2.4C: Plasmids and Transposons

Skills to Develop

1. Describe plasmids and indicate their possible benefit to bacteria.
2. State the function of the following:
   a. transposons
   b. integrons
   c. episome
   d. conjugative plasmid
3. State the most common way plasmids are transmitted from one bacterium to another.
4. Define horizontal gene transfer.

In addition to the bacterial chromosome, many bacteria often contain small nonchromosomal DNA molecules called plasmids. Plasmids usually contain between 5 and 100 genes. Plasmids are not essential for normal bacterial growth and bacteria may lose or gain them without harm. They can, however, provide an advantage under certain environmental conditions. For example, under normal environmental growth conditions, bacteria are not usually exposed to antibiotics and having a plasmid coding for an enzyme capable of denaturing a particular antibiotic is of no value. However, if that bacterium finds itself in the body when the particular antibiotic that the plasmid-coded enzyme is able to degrade is being given to treat an infection, the bacterium containing the plasmid is able to survive and grow.

Structure and Composition

Plasmids are small molecules of double stranded, helical, non-chromosomal DNA. In most plasmids the two ends of the double-stranded DNA molecule that make up plasmids covalently bond together forming a physical circle.
plasmids, however, have linear DNA. Plasmids replicate independently of the host chromosome, but some plasmids, called episomes, are able to insert or integrate into the host cell's chromosome where their replication is then regulated by the chromosome.

Although some plasmids can be transmitted from one bacterium to another by transformation and by generalized transduction, the most common mechanism of plasmid transfer is conjugation. Plasmids that can be transmitted by cell-to-cell contact are called conjugative plasmids. They contain genes coding for proteins involved in both DNA transfer and the formation of mating pairs.

Functions

Plasmids code for synthesis of a few proteins not coded for by the bacterial chromosome. For example, R-plasmids, found in some Gram-negative bacteria, often have genes coding for both production of a conjugation pilus (discussed later in this unit) and multiple antibiotic resistance. Through a process called conjugation, the conjugation pilus enables the bacterium to transfer a copy of the R-plasmids to other bacteria, making them also multiple antibiotic resistant and able to produce a conjugation pilus. In addition, some exotoxins, such as the tetanus exotoxin, Escherichia coli enterotoxin, and E. coli shiga toxin discussed later in Unit 2 under Bacterial Pathogenicity, are also coded for by plasmids. Thousands of different plasmids are known to exist.

Transposons

Transposons (transposable elements or "jumping genes") are small pieces of DNA that encode enzymes that transpose the transposon, that is, move it from one DNA location to another, either on the same molecule of DNA or on a different molecule. Transposons may be found as part of a bacterium's nucleoid (conjugative transposons) or in plasmids and are usually between one and twelve genes long. A transposon contains a number of genes, coding for antibiotic resistance or other traits, flanked at both ends by insertion sequences coding for an enzyme called transpoase. Transpoase is the enzyme that catalyzes the cutting and resealing of the DNA during transposition. Thus, such transposons are able to cut themselves out of a bacterial nucleoid or a plasmid and insert themselves into another nucleoid or plasmid and contribute in the transmission of antibiotic resistance among a population of bacteria.

Plasmids can also acquire a number of different antibiotic resistance genes by means of integrons. Integrons are transposons that can carry multiple gene clusters called gene cassettes that move as a unit from one piece of DNA to another. An enzyme called integrase enables these gene cassettes to integrate and accumulate within the integron. In this way, a number of different antibiotic resistance genes can be transferred as a unit from one bacterium to another.

Plasmids and conjugative transposons are very important in horizontal gene transfer in bacteria. Horizontal gene transfer, also known as lateral gene transfer, is a process in which an organism transfers genetic material to another organism that is not its offspring. The ability of Bacteria and Archaea to adapt to new environments as a part of bacterial evolution most frequently results from the acquisition of new genes through horizontal gene transfer rather than by the alteration of gene functions through mutations. (It is estimated that as much as 20% of the genome of Escherichia coli originated from horizontal gene transfer.)

