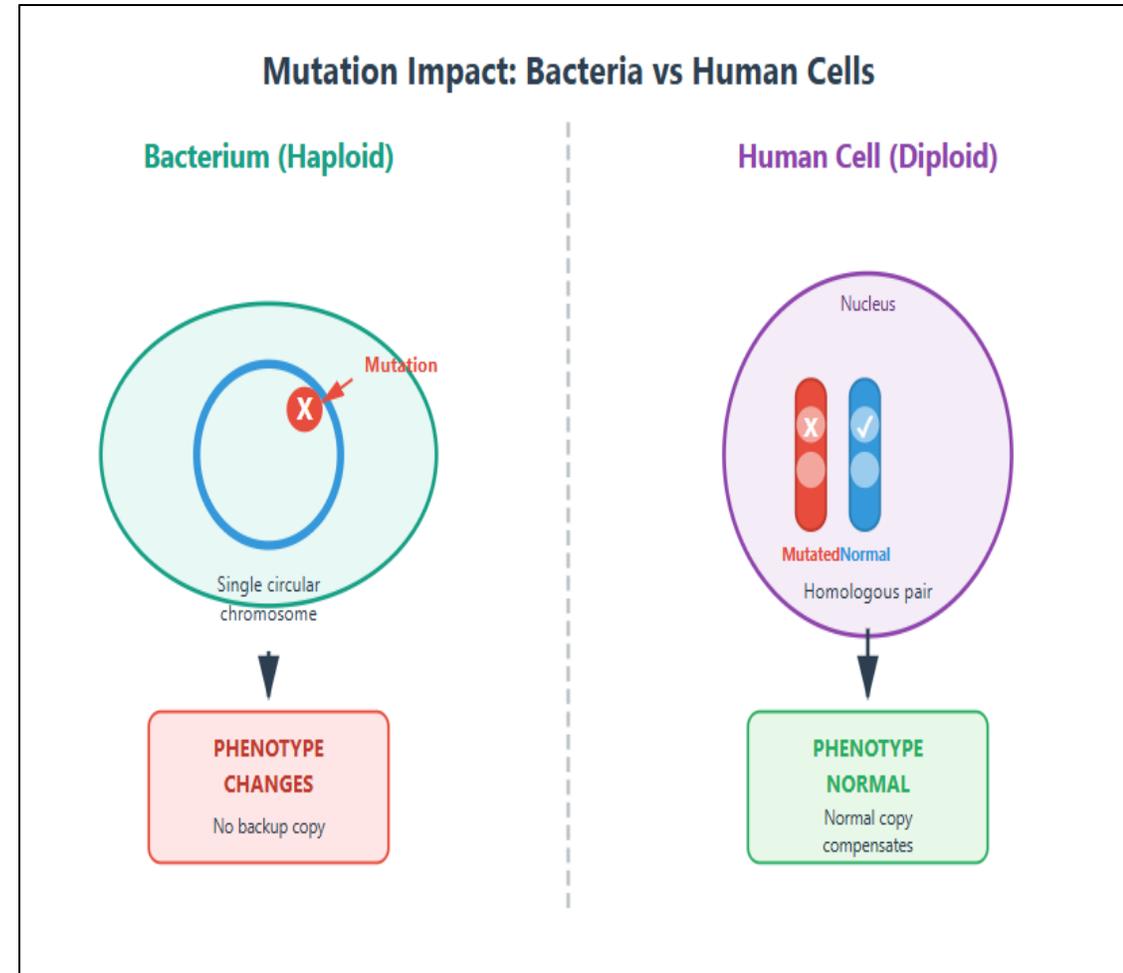
# Bacterial Genetics

## Haploid (Bacteria):

- “Haploid” means **only one copy** of each gene.

## Consequence:

- If a gene mutates, there’s **no backup copy** → the mutation **shows up immediately in the phenotype**.
- This makes bacteria adapt quickly (e.g., develop antibiotic resistance).



# Bacterial Genetics: Definitions

**Gene** is a segment of DNA that carries the instructions to produce a specific functional product — usually a protein (enzyme, structural protein, etc.) or sometimes an RNA molecule.

**Genotype:** The genetic makeup - the actual DNA sequence or set of genes an organism carries.

- *Think:* The instructions written in the DNA

**Phenotype:** The observable characteristics or traits that result from the genotype and environment.

- *Think:* What you can see, measure, or detect (appearance, behaviour, biochemistry)

# Bacterial Genetics: Definitions- Genotype vs. Phenotype

## Example:

- **Gene:** *gyrA* (DNA gyrase enzyme)
- **Genotype:** Single mutation in *gyrA* gene
- **Phenotype: Fluoroquinolone resistant** (e.g., resistant to ciprofloxacin)

## Why?

Only ONE gene copy → one mutation makes the bacteria completely resistant to Fluoroquinolone

