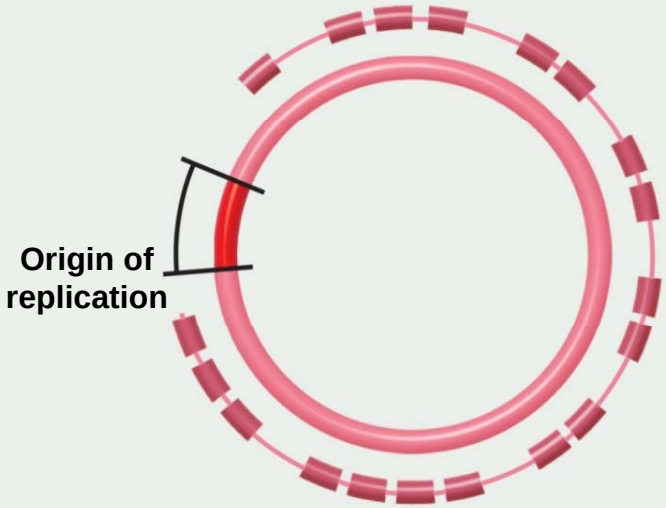
Genetic properties of bacteria

- Genes of bacteria are found in bacterial chromosomes
- Usually a single type of chromosome
- May have more than one copy of that chromosome
- Number of copies depends on the bacterial species and on growth conditions
- Typically 1-4 identical chromosomes
- Nucleoid – region where tightly packed bacterial chromosome found

- Molecules of double-stranded DNA
- Usually circular
- Tend to be shorter
- Contains a few thousand unique genes
- Mostly structural genes
- Single origin of replication

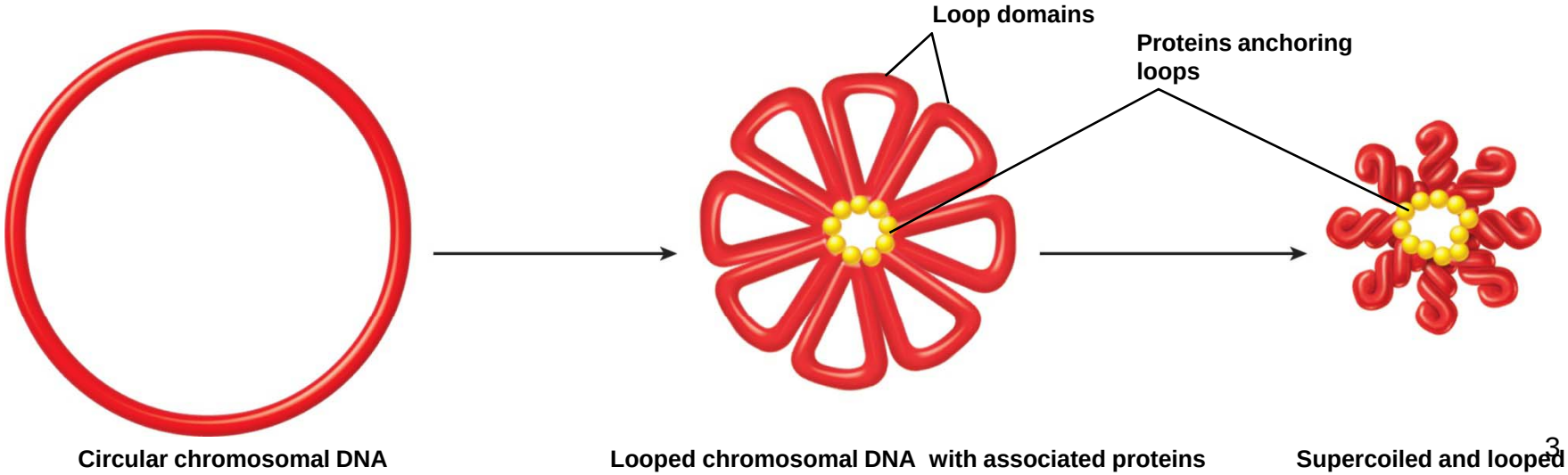


Key features

- **Most, but not all, bacterial species contain circular chromosomal DNA.**
- **A typical chromosome is a few million base pairs in length.**
- **Most bacterial species contain a single type of chromosome, but it may be present in multiple copies.**
- **Several thousand different genes are interspersed throughout the chromosome.**
- **One origin of replication is required to initiate DN A replication.**

