Fig. 17-1

Basic Principles of Transcription and Translation

- RNA is the intermediate between genes and the proteins for which they code
- **Transcription** is the synthesis of RNA under the direction of DNA
- Transcription produces **messenger RNA (mRNA)**
- **Translation** is the synthesis of a polypeptide, which occurs under the direction of mRNA
- **Ribosomes** are the sites of translation

- In prokaryotes, mRNA produced by transcription is immediately translated without more processing
- In a eukaryotic cell, the nuclear envelope separates transcription from translation
- Eukaryotic RNA transcripts are modified through **RNA processing** to yield finished mRNA

Fig. 17-3

A **primary transcript** is the initial RNA transcript from any gene

Cells are governed by a cellular chain of command: DNA → RNA → protein

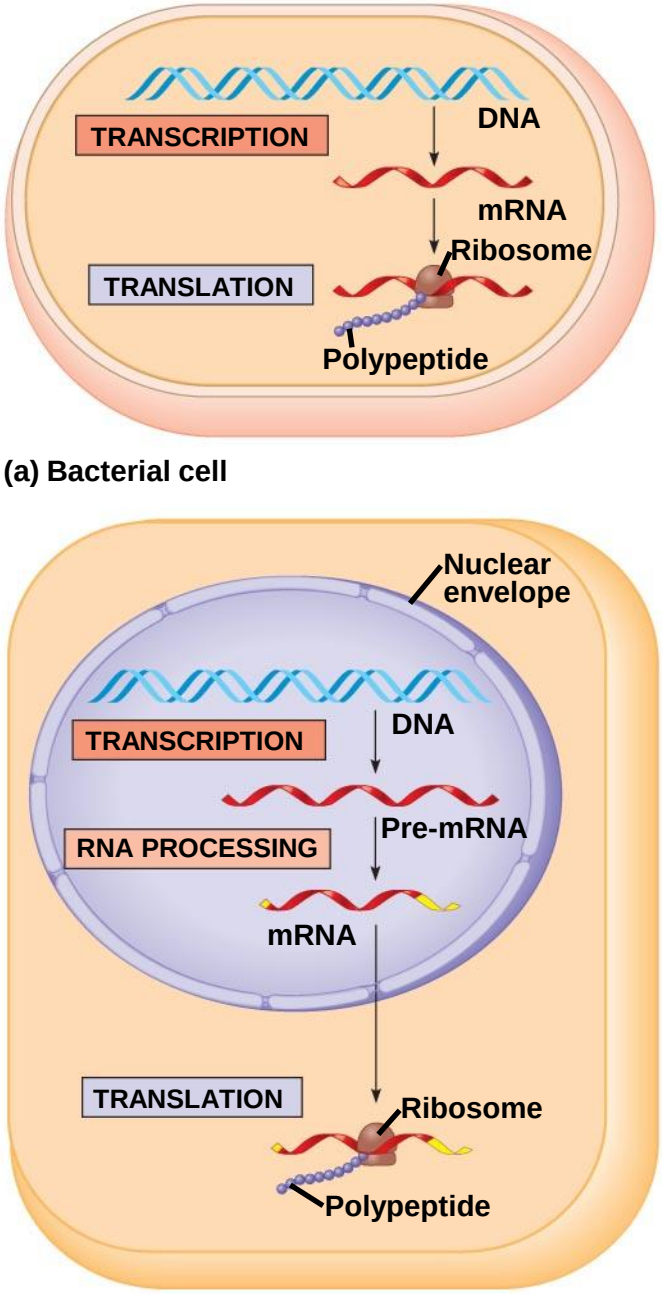
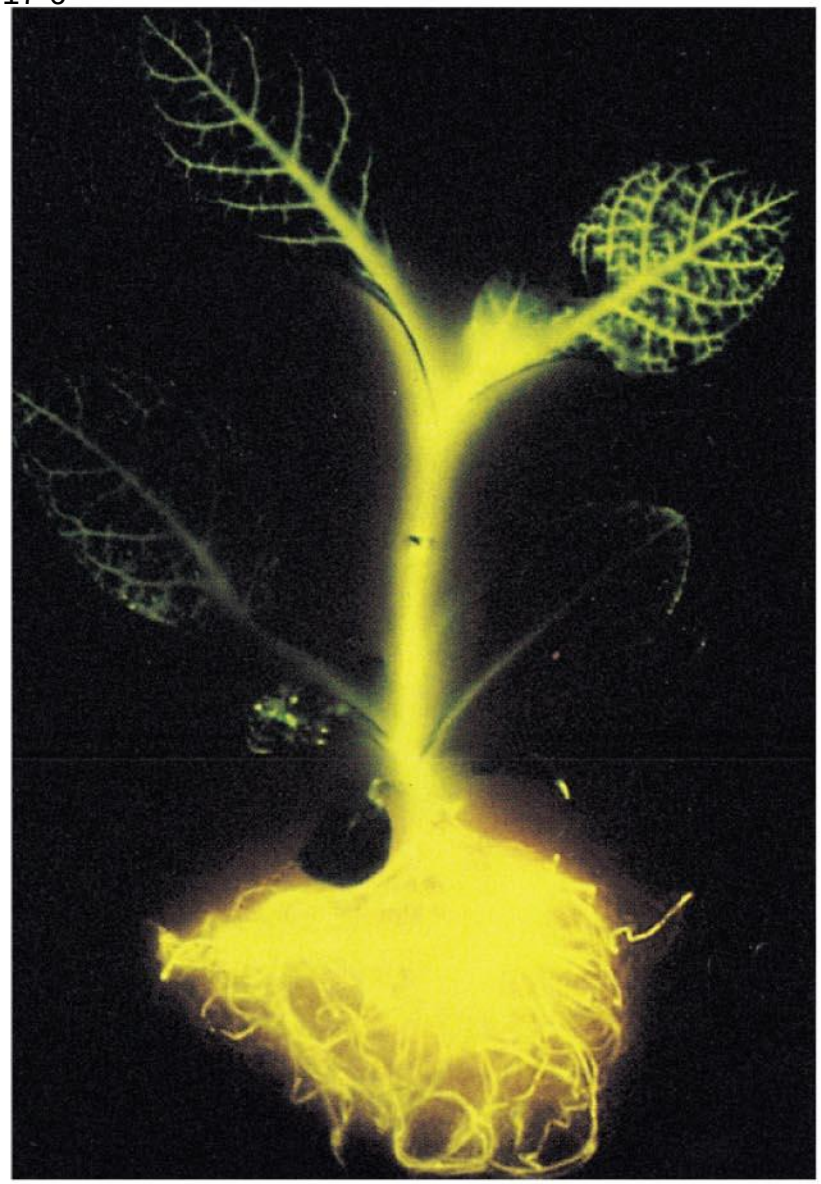


