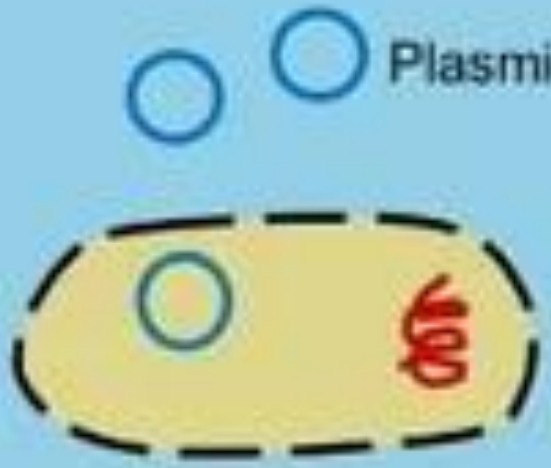
Cell Biology, Genetics and Evolution

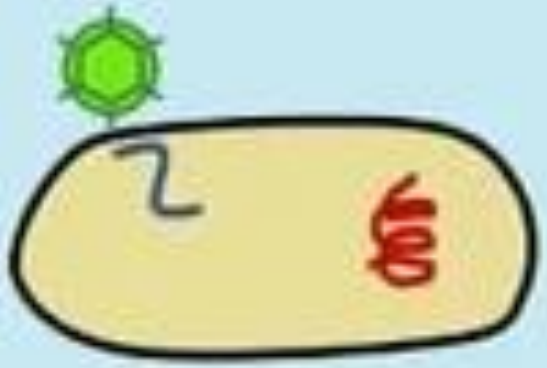
Transmission of Genetic Material in Bacteria

By: Shozab Seemab Khan (PhD Scholar)

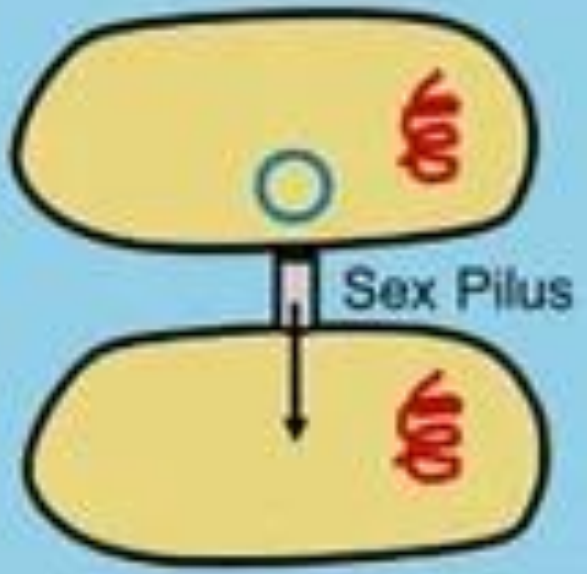
Bacterial Genetics



Transformation



Transduction



Conjugation

Bacterial Genetics

- There are numerous bacteria found on planet earth. They divide quickly by binary fission producing identical daughter cells. Thus, the genetic information is transferred from the mother to the offspring and is known as vertical transmission.
- The mutations are transferred from one bacteria to another through horizontal transmission. There are three different types of horizontal transmission for the transfer of genetic information.
- 1. Conjugation
- 2. Transduction
- 3. Transformation

Bacterial Conjugation

- Conjugation is one of the main methods of horizontal gene transfer in bacteria, meaning it transfers genes between individual bacteria, not just to offspring.
- Conjugation is the method of transfer of genetic material from one bacteria to another placed in contact. This method was proposed by Lederberg and Tatum. They discovered that the F-factor can move between E.coli cells and proposed the concept of conjugation.