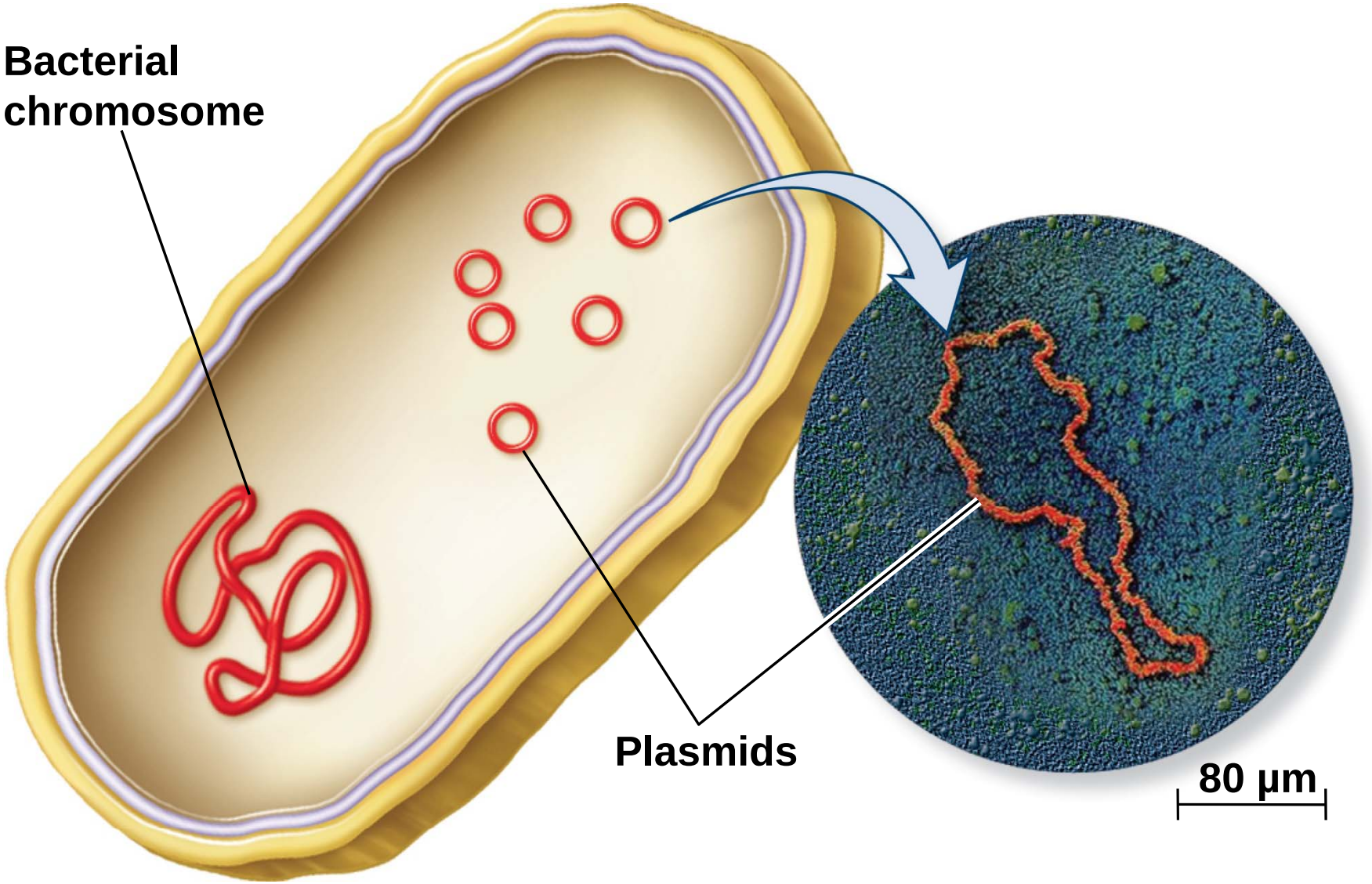
Compaction

- Typical bacterial chromosome must be compacted about 1,000-fold
- Bacterial DNA is not wound around histone proteins to form nucleosomes
- Proteins important in forming loop domains
  - Compacts DNA about 10-fold
- DNA supercoiling
  - Topoisomerases twist the DNA and control degree of supercoiling



Plasmids

- Small, circular pieces of DNA that exist independently of the bacterial chromosome
- Occur naturally in many strains of bacteria and in a few types of eukaryotic cells, such as yeast
- Own origin of replication that allows it to be replicated independently of the bacterial chromosome
- Not usually necessary for survival but can provide growth advantages
- Episome – plasmid that can integrate into bacterial chromosome

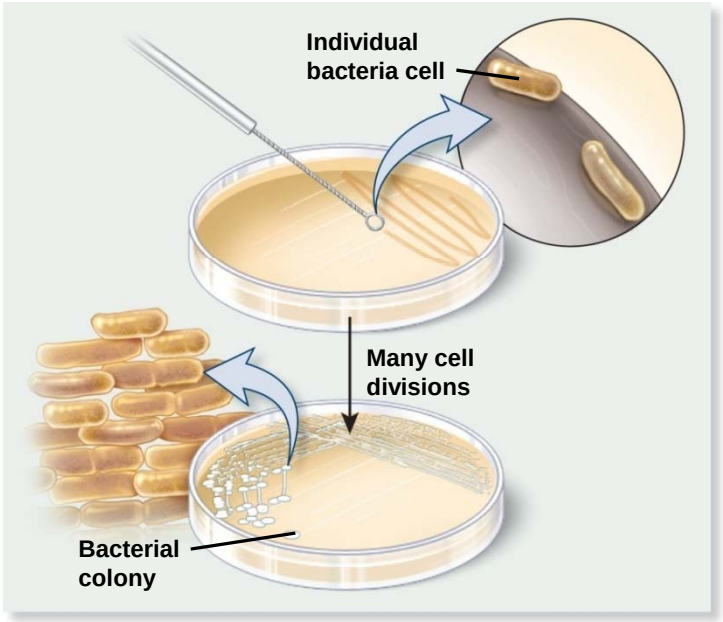


5 types of plasmids

- Resistance plasmids (R factors)
  - Contain genes that confer resistance against antibiotics and other types of toxins
- Degradative plasmids
  - Carry genes that enable the bacterium to digest and utilize an unusual substance
- Col-plasmids
  - Contain genes that encode colicines, which are proteins that kill other bacteria
- Virulence plasmids
  - carry genes that turn a bacterium into a pathogenic strain
- Fertility plasmids (F factors)
  - Allow bacteria to mate with each other

Reproduction

- Cells of some species, such as *E. coli*, can divide every 20–30 minutes
- Single cell can form a bacterial colony in less than a day
- Reproduce by binary fission – NOT mitosis
- Except when a mutation occurs, each daughter cell contains an identical copy of the mother cell's genetic material
- Does not involve genetic contributions from two different parents
- Plasmids may replicate independently of the bacterial chromosome