Fig. 17-6



(a) Tobacco plant expressing a firefly gene

(b) Pig expressing a jellyfish gene

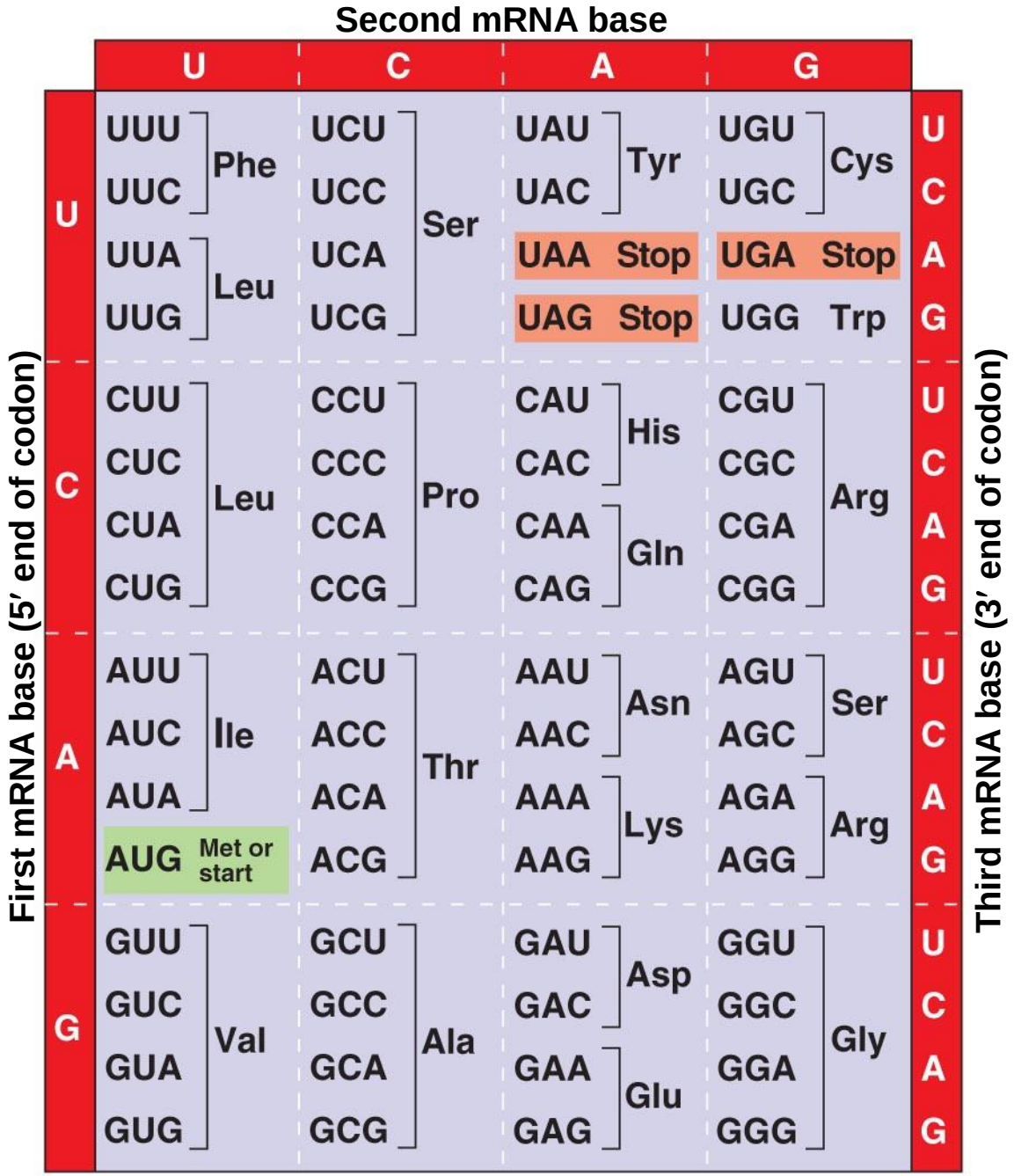
Codons: Triplets of Bases

- The flow of information from gene to protein is based on a **triplet code**: a series of nonoverlapping, three-nucleotide words
- These triplets are the smallest units of uniform length that can code for all the amino acids
- Example: AGT at a particular position on a DNA strand results in the placement of the amino acid serine at the corresponding position of the polypeptide to be produced

