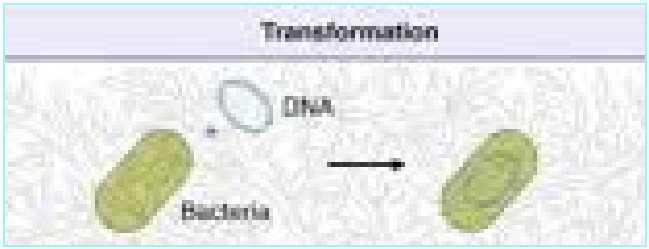
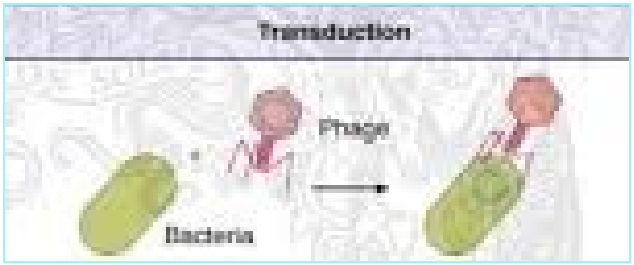
Genetic Recombination in Prokaryotes





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Genetic Recombination

- Exchange of genes between two DNA molecules to form new combinations of genes on a chromosome
- contributes to a population's genetic diversity (source of variation in evolution)
- Recombination is more likely than mutation to be beneficial
  - Less likely destroy a gene's function
  - May bring together combinations of genes

Genetic Transfer

- **Vertical gene transfer**
  - From parents to offspring
- **Horizontal gene transfer**
  - From one microbe to another
  - Between different strains and species of bacteria and viruses
  - Leads to recombination

Horizontal gene transfer

- Part of total DNA from Donor cell integrated into Recipient cell.
- Remaining amount of DNA from donor cell degraded.
- Recipient cell with DNA from donor is called Recombinant.
- 1% of population might undergo recombination

