DNA Structure and Function
Nucleotide monomer

- Nitrogenous Bases (B)
- 5-C Sugar (S)
- Phosphate (P)
Nucleotide Structure

1. 5-C sugar
   - RNA – ribose
   - DNA – deoxyribose

2. Nitrogenous Base
   - N – attaches to 1’C of sugar
   - Double or single ring
   - Four Bases – Adenine, Guanine, Thymine, Cytosine

3. Phosphate
   - Attached to 5’C of sugar
Nucleic Acids

Polymers of nucleotide monomers:

**DNA** – deoxyribonucleic acid
- The heredity compound of life
- Directs cellular activities
- Sequence of nucleotide bases is unique for each individual

**RNA** – ribonucleic acid
- Sugar – contains ribose sugar instead of deoxyribose
- Bases – Uracil replaces Thymine found in DNA
- Involved in protein synthesis

**ATP** – Adenosine Triphosphate
- Nucleotide consisting of ribose sugar, adenine & 3 phosphates

**Coenzyme** – NAD, FAD, NADP
- Nucleotides that assist enzymes by carrying electrons & hydrogen
adenine base (A)

thymine base (T)

guanine base (G)

cytosine base (C)

double-ring structures

single-ring structures
DNA Backbone

- **Sugar-Phosphate Linkage**
  - Strands of nucleotides form
  - 3′C sugar covalently bonds
  - to phosphate group

- **P – S – P – S – P – S –**
Composition of DNA

Chargaff showed amount of:

- adenine = thymine or $A=T$
- guanine = cytosine or $G=C$
- Therefore if $A = 22\%$, determine the amount of $G$

$T = 22\%$ so $A+T = 44\%$,

Remainder is $56\% / 2 = 28\%$ C and G
Experiments in the 1950s showed that DNA is the hereditary material.

Scientists raced to determine the structure of DNA.

1953 - Watson and Crick proposed that DNA is a double helix.
Watson-Crick Model
Watson-Crick Model

• DNA consists of two nucleotide strands
• Strands run in opposite directions
• Strands held together by hydrogen bonds between bases
• A binds with T and C with G
• Molecule is a double helix
Fig. 16.5
DNA

• Information center of the cell
• Particular sequence of nucleotide bases forms a gene
• Gene codes for proteins
• Before a protein is made, genes must be transcribed into RNA
DNA Replication

• DNA must be copied before cell division

• Synthesis of DNA – during S-phase of interphase
DNA Replication
Semi-Conservative Model

• Each parent strand remains intact
• Every DNA molecule is half “old” and half “new”
New nucleotides are added in the 5’ to 3’ direction
Chromosome Structure

- Chromatin – relaxed form of genetic material is necessary during protein synthesis
- Chromosomes – condensed form of genetic material
- necessary during cell division
Duplicated chromosome in its condensed form.

- centromere (restricted region)
- supercoiling of the coiled loops of DNA
- DNA double helix
- core of histone
- nucleosome
- beads on a string
- fiber

Fig. 8-3, p.127
Chromosome Structure

- Chromosomes unreplicated (no chromatids)
- Replicated (two chromatids)
- Chromosome – condensed form
- Centromere – point along the chromosome that holds 2 sister chromatids together
Gene Expression and Control

Protein Synthesis
Two steps produce all proteins:

1) Transcription
   – DNA is transcribed to form RNA
   – Occurs in the nucleus
   – RNA moves into cytoplasm

2) Translation
   – RNA is translated to form polypeptide chains which fold to become proteins
Three Classes of RNAs

• Messenger RNA
  – Carries protein-building instruction
• Ribosomal RNA
  – Major component of ribosomes
• Transfer RNA
  – Delivers amino acids to ribosomes
## Nucleic Acids