Fig. 17-5

Codons along an mRNA molecule are read by translation machinery in the 5′ to 3′ direction

Each codon specifies the addition of one amino acids



Molecular Components of Transcription

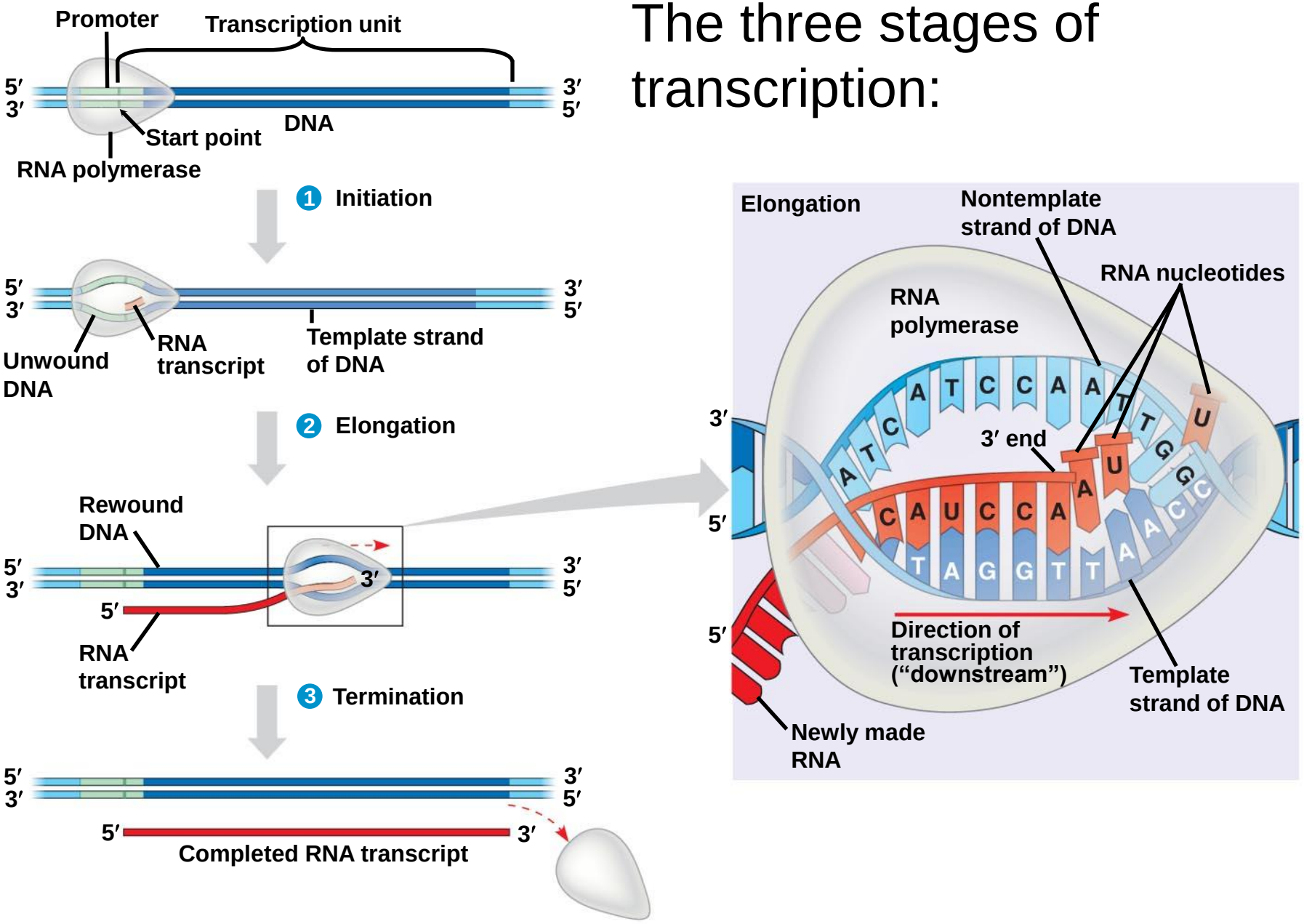
- RNA synthesis is catalyzed by **RNA polymerase**, which pries the DNA strands apart and hooks together the RNA nucleotides
- RNA synthesis follows the same base-pairing rules as DNA, except uracil substitutes for thymine

- The DNA sequence where RNA polymerase attaches is called the **promoter**; in bacteria, the sequence signaling the end of transcription is called the **terminator**
- The stretch of DNA that is transcribed is called a **transcription unit**

