Chapter 17: From Gene to Protein

AP Biology 2013

1

Flow of Genetic Information

- Information content of DNA is in the form of specific sequences of nucleotides
- DNA inherited by an organism leads to specific traits by dictating the synthesis of proteins
- Proteins are the links between genotype and phenotype
- Gene expression, the process by which DNA directs protein synthesis, includes transcription and translation

Fig. 17.1

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DNA Directs Protein Synthesis

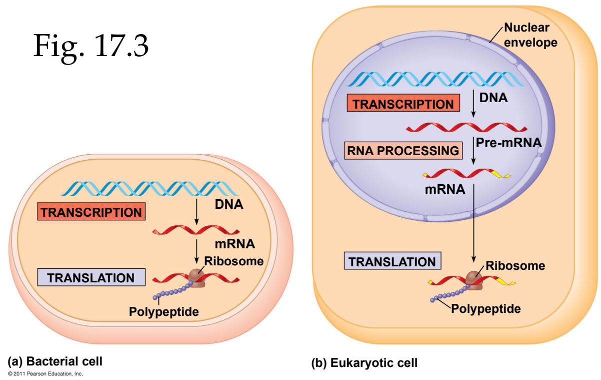
- Two stages called transcription and translation
- The ribosome is the site of translation
- Each gene controls the production of one polypeptide (sometimes referred to as the “one gene, one protein” hypothesis)
- Transcription
  - Synthesis of RNA under the direction of DNA (mRNA)
- Translation
  - Synthesis of a polypeptide from mRNA (happens at ribosomes)

3

Prokaryotic vs. Eukaryotic

- In prokaryotes, translation of mRNA can begin before transcription has finished.
    - In eukaryotes, this is not possible.

Fig. 17.3



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The Codon

- Each codon (3 nucleotide sequence) codes for an amino acid or a stop
- The gene (DNA) determines the sequence of bases along the mRNA molecule
- Codons are read from 5′ to 3′

Second mRNA base

First mRNA base (5′ end of codon)	U	C	A	G	Third mRNA base (3′ end of codon)
U	UUU Phe	UCU Ser	UAU Tyr	UGU Cys	U
U	UUC Phe	UCC Ser	UAC Tyr	UGC Cys	C
U	UUA Leu	UCA Ser	UAA Stop	UGA Stop	A
U	UUG Leu	UCG Ser	UAG Stop	UGG Trp	G
C	CUU Leu	CCU Pro	CAU His	CGU Arg	U
C	CUC Leu	CCC Pro	CAC His	CGC Arg	C
C	CUA Leu	CCA Pro	CAA Gln	CGA Arg	A
C	CUG Leu	CCG Pro	CAG Gln	CGG Arg	G
A	AUU Ile	ACU Thr	AAU Asn	AGU Ser	U
A	AUC Ile	ACC Thr	AAC Asn	AGC Ser	C
A	AUA Ile	ACA Thr	AAA Lys	AGA Arg	A
A	AUG Met or start	ACG Thr	AAG Lys	AGG Arg	G
G	GUU Val	GCU Ala	GAU Asp	GGU Gly	U
G	GUC Val	GCC Ala	GAC Asp	GGC Gly	C
G	GUA Val	GCA Ala	GAA Glu	GGA Gly	A
G	GUG Val	GCG Ala	GAG Glu	GGG Gly	G

Fig. 17.5

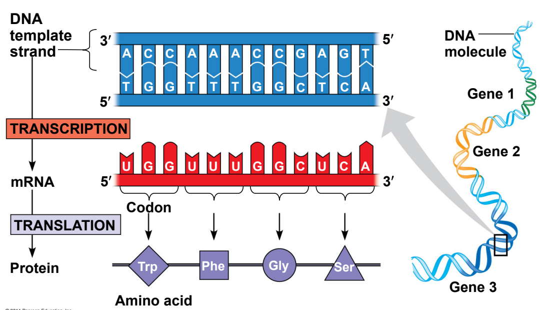

Fig. 17.4

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Universality

- Genetic code is universal
- Genes can be transcribed and translated after transplantation from one species to another

(a) Tobacco plant expressing a firefly gene

(b) Pig expressing a jellyfish gene

Fig. 17.6

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Transcription

- Started with the binding of RNA polymerase at a promoter
  - Separates the DNA strand and adds the RNA nucleotides
  - Follows same base pairing rules except, uracil substitutes for thymine
- Three stages:
  - Initiation
  - Elongation
  - Termination