Horizontal gene transfer - Mechanisms

- Recombination in prokaryotes occurs through three mechanisms

  1. Transformation

  2. Transduction

  3. Conjugation

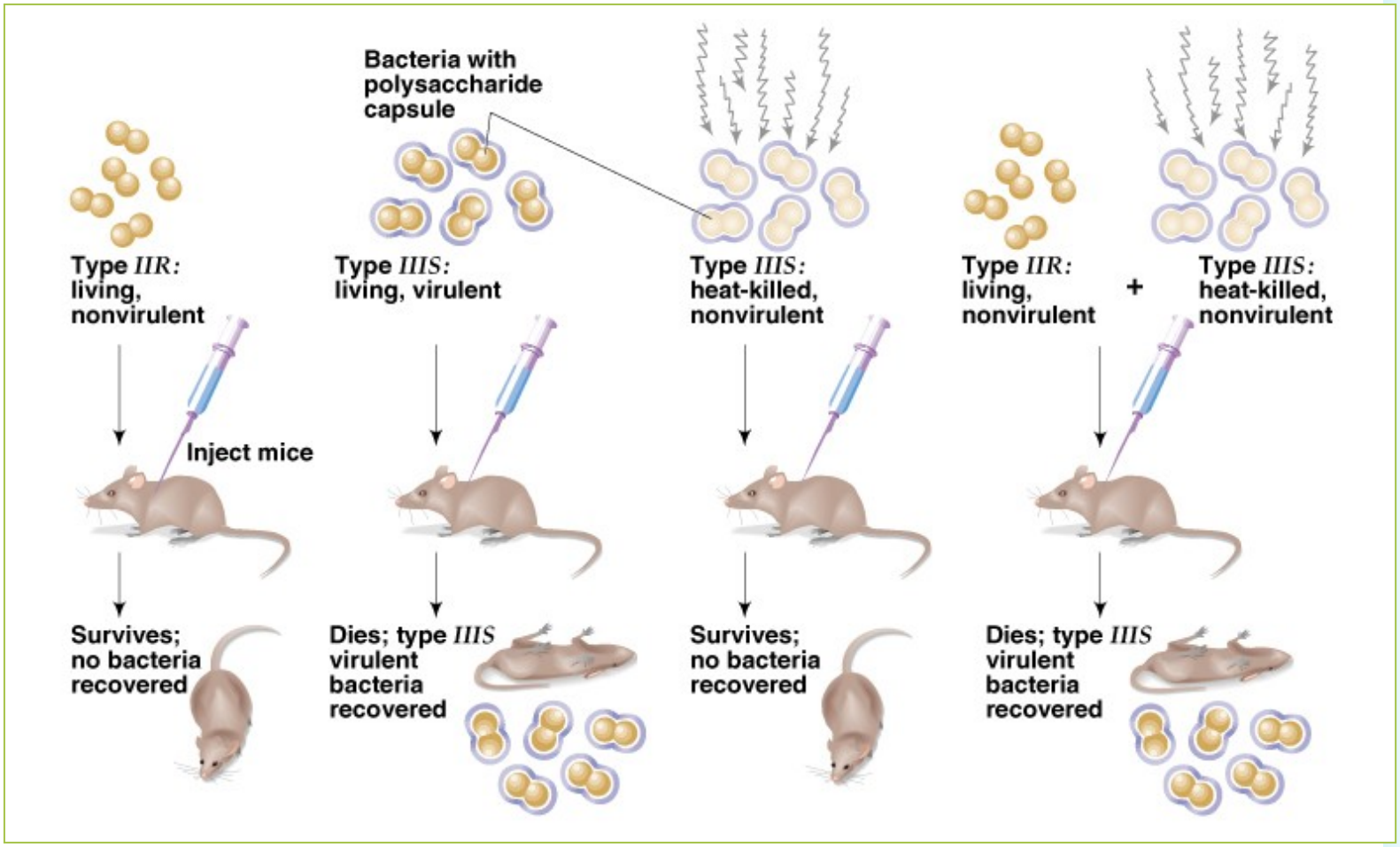
Transformation

- Transfer of naked DNA from donor to recipient cell

- Discovered by Frederick Griffith in 1928 in *Streptococcus pneumoniae*
  - Showed that DNA is the genetic material
  - Can be transferred between a donor and a recipient cell

- **Griffith's expt:** Avirulent *S. pneumonia* became virulent when exposed to heat killed virulent cell

Transformation experiment by Griffith

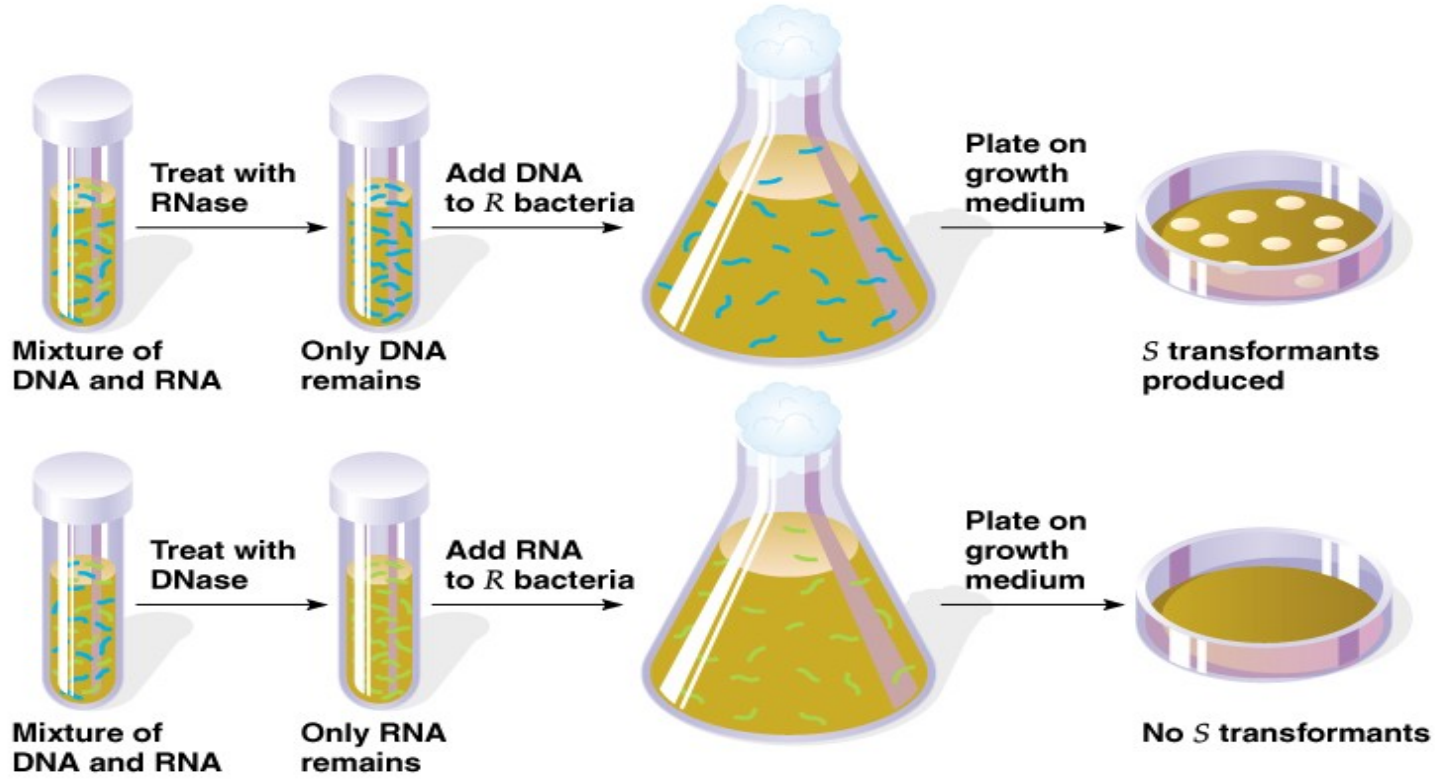


Bacterial transformation without mice

- Broth containing non-encapsulated living bacteria and dead encapsulated bacteria incubated
- After incubation, encapsulated living virulent bacteria were found
- Non-encapsulated bacteria received genes from dead encapsulated for forming a capsule
- The material responsible for transmission of this character was not known