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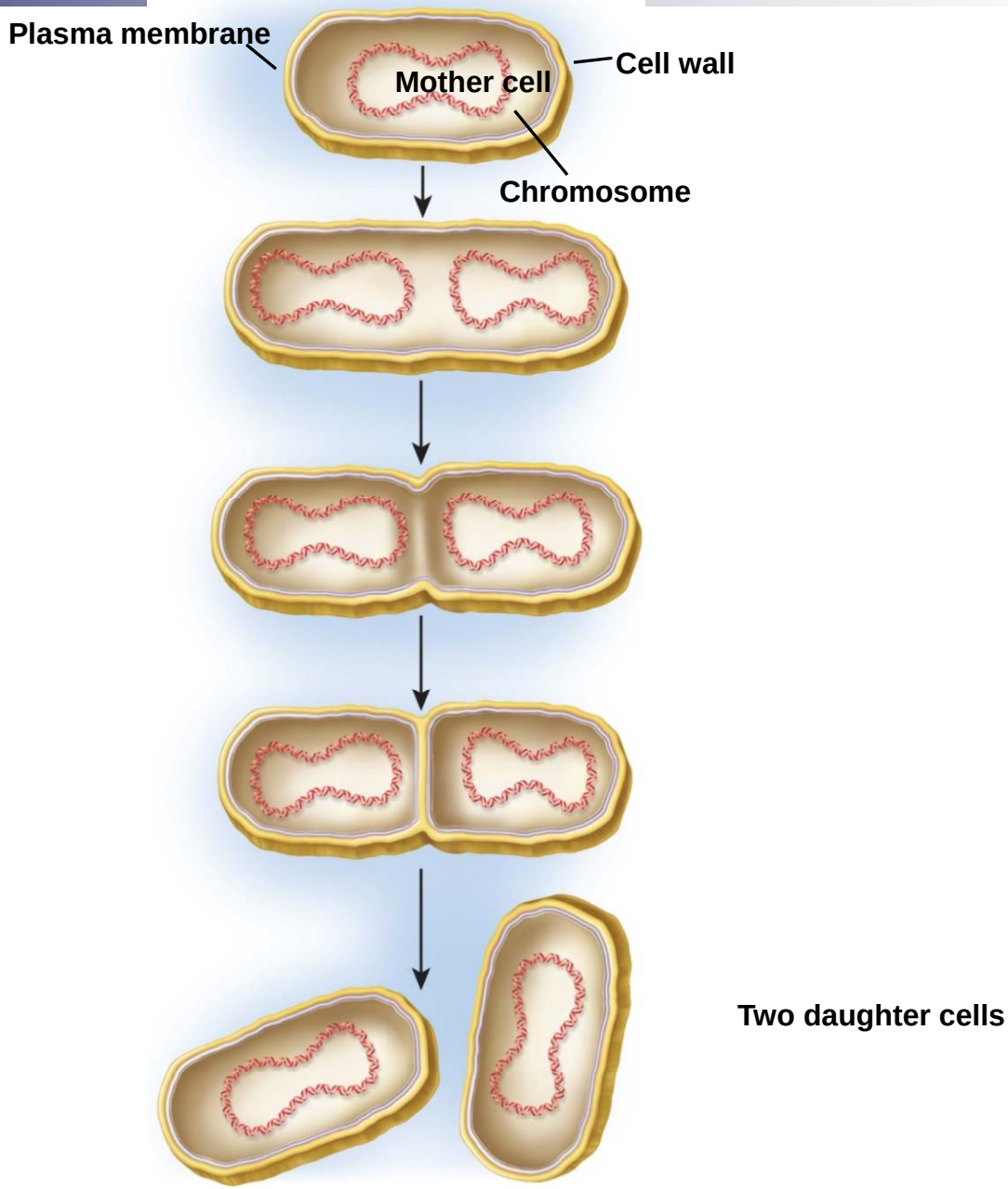

Plasma membrane
Cell wall
Mother cell
Chromosome
Two daughter cells

Genetic diversity in bacteria

- 2 sources
  1. Mutations can occur that alter the bacterial genome and affect the traits of bacterial cells
  2. Genetic transfer – genetic material is transferred from one bacterial cell to another

Genetic transfer

1. Conjugation
   - Direct physical interaction transfers genetic material from donor to recipient cell
2. Transformation
   - DNA released from a dead bacterium into the environment is taken up by another bacteria
3. Transduction
   - A virus transfers genetic information from one bacterium to another

FEATURE INVESTIGATION

Lederberg and Tatum's Work with *E. coli* Demonstrated Genetic Transfer Between Bacteria and Led to the Discovery of Conjugation

- Studying strains of *E. coli* that had different nutritional requirements for growth
- Differences in nutritional requirements correspond to allelic differences between the strains
- When 2 strains were mixed, found new genotypes
  - Not mutation
- Hypothesized that some genetic material was transferred between the two strains when they were mixed
- Either genetic material was released from one strain and taken up by the other, or cells of the two different strains made contact with each other and directly transferred genetic material
- U-tube allows pieces of DNA to transfer but not cells to touch
- Without physical contact, genetic material could not be transferred