# Gene Expression in Bacteria

**Definition:** The process by which genetic information (DNA) is converted into functional products (proteins or RNA)

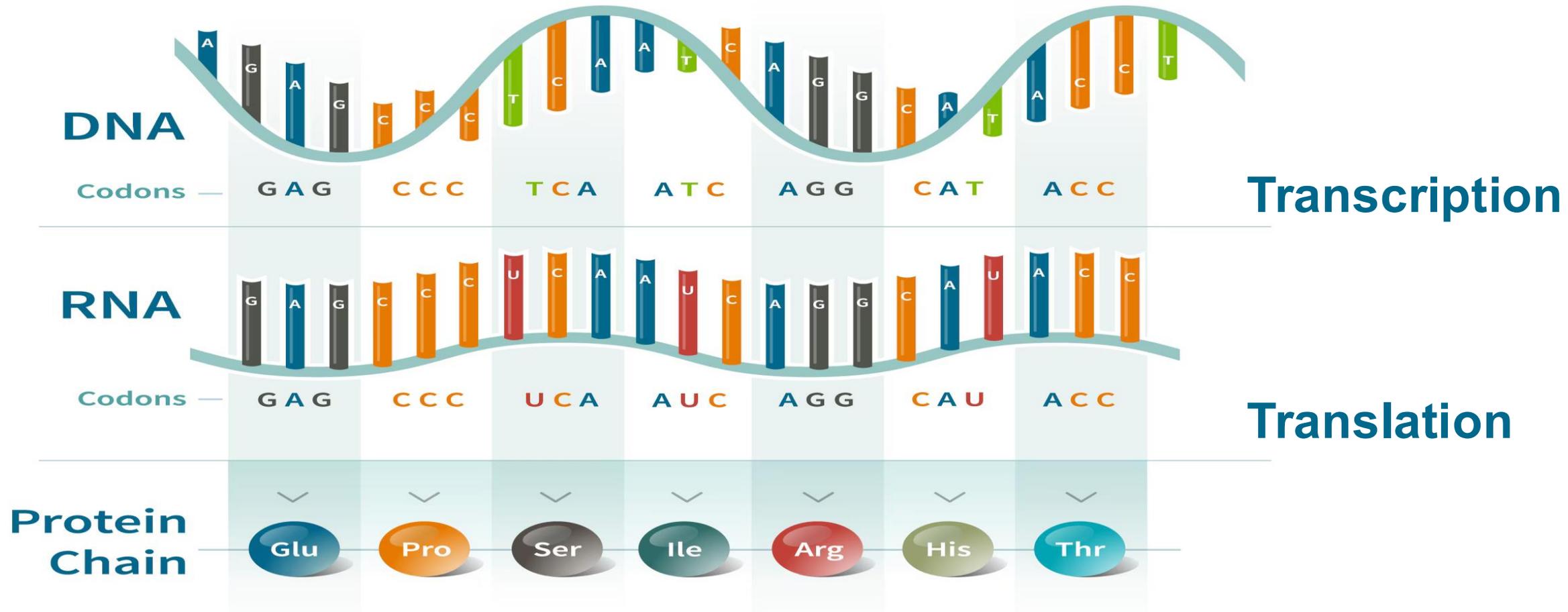
## **Two Main Steps:**

### **1. Transcription (DNA → mRNA)**

DNA is copied into messenger RNA (mRNA) by RNA polymerase.

### **2. Translation → Ribosomes read mRNA and build the protein.**

# Gene Expression in Bacteria



# Mutations in Bacteria

**Definition:** A mutation is a permanent change in the DNA sequence of a gene.

## **Consequences:**

- Can be **beneficial, harmful, or neutral**.
- In bacteria, mutations are expressed **immediately** (haploid, no backup copy).

## **Clinical importance:**

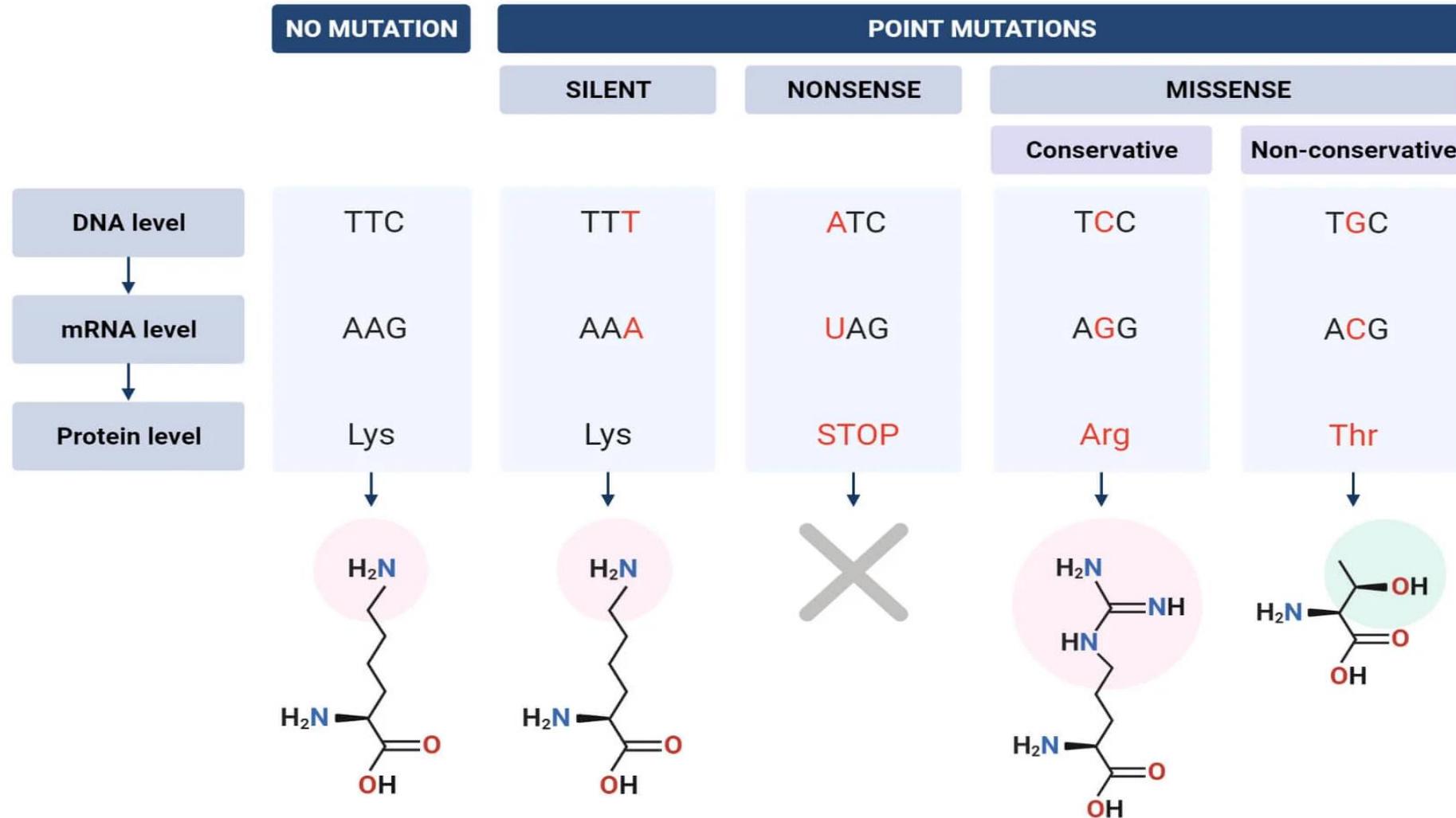
- Basis for **antibiotic resistance**
- Explains rapid bacterial adaptation