Experiment: DNA is the genetic material

- In 1944, Oswald T Avery, Colin M Macleod, Maclyn Mccarty proved that DNA is the genetic material



Competent cells & competence

- **Competence:** ability of a recipient bacterium to take up DNA from the environment
- **Competent cells:** cells which can be transformed
- *E.coli* cannot undergo transformation naturally
- It is made competent by **artificial transformation** procedures (Calcium chloride or Electroporation)

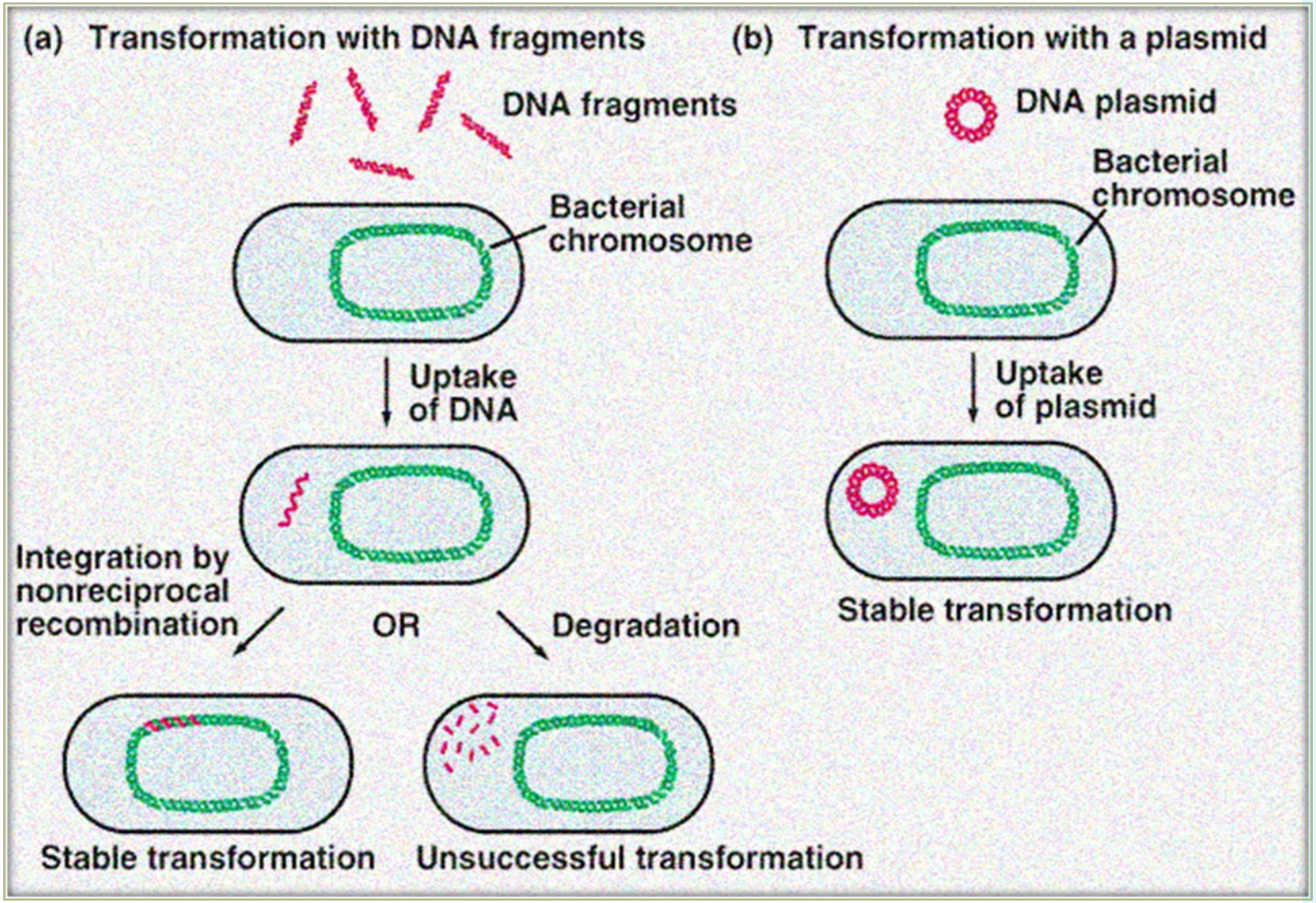
Mechanism of transformation

- After death, cell lysis leads to release of DNA from bacteria
- Other bacteria take up DNA and integrate into their chromosomes by recombination
- Recipient cell with this combination of genes will now become a hybrid or recombinant
  - Works best between closely related species
- **Transformation in nature:** ***Bacillus, Haemophilus, Streptococcus, Staphylococcus, Neisseria*** etc.

