Protein Synthesis

Function of DNA in Protein Synthesis

- DNA determines the structure and the activity of the cell by directing protein synthesis.
- Proteins are molecules constructed of polypeptide chains. Protein functions include
  - (1) providing a framework (such as cytoskeletal fibers)
  - (2) mediating chemical reactions (enzymes), and
  - (3) performing other biochemical functions (such as serving as chemical messengers.)
- Other molecules such as carbohydrates and lipids are not directly constructed by DNA coding. Their manufacture is mediated by the proteins (enzymes) that are coded for by DNA.

Transcription and Translation

Protein synthesis is divided into two stages: transcription and translation.

- **Transcription** is the rewriting of the genetic information of DNA into a strand of mRNA. After separation of the two DNA strands, transcription begins as the enzyme RNA polymerase mediates the production of a strand of mRNA.
- **Translation** is the process of the transfer of information encoded in mRNA into a sequence of amino acids - a polypeptide, or especially a protein.

DNA also directs the synthesis of the three types of RNA's used during protein synthesis: messenger RNA (mRNA), ribosomal RNA (rRNA), and transfer RNA (tRNA).

Ribonucleic Acids (RNAs)

The RNAs function in the process of protein synthesis as three structural and functional types: mRNA, tRNA, and rRNA.

Messenger RNA (mRNA)

- Messenger RNA consists of a single strand of nucleotides. It is assembled in the nucleus from a template of DNA, a gene, in a process called transcription.

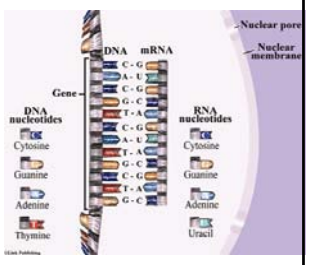

Fig. 7.1

Messenger RNA (mRNA)

- The functional mRNA strand leaves the nucleus through nuclear pores and enters the cytoplasm.
- Once in the cytoplasm the mRNA is attached to a **ribosome** and is used as the template for protein synthesis (a process called translation).

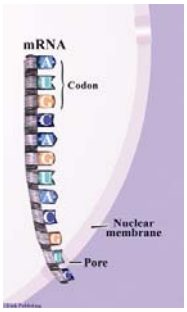

Fig. 7.2

Ribosomal RNA (rRNA)

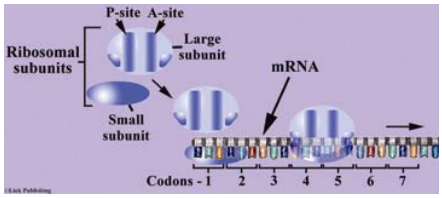

Fig. 7.3

- Ribosome subunits, constructed at the nucleolus, move into the cytoplasm and attach to mRNA.
- Once attached and associated with tRNAs, the process of **translation** begins; the transfer of information encoded in mRNA into polypeptide chains and proteins.

Transfer RNA (tRNA)

Transfer RNA (tRNA) is a highly folded molecule with two functional sites:

- (1) a site for an amino acid and
- (2) a site (anitcodon) for a codon of mRNA.

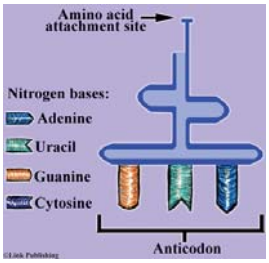

Fig. 7.4

Transfer RNA (tRNA)

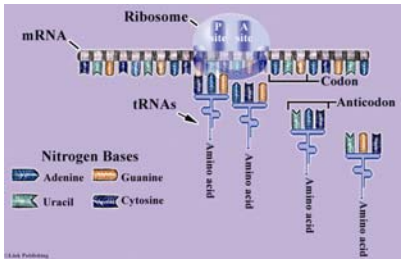

Fig. 7.5

Transfer RNA (tRNA) moves amino acids to a strand of mRNA.

DNA

- A molecule of DNA is constructed from bonded nucleotides that produce two linear strands. The four nitrogen bases are thymine (T), adenine (A), cytosine (C), and guanine (G).

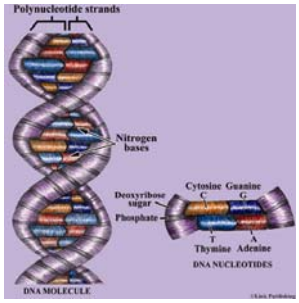

Fig. 7.6

Gene

- A gene is the functional unit of the chromosome. A gene controls the expression of one or more traits by coding for the structure of a polypeptide, or especially, a protein.
- The **sequence** of a gene's nitrogen bases is the "language" of DNA and is "read" in **triplets**, groups of three nitrogen bases. The "gene" shown contains seven triplets.
  - **Transcription** of this gene would produce a strand of mRNA with seven 3-base groups called codons.

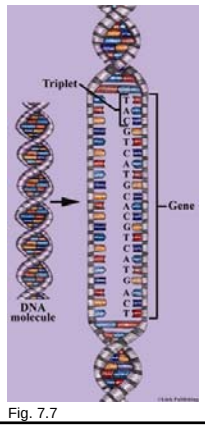

Fig. 7.7

Transcription

The assemblage of mRNA from a segment of DNA (a gene) by complementary base paring

Transcription

Transcription, which occurs in the nucleus, is the assemblage of mRNA from a segment of DNA (a gene) by complementary base paring.