Horizontal gene transfer is able to cause rather large-scale changes in a bacterial genome. For example, certain
bacteria contain multiple virulence genes called pathogenicity islands that are located on large, unstable regions of the bacterial genome. These pathogenicity islands can be transmitted to other bacteria by horizontal gene transfer. However, if these transferred genes provide no selective advantage to the bacteria that acquire them, they are usually lost by deletion. In this way the size of the bacterium's genome can remain approximately the same size over time.

CRISPR

Because bacteria are always taking in new DNA from horizontal gene transfer or being infected by bacteriophages, bacteria have developed a system for removing viral nucleic acid or DNA from self-serving or harmful plasmids. This system represents a type of adaptive immunity in bacteria, and is carried out by clustered, regularly interspaced, short palindromic repeat (CRISPR) sequences and CRISPR-associated (Cas) proteins that possess nuclease activity. The CRISPR/Cas system targets specific foreign DNA sequences in bacteria for destruction.

Video: YouTube Movie of the CRISPER/Cas9 System in Bacteria (https://www.youtube.com/v/ZsxIU5-s5Ds)

Applications of CRISPR technology has now become a common tool used in molecular biology for CRISPR/nuclease mediated genome editing (genetic engineering) in a wide variety of different cell types. Molecular biologists are now beginning to use this to carry out highly efficient, targeted alterations of genome sequence and gene expression and hope to eventually use it to repair damaged or dysfunctional genes.

Exercise: Think-Pair-Share Questions

An F⁺ plasmid is a conjugative plasmid that codes strictly for the ability to produce a conjugation pilus and a mating pair.
State what medically significant event might occur if a transposon located in the nucleoid of a normal flora intestinal bacterium and containing genes for antibiotic resistance were to cut out of the bacterium’s nucleoid and insert into the F\(^+\) plasmid.

Summary

1. Many bacteria often contain small nonchromosomal DNA molecules called plasmids.
2. While plasmids are not essential for normal bacterial growth and bacteria may lose or gain them without harm, they can provide an advantage under certain environmental conditions.
3. Plasmids code for synthesis of a few proteins not coded for by the bacterial chromosome.
4. Transposons (jumping genes) are small pieces of DNA that encode enzymes that enable the transposon to, move from one DNA location to another.
5. Transposons may be found as part of a bacterium’s chromosome or in plasmids
6. Integrons are transposons that can carry multiple gene clusters called gene cassettes that move as a unit from one piece of DNA to another
7. Horizontal gene transfer is a process in which an organism transfers genetic material to another cell that is not its offspring.
8. Horizontal gene transfer is able to cause rather large-scale changes in a bacterial genome.
9. The ability of Bacteria and Archaea to adapt to new environments as a part of bacterial evolution, most frequently results from the acquisition of new genes through horizontal gene transfer rather than by the alteration of gene functions through mutations.

Questions

Study the material in this section and then write out the answers to these questions. Do not just click on the answers and write them out. This will not test your understanding of this tutorial.

1. Describe plasmids and indicate their possible benefit to bacteria. \(\text{ans}\)
2. State why R-plasmids are presenting quite a problem today in treating many Gram-negative infections. \(\text{ans}\)
3. ___________ are small pieces of DNA that encode enzymes that cut segments of DNA from a location in a bacterial chromosome or in a plasmid and insert it into another chromosome or plasmid. These segments of translocated DNA often contain genes for antibiotic resistance. \(\text{ans}\)
4. The genes coding for antibiotic resistance in bacterial plasmids frequently change over time, enabling the bacterium to resist new antibiotics. What might account for this? \(\text{ans}\)
5. State the most common way plasmids are transmitted from one bacterium to another. \(\text{ans}\)
6. Define horizontal gene transfer. \(\text{ans}\)
7. Multiple Choice \(\text{ans}\)

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