Mechanism of transformation

- **Step1:**
  - The DNA binding receptor on a competent bacterium binds double stranded DNA
  - As the DNA enters the cell, one strand is degraded, & the other strand is coated with single-strand DNA-binding protein.
- **Step2:**
  - The single strand of donor DNA is integrated into the chromosome of the recipient cell producing a recombinant DNA

Mechanism of transformation

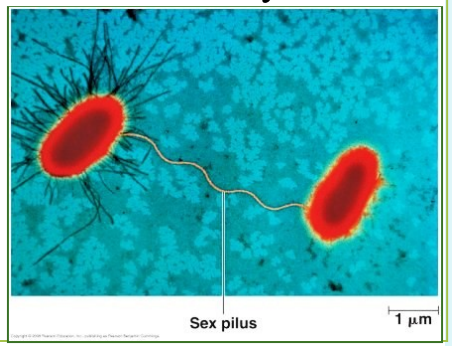


Conjugation

- Transfer of genes between cells that are in physical contact with another

- First demonstration of recombination in bacteria: **Jhosua Lederberg & Edward Tatum in 1946**

  - Found that, genetic traits could be transferred among two different strains of *E. coli*, if they are in physical contact



F+ and F- FACTORS

- William Hayes, Francois Jocob and Eli H Wolman (1950)

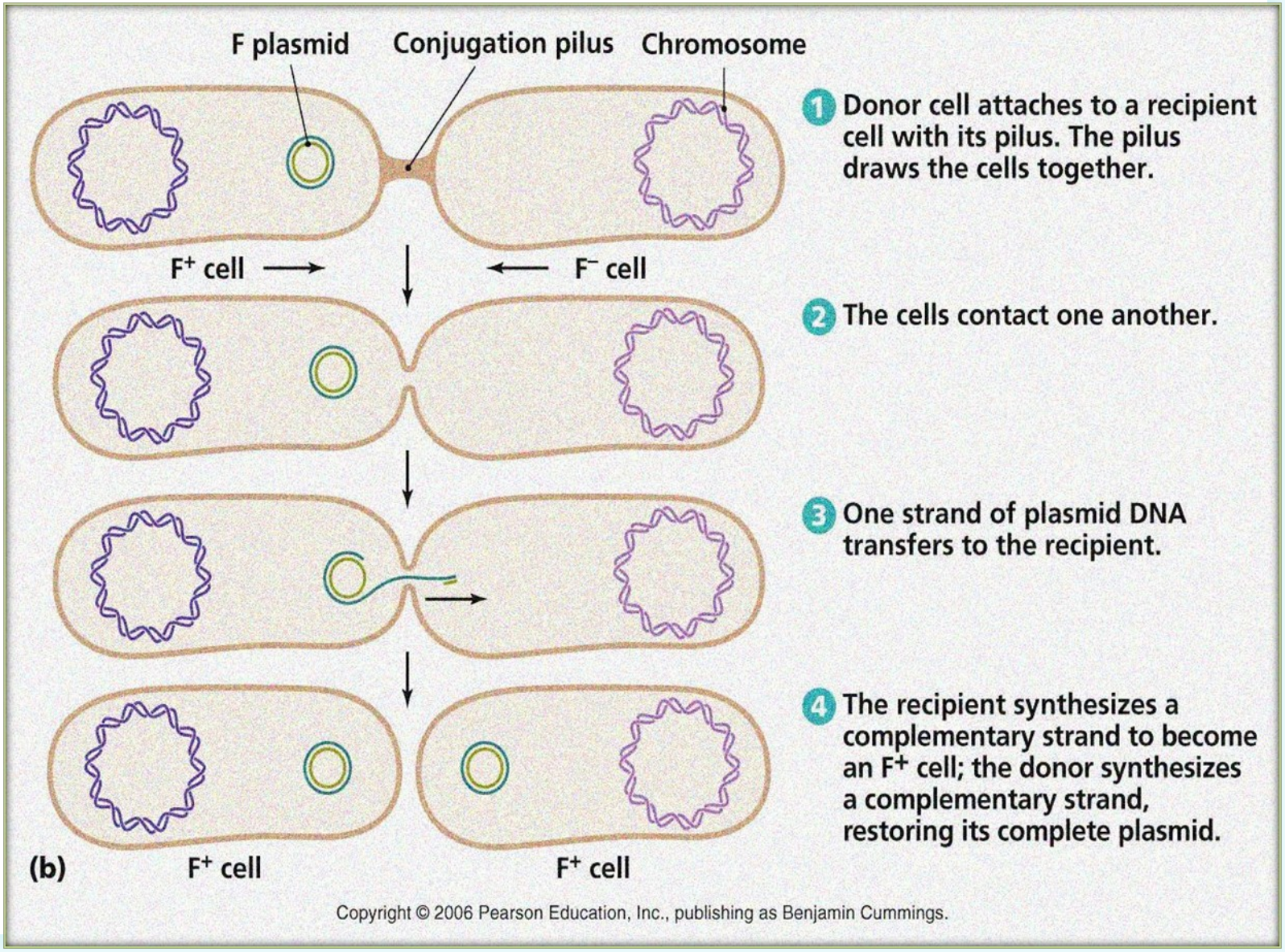
- Conjugating bacteria are of two mating types:-
  - Male types which donates their DNA, these are called F+ cells
  - Female types which are recipient of DNA donated by F+ cells and are called F- cells

