



6.2 - Transcription: Synthesizing RNA from DNA

Pages 251-256 (McGraw-Hill Ryerson, 2011)



Subtopics

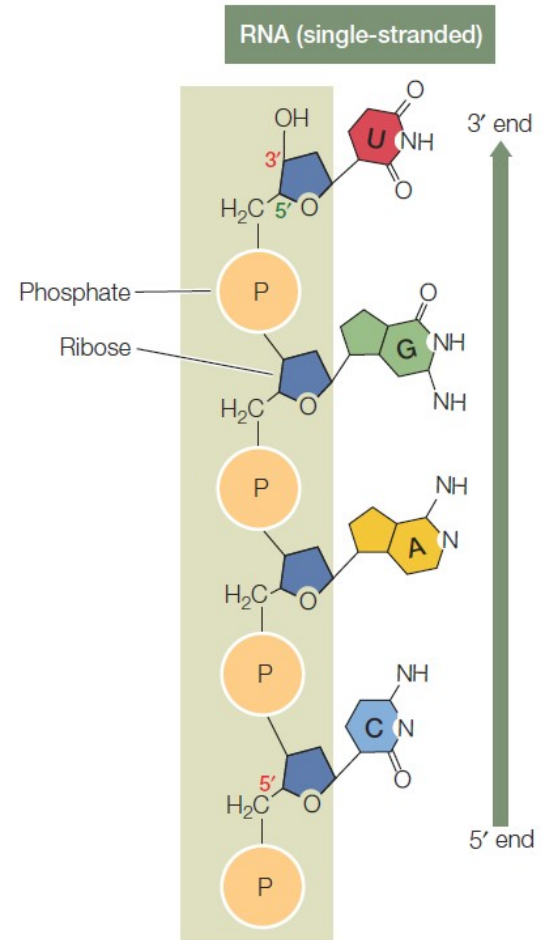
- Overview
- The Molecular Events of Transcription
 - Initiation
 - Elongation
 - Termination
- mRNA modifications in Eukaryotes

Overview

RNA - Ribonucleic acid

→ General Structure:

- ◆ **Phosphate** bonded to a **ribose sugar**
- ◆ Ribose sugar bonded to one of four nitrogenous bases
 - Adenine
 - Uracil
 - Guanine
 - Cytosine
- ◆ Single stranded



In RNA, the bases are attached to ribose. The bases in RNA are the purines adenine (A) and guanine (G) and the pyrimidines cytosine (C) and uracil (U).

Overview

Different types of

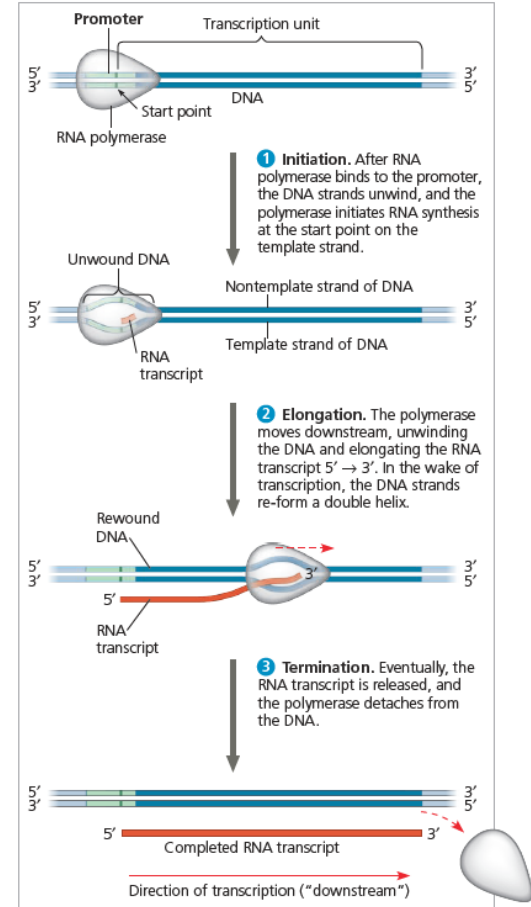
RNA	Function
Messenger RNA (mRNA)	The template for translation
Transfer RNA (tRNA)	Involved in translation of mRNA
Ribosomal RNA (rRNA)	
Small nuclear RNA (snRNA)	Involved in mRNA modification
Micro RNA (miRNA)	Involved in regulating gene expression
Small interfering RNA (siRNA)	
RNA in RNaseP	Enzyme that includes RNA
7S RNA	Protein destination targetting
Viral RNA	Found in viral genomes