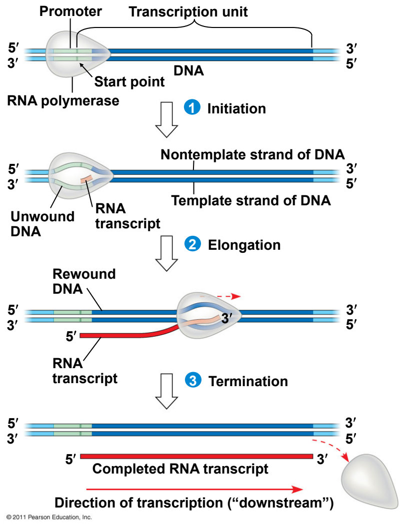


Fig. 17.7

Transcription

- Promoter regions signal a binding site for the RNA polymerase
- Transcription factors also help the RNA polymerase recognize the promoter sequence
- RNA polymerase continues down the strand exposing 10-20 DNA bases at a time
- Termination signals are different:
  - Prokaryotes: RNA polymerase stops at a termination sequence
  - Eukaryotes: RNA polymerase continues past a polyadenylation signal and will eventually fall off

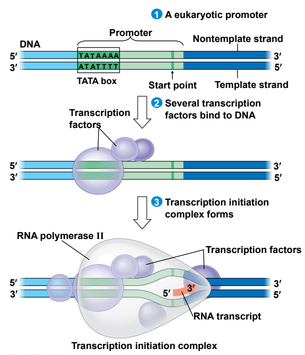


Fig. 17.8

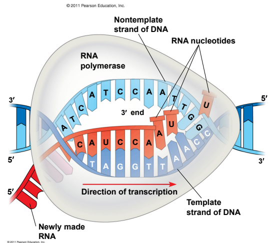
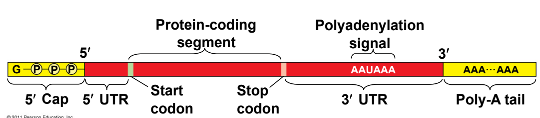
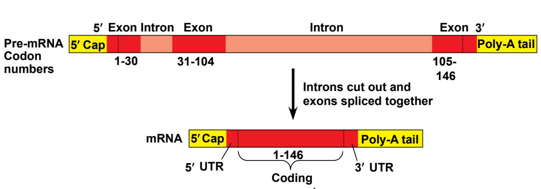


Fig. 17.9

Eukaryotic Modification

- Enzymes in the nucleus modify pre-mRNA before it is released to the cytoplasm
- The 5′ end receives a nucleotide cap
- The 3′ end receives a poly-A tail
- RNA splicing - removing introns and joins exons





Figs. 17.10 & 17.11

Spliceosomes

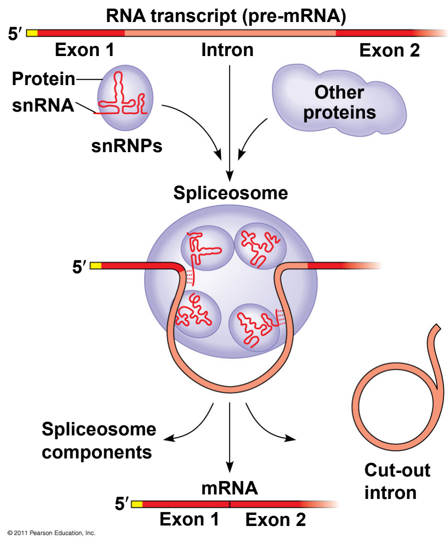


Fig. 17.12

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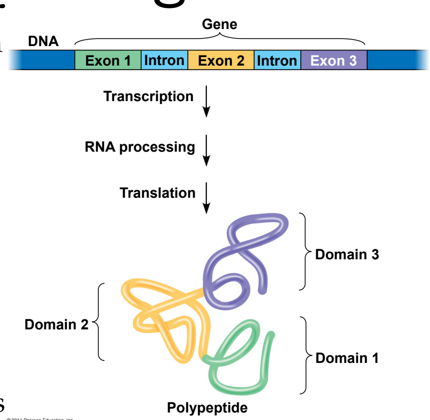
Alternative RNA Splicing

