MOLECULAR BIOLOGY

TRANSFER OF GENETIC MATERIAL

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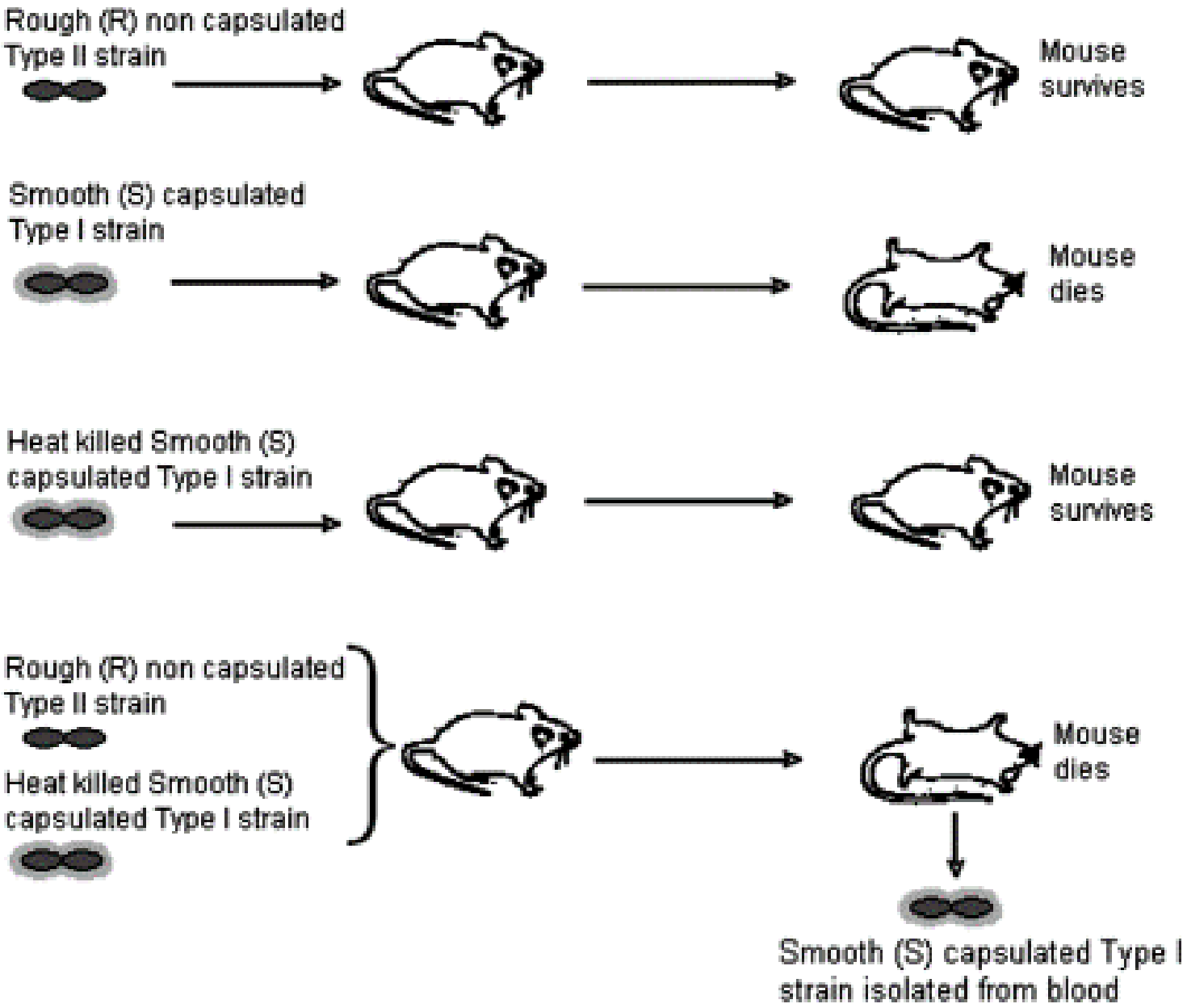
TRANSFER OF GENETIC MATERIAL