The Molecular Events of Transcription

Goal: DNA → mRNA molecule

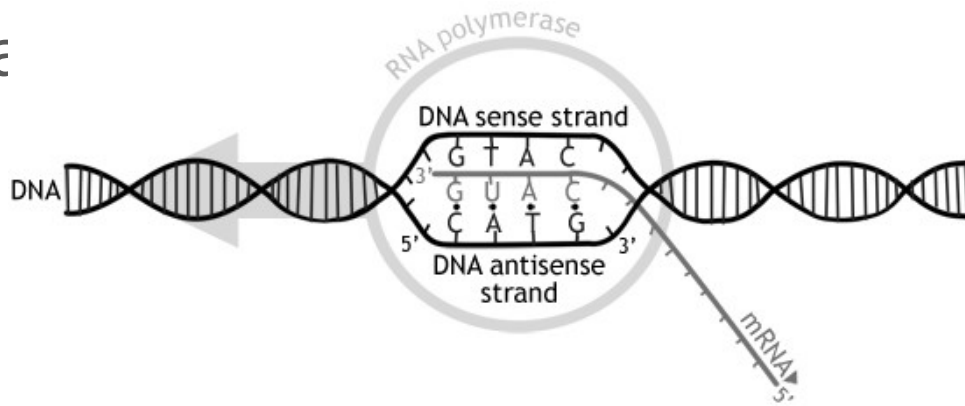
- Many similarities between prokaryotes and eukaryotes
- Differences exist in the added number of proteins involved and complexity found in eukaryotes

Figure 17.8 The stages of transcription: initiation, elongation, and termination. This general depiction of transcription applies to both bacteria and eukaryotes, but the details of termination differ, as described in the text. Also, in a bacterium, the RNA transcript is immediately usable as mRNA; in a eukaryote, the RNA transcript must first undergo processing.



Initiation

- Only one strand of the double-stranded DNA molecule is transcribed (sense strand or coding strand)
- The other strand is called anti-sense strand or non-coding strand
- Either can be the coding strand for different genes