# Mutations in Bacteria: **Types of Mutations-** **Point Mutations**

## 1. **Point Mutations (single base change):**

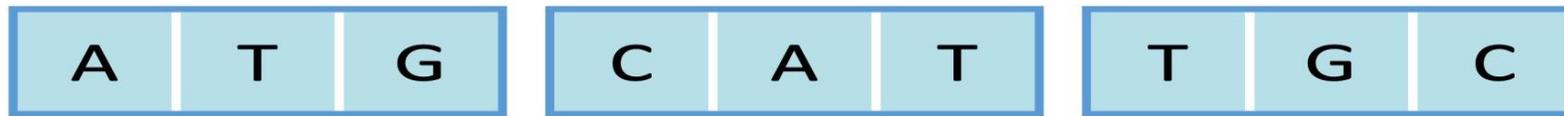
- **Silent mutation** → base change, but same amino acid (no effect).
- **Missense mutation** → base change → different amino acid.
- **Nonsense mutation** → base change → stop codon → truncated protein.

# Mutations in Bacteria: Types of Mutations- Point Mutations



# Mutations in Bacteria: Types of Mutations- Frameshift Mutations

- Insertion or deletion of bases, may shift the reading frame..
- Usually produces a **completely nonfunctional protein**.



*Normal sequence (for three distinct codons)*



***INSERTION: Reading frame has been changed***

# Mutations in Bacteria: Types of Mutations- Large-scale mutations

## 3. Large-scale mutations:

- Mutations affecting **large DNA segments** - from multiple nucleotides to entire genes or chromosomal regions
- **Deletion:** DNA segment is removed
- **Insertion:** Extra DNA added (often from transposons or viral)
- **Duplication:** DNA segment is copied
- **Inversion:** DNA segment flips 180°
- **Translocation:** DNA moves to different location

# Mutations in Bacteria

- Mutations explain how **single bacteria** can change, but mutations are **rare and slow**.

“Yet in the hospital, we see bacteria becoming resistant very quickly and spreading resistance between species. How does that happen?”