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<tr>
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<td>ribose</td>
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<tr>
<td></td>
<td>Guanine</td>
<td>Guanine</td>
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<td></td>
<td>Cytosine</td>
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<tr>
<td></td>
<td>Uracil</td>
<td>Thymine</td>
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<tr>
<td>3. Strands</td>
<td>Single-stranded</td>
<td>Double-stranded</td>
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RNA Nucleotides

phosphate group

base (uracil)

sugar (ribose)
DNA Nucleotides

Fig. 10-1b, p.147
Base Pairing

DNA

RNA

DNA

DNA

Base-pairing during transcription

Base-pairing during DNA replication
Transcription

• Like DNA replication
  – Nucleotides added in one direction

• Unlike DNA replication
  – Only small section is template
  – RNA polymerase catalyzes nucleotide addition
  – Product is a single strand of RNA
Promoter

- A base sequence in the DNA that signals the start of a gene
- For transcription to occur, RNA polymerase must first bind to a promoter
Promoter

- RNA polymerase binds DNA at promoter

RNA polymerase, the enzyme that catalyzes transcription
Gene Transcription

DNA template unwinding

DNA template at selected transcription site

newly forming RNA transcript

DNA template winding up

DNA template unwinding

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Fig. 10-2b, p.148
Adding Nucleotides

direction of transcription

growing RNA transcript
RNA Transcript
Transcript Modification

unit of transcription in a DNA strand

transcription into pre-mRNA

cap

snipped out

poly-A tail

snipped out

mature mRNA transcript
### Genetic Code

- **Set of 64 base triplets**
- **Codons**
- **61 specify amino acids**
- **3 stop translation**

#### Amino acids that correspond to base triplets:

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<th>SECOND BASE OF A CODON</th>
<th>THIRD BASE</th>
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<td>glycine</td>
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<td></td>
<td>G</td>
<td></td>
</tr>
</tbody>
</table>
DNA → mRNA → mRNA codons → amino acids

- threonine
- proline
- glutamate
- glutamate
- lysine
tRNA Structure

codon in mRNA

anticodon

amino-acid attachment site

amino acid

OH
Ribosomes

- small ribosomal subunit
- large ribosomal subunit
- intact ribosome

Fig. 10-7b, p.151
Three Stages of Translation

Initiation

Elongation

Termination
Initiation

- Initiator tRNA binds to small ribosomal subunit
- Small subunit/tRNA complex attaches to mRNA and moves along it to an AUG “start” codon
- Large ribosomal subunit joins complex
Binding Sites

$P$ (first binding site for tRNA)

binding site for mRNA

$A$ (second binding site for tRNA)
Elongation

- mRNA passes through ribosomal subunits
- tRNAs deliver amino acids to the ribosomal binding site in the order specified by mRNA
- Peptide bonds form between amino acids and the polypeptide chain grows
Elongation
Termination

- A stop codon moves into place
- No tRNA with anticodon
- Release factors bind to the ribosome
- mRNA and polypeptide are released
What Happens to New Polypeptides?

- Some enter the cytoplasm
- Many enter the endoplasmic reticulum and move through the endomembrane system where they are modified
Overview

transcription

mRNA

rRNA

tRNA

mature mRNA transcripts

ribosomal subunits

mature tRNA

translation

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Gene Mutations

Base-pair substitutions

Insertions

Deletions
Base-Pair Substitution

During replication, proofreading enzymes make a substitution.

Possible outcomes:

- Original, unmutated sequence
- A gene mutation
Frameshift Mutations

• Insertion
  – Extra base added into gene region

• Deletion
  – Base removed from gene region

• Both shift the reading frame

• Result in altered amino acid sequence
Frameshift Mutation

mRNA
parental DNA
amino acids

DNA with base insertion
altered amino-acid sequence

arginine glycine tyrosine tryptophan asparagine

arginine glycine leucine leucine glutamate
Transposons

- DNA segments that move spontaneously about the genome
- When they insert into a gene region, they usually inactivate that gene
Mutations

- Each gene has a characteristic mutation rate
- Natural and synthetic chemicals, and radiation, increase mutation rate
- Only mutations that arise in germ cells can pass on to next generation
- Important evolutionary consequences
Mutagens

- Ionizing radiation (x-rays)
- Nonionizing radiation (UV)
- Natural and synthetic chemicals