Mechanism of Bacterial Conjugation

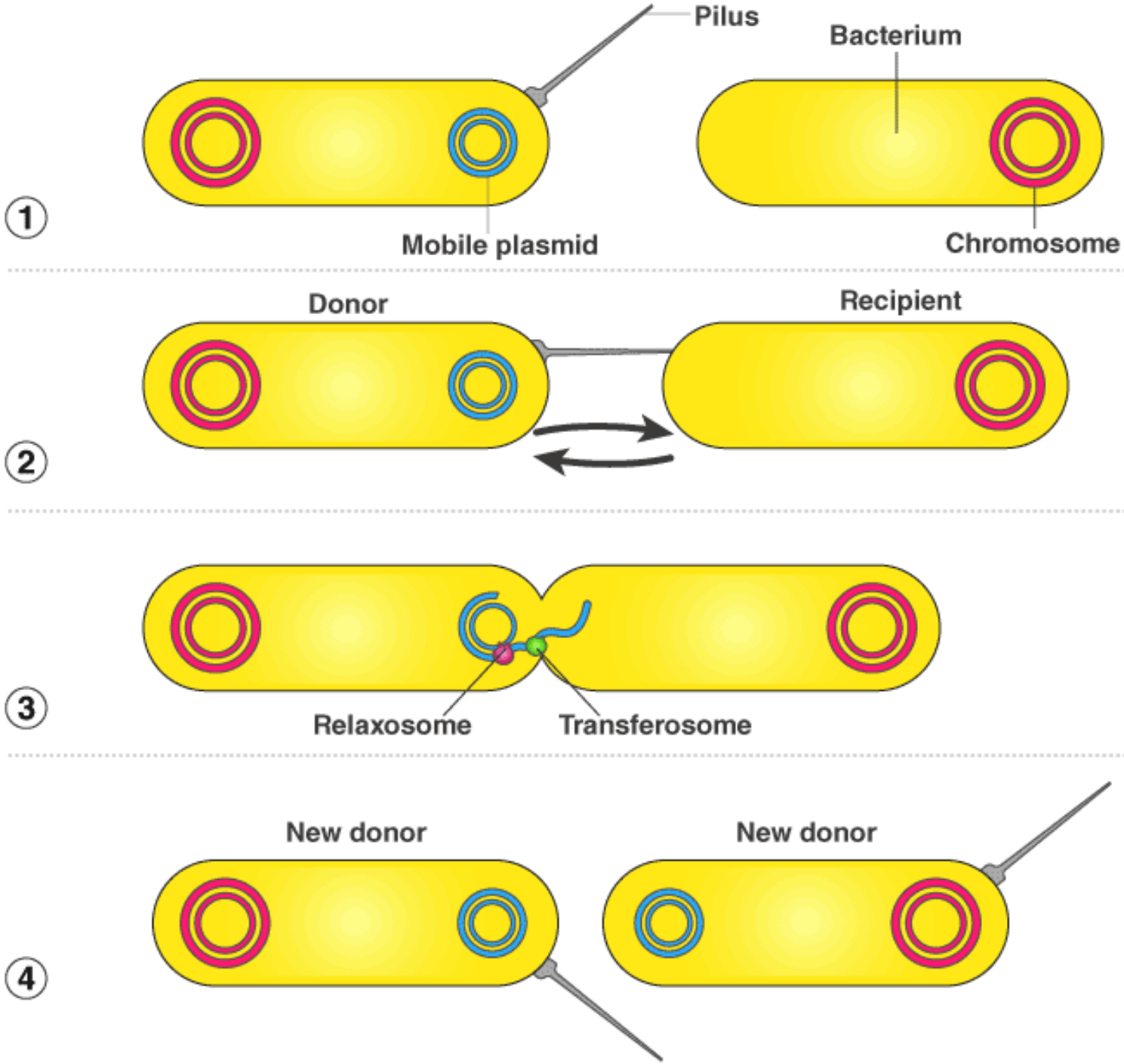
- Bacterial conjugation involves the following steps:
- 1. Pilus Formation
- 2. Physical Contact between Donor and Recipient Cell
- 3. Transfer of F-Plasmid
- 4. Synthesis of Complementary Strand

Mechanism of Bacterial Conjugation

- **1. Pilus Formation:**
- In Escherichia coli (*E. coli*), a bacterium that has a special plasmid called the F (fertility) plasmid is considered F+ (donor), while the bacterium lacking this plasmid is F- (recipient).
- The donor cells (F+ cells) form a sex pilus and begin contact with an F- recipient cell.
- **2. Physical Contact between Donor and Recipient Cell:**
- The pilus forms a conjugation tube and enables direct contact between the donor and the recipient cells.