- These F+ and F- are called **fertility factor** or **F-factor** or **sex factor**

Process of Conjugation

- The F Pili of the F+ donor cell make contact with the F- recipient cell & pull the cell together.
- Rolling circle replication transfer one strand of the F factor into the recipient cell.
- Transfer of F factor is completed, yielding two F+ factor bacteria.

Process of Conjugation



Process of Conjugation

- In donor F+ cells, F factor may integrate into the host chromosome becoming Hfr (High Frequency of Recombination).
- Thus F+ cells become Hfr cells
- Conjugation between Hfr and F- cells results in replication of the chromosome with F factor.
- A single parental strand is transferred from Hfr cell to the F- cells.

Process of Conjugation

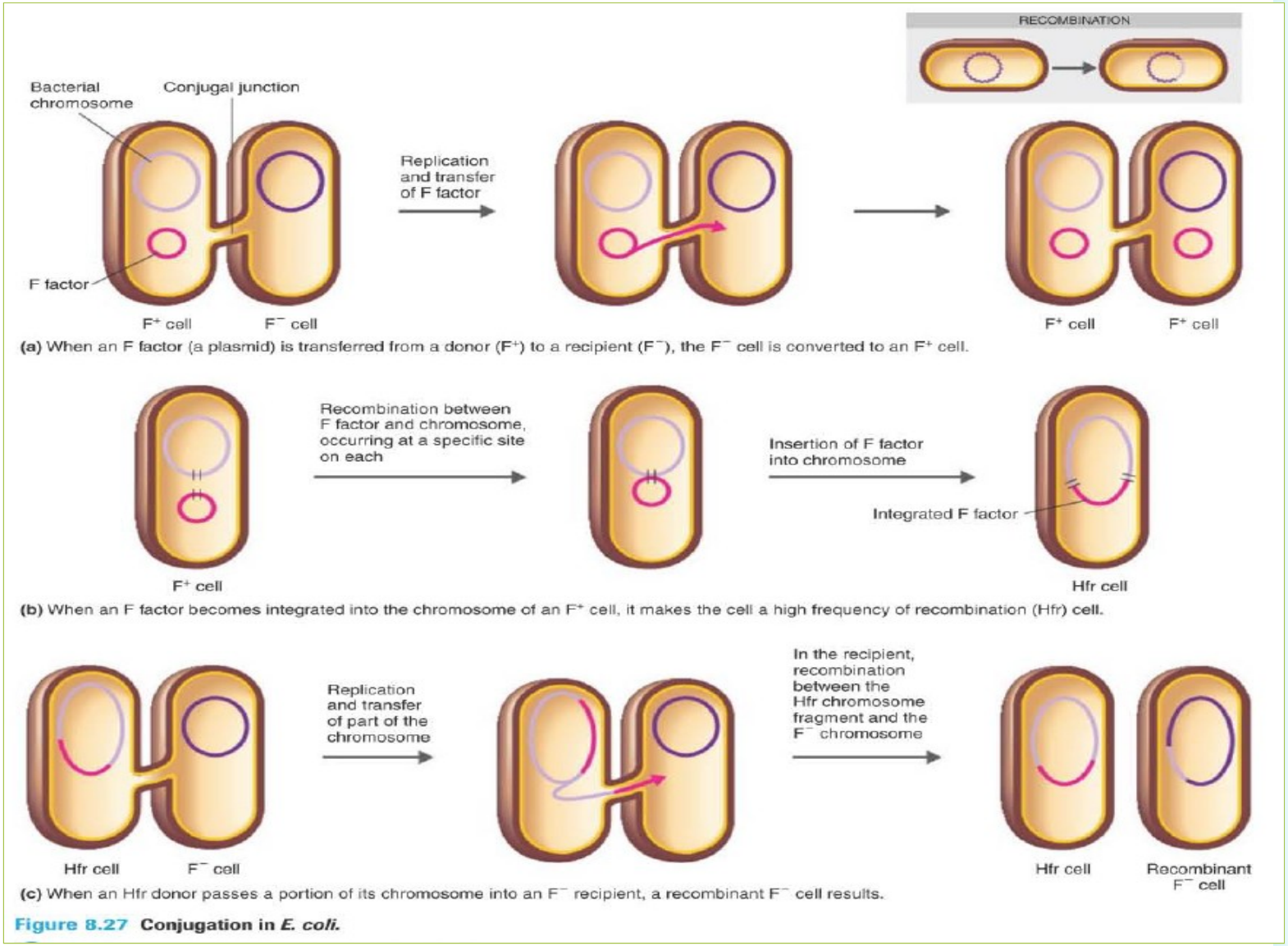


Figure 8.27 **Conjugation in *E. coli*.**

Process of Conjugation

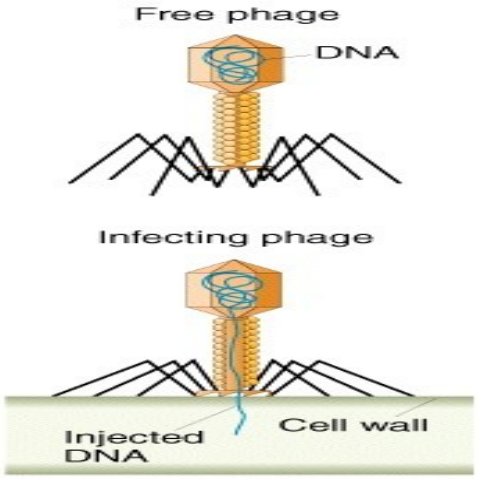
- Complete transfer of the chromosome does not take place
- Only a small piece of F factor leads the chromosomal genes into F^- cells
- Small strand containing chromosomal genes recombines with the DNA of F^- cells
- Thus F^- cells receive only a part of chromosomal genes and hence do not get converted to F^+ cells

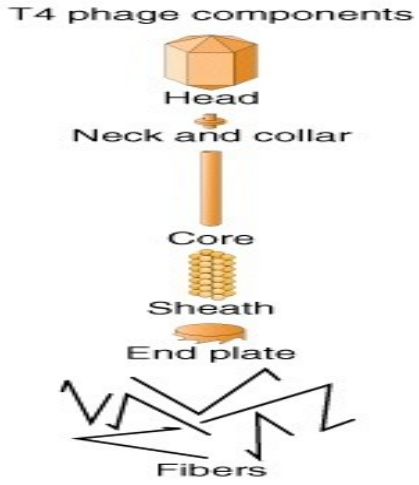
Transduction

- **Transduction** occurs when a phage (virus) carries bacterial genes from one host cell to another