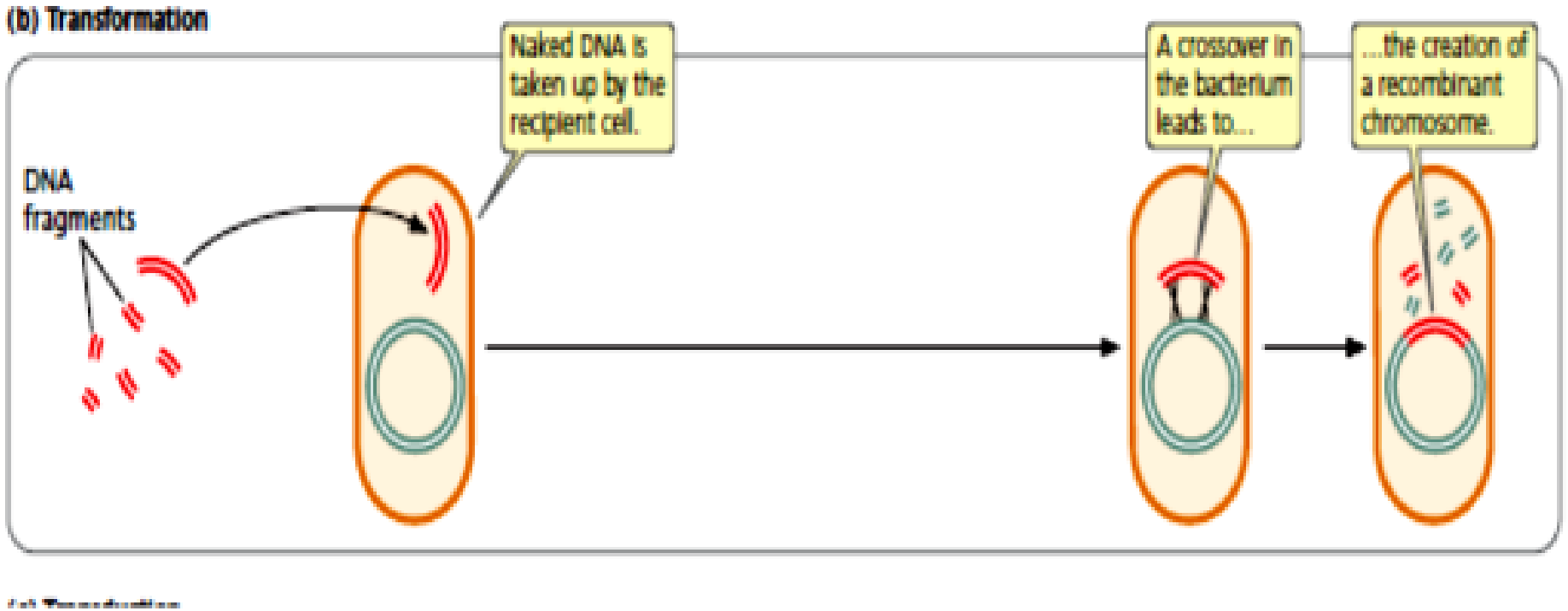
Sometimes when two pieces of DNA come into contact with each other, sections of each DNA strand will be exchanged. This is usually done through a process called crossing over in which the DNA breaks and is attached on the other DNA strand leading to the transfer of genes and possibly the formation of new genes**. Genetic recombination is the transfer of DNA from one organism to another**. The transferred donor DNA may then be integrated into the recipient's nucleoid by various mechanisms. In the case of homologous recombination, homologous DNA sequences having nearly the same nucleotide sequences are exchanged by means of breakage and reunion of paired DNA segments. **Genetic information can be transferred from organism to organism through vertical transfer (from a parent to offspring) or through horizontal transfer methods such as conjugation, transformation or transduction**. Bacterial genes are usually transferred to members of the same species but occasionally transfer to other species can also occur.

TRANSFORMATION

Transformation involves the uptake of free or naked DNA molecules from one bacterium and another bacterium
(recipient). It was the first example of genetic exchange in bacteria to have been discovered. This was first demonstrated in an experiment conducted by **Griffith** in 1928. The presence of a capsule around some strains of pneumococci gives the colonies a glistening, smooth (S) appearance while pneumococci lacking capsules have produce rough (R) colonies. Strains of pneumococci with a capsule (type I) are virulent and can kill a mouse whereas strains lacking it (type II) are harmless. Griffith found that mice died when they were injected with a mixture of live non capsulated (R, type II) strains and heat killed capsulated (S, type I) strains. Neither of these two when injected alone could kill the mice, only the mixture of two proved fatal. Live S strains with capsule were isolated from the blood of the animal suggesting that **some factor from the dead S cells converted the R strains into S type. The factor that transformed the other strain was found to be DNA by Avery, McLeod and McCarty in 1944.**


Rough (R) non capsulated
Type II strain
Mouse
survives
Smooth (S) capsulated
Type I strain
Mouse
dies
Heat killed Smooth (S)
capsulated Type I strain
Mouse
survives
Rough (R) non capsulated
Type II strain
Heat killed Smooth (S)
capsulated Type I strain
Mouse
dies
Smooth (S) capsulated Type I
strain isolated from blood

- **Transformation** takes place when a bacterium takes up DNA from the medium in which it is growing.
- After transformation, recombination may takeplace between the introduced genes and those of thebacterial chromosome



Transformation is gene transfer resulting from the uptake by a recipient cell of naked DNA from a donor cell.