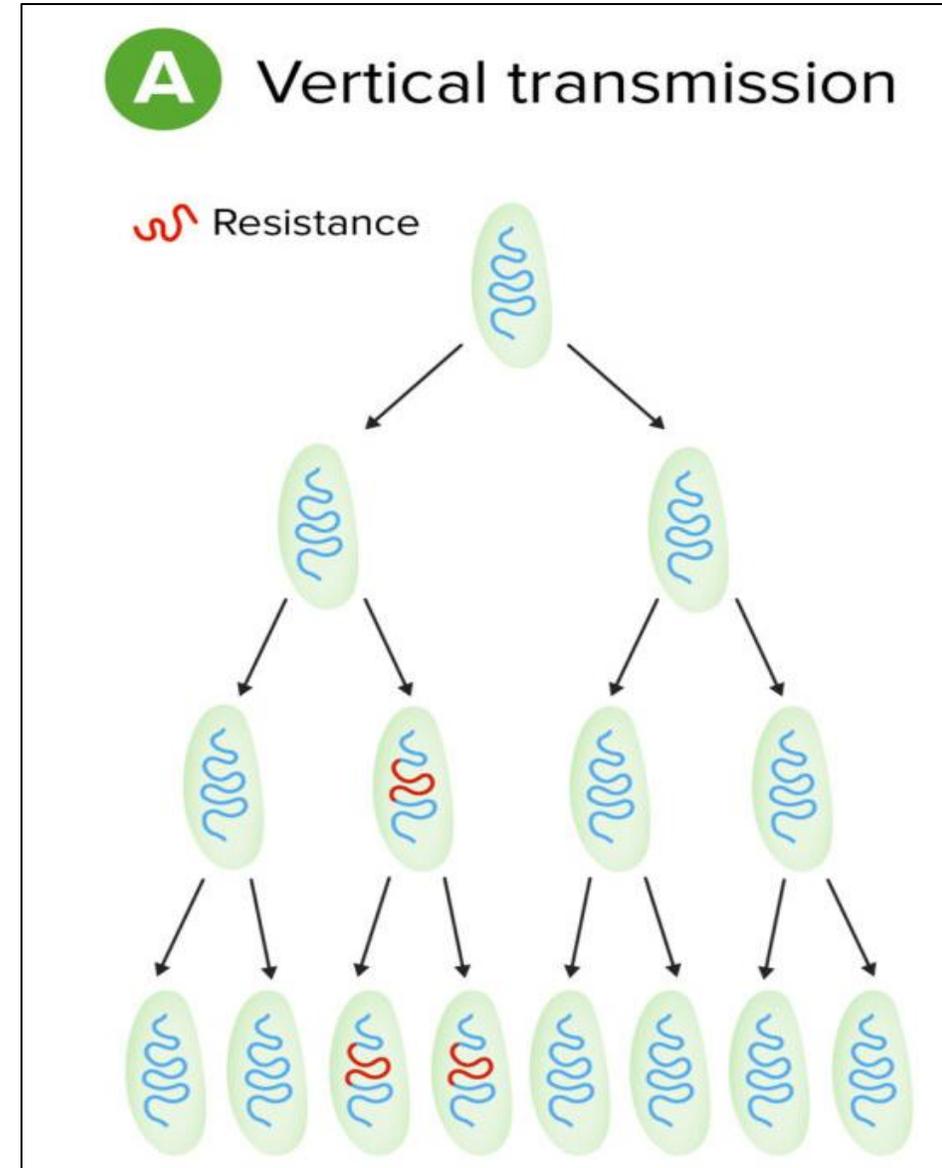


# Bacterial Gene Transfer

Bacterial genes can be transferred by two main routes:

## A. Vertical Gene Transfer

- From parent cell to daughter cells
- Occurs during binary fission (cell division)
- Genetic material passed to next generation
- Maintains genetic similarity



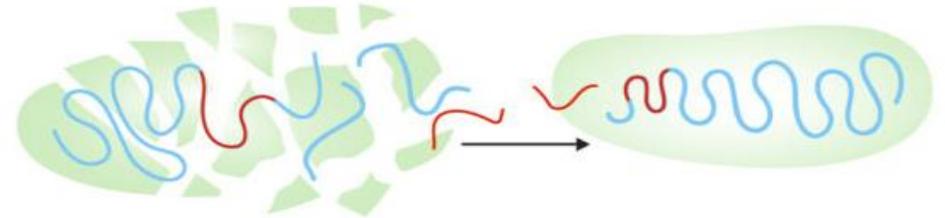
# Bacterial Gene Transfer

## B. Horizontal Gene Transfer (HGT)

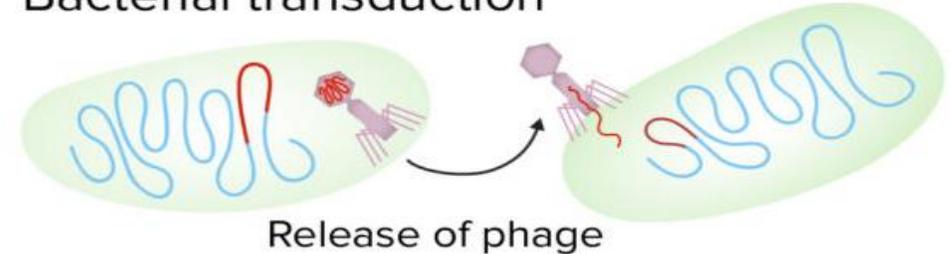
- Between bacteria of the same generation
- No parent-offspring relationship required
- Can occur between different species
- Allows bacteria to **share genes directly**.
- Rapid spread of new traits