- Discovered by Norton Zinder and Joshua Lederberg in 1952

Bacteriophage

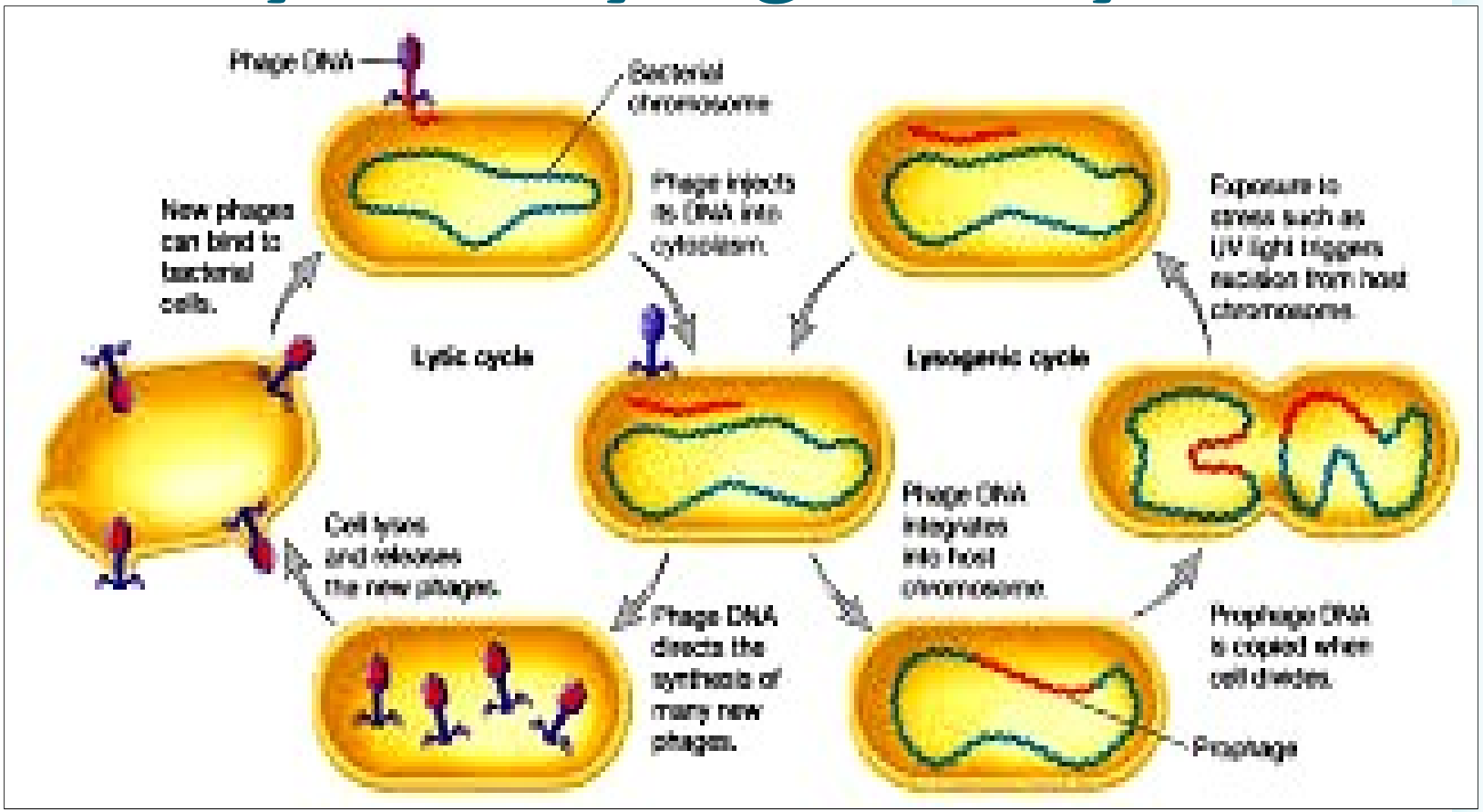




- **Two types:**
  1. Bacteriophage T4
  2. Bacteriophage λ

- **Life cycle**
  1. Lytic cycle
  2. Lysogenic cycle

Lytic & Lysogenic Cycle



Lytic & Lysogenic Cycle

- Bacteriophage attaches to donor bacteria
- Inject their nucleic acid (DNA) into bacterium
- DNA replicates rapidly, and also directs the synthesis of new phage protein