The Molecular Events of Transcription

Initiation

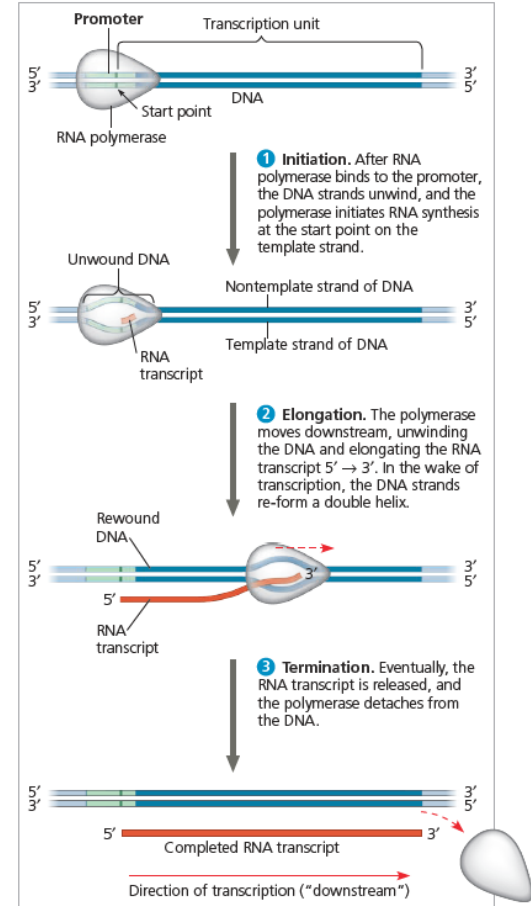
→ RNA polymerase

- ◆ The main enzyme that catalyzes the formation of RNA from a DNA template
- ◆ Binds to , unwinds and opens a section of the DNA double helix

→ Promoter region

- ◆ A sequence of nucleotides in DNA that indicates where the RNA polymerase complex should bind to initiate transcription

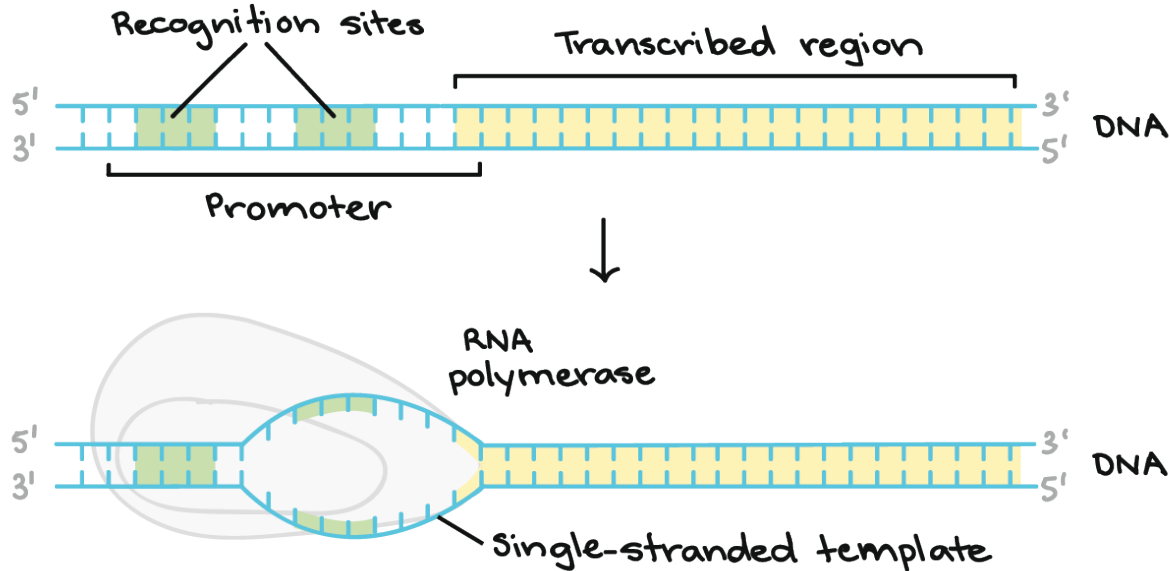
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The Molecular Events of Transcription

Initiation

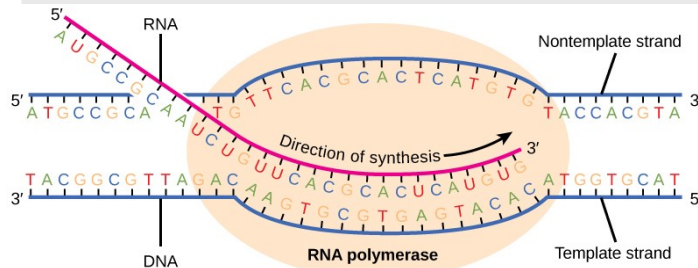
→ **RNA polymerase** binds to promoter regions



Elongation

- As RNA polymerase complex move along DNA, a second complex binds to promoter region. This means hundreds of copies of RNA molecules can be made from one gene at one time