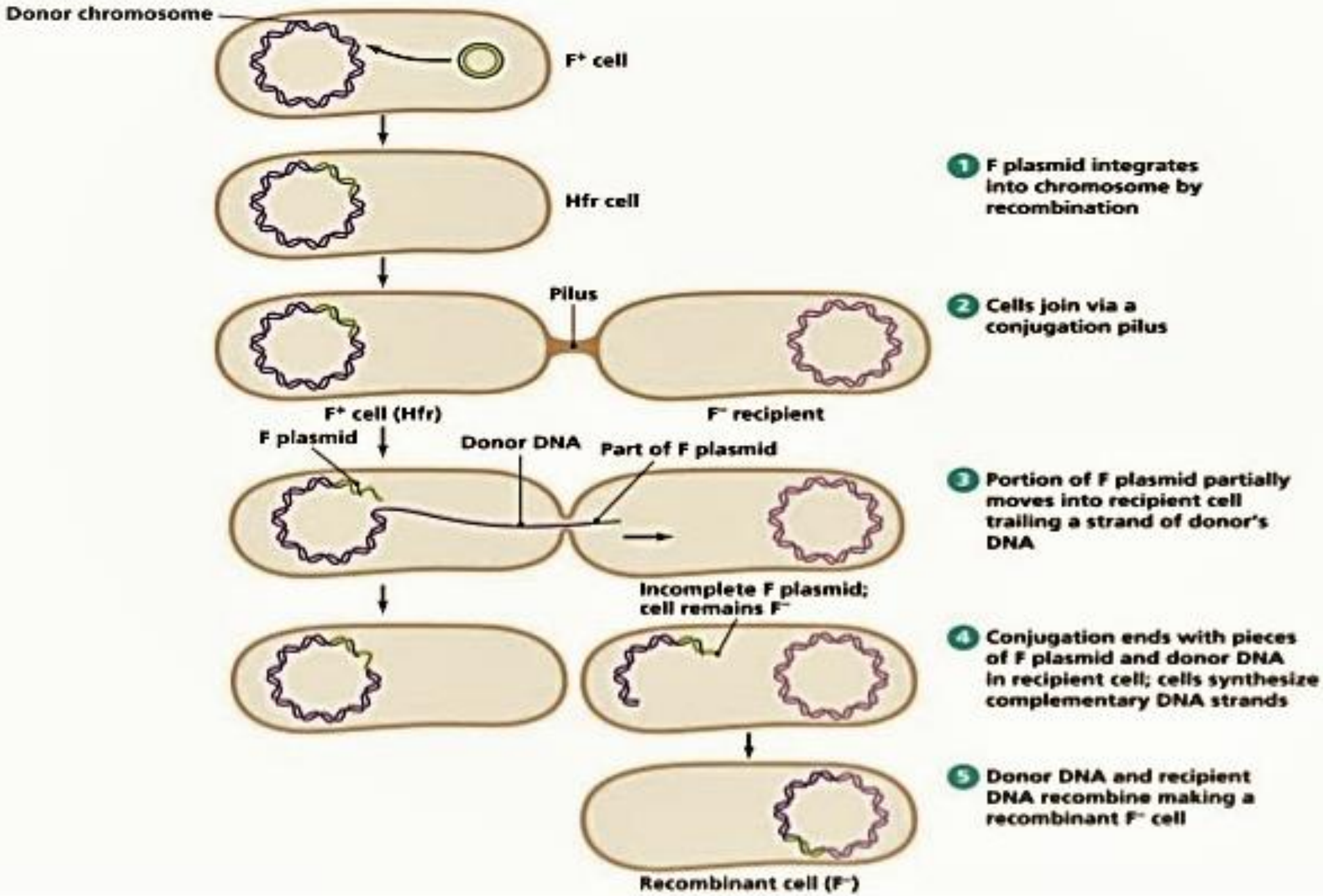
Mechanism of Bacterial Conjugation

- **3. Transfer of F-Plasmid:**
- Once the pilus connects to the recipient, one strand of the plasmid's DNA is transferred to the recipient through the pilus.
- The F-factor opens at the origin of replication. One strand is cut at the origin of replication, and the 5’ end enters the recipient cell.
- **4. Synthesis of Complementary Strand:**
- The donor and the recipient bacteria both contain a single strand of the F-plasmid. Thus, a complementary strand is synthesized in both the recipient and the donor. The recipient cell now contains a copy of F plasmid and becomes a donor cell.


Pilus
Bacterium
1
Mobile plasmid
Chromosome
Donor
Recipient
2
3
Relaxosome
Transferosome
New donor
New donor
4

Hfr Conjugation

- Hfr Conjugation (High-frequency recombination strain):
- In some cases, the F plasmid integrates into the donor bacterium's chromosomal DNA, creating an Hfr cell.
- When this Hfr cell mates with an F- cell, parts of the chromosomal DNA can also be transferred along with the plasmid. However, the transfer is often incomplete.
- So the recipient usually stays F- but incorporates new chromosomal genes from the donor. This process increases genetic diversity.


Donor chromosome
F+ cell
Hfr cell
Pilus
F+ cell (Hfr)
F− recipient
F plasmid
Donor DNA
Part of F plasmid
Incomplete F plasmid; cell remains F−
Recombinant cell (F−)
1 F plasmid integrates into chromosome by recombination
2 Cells join via a conjugation pilus
