Genetic variation in prokaryotes

Mechanisms that generate variation in prokaryote populations. Transduction, transformation, conjugation, transposable elements.

Key points:

In transformation, a bacterium takes up a piece of DNA floating in its environment.

In transduction, DNA is accidentally moved from one bacterium to another by a virus.
In conjugation, DNA is transferred between bacteria through a tube between cells.

Transposable elements are chunks of DNA that "jump" from one place to another. They can move bacterial genes that give bacteria antibiotic resistance or make them disease-causing.

Introduction

When you hear the word "clone," what do you think of? Maybe Dolly the sheep, or experiments carried out in molecular biology labs. But it's also true that the bacteria around you—on your skin, in your gut, growing on your kitchen sink—are "cloning" themselves all the time!

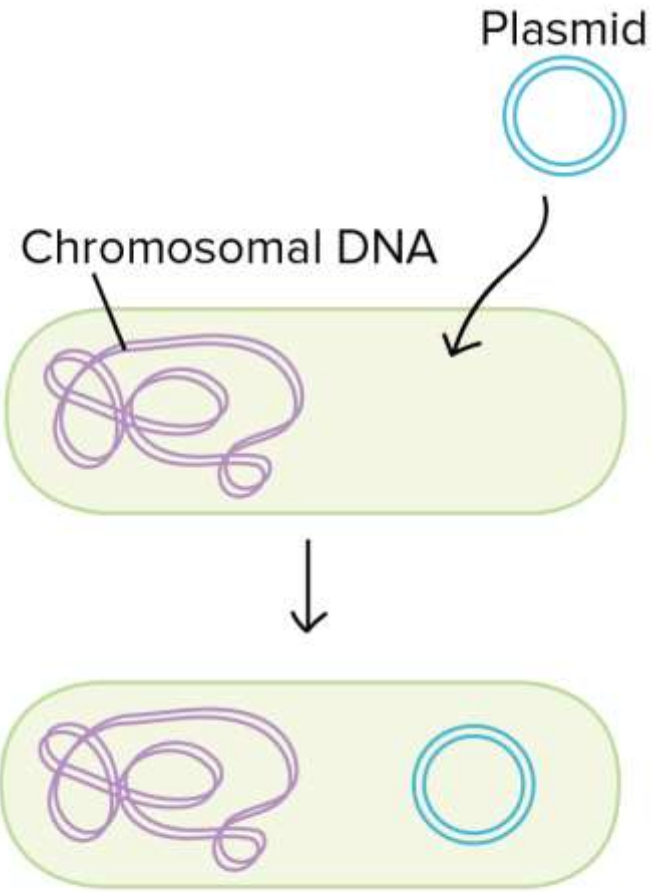
Bacteria reproduce by splitting in two via binary fission. Binary fission makes clones, or genetically identical copies, of the parent bacterium. Since the "child" bacteria are genetically identical to the parent, binary fission doesn't provide an opportunity for genetic recombination or genetic diversity (aside from

the occasional random mutation). This contrasts with sexual reproduction.

Still, genetic variation is key to the survival of a species, allowing groups to adapt to changes in their environment by natural selection. That's true for bacteria as well as plants and animals. So it's not too surprising that prokaryotes can share genes by three other mechanisms: conjugation, transformation, and transduction.

Transformation

In transformation, a bacterium takes in DNA from its environment, often DNA that's been shed by other bacteria. In a laboratory, the DNA may be introduced by scientists (see biotechnology article). If the DNA is in the form of a circular DNA called a plasmid, it can be copied in the receiving cell and passed on to its descendants.



Why would this be important? Imagine that a harmless bacterium takes up DNA for a toxin gene from a pathogenic (disease-causing) species of bacterium. If the receiving cell incorporates the new DNA into its own chromosome (which can happen by a process called homologous recombination), it too may become pathogenic.

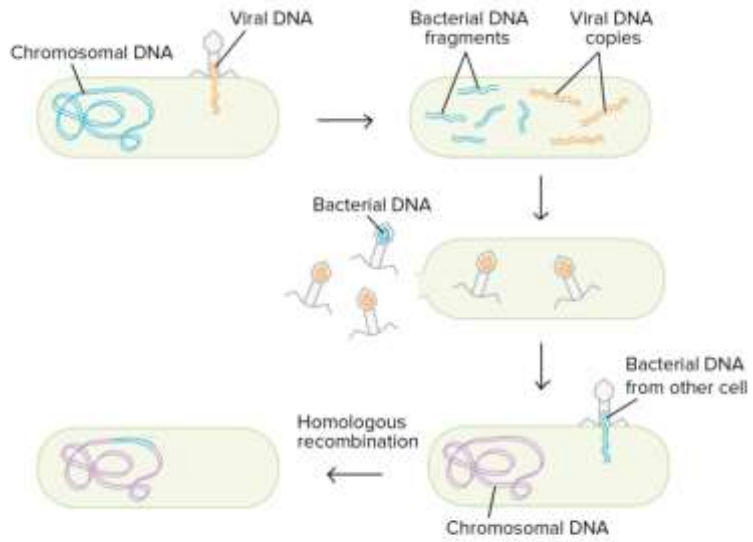
Transduction

In transduction, viruses that infect bacteria move short pieces of chromosomal DNA from one bacterium to another "by accident."