RNA polymerase	DNA polymerase
-Synthesize at a faster speed	-Synthesize at a slower speed
-No proofreading (if error, result in error in one protein molecule at a time)	-Proofreading (if error, alter the genetic make up of an organism)



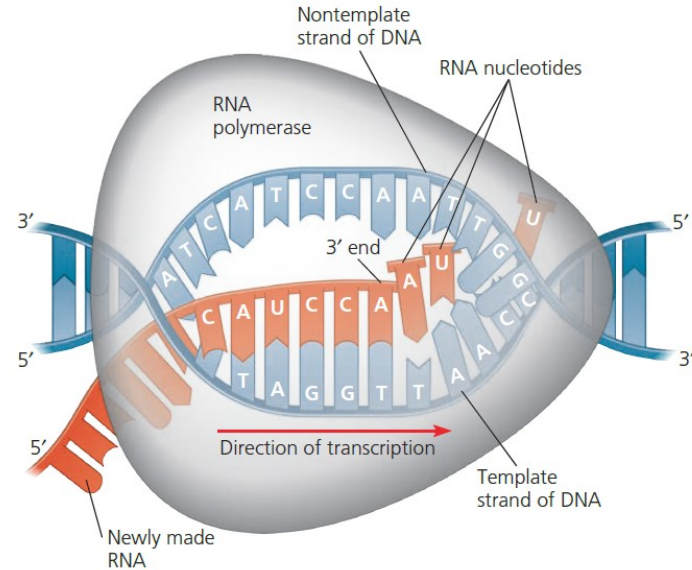
No lagging strand and no Okazaki fragments!

The Molecular Events of Transcription

Elongation

- The template strand is read (3' to 5') and the complementary strand is synthesized as an RNA molecule in the 5' to 3' direction
 - ◆ Nucleotides are added to the 3' - OH group of the previous nucleotide
- As soon as the RNA polymerase starts elongating, a new RNA polymerase can come in and start another mRNA

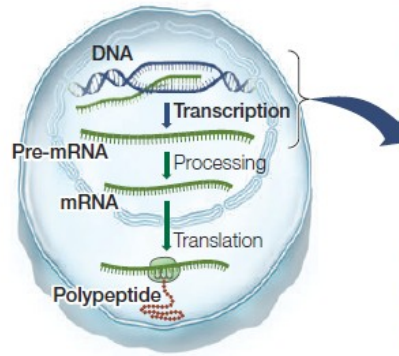
▼ **Figure 17.10 Transcription elongation.** RNA polymerase moves along the DNA template strand, joining complementary RNA nucleotides to the 3' end of the growing RNA transcript. Behind the polymerase, the new RNA peels away from the template strand, which re-forms a double helix with the nontemplate strand.