Transcription video

Fig. 17-7

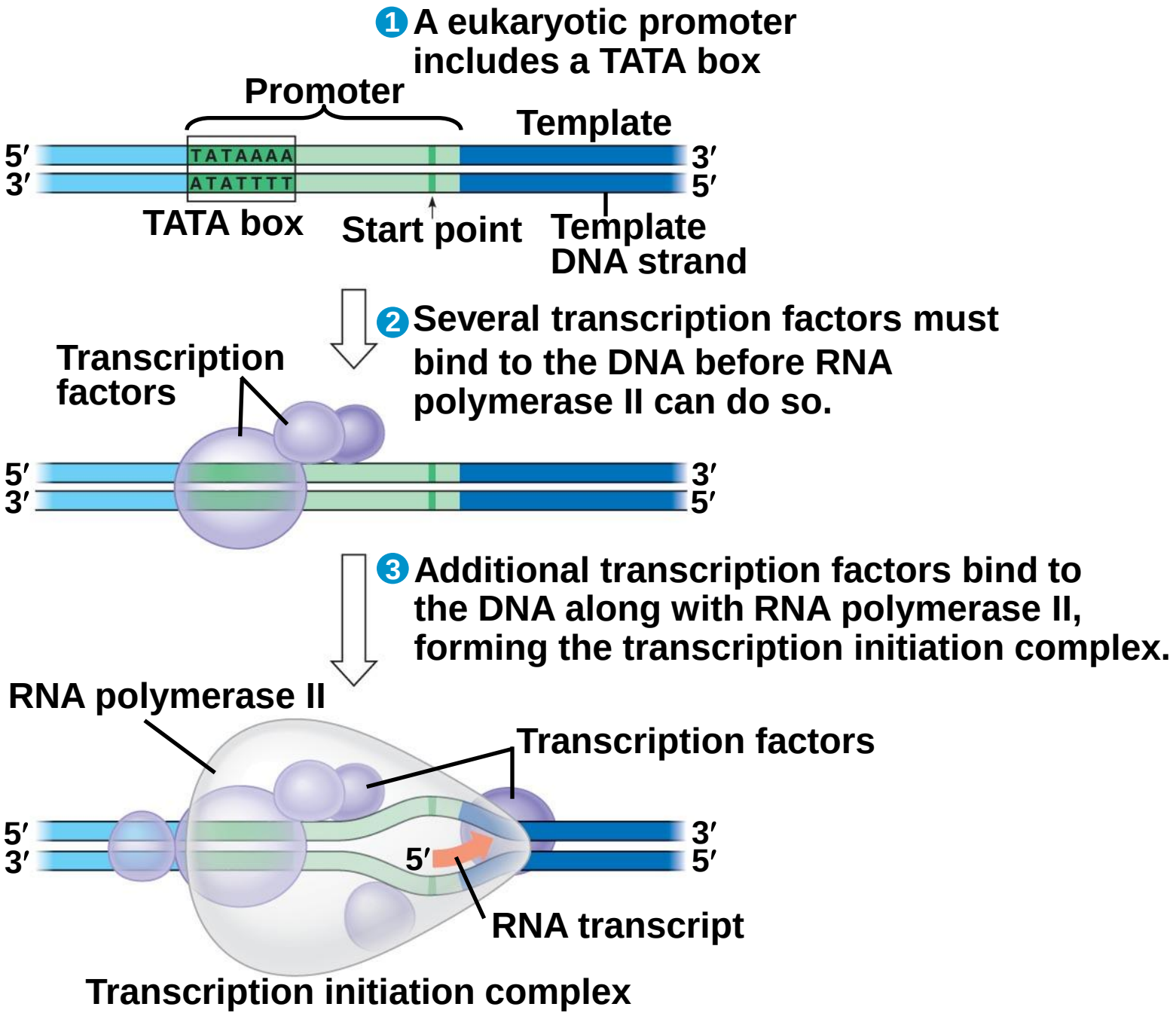
The three stages of transcription:



RNA Polymerase Binding and Initiation of Transcription

- Promoters signal the initiation of RNA synthesis
- **Transcription factors** mediate the binding of RNA polymerase and the initiation of transcription
- The completed assembly of transcription factors and RNA polymerase II bound to a promoter is called a **transcription initiation complex**
- A promoter called a **TATA box** is crucial in forming the initiation complex in eukaryotes

Fig. 17-8



Elongation of the RNA Strand

- As RNA polymerase moves along the DNA, it untwists the double helix, 10 to 20 bases at a time
- It moves in the 3’ to 5’ direction!
- Transcription progresses at a rate of 40 nucleotides per second in eukaryotes
- A gene can be transcribed simultaneously by several RNA polymerases

Termination of Transcription

- The mechanisms of termination are different in bacteria and eukaryotes
- In bacteria, the polymerase stops transcription at the end of the terminator
- In eukaryotes, the polymerase continues transcription after the pre-mRNA is cleaved from the growing RNA chain; the polymerase eventually falls off the DNA

Concept 17.3: Eukaryotic cells modify RNA after transcription

- Enzymes in the eukaryotic nucleus modify pre-mRNA before the genetic messages are dispatched to the cytoplasm
- During RNA processing, both ends of the primary transcript are usually altered
- Also, usually some interior parts of the molecule are cut out, and the other parts spliced together