- Then, the new DNA combines with new proteins, to make whole phage particles
- These are then released by destruction of cell wall and lysis of the cell

Process of Transduction

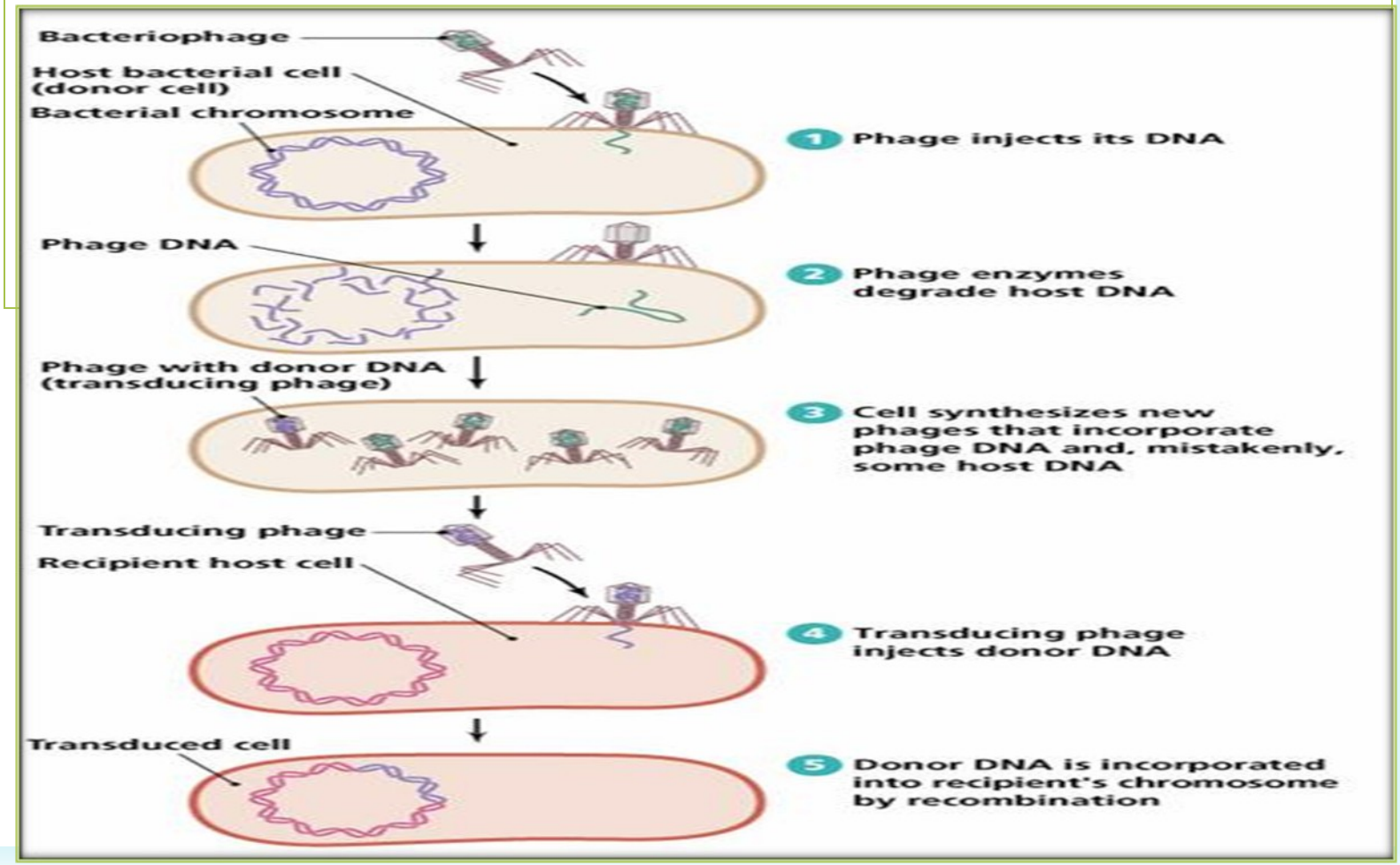
- These phages may composed of DNA of the host
- This phage attacks the another host and infect it
- Recipient DNA integrates with this DNA
- Results in the transfer of DNA
- Recipient cell is now called **transduced cell**