3 Portion of F plasmid partially moves into recipient cell trailing a strand of donor's DNA
4 Conjugation ends with pieces of F plasmid and donor DNA in recipient cell; cells synthesize complementary DNA strands
5 Donor DNA and recipient DNA recombine making a recombinant F− cell

Gene Recombination in *E. coli*

- In bacteria like *E. coli*, recombination typically involves the exchange of genetic material between homologous (similar) DNA sequences from different sources.
- After conjugation or other forms of gene transfer, the introduced DNA can undergo homologous recombination, where parts of the donor DNA replace the corresponding sections of the recipient's DNA.
- Proteins like RecA play a major role in facilitating recombination. RecA binds to the single-stranded DNA in the recipient and helps it align with the homologous region of the host genome.
- This leads to the replacement of sections of the recipient's genome with those from the donor, thus creating a new combination of genes. This can lead to new traits or abilities, such as antibiotic resistance.

Bacterial Transduction

- Transduction is the process of transfer of genes from the recipient to the donor through bacteriophage (a virus that infects bacteria).
- Transduction is of two types:
  - 1. Generalized Transduction
  - 2. Specialized Transduction
- In both cases, transduction allows bacteria to receive new genes, such as those for antibiotic resistance or virulence factors (traits that increase the ability of the bacterium to cause disease).