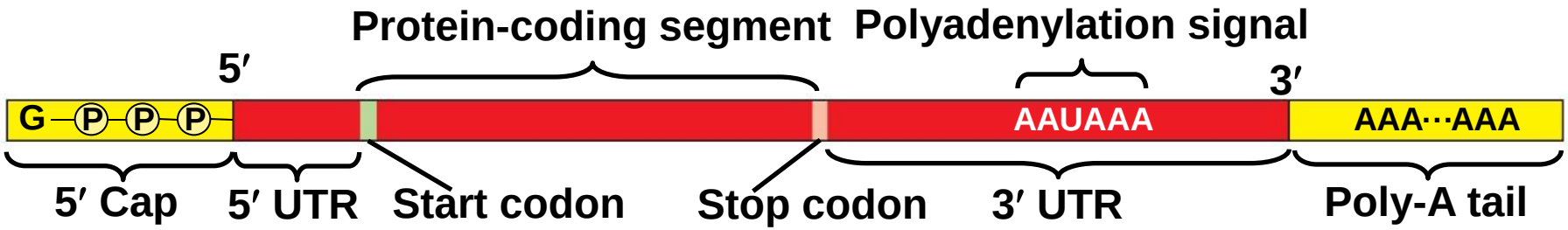
Alteration of mRNA Ends

- Each end of a pre-mRNA molecule is modified in a particular way:
  - The 5′ end receives a modified nucleotide **5′ cap**
  - The 3′ end gets a **poly-A tail**

Fig. 17-9

These modifications share several functions:

- They seem to facilitate the export of mRNA
- They protect mRNA from hydrolytic enzymes
- They help ribosomes attach to the 5′ end

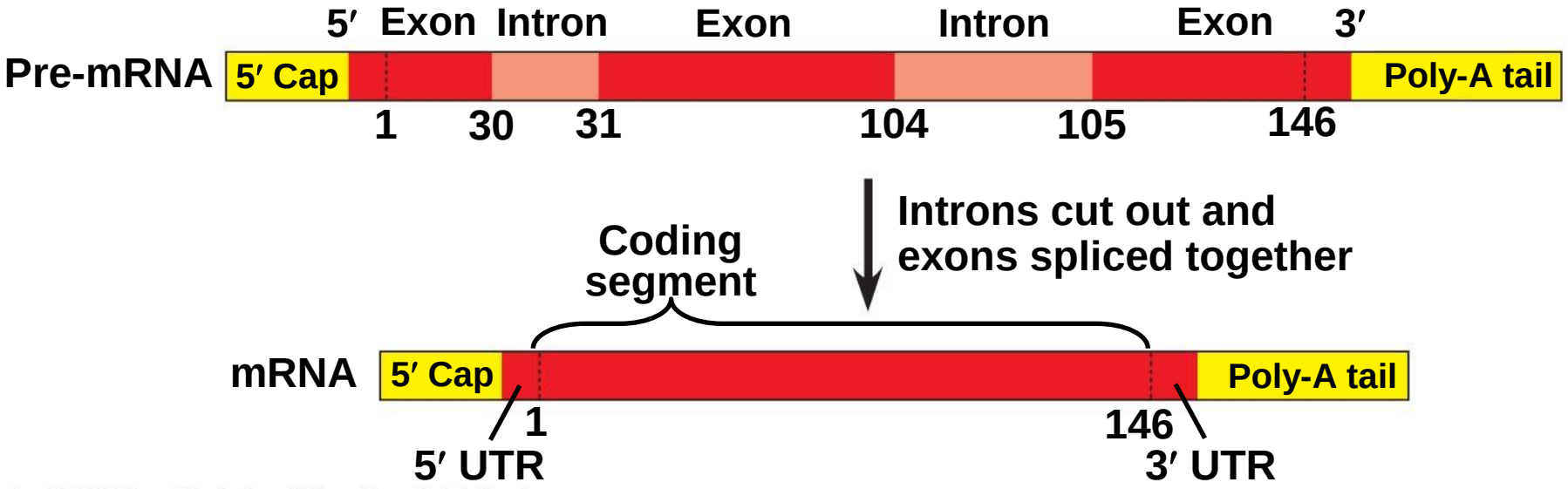


Split Genes and RNA Splicing

- Most eukaryotic genes and their RNA transcripts have long noncoding stretches of nucleotides that lie between coding regions
- These noncoding regions are called intervening sequences, or **introns**
- The other regions are called **exons** because they are eventually expressed, usually translated into amino acid sequences
- **RNA splicing** removes introns and joins exons, creating an mRNA molecule with a continuous coding sequence

Fig. 17-10

- **RNA splicing** removes introns and joins exons, creating an mRNA molecule with a continuous coding sequence