Types of Transduction

- Mainly there are two types
  - Generalised or Non-specialised Transduction
  - Restricted or Specialized Transduction

Generalized Transduction

- All fragments of bacterial DNA have a chance to enter a transducing phage



Specialized Transduction

- Certain phages can transfer only a few restricted genes of the bacterial chromosomes
- Only those bacterial genes adjacent to prophage in bacterial chromosomes
- Mediates the exchange of only limited numbers of specific genes
- Mediated by **Bacteriophage λ**

Specialized Transduction

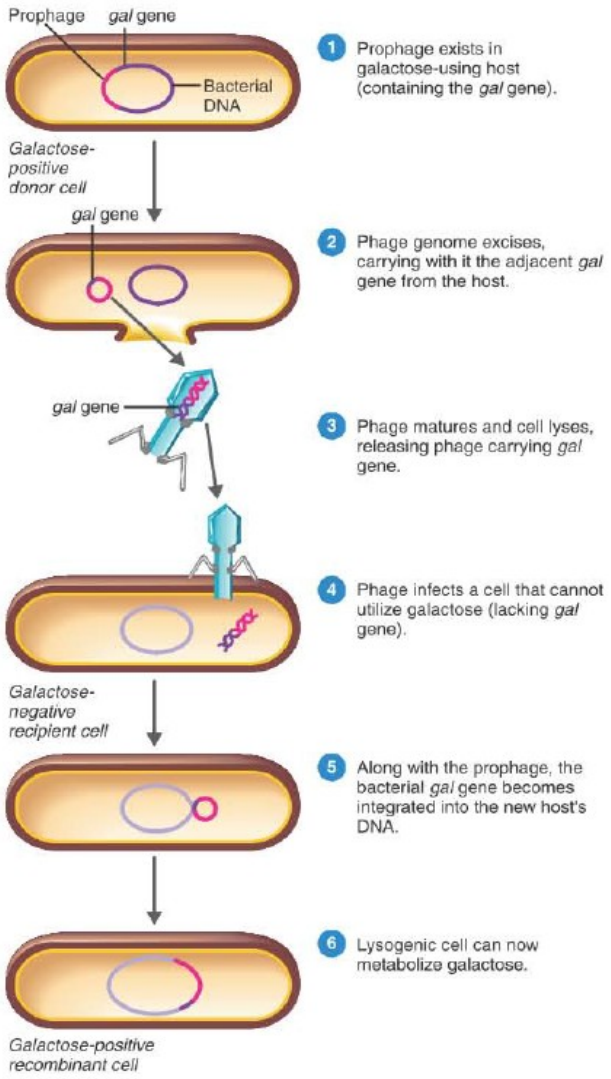


Figure 13.13 Specialized transduction. When a prophage is excised from its host chromosome, it can take with it a bit of the adjacent DNA from the bacterial chromosome.

- **λ phage** can only incorporate into a specific site (*att*λ)
- *gal* gene is on one side of *att*λ and *bio* gene (biotin synthesis) is on the other side
- Wrong cross over of **λ phage** at the end of the lysogenic phase
- Piece of the *E. coli* chromosome incorporated into **λ** phage chromosome
  - *gal* gene or *bio* gene can be transferred