Transduction

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Bacteriophage & Transduction

- Bacterial viruses or bacteriophages participate in this mode of bacterial gene transfer.
- These viruses have relatively simple structures in which virus genetic material is enclosed within an outer coat, composed mainly or solely of protein.
- The coat protects the genome and transmits it between host cells.
- After infecting the host cell, a bacteriophage (phage for short) often takes control and forces the host to make many copies of the virus.
- Eventually the host bacterium bursts or lyses and releases new phages.
- This reproductive cycle is called a lytic cycle because it ends in lysis of the host.
- **The Lytic cycle has four phases:**
  - First, the virus particle attaches to a specific receptor site on the bacterial surface. The genetic material, which is often double-stranded DNA, then enters the cell.
  - After adsorption and penetration, the virus chromosome forces the bacterium to make virus nucleic acids and proteins.
  - The third stage begins after the synthesis of virus components. Phages are assembled from these components. The assembly process may be complex, but in all cases phage nucleic acid is packed within the virus's protein coat.
  - Finally, the mature viruses are released by cell lysis.

… Bacteriophage & Transduction

- Bacterial viruses that reproduce using a lytic cycle often are called virulent bacteriophages because they destroy the host cell.
- Many DNA phages, such as the lambda phage, are also capable of a different relationship with their host.
- **Lysogenic cycle:** After adsorption and penetration, the viral genome does not take control of its host and destroy it while producing new phages.
- Instead the genome remains within the host cell and is reproduced along with the bacterial chromosome.
- A clone of infected cells arises and may grow for long periods while appearing perfectly normal.
- This relationship between the phage and its host is called **lysogeny.**
- Bacteria that can produce phage particles under some conditions are said to be **lysogens or lysogenic, and phages able to establish** this relationship are **temperate phages.**
- The latent form of the virus genome that remains within the host without destroying it is called the **prophage.**
- Sometimes phage reproduction is triggered in a lysogenized culture by exposure to UV radiation or other factors.
- The lysogens are then destroyed and new phages released, called as induction.

Transduction

- **Transduction is the transfer of bacterial genes by viruses.**
- Bacterial genes are incorporated into a phage capsid because of errors made during the virus life cycle.
- The virus containing these genes then injects them into another bacterium, completing the transfer.
- Transduction may be the most common mechanism for gene exchange and recombination in bacteria.
- There are two very different kinds of transduction:
  - Generalized
  - Specialize