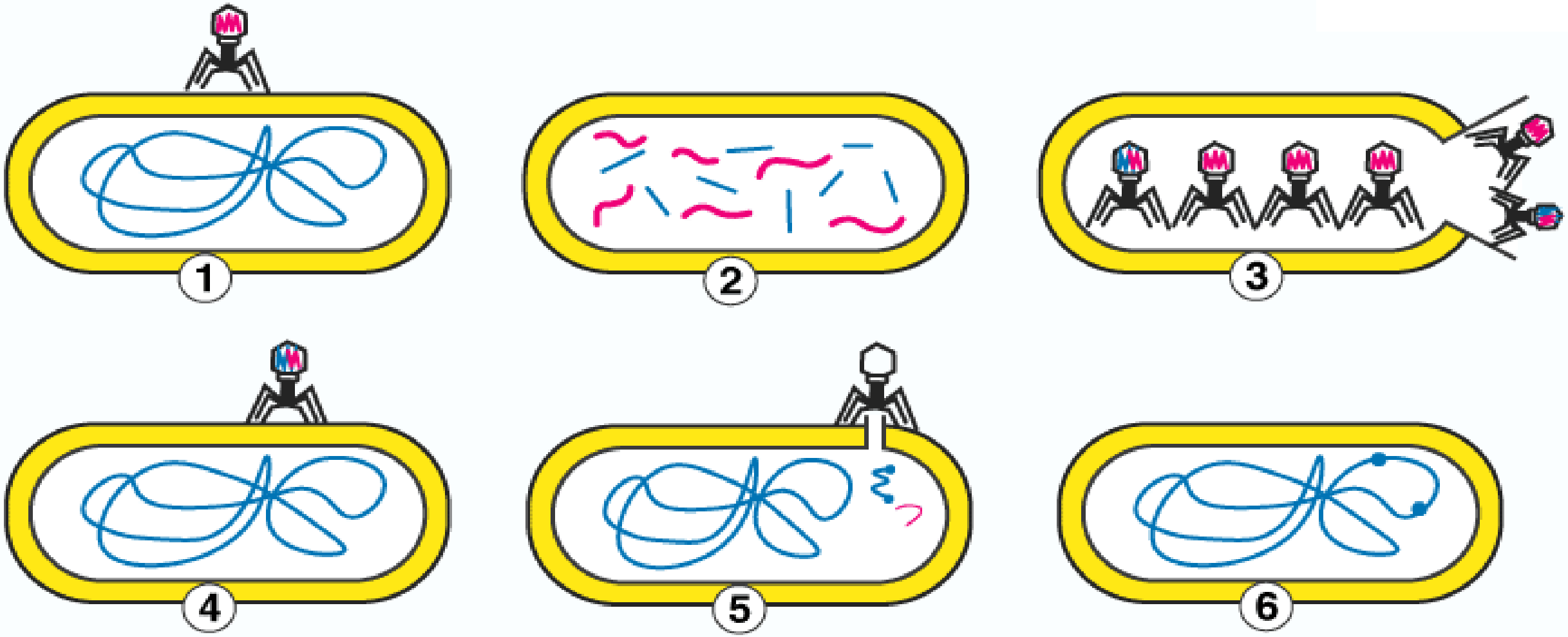
Generalized Transduction

- In this type, the bacteriophage first infects the donor cells and begins the lytic cycle. The virus then develops its components using the host cell machinery. The host cell DNA is hydrolyzed into small fragments by the viral enzymes.
- Small pieces of bacteria DNA is now integrated into viral genome. When the virus infects another bacteria the DNA is transferred into it.

