

## Chapter 8 Microbial Genetics

### Overview

- Terminology
- Flow of genetic information
- Structure of DNA and DNA synthesis
- Protein production
  - Transcription and translation
  - Regulation
- Genetic changes
  - Mutation
  - Recombination
    - Transformation
    - Conjugation
    - Transduction
  - Plasmids
  - Transposons

### Terminology

- Genetics: The study of what genes are, how they carry information, how information is expressed, and how genes are replicated
- Gene: A segment of DNA that encodes a functional product, usually a protein
- Chromosome: Structure containing DNA that physically carries hereditary information; the chromosomes contain the genes
- Genome: All the genetic information in a cell
- Genomics: The molecular study of genomes
- Genotype: The genes of an organism
- Phenotype: Expression of the genes

### DNA Structure

- Polymer of nucleotides: Adenine, thymine, cytosine, and guanine
- Double helix associated with proteins
- "Backbone" is deoxyribose-phosphate
- Strands are held together by hydrogen bonds between AT and CG
- Strands are antiparallel

### DNA Synthesis

- DNA is copied by DNA polymerase
  - In the 5' -> 3' direction
  - Initiated by an RNA primer

- Leading strand is synthesized continuously
- Lagging strand is synthesized discontinuously
- Okazaki fragments
- RNA primers are removed and Okazaki fragments joined by a DNA polymerase and DNA ligase

### Transcription

- DNA is transcribed to make RNA (mRNA, tRNA, and rRNA)
- Transcription begins when RNA polymerase binds to the promoter sequence
- Transcription proceeds in the 5' -> 3' direction
- Transcription stops when it reaches the terminator sequence

### Translation

- mRNA is translated in codons (three nucleotides)
- Translation of mRNA begins at the start codon: AUG
- Translation ends at nonsense codons: UAA, UAG, UGA

### The Genetic Code

- 64 sense codons on mRNA encode the 20 amino acids
- The genetic code is degenerate (or, redundant)
- tRNA carries the complementary anticodon

### Regulation

- Constitutive genes are expressed at a fixed rate (expression is always "on")
- Other genes are expressed only as needed
  - Repressible genes must be turned "off" (i.e., they are normally induced, or "on")
  - Inducible genes must be turned "on" (i.e., they are normally repressed, or "off")

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- Catabolite repression inhibits expression (e.g., lac gene inhibition is related to inactive catabolite activator protein [CAP]; if cAMP is not present to activate CAP, which then stimulates the lac operon, lac expression is repressed)

### Mutation

- A change in the genetic material
- Mutations may be neutral, beneficial, or harmful
- Mutagen: Agent that causes mutations
- Spontaneous mutations: Occur in the absence of a mutagen (as a result of sloppy DNA replication or repair)
- Base substitution (point mutation)
  - Change in one base
- Missense mutation
  - Result in change in amino acid
- Nonsense mutation
  - Results in a nonsense codon, usually a stop codon in the middle of an mRNA
- Frameshift mutation
  - Insertion or deletion of one or more nucleotide pairs, causing all downstream nucleotides to “shift” into new codon reading frames

### The Frequency of Mutation

- Spontaneous mutation rate = 1 in  $10^9$  replicated base pairs or 1 in  $10^6$  replicated genes
- Mutagens increase to  $10^{-5}$  or  $10^{-3}$  per replicated gene

### Radiation

- Ionizing radiation (X rays and gamma rays) causes the formation of ions that can react with nucleotides and the deoxyribose-phosphate backbone

### Radiation

- UV radiation causes thymine dimers

### Repair

- Photolyases separate thymine dimers
- Nucleotide excision repair

### Selection

- Positive (direct) selection detects mutant cells because they grow or appear different (e.g., penicillin resistant cell appears on penicillin-infused medium)
- Negative (indirect) selection detects mutant cells because they do not grow
  - Replica plating

### Genetic Recombination

- Vertical gene transfer: Occurs during reproduction between generations of cells.
- Horizontal gene transfer: The transfer of genes between cells of the same generation.
- Exchange of genes between two DNA molecules
  - Crossing over occurs when two chromosomes break and rejoin

### Plasmids

- Conjugative plasmid: Carries genes for sex pili and transfer of the plasmid
- Dissimilation plasmids: Encode enzymes for catabolism of unusual compounds
- R factors: Encode antibiotic resistance

### Transposons

- Segments of DNA that can move from one region of DNA to another
- Contain insertion sequences for cutting and resealing DNA (transposase)
- Complex transposons carry other genes

### Genes and Evolution

- Mutations and recombination provide diversity
- Fittest organisms for an environment are selected by natural selection