### **B** Horizontal transmission

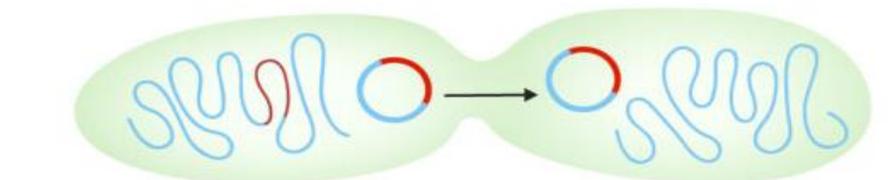
Bacterial transformation



Bacterial transduction



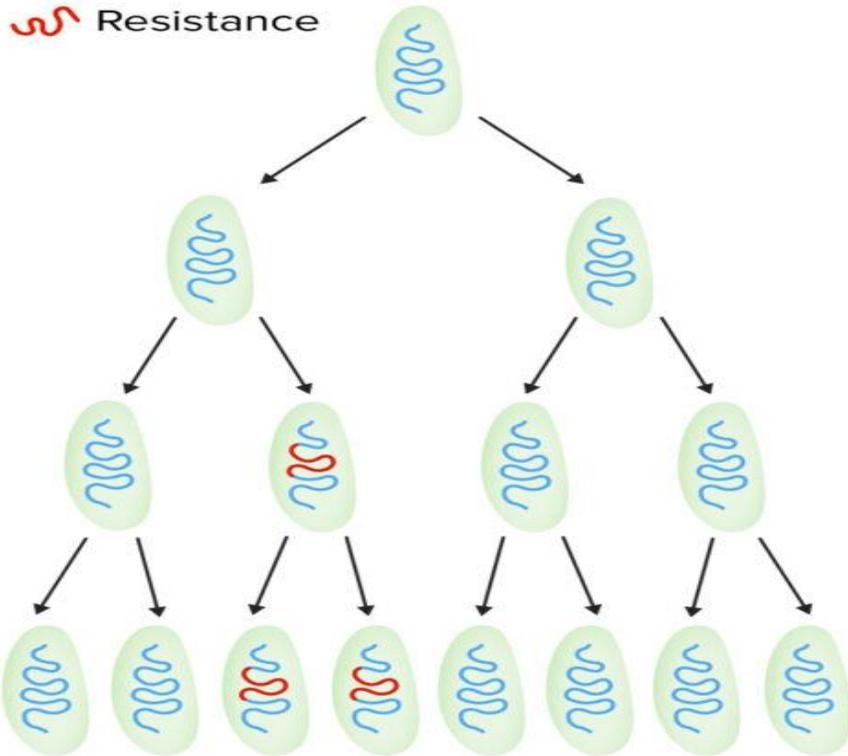
Bacterial conjugation



# Bacterial Gene Transfer: Vertical Vs. Horizontal Gene Transfer

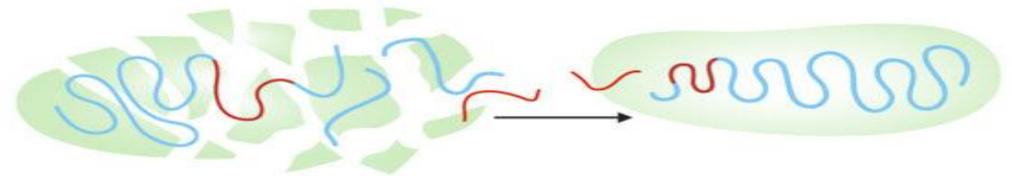
## A Vertical transmission

 Resistance

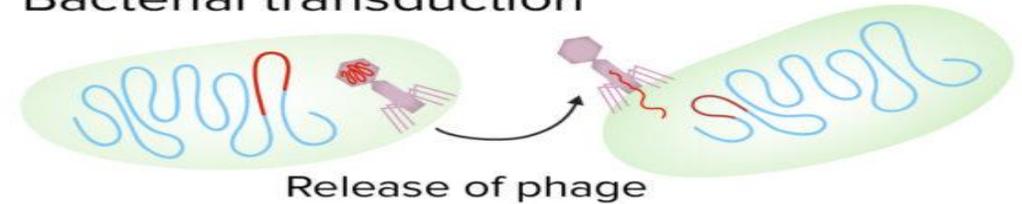


## B Horizontal transmission

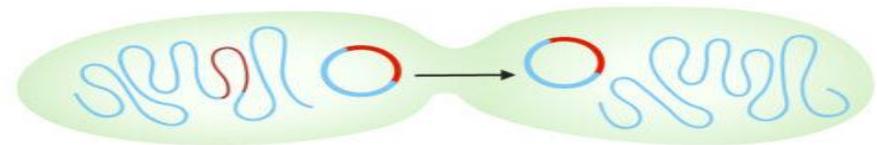
Bacterial transformation



Bacterial transduction



Bacterial conjugation



# Bacterial Gene Transfer: Horizontal Gene Transfer (HGT)- Transformation

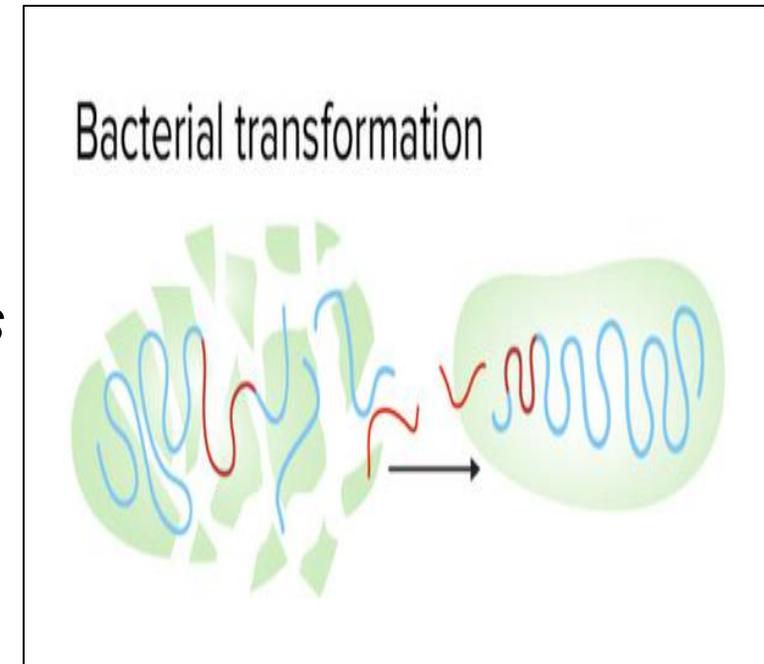
**Definition:** Uptake of **naked DNA fragments** from the environment by a bacterium.

