

Horizontal Gene Transfer in Prokaryotes

Slide 2 Before we explain horizontal gene transfer, some background on prokaryotic organisms is required. Prokaryotes represent all single-cell organisms that are not eukaryotic and can be subdivided into two major groups: the Bacteria and the Archaea. Humans and other animals, plants and fungi are examples of eukaryotic organisms.

Slide 3 Prokaryotic cells are about 1 micrometer or less in size, and the cells come in a few different shapes. Unlike in the eukaryotes, the double-stranded chromosome of prokaryotes is not surrounded by a membrane; prokaryotes do not have a nucleus. They have about 1/1000 of the DNA of human cells. Prokaryotes play important ecological roles, including cycling elements in the soil, atmosphere and water. They present disease challenges to humans, animals and plants. Prokaryotes also play a central role as tools for biotechnology. In this lecture we will mainly focus on the group of the Bacteria.

Slide 4 Prokaryotes usually reproduce asexually by cell division, also referred to as 'vertical gene transfer'. The division of single cells into two identical offspring produces clones, or genetically identical individuals. Prokaryotes can grow rapidly: *Escherichia coli* can double every 20 minutes. In addition to this asexual cell division, prokaryotes have several mechanisms through which they may acquire new genes by 'horizontal gene transfer'.

Slide 5 There are three well-known mechanisms of horizontal gene transfer in Bacteria:

- **Transformation** is the process by which bacteria take up extracellular DNA from their environment. These DNA fragments may recombine with the host chromosome, permanently adding new genes. This mechanism was discovered more than 75 years ago, and was at the basis for the discovery that DNA is the heredity factor in all living organisms.
- A second mechanism of gene transfer is **transduction**. During transduction, viruses carry genes from one bacterial cell to another. Viruses are obligate intracellular parasites, needing the biochemical machinery of living cells to reproduce. Viruses that infect bacteria are called bacteriophages. Many get their genetic material into the cell by attaching with tail assemblies that then inject the DNA into the cell. During the lytic cycle (when the host cell breaks open), some bacteriophages package some of the host bacteria's DNA. Cells that are subsequently infected by such viruses get a segment of DNA from another bacterium which can recombine with the chromosomal DNA of the host and thus alter its genetic composition.
- Several bacteria can conjugate. **Conjugation** is the exchange of genetic information (DNA) by direct cell-cell contact. Physical contact is initiated by a pilus, which is a fine 'tube' produced by the donor cell. Before we can discuss conjugation, we must introduce another kind of genetic element called a plasmid.

Slide 6 **Plasmids** are genetic elements that replicate independently of the host chromosome. Almost all known plasmids are double-stranded DNA, and most often

circular. They typically carry genes that are only required by the host under specific conditions. For example, genes that confer antibiotic resistance to their host are often found on plasmids; in the presence of antibiotics, only the resistant bacterial cells will survive. Plasmids can also carry genes that code for a wide variety of other functions, such as resistance to heavy metals and UV light, degradation of organic compounds, including environmental pollutants, production of antibiotics, and production of virulence factors.

Slide 7 **Conjugation** is the process whereby a plasmid is replicated and transferred to another cell by cell-to-cell contact. It was first demonstrated in 1946 by Joshua Lederberg and Edward Tatum. Some, but not all plasmids are conjugative. This means that these plasmids have the required genetic information to govern their own transfer. Some plasmids are transferable to a broad range of bacteria. They are called broad host range plasmids.

The conjugation process is as follows:

First the plasmid initiates conjugation in the ‘Donor’ cell (bacterium with plasmid) by making a pilus that makes contact with the ‘Recipient’ cell (bacterium without plasmid). *Next*, a copy of the plasmid is transferred to the Recipient, which then becomes a ‘Transconjugant’ (recipient cell with new plasmid)

Plasmids can have 1 to about 40 copies per cell.

Slide 8 **Transposable elements**, found in most organisms, move genes among plasmids and chromosomes. They facilitate gene transport within an individual cell, and are sometimes also called ‘jumping genes’. Long transposable elements that include one or more genes are called **transposons**. Transposons have contributed to the evolution of plasmids. They often carry genes that encode antibiotic resistance or degradation of pollutants. Recently several other mobile genetic elements have been found in bacterial chromosomes, such as the ‘pathogenicity islands’, which code for virulence factors.