Mutation: Change in the Genetic Material

I . A mutation is a change in the nitrogenous base sequence of DNA; that change causes a change in the product coded for by the mutated gene.

2. Many mutations are neutral, some are disadvantageous, and others are beneficial.

Types of Mutations:

3. A base substitution occurs when one base pair in DNA is replaced with a different base pair.

4. Alterations in DNA can result in missense mutations (which cause amino acid substitutions) or nonsense mutations (which create stop codons).

5. In a frameshift mutation, one or a few base pairs are deleted or added to DNA.

6. Mutagens are agents in the environment that cause permanent changes in DNA.

7. Spontaneous mutations occur without the presence of any mutagen.

Mutagens:

8. Chemical mutagens include base-pair mutagens, nucleoside

analogs, and frameshift mutagens.

9. Ionizing radiation causes the formation of ions and free radicals that react with DNA; base substitutions or breakage of the sugar phosphate backbone results.

10. Ultraviolet (UV) radiation is nonionizing; it causes bonding between adjacent thymines.

II . Damage to DNA caused by UV radiation can be repaired by enzymes that cut out and replace the damaged portion of DNA.

12. Light-repair enzymes repai r thymine dimers in the presence of visible light.

Plasmids and Transposons:

14. Plasmids are self-replicating circular molecules of DNA carrying genes that arc not usually essential for the cell's survival.

IS. There arc several types of plasm ids, including conjugative plasmids, dissimilation plasm ids, plasmids carrying genes for toxins or bacteriocins, and resistance factors.

16. Transposons arc small segments of DNA that can move from one region to another region of the same chromosome or to a different chromosome or a plasmid.

17. Transposons are found in chromosomes, in plasmids, and in the

genetic material of viruses. They vary from simple (insertion sequences) to complex.

18. Complex transposons can carry any type of gene, including antibiotic-resistance genes, and are thus a natural mechanism for moving genes from one chromosome to another.

References': 1- Microbiology an introduction TWELFTH EDITION. Gerard. .Tortora.2016

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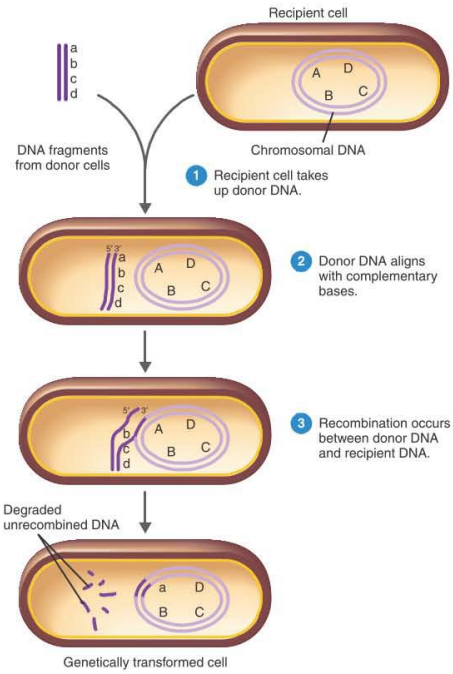


Figure 8.25 The mechanism of genetic transformation in bacteria. Some similarity is needed for the donor and recipient to align. Genes *a*, *b*, *c*, and *d* may be mutations of genes *A*, *B*, *C*, and *D*.

Q What type of enzyme cuts the donor DNA?

Since the time of Griffith's experiment, considerable information has been gathered about transformation. In nature, some bacteria, perhaps after death and cell lysis, release their DNA into the environment. Other bacteria can then encounter the DNA and, depending on the particular species and growth conditions, take up fragments of DNA and integrate them into their own chromosomes by recombination. A protein called RecA (see Figure 3.11a, page 65) binds to the cell's DNA and then to donor DNA causing the exchange of strands. A recipient cell with this new combination of genes is a kind of hybrid, or recombinant cell (**Figure 8.25**). All the descendants of such a recombinant cell will be identical to it. Transformation occurs naturally among very few genera of bacteria, including *Bacillus*, *Haemophilus* (hē-mā′fi-lus), *Neisseria*, *Acinetobacter* (a-si-ne′tō-bak-tĕr), and certain strains of the genera *Streptococcus* and *Staphylococcus*.

Transformation works best when the donor and recipient cells are very closely related. Even though only a small portion of a cell's DNA is transferred to the recipient, the molecule that must pass through the recipient cell wall and membrane is still very large. When a recipient cell is in a physiological state in which it can take up the donor DNA, it is said to be competent. **Competence** results from alterations in the cell wall that make it permeable to large DNA molecules.