## Key Points:

- Requires the cell to be in a “**competent state**” (able to take up DNA).
- Natural process in some bacteria (e.g., *Streptococcus pneumoniae*).
- Can also be induced in lab (basis of molecular cloning).

## Clinical Relevance:

*Streptococcus pneumoniae* acquires **capsule genes** → transforms from non-virulent to virulent.

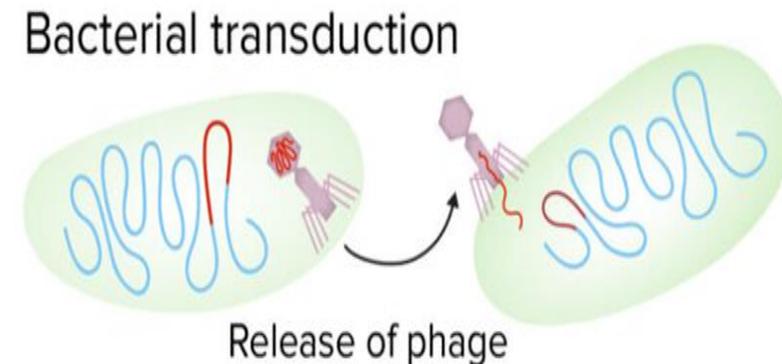


# Bacterial Gene Transfer: Horizontal Gene Transfer (HGT)- Transduction

**Definition:** Transfer of bacterial DNA from one cell to another via a **bacteriophage** (virus that infects bacteria).

## How it happens:

- Phage infects a bacterium.
- During phage assembly, fragments of bacterial DNA may be mistakenly packaged inside the phage.
- When that phage infects another bacterium, it delivers the previous host's DNA.
- The new DNA may integrate into the recipient's chromosome.



# Bacterial Gene Transfer: Horizontal Gene Transfer (HGT)- Transduction

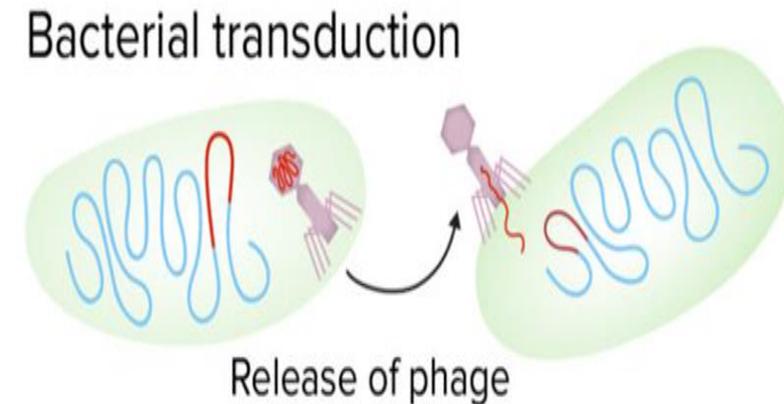
## Clinical Relevance:

- Explains how some pathogens acquire **toxin genes**:

- *Corynebacterium diphtheriae* → diphtheria toxin.
- *Vibrio cholerae* → cholera toxin.

- **USMLE connection:**

*“toxin genes carried by phages”* = high-yield fact

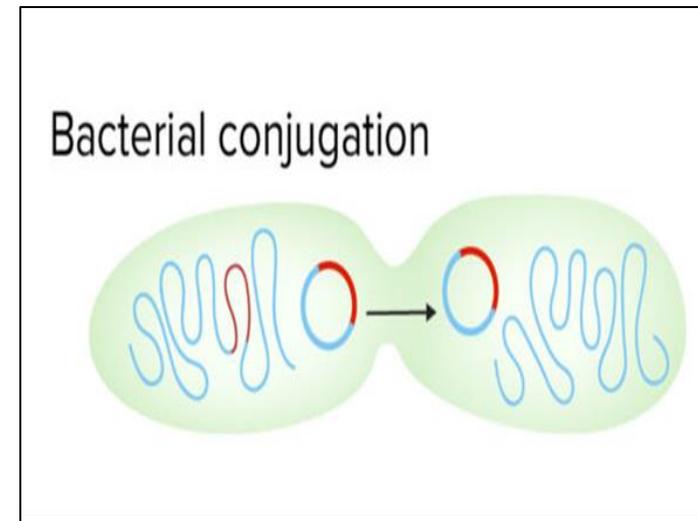
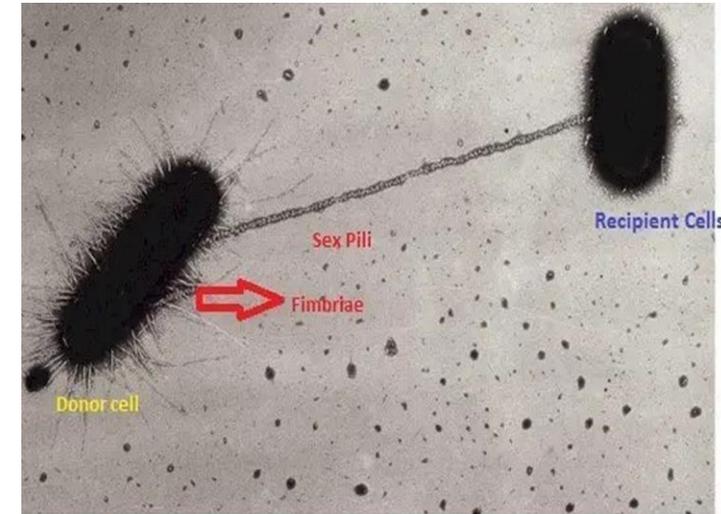