Specialized Transduction

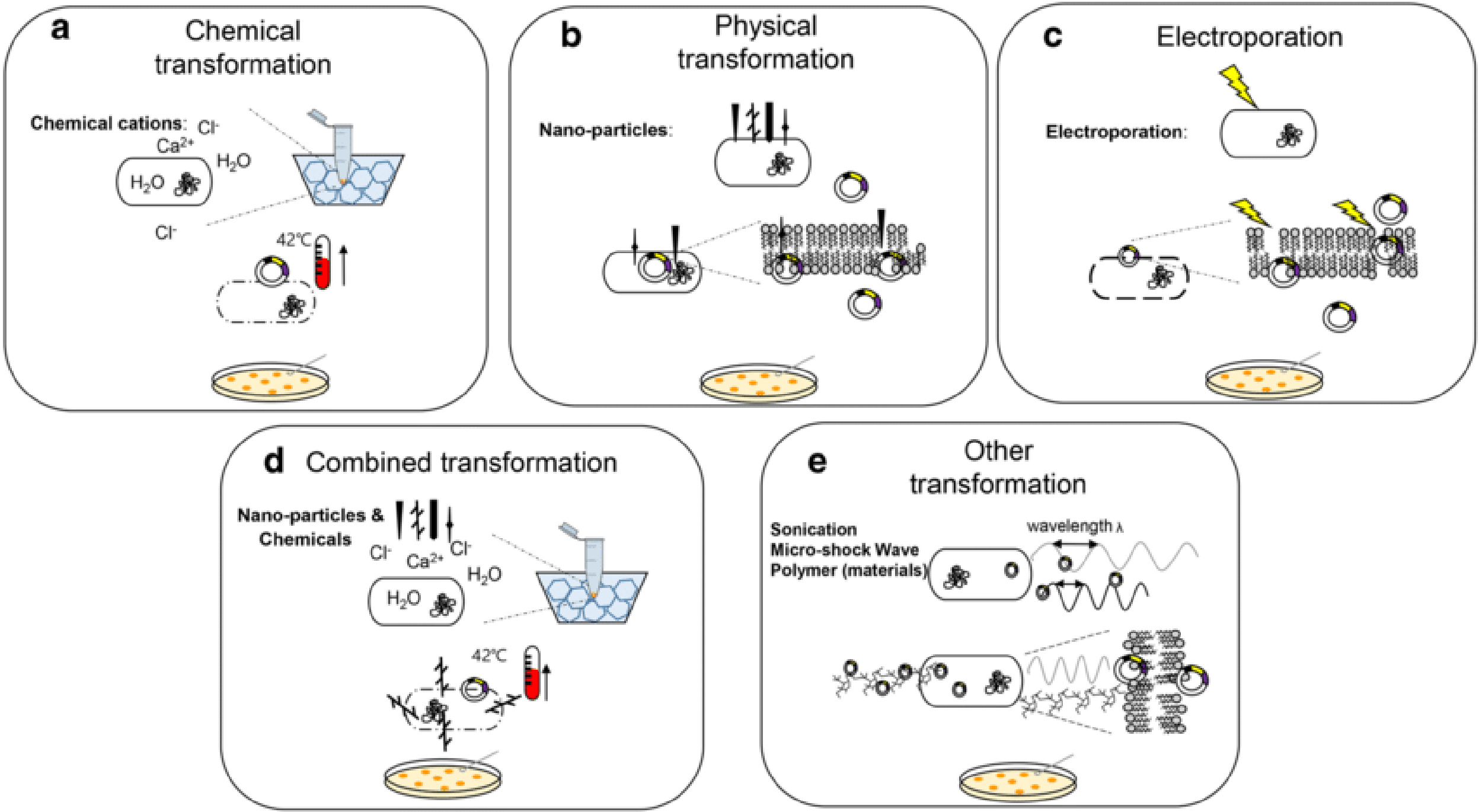
- This is carried out by temperate bacteriophage which undergoes the lysogenic cycle.
- The virus enters the bacteria and integrates its genome within the host cell DNA. It remains dormant and passes on from generation to generation. When the lysogenic cell is exposed to some external stimulus, the lytic cycle begins.
- The viral genome is induced in the host cell genome. Due to this, the phage genome sometimes carries the bacterial genome with it and integrates it into the genome of the recipient cell.