Feature Investigation

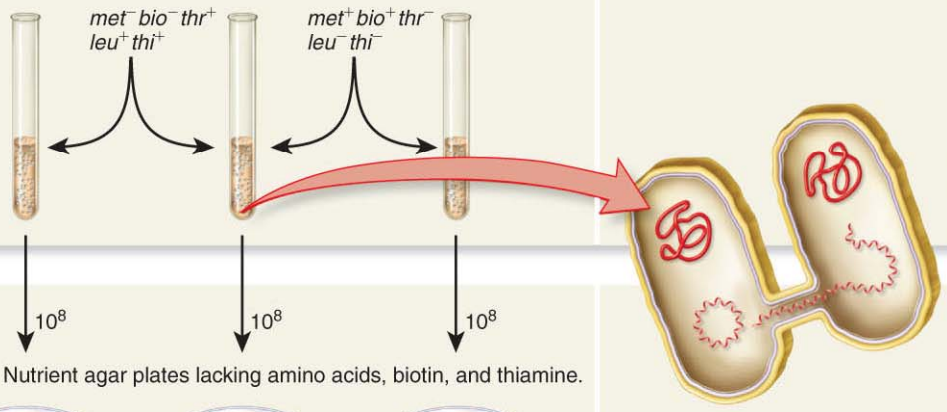
HYPOTHESIS Genetic material can be transferred from one bacterial strain to another.

STARTING MATERIALS Two bacterial strains, one that was *met*$^-$ *bio*$^-$ *thr*$^+$ *leu*$^+$ *thi*$^+$ and the other that was *met*$^+$ *bio*$^+$ *thr*$^-$ *leu*$^-$ *thi*$^-$.

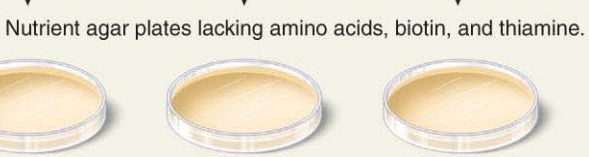
Experimental level **Conceptual level**

1 In 3 separate tubes, add either the *met*$^-$ *bio*$^-$ *thr*$^+$ *leu*$^+$ *thi*$^+$ strain, the *met*$^+$ *bio*$^+$ *thr*$^-$ *leu*$^-$ *thi*$^-$ strain, or a mixture of both strains.

Incubate several hours.



2 Remove 10^8 cells from each tube and spread onto plates that lack methionine, biotin, threonine, leucine, and thiamine.