The Functional and Evolutionary Importance of Introns

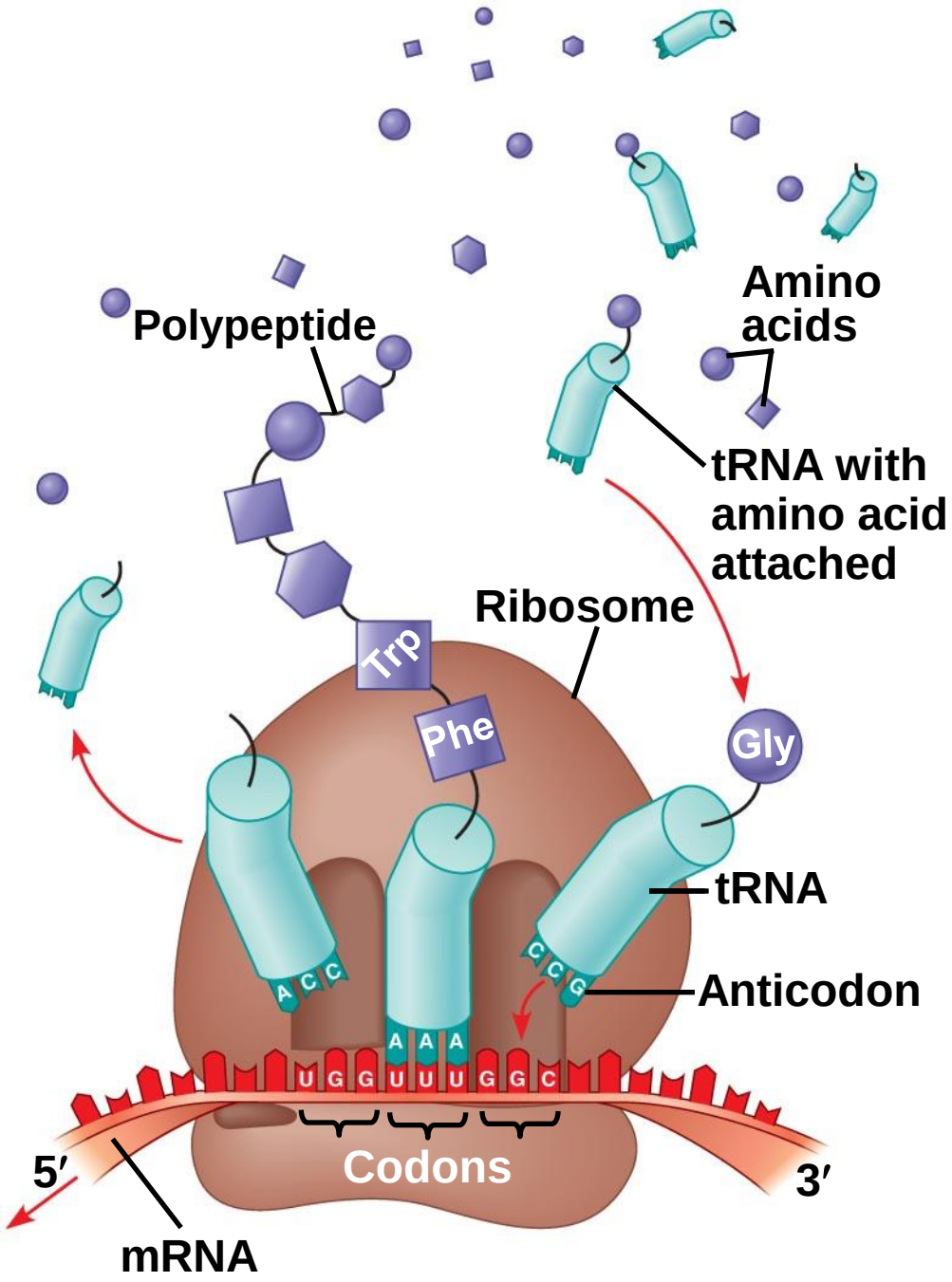
- Some genes can encode more than one kind of polypeptide, depending on which segments are treated as exons during RNA splicing
- Such variations are called **alternative RNA splicing**
- Because of alternative splicing, the number of different proteins an organism can produce is much greater than its number of genes

- Proteins often have a modular architecture consisting of discrete regions called **domains**
- In many cases, different exons code for the different domains in a protein
- Exon shuffling may result in the evolution of new proteins

Molecular Components of Translation

- A cell translates an mRNA message into protein with the help of **transfer RNA (tRNA)**
- Molecules of tRNA are not identical:
  - Each carries a specific amino acid on one end
  - Each has an **anticodon** on the other end; the anticodon base-pairs with a complementary codon on mRNA

Fig. 17-13



The Structure and Function of Transfer RNA

- A tRNA molecule consists of a single RNA strand that is only about 80 nucleotides long
- Flattened into one plane to reveal its base pairing, a tRNA molecule looks like a cloverleaf

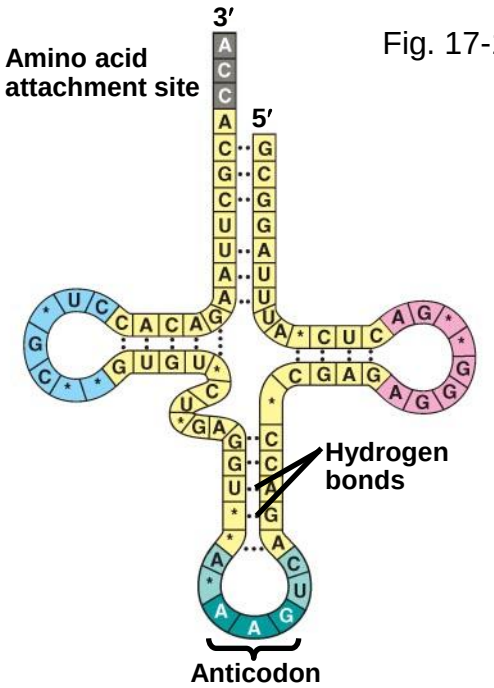
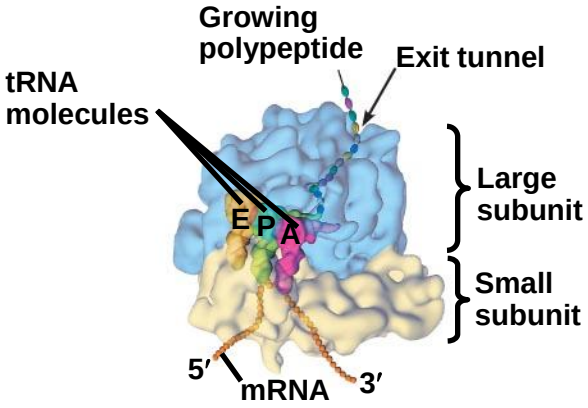