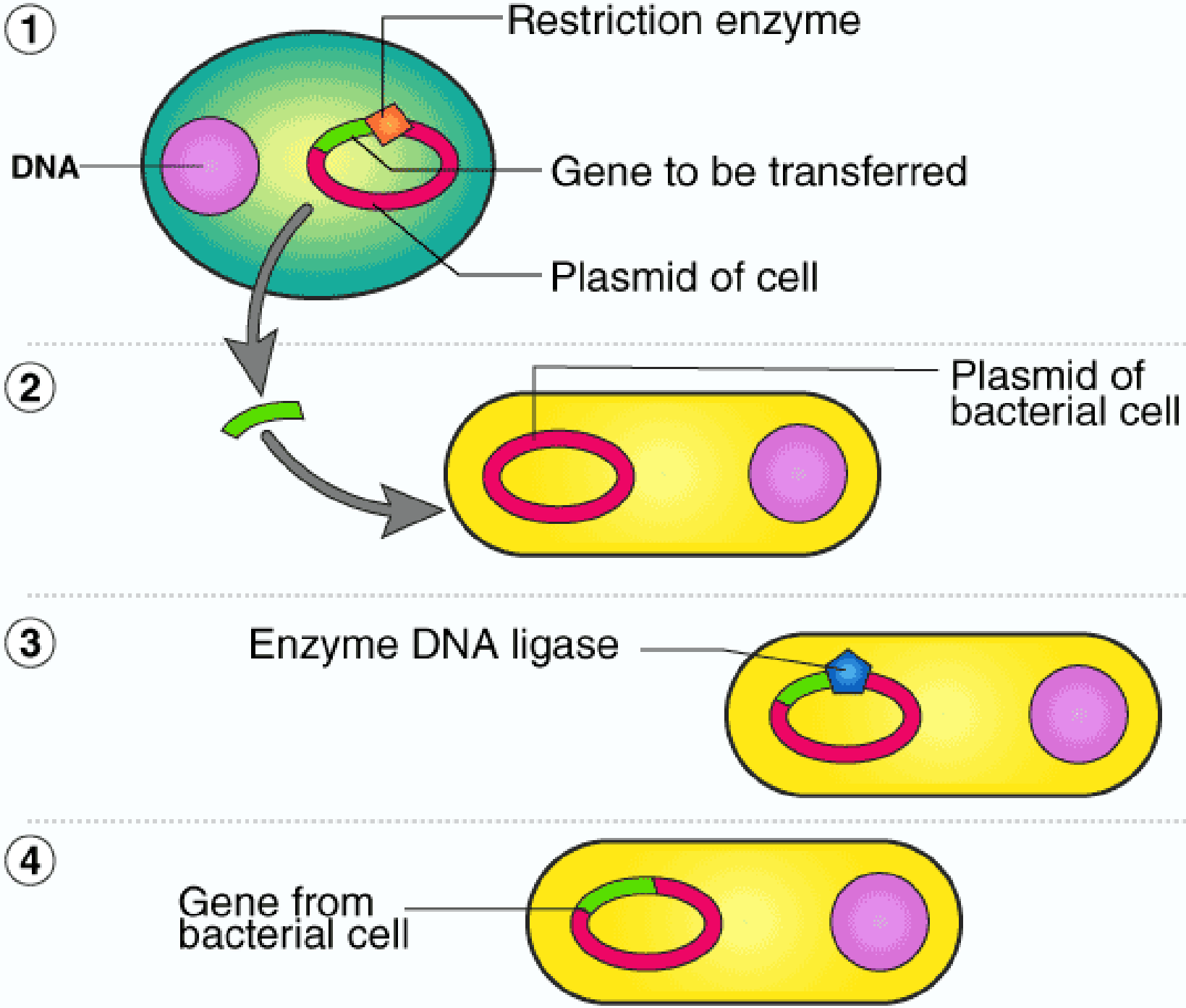
BACTERIAL TRANSDUCTION



Bacterial Transformation

- Transformation occurs when bacteria take up foreign DNA directly from their environment.
- Transformation is the process of DNA uptake by the bacteria from the surrounding environment. The cells that have the ability to uptake DNA are known as competent cells. This process was first reported in *Streptococcus pneumonia* by Griffith.


a
Chemical transformation
Chemical cations:
Cl-
Ca2+
H2O
H2O
H2O
Cl-
42℃
b
Physical transformation
Nano-particles:
c
Electroporation
Electroporation:
d
Combined transformation
Nano-particles &
Chemicals
Cl-
Ca2+
Cl-
H2O
H2O
42℃
e
Other transformation
Sonication
Micro-shock Wave
Polymer (materials)
wavelength λ


1
Restriction enzyme
DNA
Gene to be transferred
Plasmid of cell
2
Plasmid of
bacterial cell
3
Enzyme DNA ligase
4
Gene from
bacterial cell

Bacterial Competence

- Not all bacteria are capable of taking up DNA from the surrounding environment. Such bacteria are made artificially competent. This is achieved by using chemicals and electrical pulses.
- **Chemicals-** The cells are chilled and made permeable in the presence of calcium phosphate. They are then incubated with the DNA and provided with a heat shock treatment that causes the DNA to enter the cells.
- **Electroporation-** The bacterial cells are subjected to electrical pulses to make them permeable and cause the DNA to enter into cells.