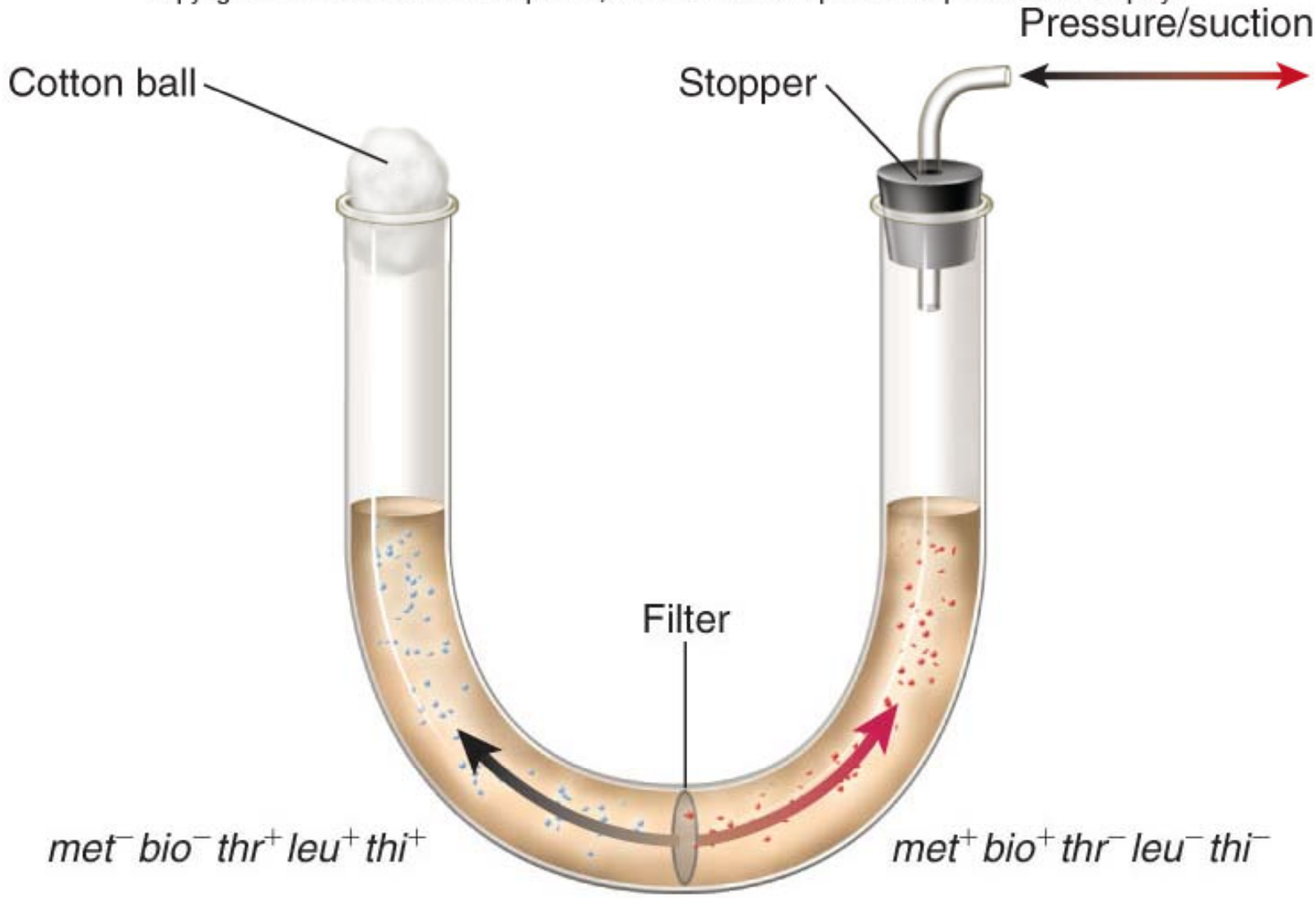


3 Incubate overnight to allow growth of bacterial colonies.

4 **THE DATA**

Strain	Number of colonies after overnight growth
met$^-$ *bio*$^-$ *thr*$^+$ *leu*$^+$ *thi*$^+$	0
met$^+$ *bio*$^+$ *thr*$^-$ *leu*$^-$ *thi*$^-$	0
Both strains together	~10