- Depending on which segments are treated as introns, different proteins can be formed.
- Consists of regions called domains
- Different exons code for different domains



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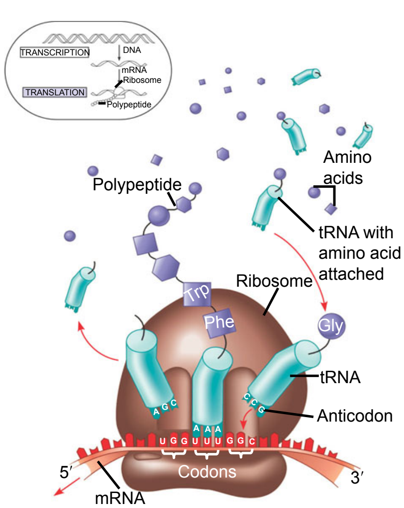
Translation



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tRNA

- Single RNA strand that is about 80 nucleotides long
- Joining of amino acid to the correct tRNA is accomplished by aminoacyl-tRNA synthetase

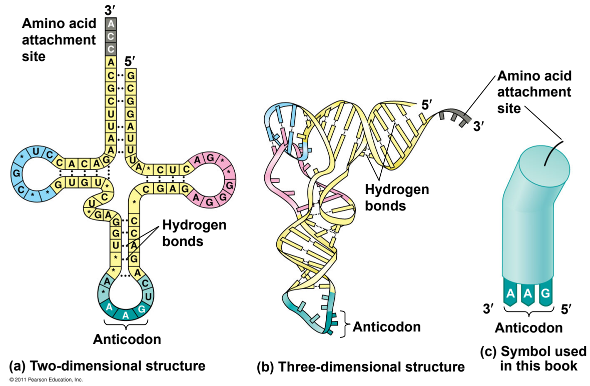

Fig. 17.15

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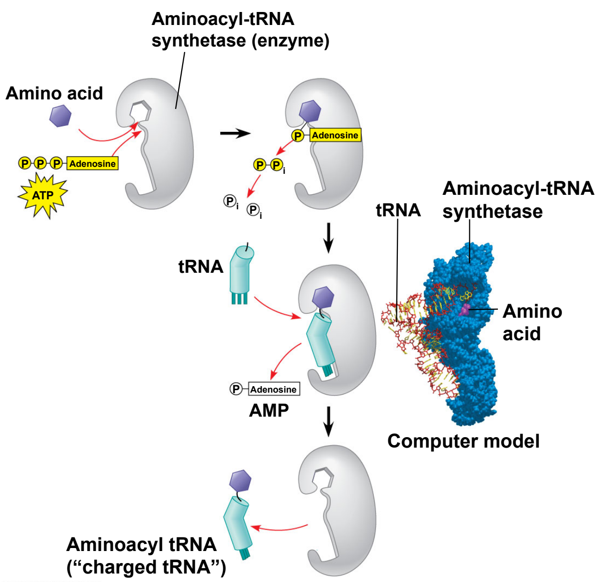

Fig. 17.16

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Ribosomes

- Facilitate the coupling of tRNA anticodons with mRNA codons
- Made of proteins and RNA molecules (rRNA)