# Bacterial Gene Transfer: Horizontal Gene Transfer (HGT)- Conjugation

**Definition:** Transfer of DNA between bacteria by direct cell-to-cell contact, usually through a sex pilus.

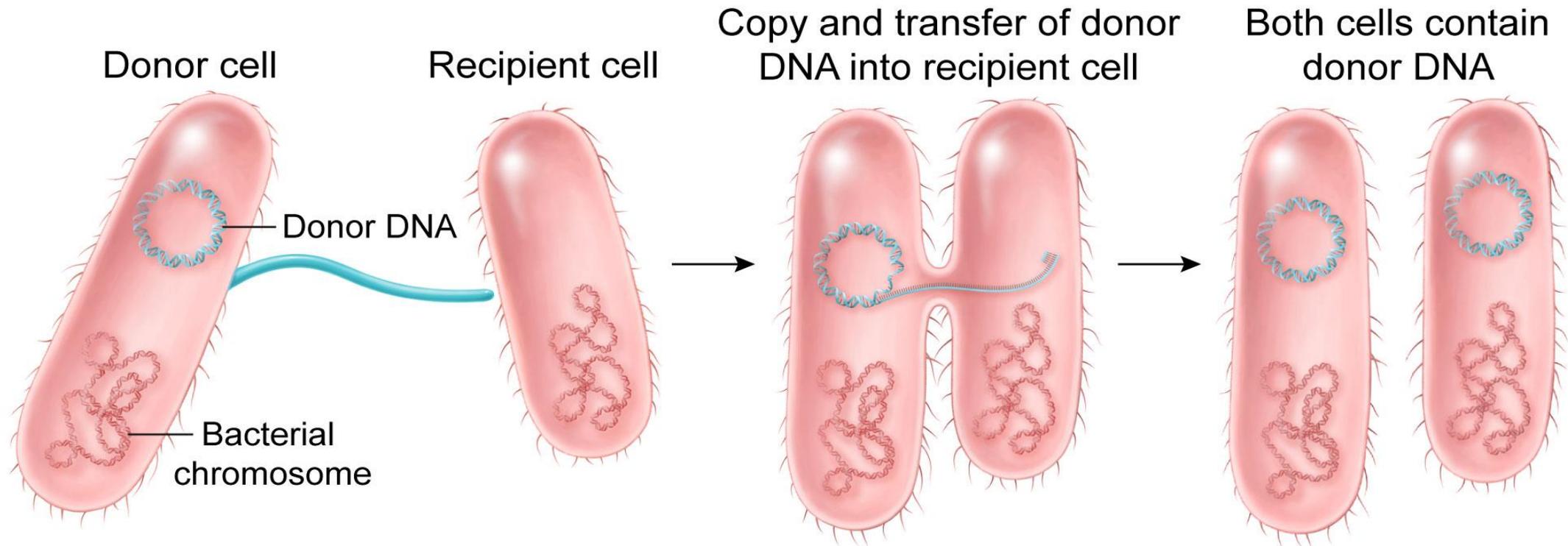
## Key Points:

- Mediated by **Fertility** (F) plasmids (conjugative plasmids).
- Donor cell ( $F^+$ ) forms sex pili  $\rightarrow$  connects to recipient cell ( $F^-$ ).
- Plasmid DNA is replicated and transferred into the recipient.
- Both cells end up with a copy of the plasmid.



# Bacterial Gene Transfer: Horizontal Gene Transfer (HGT)- Conjugation

## Conjugation

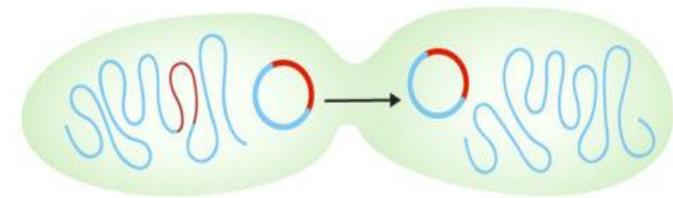


# Bacterial Gene Transfer: Horizontal Gene Transfer (HGT)- Conjugation

## Clinical Relevance:

- **Major route of antibiotic resistance spread** in hospitals.
- Resistance plasmids (R-plasmids) carry genes for  $\beta$ -lactamases, carbapenemases, etc.
- Can occur between different species or genera

Bacterial conjugation



# Bacterial Gene Transfer: Horizontal Gene Transfer (HGT)- Summary

Mechanism	Definition	Key Features	Clinical Relevance (USMLE)
<b>Transformation</b>	Uptake of <b>naked DNA</b> from the environment	Requires competent bacteria (e.g., <i>S. pneumoniae</i> )	Capsule genes → virulence
<b>Conjugation</b>	DNA transfer via <b>direct cell-to-cell contact</b> using a <b>sex pilus</b>	Requires conjugative plasmid (F plasmid, R plasmid)	Major route of <b>antibiotic resistance plasmid</b> spread
<b>Transduction</b>	DNA transfer by <b>bacteriophages (viruses)</b>	Two types: generalized (any gene), specialized (specific genes)	Toxin genes via phages: diphtheria, cholera