Feature Investigation

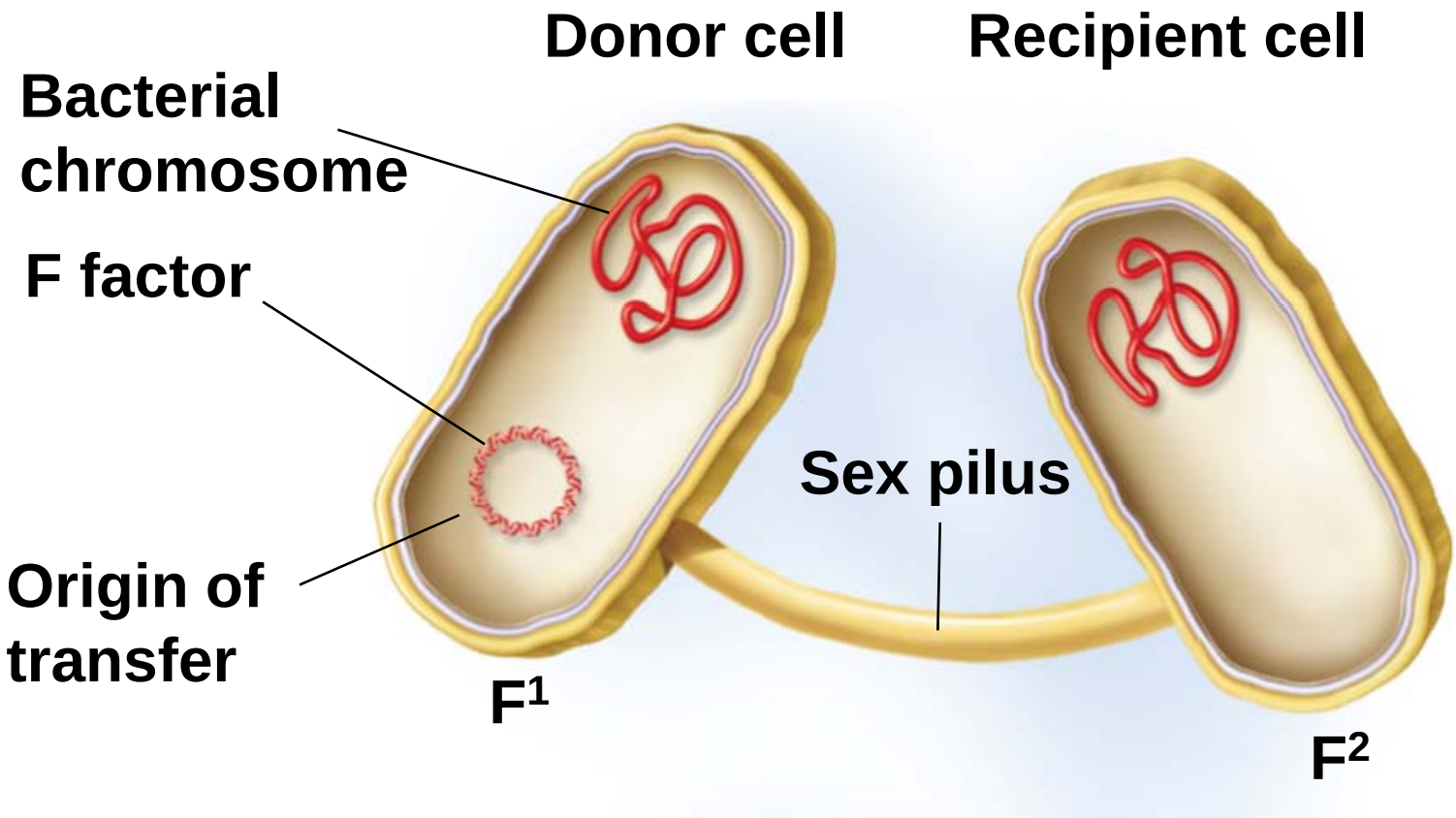


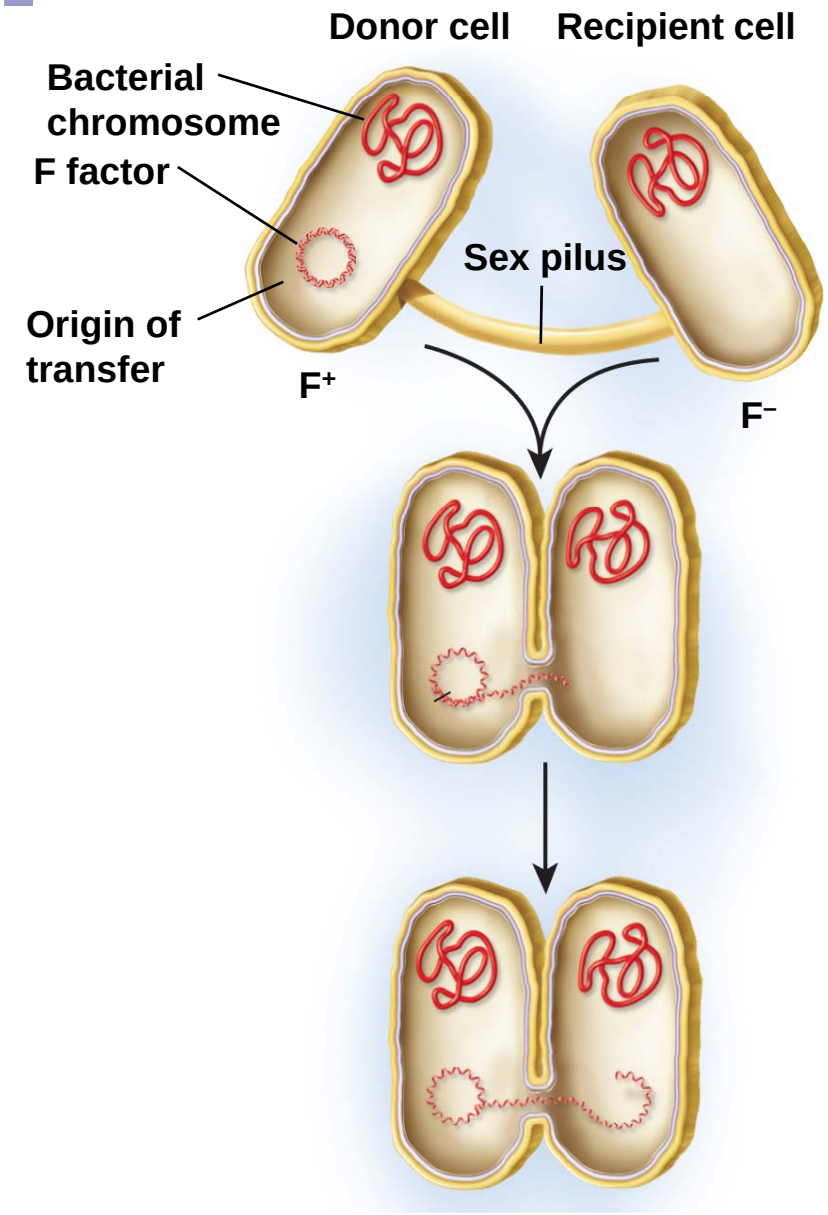
Conjugation

- Only about 5% of *E. coli* strains found in nature can act as donor strains
- Donor strains contain a fertility factor (F factor) that can be transferred to recipient strains
  - Some donor strains are Hfr (for *H*igh *fr*equency of recombination)

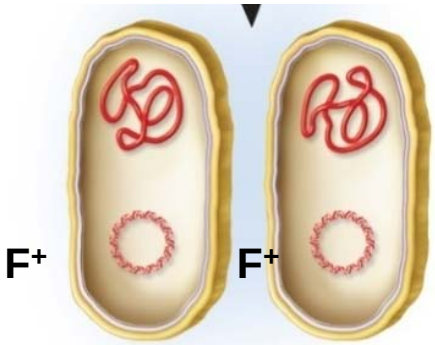
F factors

- Carry several genes that are required for conjugation and also may carry genes that confer a growth advantage for the bacterium
- F^+ has an F factor, F^- does not
- Sex pili are made by F^+ cells that bind specifically to F^- cells
- Once contact is made, the pili shorten, drawing the donor and recipient cells closer together
- One strand of F factor is transferred, other strand stays in donor
- Both replicate so that donor and recipient now have complete double stranded F factor