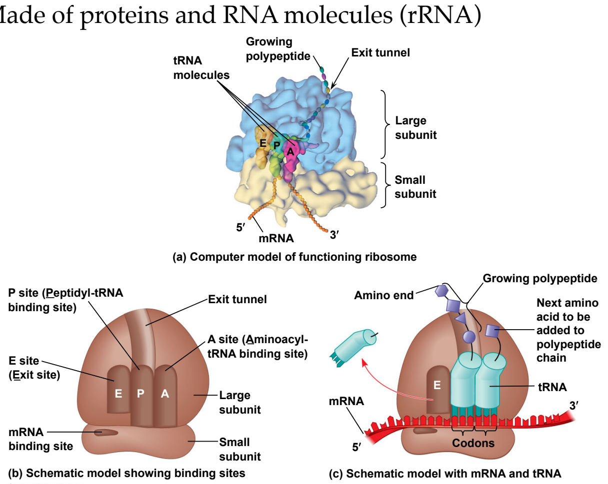

Fig. 17.17

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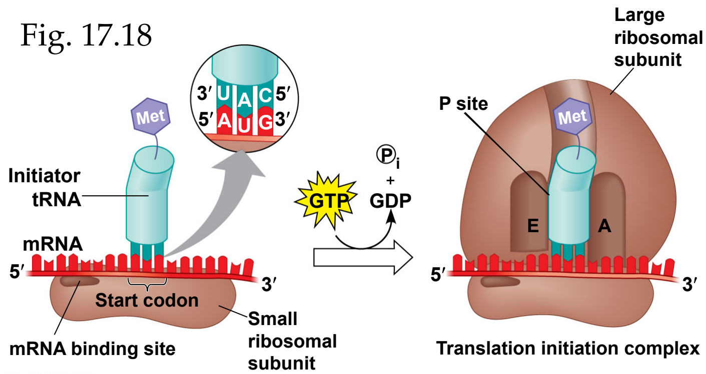
Translation

- Three stages:
  - INITIATION
  - Elongation
  - Termination

Fig. 17.18



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Translation

- Three stages:
  - Initiation
  - ELONGATION
  - Termination

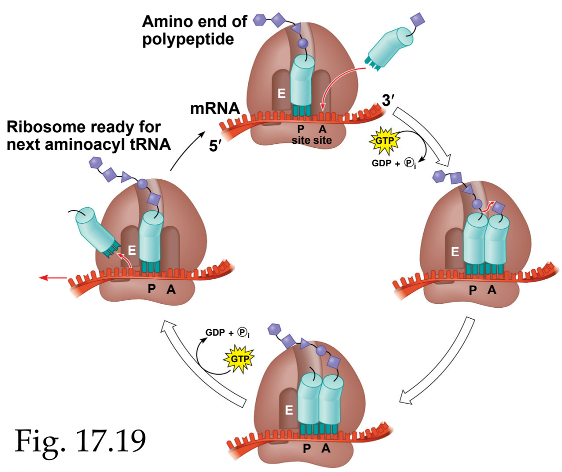

Fig. 17.19

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Translation

- Three stages:
  - Initiation
  - ELONGATION
  - Termination

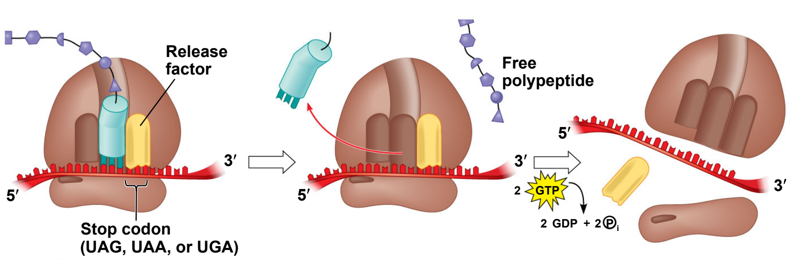

Fig. 17.20

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Polyribosomes

- Many ribosomes can simultaneously tranlate a single mRNA molecule
  - This can result in signal amplification

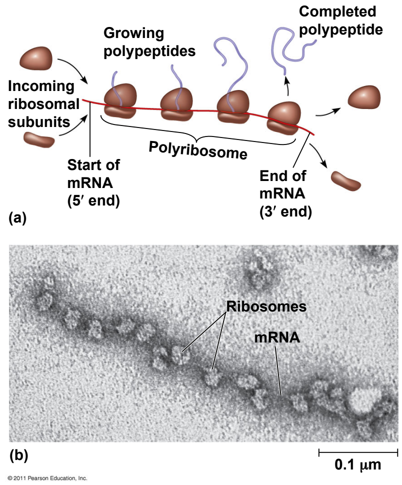

Fig. 17.21

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Post-translational Modifications

- May be modified to impact the 3-D shape of the protein
- Proteins destined for the endomembrane system or for secretion must be transported into the ER
  - Have signal peptides to which SRP (signal-recognition particle) binds, enabling the translation ribosome to bind to the ER