Fig. 17-14

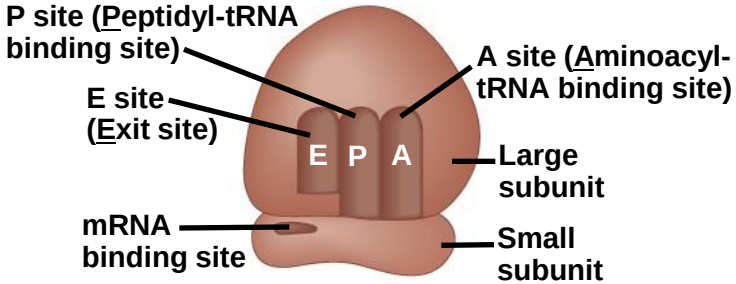
(a) Two-dimensional structure

Ribosomes

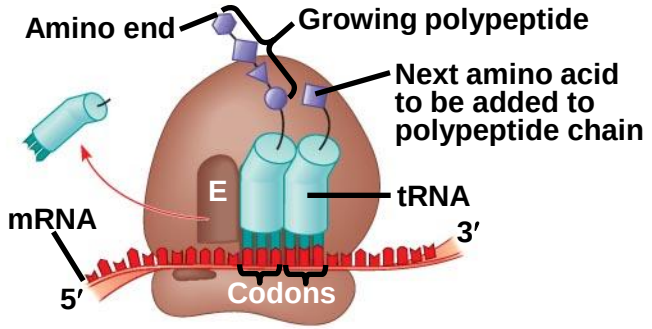
- Ribosomes facilitate specific coupling of tRNA anticodons with mRNA codons in protein synthesis
- The two ribosomal subunits (large and small) are made of proteins and **ribosomal RNA (rRNA)**



(a) Computer model of functioning ribosome



(b) Schematic model showing binding sites



(c) Schematic model with mRNA and tRNA

- A ribosome has three binding sites for tRNA:
  - The **P site** holds the tRNA that carries the growing polypeptide chain
  - The **A site** holds the tRNA that carries the next amino acid to be added to the chain
  - The **E site** is the exit site, where discharged tRNAs leave the ribosome