Yep, even bacteria can get a virus! The viruses that infect bacteria are called bacteriophages.

Bacteriophages, like other viruses, are the pirates of the biological world—they commandeer a cell's resources and use them to make more bacteriophages.

However, this process is can be a little sloppy. Sometimes, chunks of host cell DNA get caught inside the new bacteriophage as they are made. When one of these "defective" bacteriophages infects a cell, it transfers the DNA. Some bacteriophages chop the DNA of their host cell into pieces, making this transfer process more likely.



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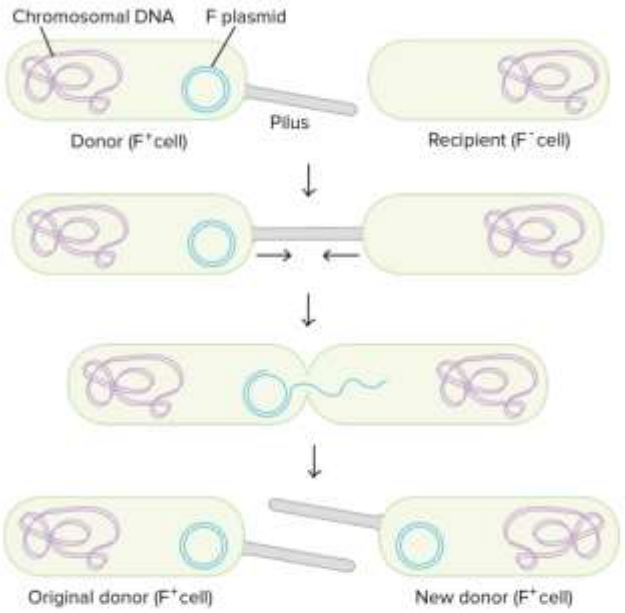
Archaea, the other group of prokaryotes besides bacteria, are not infected by bacteriophages but have their own viruses that move genetic material from one individual to another.

Conjugation

In conjugation, DNA is transferred from one bacterium to another. After the donor cell pulls itself close to the recipient using a structure called a pilus, DNA is

transferred between cells. In most cases, this DNA is in the form of a plasmid



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Donor cells typically act as donors because they have a chunk of DNA called the fertility factor (or F factor). This chunk of DNA codes for the proteins that make up the sex pilus. It also contains a special site where DNA transfer during conjugation begins.

If the F factor is transferred during conjugation, the receiving cell turns into an F donor that can make its own pilus and transfer DNA to other cells. Here's one analogy: this process is sort of like how a vampire can turn other people into vampires by biting them.

Transposable elements

Transposable elements are also important in bacterial genetics. These chunks of DNA "jump" from one place to another within a genome, cutting and pasting themselves or inserting copies of themselves in new

spots. Transposable elements are found in many organisms (including you and me!), not just in bacteria. In bacteria, transposable elements sometimes carry antibiotic resistance and pathogenicity genes (genes that make bacteria disease-causing). If one of these transposable elements "jumps" from the chromosome into a plasmid, the genes it carries can be easily passed to other bacteria by transformation or conjugation. That means the genes can spread quickly through the population.

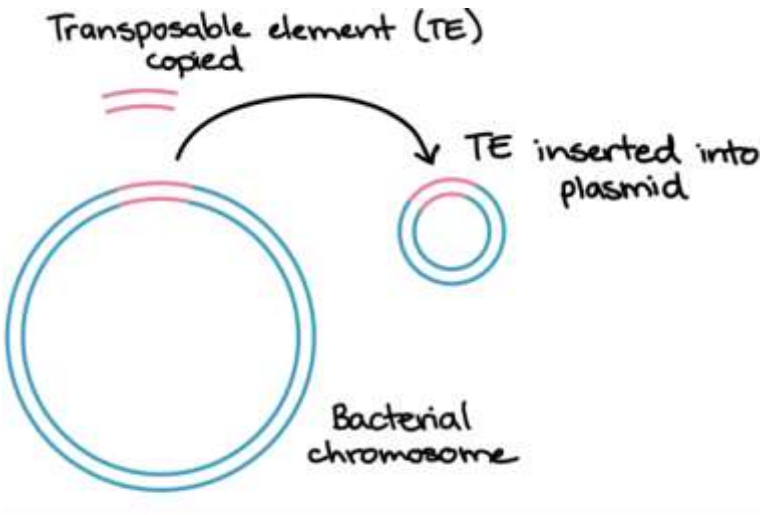

Image based on similar image in Reece et al.[7]

Conclusion

In bacteria, reproduction can be very fast, with a generation taking little more than a few minutes for some species. This short generation time, together with random mutations and the mechanisms of genetic recombination we saw in this article, allow bacteria (and other prokaryotes) to evolve very quickly.

Is that a good thing? It depends on your perspective. Rapid evolution means that bacteria can adapt to environmental changes, such as the introduction of an

antibiotic, very quickly. That's good for them—but bad for us, when we are the ones with the infection!