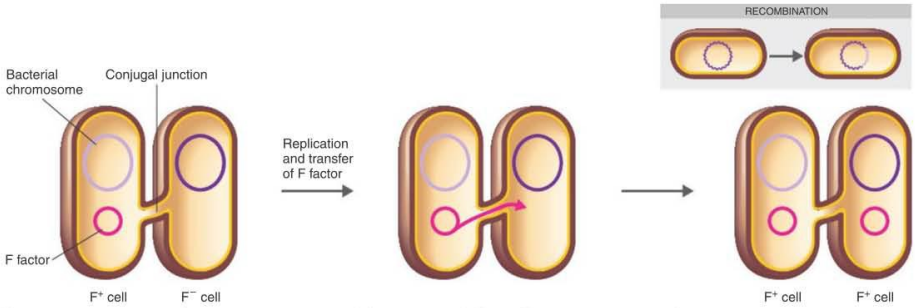
The well-understood and widely used bacterium *E. coli* is not naturally competent for transformation. However, a simple laboratory treatment enables *E. coli* to readily take up DNA. The discovery of this treatment has enabled researchers to use *E. coli* for genetic engineering, discussed in Chapter 9.

Conjugation in Bacteria

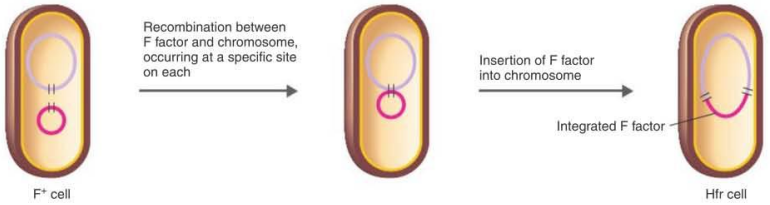
Another mechanism by which genetic material is transferred from one bacterium to another is known as **conjugation.** Conjugation is mediated by one kind of *plasmid,* a circular piece of DNA that replicates independently from the cell's chromosome (discussed on page 238). However, plasmids differ from bacterial chromosomes in that the genes they carry are usually not essential for the growth of the cell under normal conditions. The plasmids responsible for conjugation are transmissible between cells during conjugation.

Conjugation differs from transformation in two major ways. First, conjugation requires direct cell-to-cell contact. Second, the conjugating cells must generally be of opposite mating type; donor cells must carry the plasmid, and recipient cells usually do not. In gram-negative bacteria, the plasmid carries genes that code for the synthesis of *sex pili,* projections from the donor's cell surface that contact the recipient and help bring the two cells into direct contact (**Figure 8.26a**). Gram-positive bacterial cells produce sticky surface molecules that cause cells to come into direct contact with each other. In the process of conjugation, the plasmid is replicated during the transfer of a single-stranded copy of the plasmid DNA to the recipient, where the complementary strand is synthesized (**Figure 8.26b**).

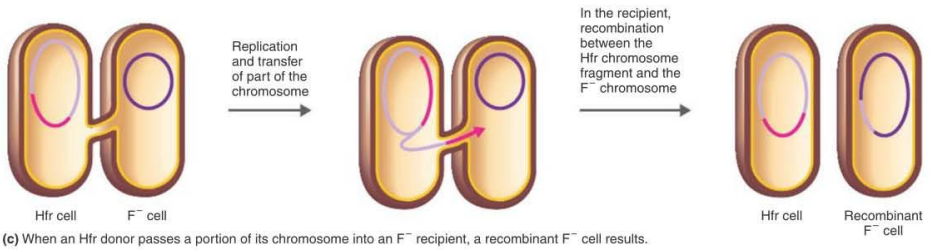
Because most experimental work on conjugation has been done with *E. coli,* we will describe the process in this organism. In *E. coli,* the **F factor (fertility factor)** was the first plasmid observed to be transferred between cells during conjugation. Donors carrying F factors (F^+ cells) transfer the plasmid to recipients (F^- cells), which become F^+ cells as a result (**Figure 8.27a**). In some cells carrying F factors, the factor integrates into the chromosome, converting the F^+ cell to an **Hfr cell** (high frequency of recombination) (**Figure 8.27b**). When conjugation occurs between an Hfr cell and an F^- cell, the Hfr cell's chromosome (with its integrated F factor) replicates, and a parental strand of the chromosome is transferred to the recipient



(a) When an F factor (a plasmid) is transferred from a donor (F^+) to a recipient (F^-), the F^- cell is converted to an F^+ cell.



(b) When an F factor becomes integrated into the chromosome of an F^+ cell, it makes the cell a high frequency of recombination (Hfr) cell.



(c) When an Hfr donor passes a portion of its chromosome into an F^- recipient, a recombinant F^- cell results.

Figure 8.27 Conjugation in *E. coli*.

Q How does conjugation differ from transformation?

prokaryotic and eukaryotic organisms, but this discussion focuses on their role in genetic change in prokaryotes.