Certain bacteria (e.g. Bacillus, Haemophilus, Neisseria, Pneumococcus) can take up DNA from the environment and the DNA that is taken up can be incorporated into the recipient's chromosome.

THE STEPS INVOLVED IN TRANSFORMATION

1. A donor bacterium dies and is degraded.
2. A fragment of DNA (usually about 20 genes long) from the dead donor bacterium binds to DNA binding proteins on the cell wall of a competent, living recipient bacterium.
3. Nuclease enzymes then cut the bound DNA into fragments.
4. One strand is destroyed and the other penetrates the recipient bacterium.
3. The Rec A protein promotes genetic exchange (recombination) between a fragment of the donor's DNA and the recipient's DNA

Some bacteria are able to take up DNA naturally. However, these bacteria only take up DNA a particular time in their growth cycle (log phase) when they produce a specific protein called a competence factor. Uptake of DNA by Gram positive and Gram negative bacteria differs. In Gram positive bacteria the DNA is taken up as a single stranded molecule and the complementary strand is made in the recipient. In contrast, Gram negative bacteria take up double stranded DNA.

SIGNIFICANCE: Transformation occurs in nature and it can lead to increased virulence. In addition transformation is widely used in recombinant DNA technology.

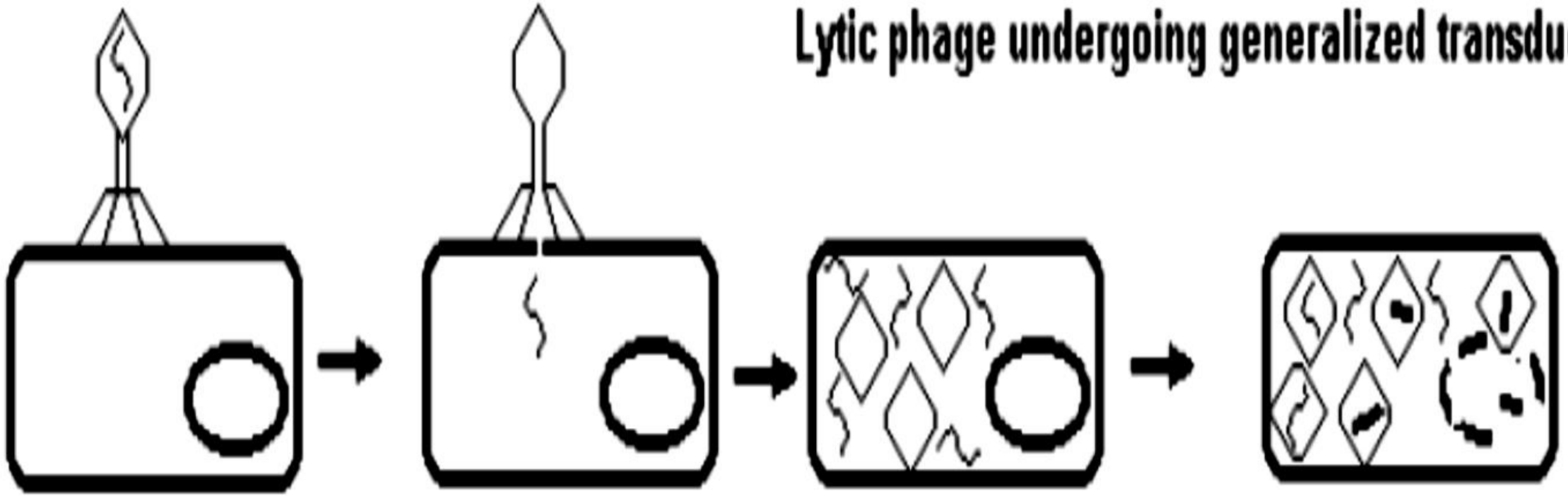
TRANSDUCTION

Bacteriophage are viruses that parasitize bacteria and use their machinery for their own replication. During the process of replication inside the host bacteria the bacterial chromosome or plasmid is erroneously packaged into the bacteriophage capsid. Thus newer progeny of phages may contain fragments of host chromosome along with their own DNA or entirely host chromosome. When such phage infects another bacterium, the bacterial chromosome in the phage also gets transferred to the new bacterium. This fragment may undergo recombination with the host chromosome and confer new property to the bacterium. Life cycle of bacteriophage may either by lytic or lysogenic. In the former, the parasitized bacterial cell is killed with the release of mature phages while in the latter the phage DNA gets incorporated into the bacterial chromosome as prophage

STAGES OF TRANSDUCTION INVOLVING A LYTIC PHAGE

1. A lytic bacteriophage adsorbs to a susceptible bacterium.
2. The bacteriophage genome enters the bacterium. The phage DNA directs the bacterium's metabolic machinery to manufacture bacteriophage components and enzymes.
3. Occasionally during maturation, a bacteriophage capsid incorporates a fragment of donor bacterium's chromosome or a plasmid instead of a phage genome by mistake.
4. The bacteriophages are released with the lysis of bacterium. 5. The bacteriophage carrying the donor bacterium's DNA adsorbs to another recipient bacterium.
6. The bacteriophage inserts the donor bacterium's DNA it is carrying into the recipient bacterium.
7. The donor bacterium's DNA is exchanged by recombination for some of the recipient's DNA.