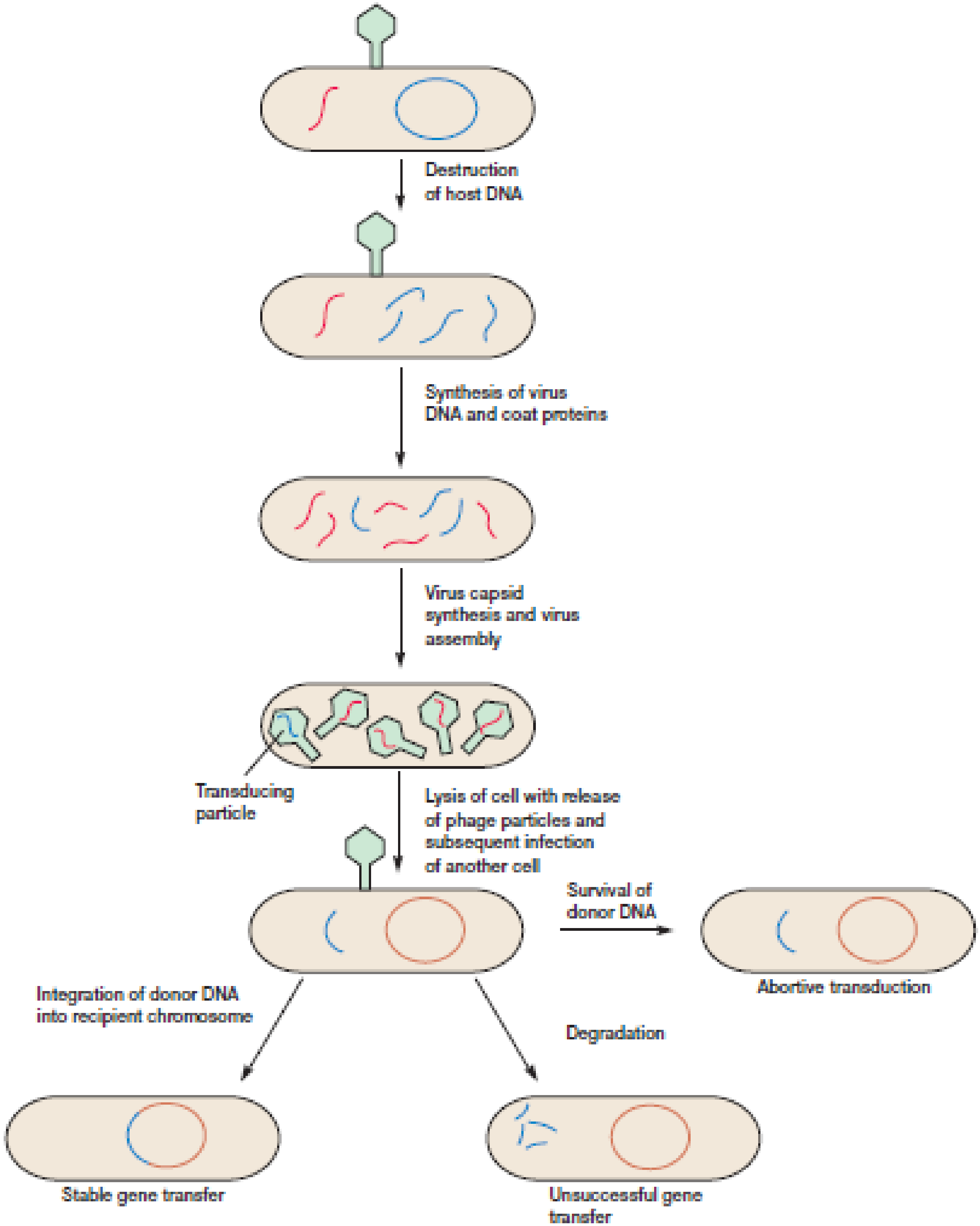
Generalized Transduction

- Generalized transduction occurs during the lytic cycle of virulent and temperate phages and can transfer any part of the bacterial genome.
- During the assembly stage, when the viral chromosomes are packaged into protein capsids, random fragments of the partially degraded bacterial chromosome also may be packaged by mistake.
- Because the capsid can contain only a limited quantity of DNA, viral DNA is left behind.
- The quantity of bacterial DNA carried depends primarily on the size of the capsid.
- The P22 phage of *Salmonella typhimurium* usually carries about 1% of the bacterial genome; the P1 phage of *E. coli* and a variety of Gram-negative bacteria carries about 2.0 to 2.5% of the genome.
- The resulting virus particle often injects the DNA into another bacterial cell but does not initiate a lytic cycle.
- This phage is known as a **generalized transducing particle or phage** and is simply a carrier of genetic information from the original bacterium to another cell.
- As in transformation, once the DNA has been injected, it must be incorporated into the recipient cell's chromosome to preserve the transferred genes.
- The DNA remains double stranded during transfer, and both strands are integrated into the endogenote's genome.
- About 70 to 90% of the transferred DNA is not integrated but often is able to survive and express itself.