Plasmids

Recall from Chapter 4 (page 85) that plasmids are self-replicating, gene-containing circular pieces of DNA about 1–5% the size of the bacterial chromosome (**Figure 8.29a**). They are found mainly in bacteria but also in some eukaryotic microorganisms, such as *Saccharomyces cerevisiae*. The F factor is a **conjugative plasmid** that carries genes for sex pili and for the transfer of the plasmid to another cell. Although plasmids are usually dispensable, under certain conditions genes carried by plasmids can be crucial to the survival and growth of the cell. For example, **dissimilation plasmids** code for enzymes

that trigger the catabolism of certain unusual sugars and hydrocarbons. Some species of *Pseudomonas* can actually use such exotic substances as toluene, camphor, and hydrocarbons of petroleum as primary carbon and energy sources because they have catabolic enzymes encoded by genes carried on plasmids. Such specialized capabilities permit the survival of those microorganisms in very diverse and challenging environments. Because of their ability to degrade and detoxify a variety of unusual compounds, many of them are being investigated for possible use in the cleanup of environmental wastes. (See the box in Chapter 2, page 33.)

Other plasmids code for proteins that enhance the pathogenicity of a bacterium. The strain of *E. coli* that causes infant diarrhea and traveler's diarrhea carries plasmids that code for toxin production and for bacterial attachment to intestinal cells. Without these plasmids, *E. coli* is a harmless resident of the large intestine; with them, it is pathogenic. Other plasmid-encoded toxins include the exfoliative toxin of *Staphylococcus aureus, Clostridium tetani* neurotoxin, and toxins of *Bacillus anthracis.* Still other plasmids contain genes for the synthesis of **bacteriocins,** toxic proteins that kill other bacteria. These plasmids have been found in many bacterial genera, and they are useful markers for the identification of certain bacteria in clinical laboratories.

Resistance factors (R factors) are plasmids that have significant medical importance. They were first discovered in Japan in the late 1950s after several dysentery epidemics. In some of these epidemics, the infectious agent was resistant to the usual antibiotic. Following isolation, the pathogen was also found to be resistant to a number of different antibiotics. In addition, other normal bacteria from the patients (such as *E. coli*) proved to be resistant as well. Researchers soon discovered that these bacteria acquired resistance through the spread of genes from one organism to another. The plasmids that mediated this transfer are R factors.

R factors carry genes that confer upon their host cell resistance to antibiotics, heavy metals, or cellular toxins. Many R factors contain two groups of genes. One group is called the **resistance transfer factor (RTF)** and includes genes for plasmid replication and conjugation. The other group, the **r-determinant,** has the resistance genes; it codes for the production of enzymes that inactivate certain drugs or toxic substances (**Figure 8.29b**). Different R factors, when present in the same cell, can recombine to produce R factors with new combinations of genes in their r-determinants.

In some cases, the accumulation of resistance genes within a single plasmid is quite remarkable. For example, Figure 8.29b shows a genetic map of resistance plasmid R100. Carried on this plasmid are resistance genes for sulfonamides, streptomycin, chloramphenicol, and tetracycline, as well as genes for resistance to mercury. This particular plasmid can be transferred between a number of enteric species, including *Escherichia, Klebsiella,* and *Salmonella.*

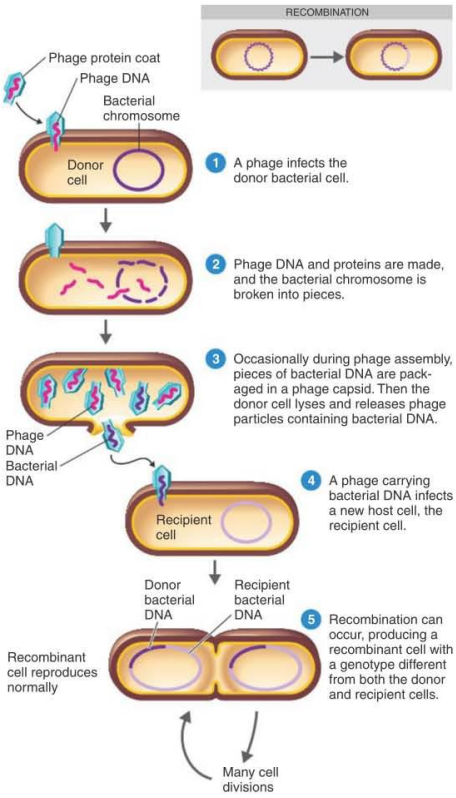


Figure 8.28 Transduction by a bacteriophage. Shown here is generalized transduction, in which any bacterial DNA can be transferred from one cell to another.

Q **What is transduction?**

R factors present very serious problems for treating infectious diseases with antibiotics. The widespread use of antibiotics in medicine and agriculture (see the box in Chapter 20 on page 577) has led to the preferential survival (selection) of bacteria that have R factors, so populations of resistant bacteria grow larger and larger. The transfer of resistance between bacterial cells of a population, and even between bacteria of different genera, also contributes to the problem. The ability to reproduce sexually with