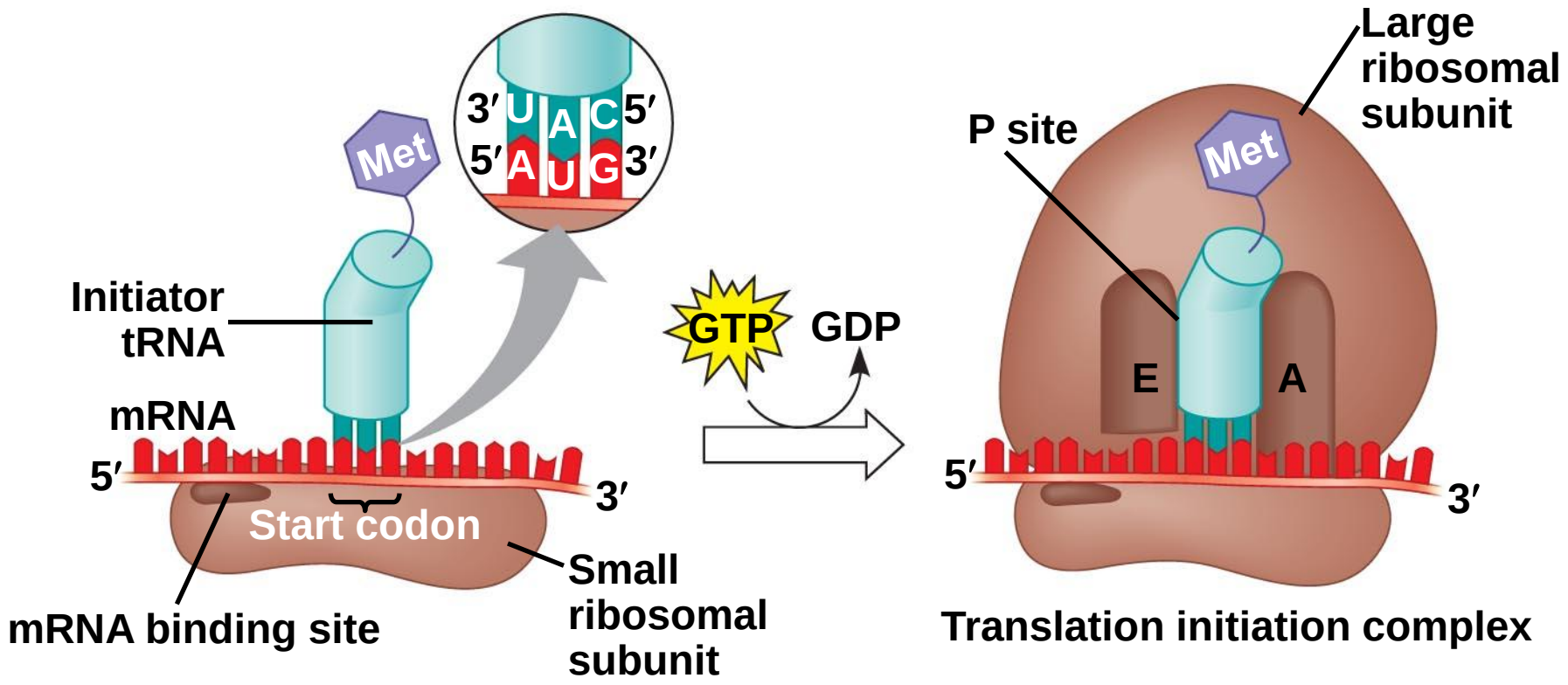
Building a Polypeptide

- The three stages of translation:
  - Initiation
  - Elongation
  - Termination
- All three stages require protein “factors” that aid in the translation process

Ribosome Association and Initiation of Translation

- The initiation stage of translation brings together mRNA, a tRNA with the first amino acid, and the two ribosomal subunits
- First, a small ribosomal subunit binds with mRNA and a special initiator tRNA
- Then the small subunit moves along the mRNA until it reaches the start codon (AUG)
- Proteins called initiation factors bring in the large subunit that completes the translation initiation complex

Fig. 17-17



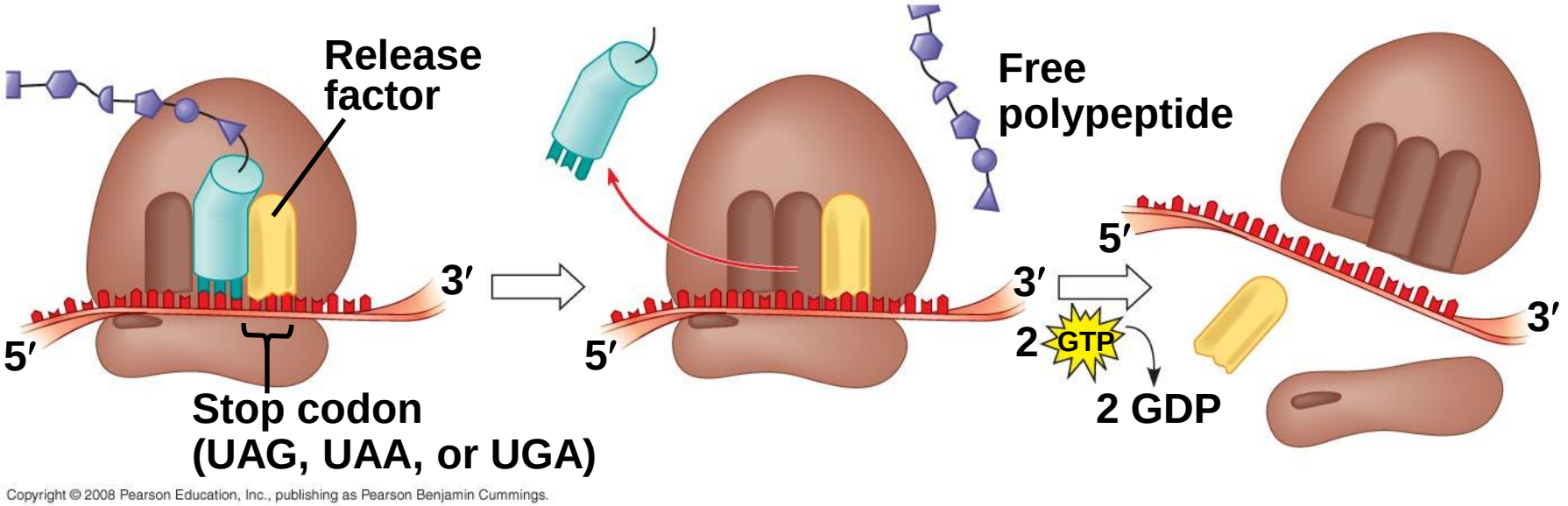
Elongation of the Polypeptide Chain

- During the elongation stage, amino acids are added one by one to the preceding amino acid
- Each addition involves proteins called elongation factors and occurs in three steps: codon recognition, peptide bond formation, and translocation

Termination of Translation

- Termination occurs when a stop codon in the mRNA reaches the A site of the ribosome
- The A site accepts a protein called a release factor
- The release factor causes the addition of a water molecule instead of an amino acid
- This reaction releases the polypeptide, and the translation assembly then comes apart

Fig. 17-19-3



What Is a Gene? *Revisiting the Question*

- The idea of the gene itself is a unifying concept of life
- We have considered a gene as:
  - A discrete unit of inheritance
  - A region of specific nucleotide sequence in a chromosome
  - A DNA sequence that codes for a specific polypeptide chain

- In summary, a gene can be defined as a region of DNA that can be expressed to produce a final functional product, either a polypeptide or an RNA molecule