Mader/*Biology*, 11/e – Chapter Outline

<u>Chapter 12</u>

12.5 Second Step: Translation

1. Translation takes place in the cytoplasm of eukaryotic cells.
2. Translation is the second step by which gene expression leads to protein synthesis.
3. One language (nucleic acids) is translated into another language (protein).

A. The Role of Transfer RNA
   1. **Transfer RNA (tRNA)** molecules transfer amino acids to the ribosomes.
   2. The tRNA is a single-stranded ribonucleic acid that doubles back on itself to create regions where complementary bases are hydrogen-bonded to one another.
   3. The amino acid binds to the 3’ end; the opposite end of the molecule contains an **anticodon** that binds to the mRNA codon in a complementary fashion.
   4. There is at least one tRNA molecule for each of the 20 amino acids found in proteins.
   5. There are fewer tRNAs than codons because some tRNAs pair with more than one codon; if an anticodon contains a U in the third position, it will pair with either an A or G—this is called the **wobble hypothesis.**
   6. The **tRNA synthetases** are amino acid-activating enzymes that recognize which amino acid should join which tRNA molecule, and covalently joins them. This requires ATP.
   7. An *amino acid–tRNA complex* forms, which then travels to a ribosome to “transfer” its amino acid during protein synthesis.

B. The Role of Ribosomal RNA
   1. Ribosomal RNA (rRNA) is produced from a DNA template in the nucleolus of the nucleus.
   2. The rRNA is packaged with a variety of proteins into ribosomal subunits, one larger than the other.
   3. Subunits move separately through nuclear envelope pores into the cytoplasm where they combine when translation begins.
   4. Ribosomes can float free in cytosol or attach to endoplasmic reticulum.
   5. Prokaryotic cells contain about 10,000 ribosomes; eukaryotic cells contain many times more.
   6. Ribosomes have a binding site for mRNA and binding sites for two tRNA molecules.
   7. They facilitate complementary base pairing between tRNA anticodons and mRNA codons; rRNA acts as an enzyme (*ribozyme*) that joins amino acids together by means of a peptide bond.
   8. A ribosome moves down the mRNA molecule, new tRNAs arrive, the amino acids join, and a polypeptide forms.
   9. Translation terminates once the polypeptide is formed; the ribosome then dissociates into its two subunits.
   10. **Polyribosomes** are clusters of several ribosomes synthesizing the same protein.
   11. To get from a polypeptide to a function protein requires correct bending and twisting; *chaperone molecules* assure that the final protein develops the correct shape.
   12. Some proteins contain more than one polypeptide; they must be joined to achieve the final three-dimensional shape.

C. Translation Requires Three Steps
   1. During translation, mRNA codons base-pair with tRNA anticodons carrying specific

amino acids.

2. Codon order determines the order of tRNA molecules and the sequence of amino acids in polypeptides.
3. Protein synthesis involves *initiation*, *elongation*, and *termination*.
4. Enzymes are required for all three steps; energy (ATP) is needed for the first two steps.
5. Chain Initiation
    a. A small ribosomal subunit attaches to mRNA in the vicinity of the *start codon* (AUG).
    b. First or initiator tRNA pairs with this codon; then the large ribosomal subunit joins to the small subunit.
    c. Each ribosome contains three binding sites: the **P** (for peptide) **site,** the **A** (for amino acid) **site,** and the **E** (for exit) **site.**
    d. The initiator tRNA binds to the P site although it carries one amino acid, methionine.
    e. The A site is for the next tRNA carrying the next amino acid.
    f. The E site is to discharge tRNAs from the ribosome.
    g. Initiation factor proteins are required to bring together the necessary translation components: the small ribosomal subunit, mRNA, initiator tRNA, and the large ribosomal subunit.
6. Chain Elongation
    a. The tRNA with attached polypeptide is at the P site; a tRNA-amino acid complex arrives at the A site.
    b. Proteins called *elongation factors* facilitate complementary base pairing between the tRNA anticodon and the mRNA codon.
    c. The polypeptide is transferred and attached by a peptide bond to the newly arrived amino acid in the A site.
    d. This reaction is catalyzed by a *ribozyme*, which is part of the larger subunit.
    e. The tRNA molecule in the P site is now empty.
    f. **Translocation** occurs with mRNA, along with peptide-bearing tRNA, moving to the P site and the spent tRNA moves from the P site to the E site and exits the ribosome.
    g. As the ribosome moves forward three nucleotides, there is a new codon now located at the empty A site.
    h. The complete cycle is rapidly repeated, about 15 times per second in *Escherichia coli*.
    i. The ribosomes will reach a stop codon, termination will occur, and the peptide will be released.
7. Chain Termination
    a. **Termination** of polypeptide synthesis occurs at a stop codon that does not code for amino acid.
    b. The polypeptide is enzymatically cleaved from the last tRNA by a release factor.
    c. The tRNA and polypeptide leave the ribosome, which dissociates into its two subunits.
    d. **Proteomics** is a new field of biology that aims to understand protein structures, and the functions of metabolic pathways.

D. Gene Expression
    1. Gene expression involves transcription, translation, and protein activation.

2. The first few amino acids of a polypeptide act as a signal peptide that indicates where the polypeptide belongs in the cell or if it is to be secreted by the cell.
2. After the polypeptide enters the lumen of the ER, it is folded and further processed by addition of sugars, phosphates, or lipids.
3. Transport vesicles carry the proteins between organelles and to the plasma membrane.

12.6 Structure of Eukaryotic Chromosomes and Genes

1. The DNA is wound around a core of eight protein molecules ("beads on a string"); the proteins are called **histones** and each "bead" is called a **nucleosome.**
    a. Histones play a structural role in chromosome structure and package the large DNA into the small nucleus.
    b. The nucleosomes also contribute to the shortening of DNA by folding it into a "zigzag" structure.
2. During interphase, some chromatin is highly compact, darkly stained, and genetically inactive **heterochromatin.**
3. The rest is diffuse, lightly colored **euchromatin** thought to be genetically active.
    a. **Euchromatin** activity is related to the extent nucleosomes are coiled and condensed.
    b. A nucleosome is a bead-like unit made of a segment of DNA wound around a complex of histone proteins.