Lytic phage undergoing generalized transduction



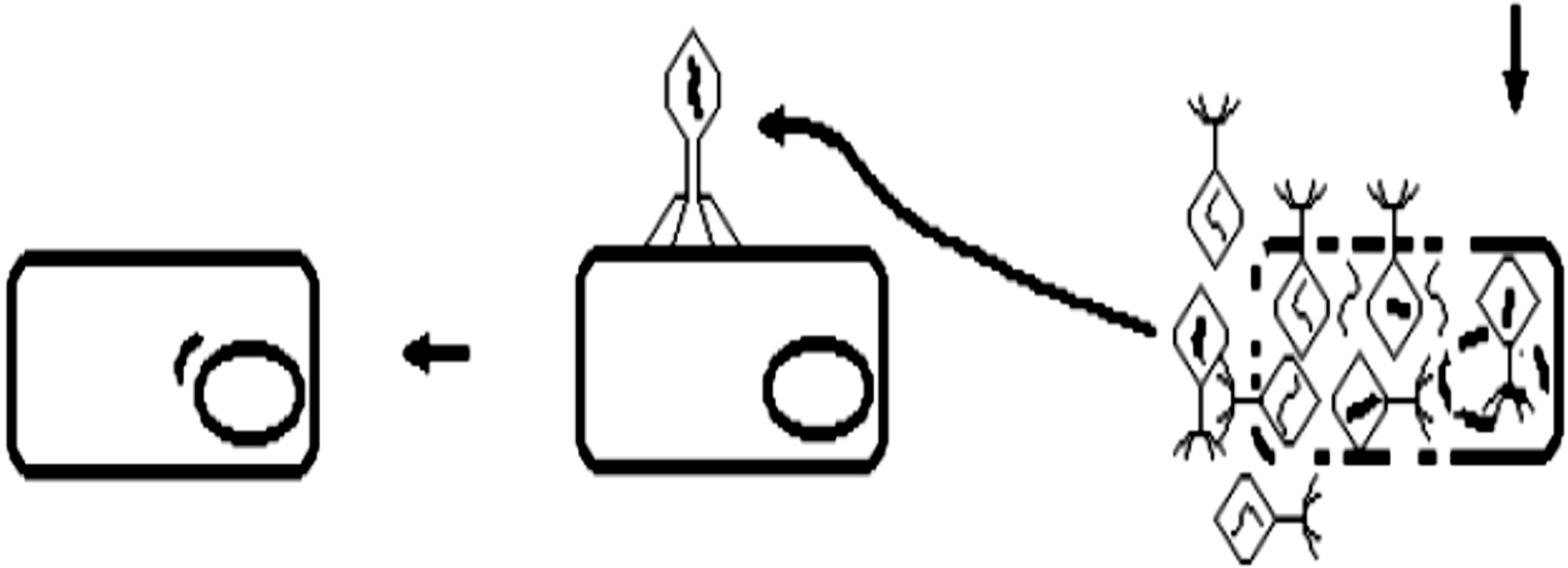
Adsorption of a lytic phage on bacterium

Introduction of phage DNA into host bacterium

Multiplication of phage DNA and production of phage capsids

Packaging of phage DNA into capsid and accidental packaging of host DNA into capsid

capsid



Lysis of cell with release of mature phages, many with own DNA and few with host chromosomal DNA fragments

Infection of another bacterium by a phage containing bacterial chromosomal DNA

The transduced chromosomal fragment exchanges genes with host chromosome by recombination, thus conferring new properties

TWO TYPES OF TRANSDUCTION

- **restricted transduction and generalized transduction**.
- **Generalized transduction can transfer any bacterial gene to the recipient**. This process may occur with phages (lytic phages) that degrade their host DNA into pieces the size of viral genomes. If these pieces are erroneously packaged into phage particles, they can be delivered to another bacterium in the next phage infection cycle. Phages P22 of Salmonella typhimurium and P1 and μ of E. coli carry out generalized transduction.
- **In restricted transduction only those chromosomal genes that lie adjacent to the prophage are transmitted**. The lambda phage that infects E.coli always transfers gal+ gene (responsible for galactose fermentation). **Specialized transduction is only effective in transducing a few special bacterial genes while generalized transduction can transduce any bacterial gene**.