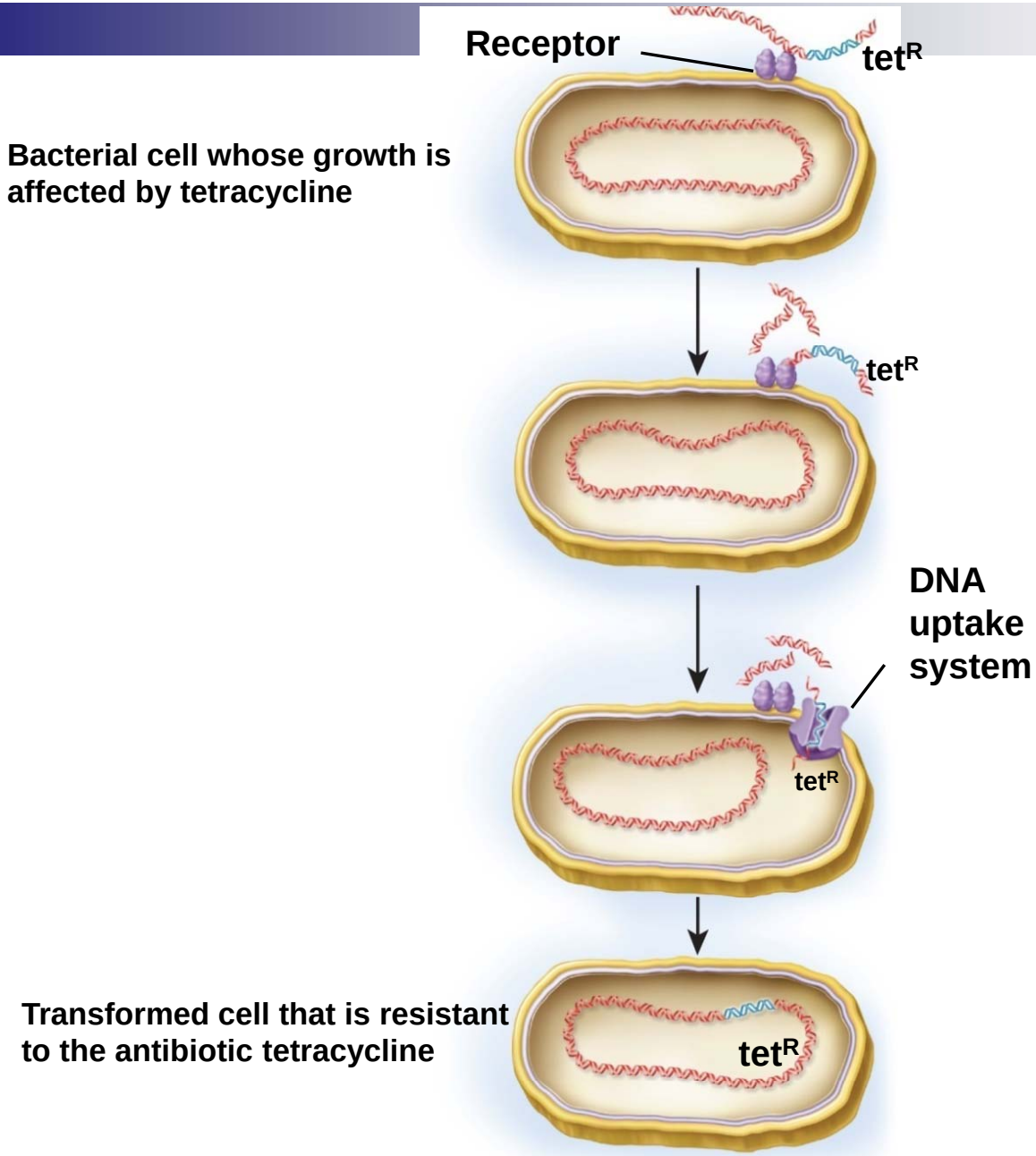


(b) Transfer of an F factor



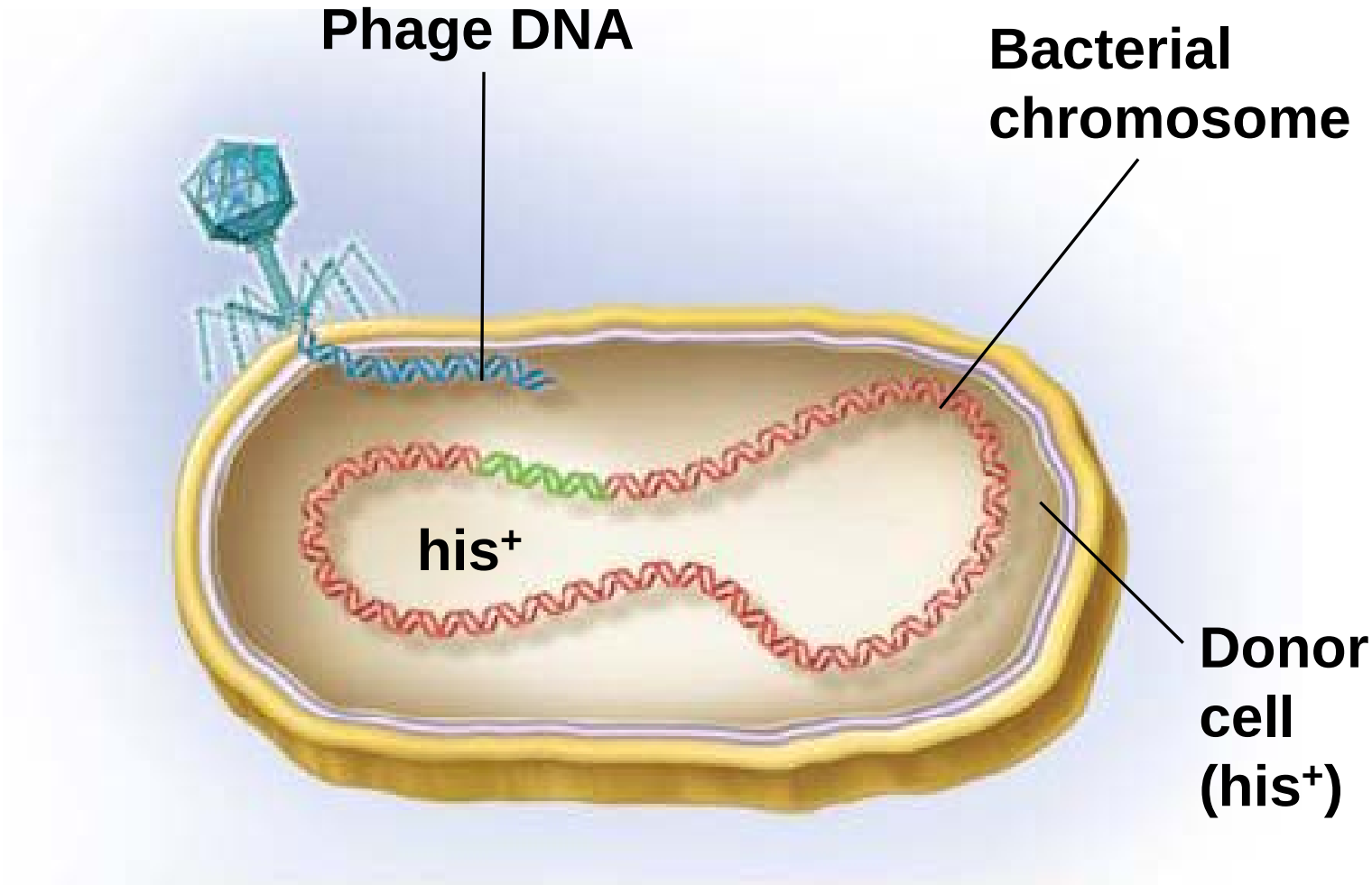
Transformation

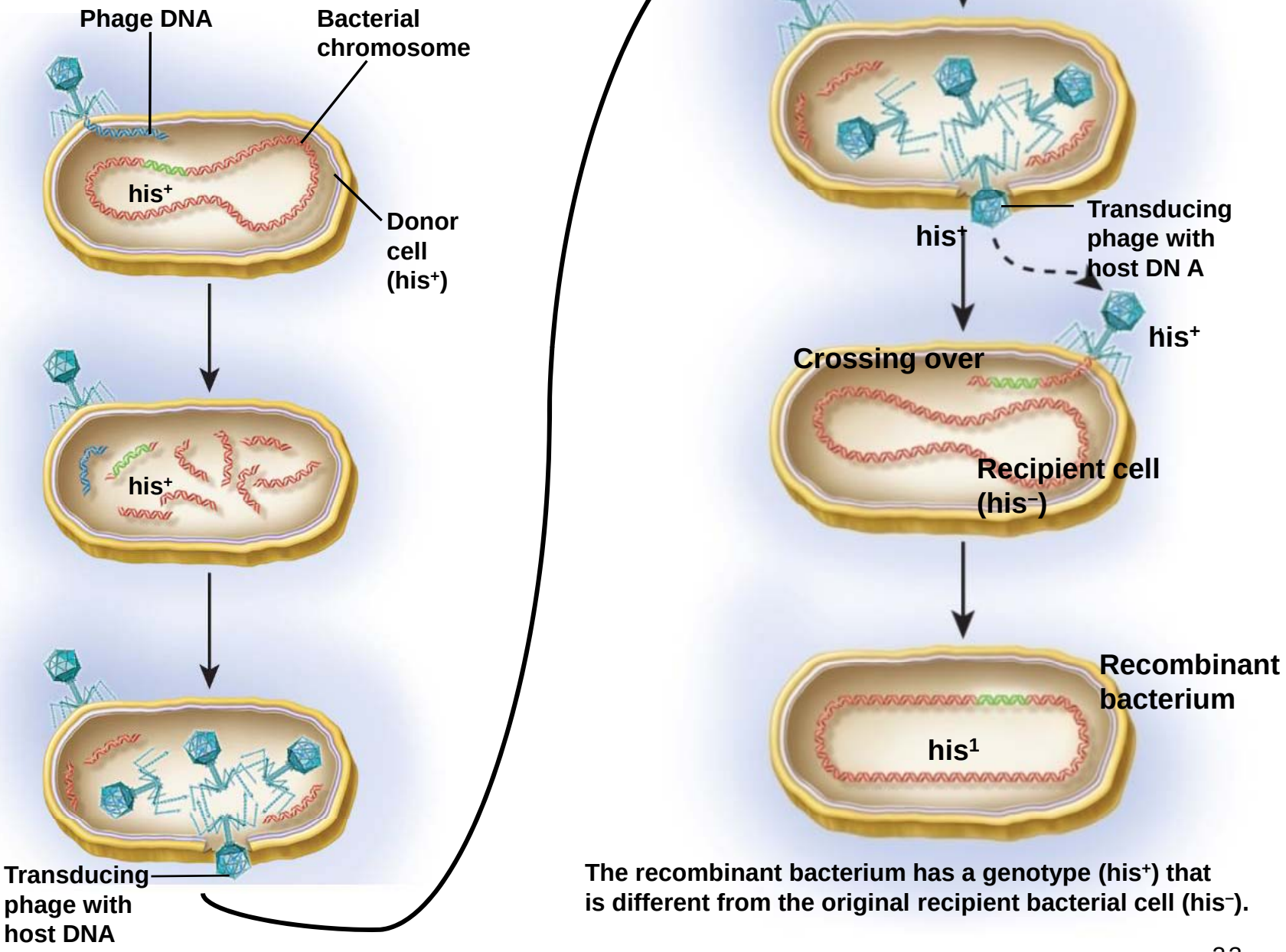
- Does not require direct contact between bacterial cells
- Living bacterial cell imports a strand of DNA that another bacterium released into the environment when it died
- Only competent cells with competence factors can do this
- Facilitate the binding of DNA fragments to the bacterial cell surface, the uptake of DNA into the cytoplasm, and the incorporation of the imported DNA into the bacterial chromosome


Receptor
tetR
Bacterial cell whose growth is affected by tetracycline
tetR
DNA uptake system
tetR
Transformed cell that is resistant to the antibiotic tetracycline
tetR

Transduction

- Viruses that infect bacteria transfer bacterial genes from one bacterium to another
- Usually an error in a phage lytic cycle
- Newly assembled phages incorporate piece of host DNA instead





The recombinant bacterium has a genotype (his+) that is different from the original recipient bacterial cell (his–).

Horizontal Gene Transfer Is the Transfer of Genes Between Different Species

- Vertical gene transfer that occurs when genes are passed from one generation to the next among individuals of the same species
- Roughly 17% of the genes of *E. coli* and of *Salmonella typhimurium* have been acquired by horizontal transfer during the past 100 million years
- Medical relevance of horizontal gene transfer is profound – acquired antibiotic resistance