# Bacterial Gene Transfer: Horizontal Gene Transfer (HGT)- Memory aid

**TRANSFORMATION:** Think "Take up" or "Trash Pickup"

**TRANSDUCTION** - "Taxi Service"



**CONJUGATION:** Conjugation = Connection/Contact

# USMLE question

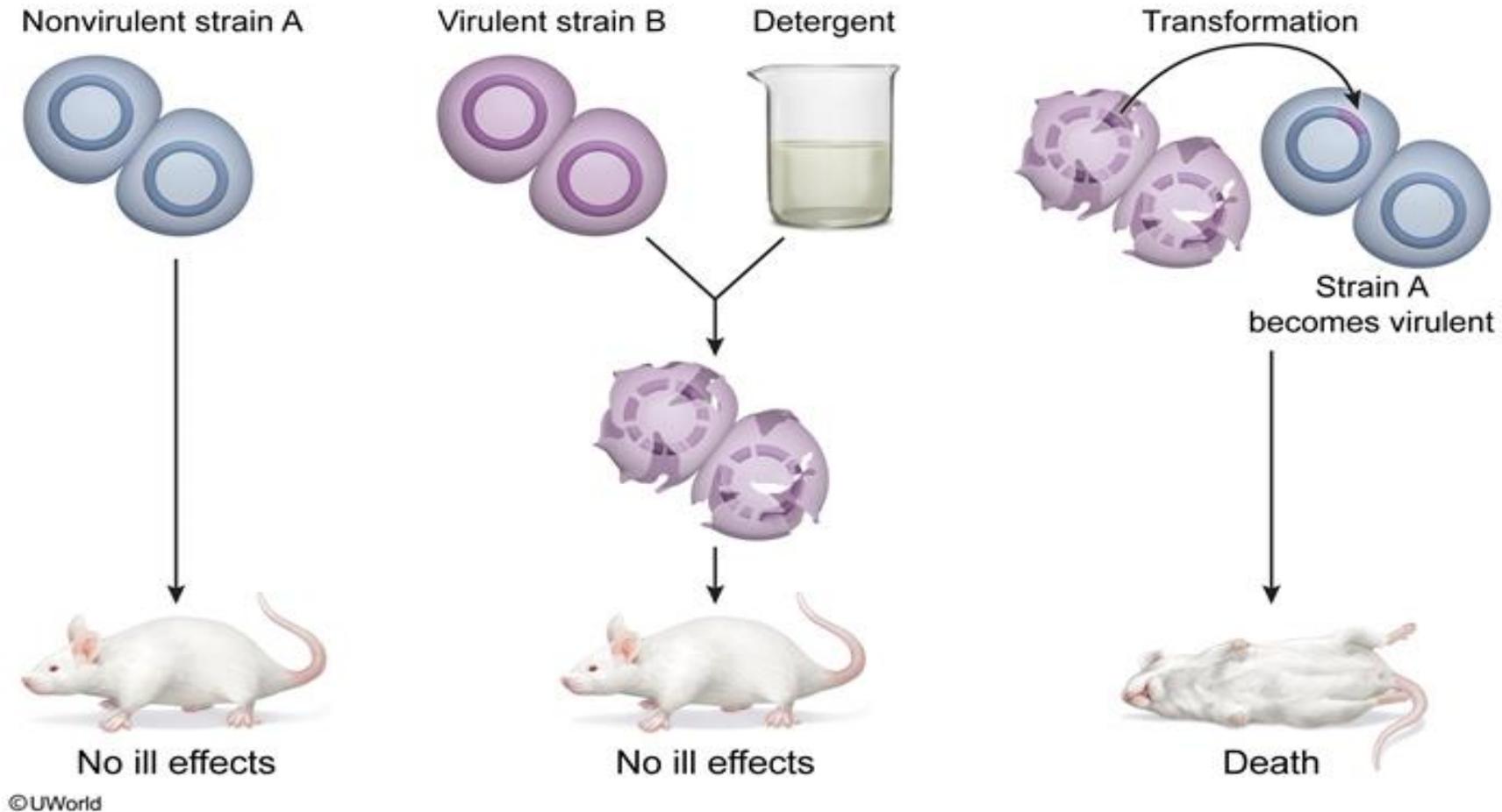
Microbiology researchers conduct a series of experiments to determine how pathogenicity is transmitted among different strains of *Streptococcus pneumoniae*.

In the first experiment, they inject nonvirulent strain A into laboratory mice and observe no ill effects.

In the second experiment, researchers subject virulent strain B to a detergent agent that kills and lyses the bacterial cells. They then inject the lysate into a new group of mice and again observe no ill effects.

During a third experiment, they inject live strain A bacteria in combination with the killed strain B lysate, resulting in death of the mice.

# USMLE question



# USMLE question

Which of the following genetic processes most likely accounts for the observed findings of these experiments?

- A. Direct uptake of extracellular DNA
- B. Phage-mediated DNA transfer
- C. Pilus-mediated DNA transfer
- D. Spontaneous DNA mutation
- E. Transposon-mediated DNA transfer

Thank you