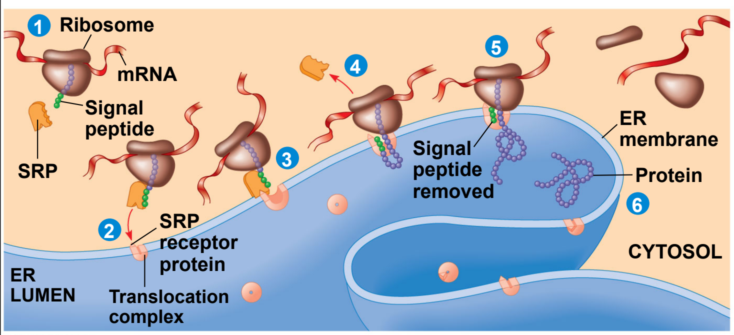

Fig. 17.22

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Type of RNA	Functions
Messenger RNA (mRNA)	Carries information specifying amino acid sequences of proteins from DNA to ribosomes.
Transfer RNA (tRNA)	Serves as adapter molecule in protein synthesis; translates mRNA codons into amino acids.
Ribosomal RNA (rRNA)	Plays catalytic (ribozyme) roles and structural roles in ribosomes.
Primary transcript	Serves as a precursor to mRNA, rRNA, or tRNA, before being processed by splicing or cleavage. Some intron RNA acts as a ribozyme, catalyzing its own splicing.
Small nuclear RNA (snRNA)	Plays structural and catalytic roles in spliceosomes, the complexes of protein and RNA that splice pre-mRNA.
SRP RNA	Is a component of the signal-recognition particle (SRP), the protein-RNA complex that recognizes the signal peptides of polypeptides targeted to the ER.
Small nucleolar RNA (snoRNA)	Aids in processing of pre-rRNA transcripts for ribosome subunit formation in the nucleolus.
Small interfering RNA (siRNA) and microRNA (miRNA)	Are involved in regulation of gene expression.

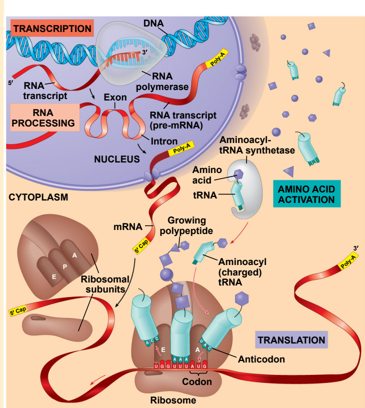

Fig. 17.26

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Point Mutations

- Mutations - changes in genetic material
- Point mutations - changes in one base pair
  - Substitutions - can cause missense or nonsense
  - Insertions and deletions - can cause frameshifts

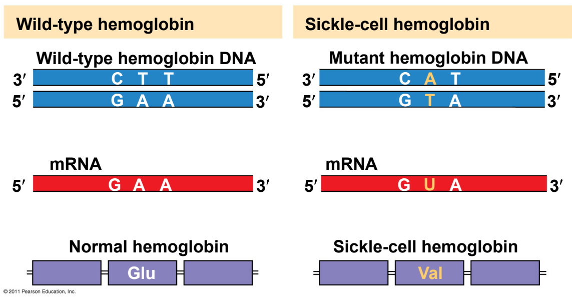

Fig. 17.23

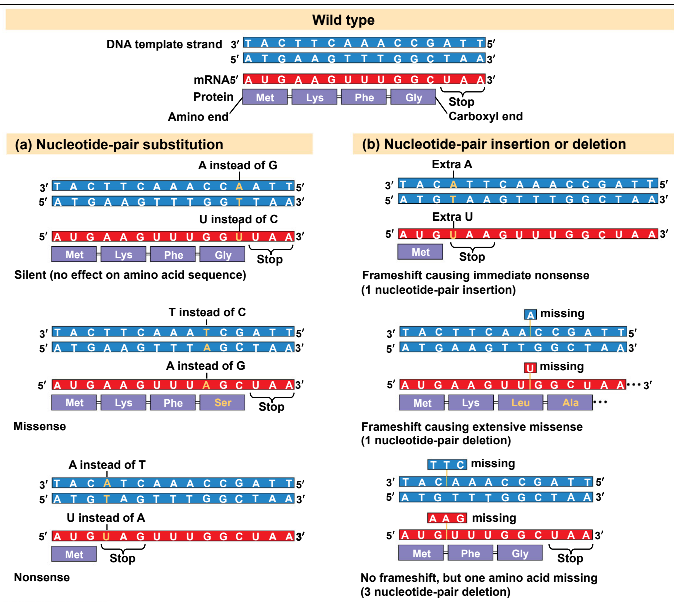

Fig. 17.24

Proks vs. Euks

- In prokaryotes, translation can begin while transcription is still in progress
- In eukaryotes, RNA processing happens in the nucleus.