… Generalized Transduction

- Abortive transductants are bacteria that contain this nonintegrated, transduced DNA and are partial diploids.
- Generalized transduction was discovered in 1951 by Joshua Lederberg and Norton Zinder during an attempt to show that conjugation, discovered several years earlier in *E. coli*, could occur in other bacterial species. Lederberg and Zinder were repeating the earlier experiments with *Salmonella typhimurium.*
- They found that incubation of a mixture of two multiple auxotrophic strains yielded prototrophs at the level of about one in 10^5.
- When these investigators performed the U-tube experiment with *Salmonella,* they still recovered prototrophs.
- The filter in the U tube had small enough pores to block the movement of bacteria between the two sides but allowed the phage P22 to pass.
- Lederberg and Zinder had intended to confirm that conjugation was present in another bacterial species and had instead discovered a completely new mechanism of bacterial gene transfer.
- A scientist must always keep an open mind about results and be prepared for the unexpected.

Generalized Transduction



Specialized Transduction

- In **specialized or restricted transduction, the transducing particle** carries only specific portions of the bacterial genome.
- Specialized transduction is made possible by an error in the lysogenic life cycle.
- When a prophage is induced to leave the host chromosome, excision is sometimes carried out improperly.
- The resulting phage genome contains portions of the bacterial chromosome (about 5 to 10% of the bacterial DNA) next to the integration site, much like the situation with F′ plasmids**.**
- **A transducing phage genome usually is defective** and lacks some part of its attachment site.
- The transducing particle will inject bacterial genes into another bacterium, even though the defective phage cannot reproduce without assistance.
- The bacterial genes may become stably incorporated under the proper circumstances.

