Transduction

Introduction

- **Transduction** is one of the three main mechanisms of **horizontal gene transfer (HGT) in bacteria**, the others being **transformation** and **conjugation**.
- It involves the **transfer of bacterial DNA from one cell to another via bacteriophages** (viruses that infect bacteria).
- First discovered by **Zinder and Lederberg (1952)** in *Salmonella typhimurium*.
- Plays a key role in **genetic variation, evolution, virulence, and antibiotic resistance** among bacteria.

Definition

Transduction is the process by which bacteriophages (phages) transfer fragments of bacterial DNA from a donor cell to a recipient cell, leading to genetic recombination.

Types of Transductions

There are two main types, depending on the phage life cycle:

1. Generalized Transduction

- **Any bacterial gene** can be transferred.
- Occurs during **lytic cycle** of a bacteriophage.
- Process:
    1. Phage infects donor bacterium.
    2. Bacterial chromosome is broken into fragments.
    3. Occasionally, a phage head mistakenly packages bacterial DNA instead of viral DNA.
    4. Such a "defective phage" injects bacterial DNA into a new host.
    5. The new DNA recombines with recipient genome.
- Example: **P22 phage in *Salmonella***, **P1 phage in *E. coli***.

2. Specialized Transduction

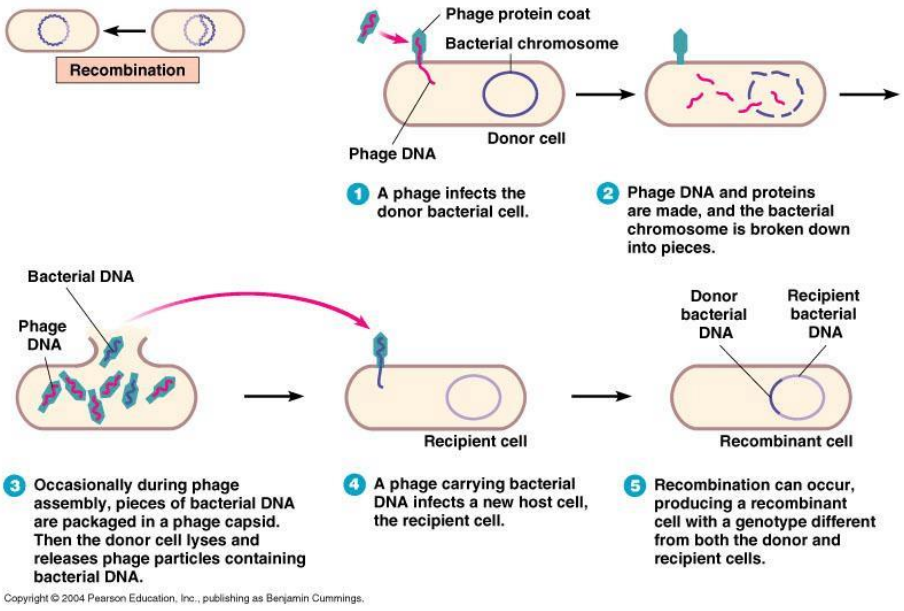
- **Only specific bacterial genes near the prophage integration site** are transferred.
- Occurs during **lysogenic cycle** of a temperate phage.
- Process:
    1. Temperate phage (like λ phage) integrates into bacterial chromosome at specific site.
    2. During excision, it may accidentally take adjacent bacterial genes along with viral DNA.
    3. This hybrid DNA is packaged into new phage particles.
    4. When the phage infects another bacterium, the carried bacterial genes are transferred.
- Example: **λ phage in *E. coli***.

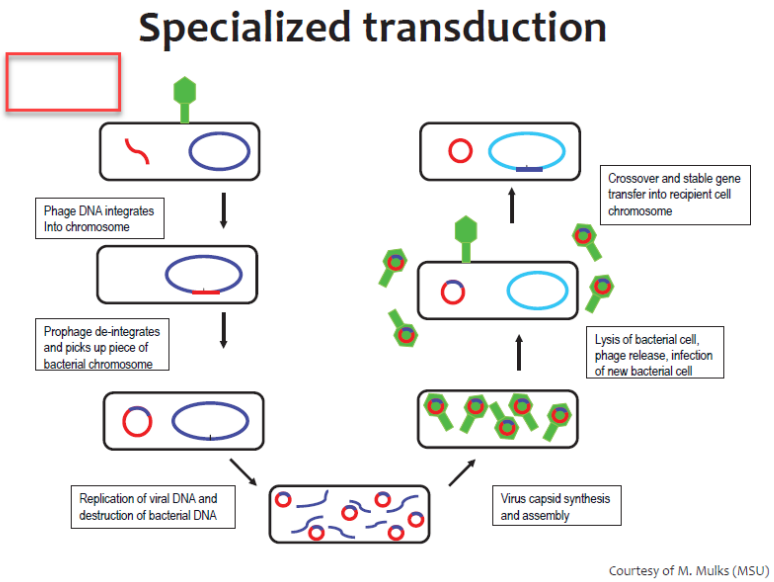
Steps in Transduction

1. **Phage infection of donor cell**.
2. **Mistaken packaging of bacterial DNA** (generalized) or **incorrect excision with host DNA** (specialized).
3. **Release of phage particles**.
4. **Infection of recipient cell**.
5. **Integration of donor bacterial DNA into recipient genome** by recombination.

Diagrams (Exam Sketches)

Generalized Transduction





Courtesy of M. Mulks (MSU)

Examples of Transduction

- **Generalized:** P1 phage transferring drug resistance genes in *E. coli*.
- **Specialized:** λ phage transferring galactose and biotin operons in *E. coli*.

Significance of Transduction

1. **In Nature**
   - Promotes **genetic diversity** in bacterial populations.
   - Helps spread **virulence factors** (e.g., toxins in *Corynebacterium diphtheriae*, *Vibrio cholerae*).
   - Plays a role in the evolution of **pathogenic bacteria**.
2. **In Medicine**
   - Responsible for **antibiotic resistance transfer**.
   - Important in **phage therapy** research.
3. **In Biotechnology**
   - Used for **bacterial gene mapping** (since transduction frequency depends on gene proximity).
   - Phage vectors are used in **molecular cloning**.
   - Basis for **specialized vectors like λ phage vectors** in recombinant DNA technology.

Comparison: Generalized vs Specialized Transduction

Feature	Generalized Transduction	Specialized Transduction
Phage type	Lytic or temperate phage	Temperate phage (lysogenic cycle)
Genes transferred	Any bacterial gene	Only genes near prophage site
Mechanism	Accidental packaging of host DNA	Faulty excision of prophage
Examples	P1 phage (*E. coli*), P22 (*Salmonella*)	λ phage (*E. coli*)

Conclusion

- **Transduction** is a vital process of genetic exchange in bacteria mediated by bacteriophages.
- It contributes to **genetic variation, antibiotic resistance, and virulence spread** in microbial populations.
- Experimentally, it is useful for **gene mapping and cloning**.
- Thus, transduction highlights the close interaction between viruses and bacteria and forms the basis for many advances in **genetics and biotechnology**.