- The four nitrogen bases of RNA are adenine (A), uracil (U), cytosine (C), and guanine (G). The base thymine found in DNA is not found in RNA

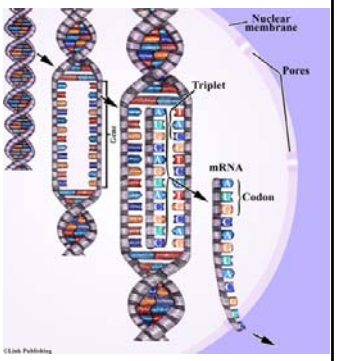

Fig. 7.8

Codons

- Groups of three nitrogen bases of mRNA are called **codons**. Thus, the information of triplets (DNA) is **passed** to mRNA codons as complementary bases. Since codons are directly involved in protein synthesis (translation), they are listed in tables (codon tables) with respect to their associated amino acids.

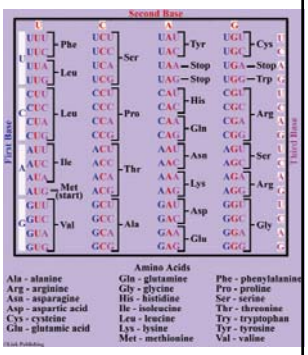

Fig. 7.9

TRANSLATION

Translation is the process of the transfer of information encoded in mRNA into a sequence of amino acids - a polypeptide, or especially a protein..

Translation

- Translation occurs in the cytoplasm and can be divided into three events:
  - (1) initiation,
  - (2) elongation, and
  - (3) termination.

Initiation

- First, with the help of proteins called initiation factors, a small ribosome subunit binds to a mRNA strand at a base sequence just upstream to the start codon, AUG. (AUG is always the start codon.)
- Next a tRNA with the anticodon UAC binds (complementary base pairing) to the mRNA start codon AUG. This tRNA always carries the amino acid, methionine. After binding of the tRNA carrying methionine, the large ribosome subunit binds to this complex.

Initiation

- Initiation of protein synthesis begins when a small ribosome subunit binds to a mRNA strand at a base sequence just upstream to the start codon, AUG.

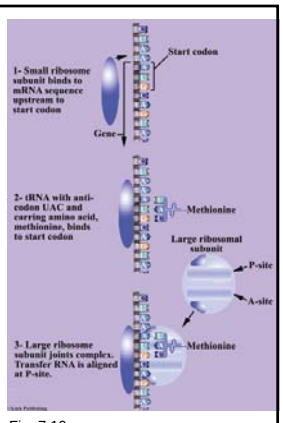

Fig. 7.10

Elongation

- Elongation begins with the arrival of a second tRNA and its amino acid at the large subunit's A-site (arrival site.) Once the arrived tRNA is secure in the A-site, enzymes associated with the P-site mediate **peptide bond** formation between the two associated amino acids (in this case methionine in the P-site is peptide bonded to the arrived amino acid in the A-site).

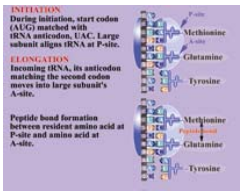

Fig. 7.11

Elongation

- Process of elongation repeats until a stop codon is reached:

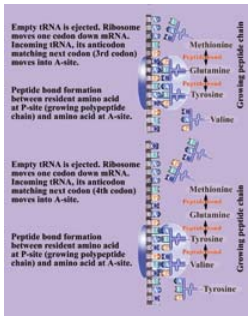

Fig. 7.11

Termination

- When the ribosome encounters a stop codon the tRNA at the large ribosomal subunit's P-site releases its attached polypeptide chain, the ribosome releases from the strand of mRNA, and the ribosomal subunits separate.

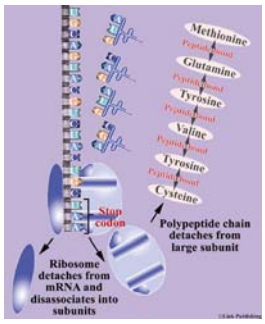

Fig. 7.12

Polyribosome

- A polyribosome is a cluster of ribosomes that are linked together by a strand of mRNA.
- A polyribosome allows a large quantity of identical polypeptide strands to be produced within a short time.

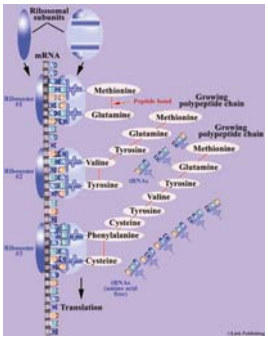

Fig. 7.13

Summary of Transcription and Translation

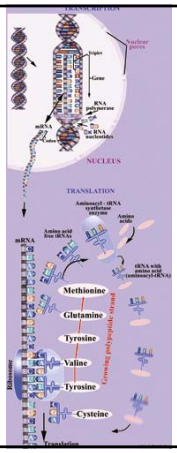

Fig. 7.14