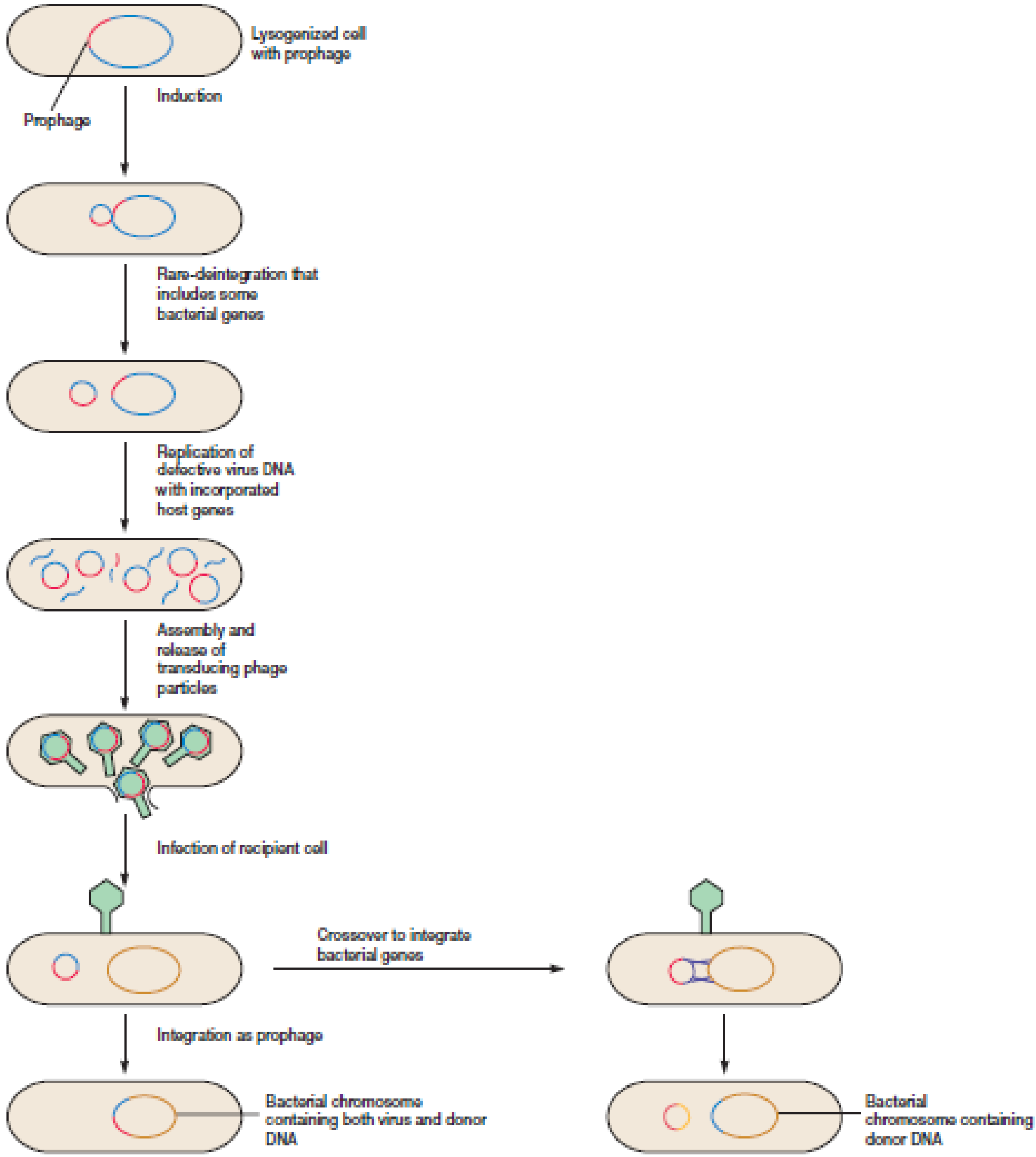
… Specialized Transduction

- The best-studied example of specialized transduction is the lambda phage.
- The lambda genome inserts into the host chromosome at specific locations known as attachment or *att* sites***.***
- The phage *att* sites and bacterial *att* sites are similar and can complex with each other, although they are not identical. The *att* site for lambda is next to the *gal* and *bio* genes on the *E. coli* chromosome; consequently, specialized transducing lambda phages most often carry these bacterial genes.
- The lysate, or product of cell lysis, resulting from the induction of lysogenized *E. coli* contains normal phage and a few defective transducing particles.
- These particles are called lambda *dgal* because they carry the galactose utilization genes.
- Because these lysates contain only a few transducing particles, they often are called **low-frequency transduction lysates (LFT lysates).**
- **Whereas the normal phage has a complete *att*** site, defective transducing particles have a nonfunctional hybrid integration site that is part bacterial and part phage in origin.
- Integration of the defective phage chromosome does not readily take place. Transducing phages also may have lost some genes essential for reproduction.
- Stable transductants can arise from recombination between the phage and the bacterial chromosome because of crossovers on both sides of the *gal* site*.*

… Specialized Transduction

- Defective lambda phages carrying the *gal* gene can integrate if there is a normal lambda phage in the same cell.
- The normal phage will integrate, yielding two bacterial/phage hybrid *att* sites where the defective lambda *dgal* phage can insert.
- It also supplies the genes missing in the defective phage.
- The normal phage in this instance is termed the **helper phage because it** aids integration and reproduction of the defective phage.
- These transductants are unstable because the prophages can be induced to excise by agents such as UV radiation.
- Excision, however, produces a lysate containing a fairly equal mixture of defective lambda *dgal* phage and normal helper phage. Because it is very effective in transduction, the lysate is called a **high-frequency transduction lysate (HFT lysate).**
- Reinfection of bacteria with this mixture will result in the generation of considerably more transductants.
- LFT lysates and those produced by generalized transduction have one transducing particle in 10^5 or 10^6 phages;
- HFT lysates contain transducing particles with a frequency of about 0.1 to 0.5.

Specialized Transduction



The Mechanism of Transduction for Phage Lambda and *E. coli.*

- Integrated lambda phage lies next to the gal genes.
- When it excises normally (top left), the new phage is complete and contains no bacterial genes.
- Rarely excision occurs asymmetrically (top right), and the *gal* genes are then picked up and some phage genes are lost.
- The result is a defective lambda phage that carries bacterial genes and can transfer them to a new recipient.