Bacterial Genetics (Learning Objectives)

• Review the structure of bacterial genomes and their major source of genetic variability.
• Explain the phenomenon of transposition and its role introducing genetic variability in prokaryotic genomes.
• Compare and contrast vertical and horizontal gene transfer.
• Explain how genetic recombination can take place in prokaryotic organisms with haploid genomes.
• Explain the three mechanisms of horizontal gene transfer that can introduce homologous sequences into prokaryotes leading to partial diploidy and genetic recombination.
• Compare and contrast transformation as it takes place in nature and its use as a biotechnology tool.
• Compare and contrast transduction and conjugation.
• Explain how transposition and conjugation together lead to fast spread of antibiotic resistance in bacterial population.
Bacterial Genetics

• The bacterial genome
  - haploid consisting of one double-stranded, circular DNA molecule.

• Bacteria contain plasmids, much smaller circles of DNA.
  – a small number of genes, from just a few to several dozen.
Genetic diversity in bacteria

Fidelity of DNA replication vs. genetic variability crucial for natural selection
Sources of variability in bacteria

1. Mutation is the major source, including transposition.

2. Genetic recombination, following horizontal transfer of genetic material, are additional sources:
   - Transformation
   - Transduction
   - Conjugation
Transposition

• Transposons “jumping genes”
• Do jump from one location to another (cut-and-paste translocation)
• Can jump from bacterial genomic DNA to plasmid
• Simple and composite transposons
• Can move genes to a new site
DNA

5' ATCCG GT... ...ACCGGAT 3'
3' TAGGCCA... ...TGGCCTA 5'

Inverted repeat Transposase gene Inverted repeat

Insertion sequence (simple transposon)

Composite transposon

5' Insertion sequence Antibiotic resistance gene Insertion sequence 3'
3' Inverted repeats Transposase gene Direct repeat 5'

Direct repeat
Sources of variability in bacteria

1. Mutation is the major source, including transposition.

2. Genetic recombination, following horizontal transfer of genetic material, are additional sources:
   - Transformation
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Review of Genetic Recombination

Chromosome A

Chromosome B

Crossing over

Recombinant chromosomes

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<thead>
<tr>
<th>Gene Transfer</th>
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<td><strong>Vertical</strong></td>
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<td>Takes place between generations of</td>
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<td>reproducing cells</td>
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<td><strong>Horizontal</strong></td>
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<td>Takes place between cells of the</td>
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<td>same generation</td>
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Horizontal Gene Transfer

- Leads to homology-based recombination events

- Introduces variability within the bacterial population
Bacterial genomes are haploid and consist of single circular chromosome.
Recombination occurs after horizontal transfer of a homologous fragment.
• Where do homologous DNA fragments come from?

• How are they introduced into a bacterial cell?
Mechanisms of Horizontal Gene Transfer

1. DNA-mediated transformation (naked DNA)

2. Transduction (mediated by bacterial viruses)

3. Conjugation (mediated by plasmids)
Transformation

• When bacteria die their cell wall ruptures and the contents including DNA breakup
• DNA pieces containing ~20 genes
• Enter other competent cells
• Competent cells found at end of log phase
Gene conferring $\text{Str}^R$

Transforming DNA (double-stranded) attaches to recipient cell surface

Gene conferring $\text{Str}^S$

Recipient DNA

Degradation of one donor strand by nucleases

Single strand of donor DNA enters

Pairing of donor DNA with homologous region of recipient chromosome
Integration of single-stranded donor DNA by breakage and reunion

(d)

Bacteria placed on streptomycin medium

Non-transformed cell dies

Transformed cells multiply

(e)

(f)
Transduction Mediated by bacterial viruses
Conjugation: Plasmid-mediated Gene Transfer
Conjugation: Transfer of Fertility (F) plasmid

The F+ donor cell containing an F plasmid is capable of synthesizing a sex pilus.

Donor cell $F^+$

Recipient cell $F^-$

The sex pilus contacts the recipient $F^-$ cell.
STEP 2  
Activation of DNA for transfer

Origin of transfer

STEP 3  
Plasmid transfer

F plasmid transfer

STEP 4  
Synthesis of a functional plasmid

The plasmid is activated for transfer when an endonuclease cleaves one strand of DNA at the origin of transfer.

The sex pilus retracts and pulls the donor and recipient cells together. The F plasmid is transferred as a single-stranded DNA molecule.

The complementary strands to both F plasmid strands are synthesized in the donor and recipient cells. Both cells are F⁺ and synthesize the sex pilus.