How to Identify Transformed Cells?

- The bacteria are grown on an agar medium with antibiotics to check for transformed cells.
- Only the bacteria containing the antibiotic resistance gene will grow in the presence of antibiotics.
- The cells that survive and grow are transformed cells.
- The others are non-transformed.

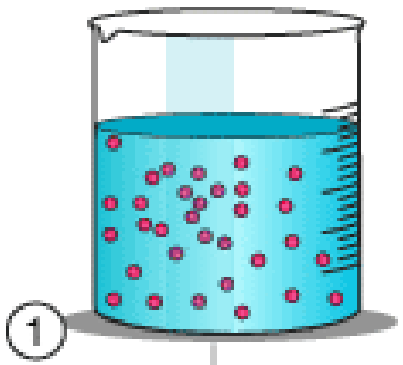
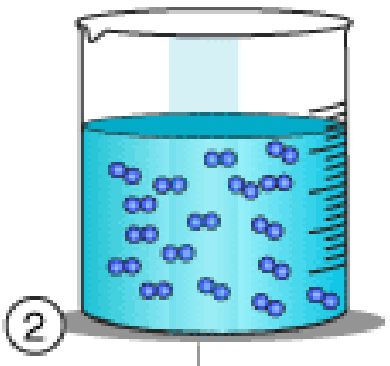
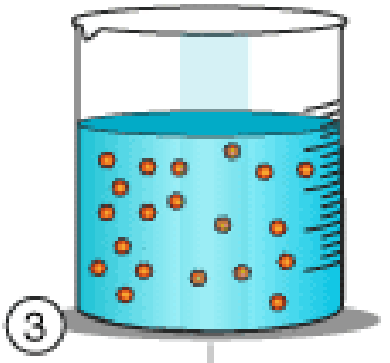
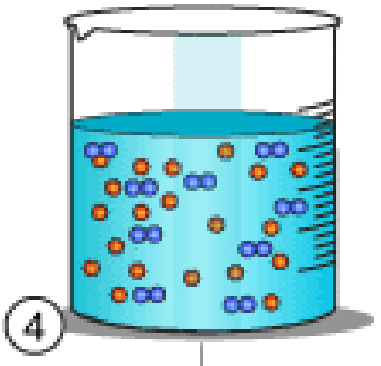
Griffith's Experiment:

- A classic experiment in 1928 by Frederick Griffith demonstrated transformation.
- He worked with two strains of *Streptococcus pneumoniae*: a virulent, smooth strain (S) and a non-virulent, rough strain (R).
- When he killed the S strain with heat and mixed it with live R strain, some of the R strain bacteria became virulent.
- This was because the R strain took up DNA from the dead S strain, showing transformation in action.

GRIFFITH EXPERIMENT & TRANSFORMING PRINCIPLE

Method

Result

Living S strain (Virulent)	Living R strain (Non-virulent)	Dead S strain (Heated)	Mix living R strain Dead S strain
			
			
Mouse dies	Mouse lives	Mouse lives	Mouse dies

Importance of These Mechanisms

- These gene transfer mechanisms are crucial for bacterial adaptation and evolution. They allow bacteria to:
- Quickly acquire new traits, such as antibiotic resistance, without waiting for slow mutations to occur.
- Share beneficial genes between different species or strains, enhancing survival in hostile environments.
- Generate genetic diversity, which helps populations of bacteria survive changing conditions.
- For example, the rapid spread of antibiotic resistance among bacteria in hospitals can be attributed to processes like conjugation and transduction, where resistance genes are transferred across populations.

Summary

- **Conjugation:** Direct transfer of DNA between bacteria via a pilus.
- **Gene Recombination:** Integration of foreign DNA into the host genome, leading to new gene combinations.
- **Transduction:** Transfer of bacterial DNA by bacteriophages (viruses).
- **Transformation:** Absorption of free DNA from the environment.
- These processes help bacteria evolve rapidly and can have significant implications for public health, especially in the spread of antibiotic resistance.


Thank
You!