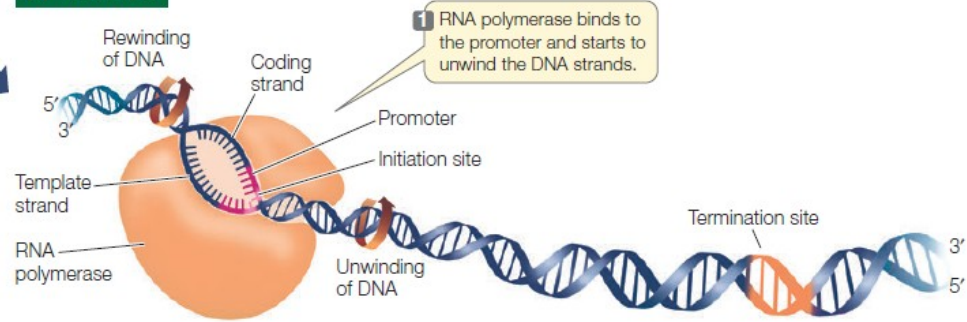
The Molecular Events of Transcription

Termination

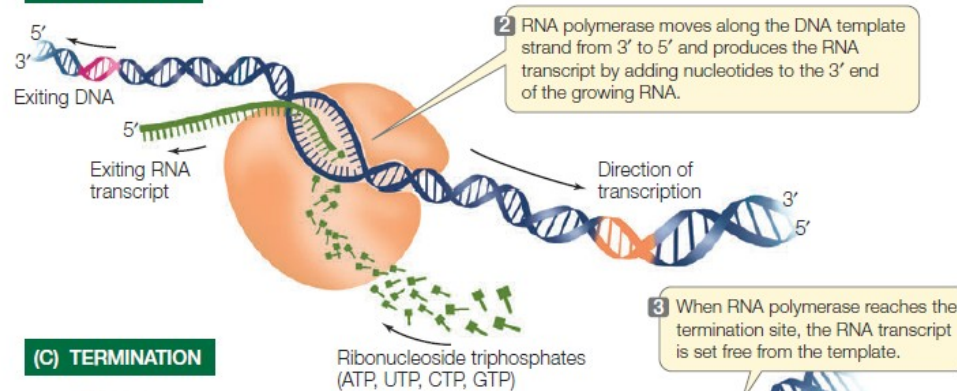
- A specific nucleotide sequence on the template DNA strand signals the termination of transcription
 - ◆ When RNA polymerase reaches this sequence it detaches from the DNA strand
 - ◆ The mRNA is released



(A) INITIATION



(B) ELONGATION



(C) TERMINATION

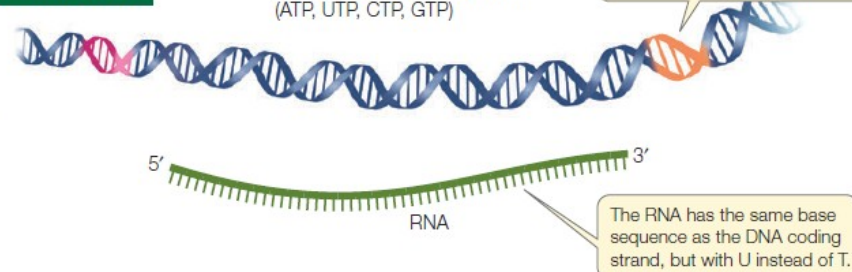


FIGURE 10.5 DNA Is Transcribed to Form RNA DNA is partially unwound by RNA polymerase so that one strand can serve as a template for RNA synthesis. The RNA transcript is formed and then peels away, allowing the DNA that has already been transcribed to rewind into a double helix.



Go to **ANIMATED TUTORIAL 10.1**

Transcription

Pol2e.com/at10.1

https://www.youtube.com/watch?v=oefAl2x2CQM&ab_channel=AmoebaSisters



Learning Check

Learning Check

- 7.** List three differences between DNA and RNA.
- 8.** How is RNA involved in protein synthesis?
- 9.** List and describe the three stages of transcription.
- 10.** Predict where mRNA is transported in the cell after transcription is finished.
- 11.** How do cells synthesize multiple strands of mRNA from one gene simultaneously? Why is this advantageous?
- 12.** Would errors in transcription be more or less damaging than errors in DNA replication? Explain your answer.

7. Answers could include the following: DNA is the genetic material that controls protein synthesis whereas RNA helps DNA and is involved in protein synthesis. DNA has the sugar called deoxyribose whereas RNA has ribose sugar. The bases in DNA are adenine, guanine, thymine, and cytosine; the bases in RNA include adenine, guanine, cytosine, and uracil. DNA is a double-stranded helix whereas RNA is single stranded without a helix.

8. Answers could include information referenced in **Table 6.3** on page 252 of the student textbook: mRNA is the template for translation, while tRNA and rRNA are involved in the translation of mRNA.

9. Initiation: Transcriptional machinery is assembled on the sense strand. RNA polymerase binds to the promoter region of the sense strand.

Elongation: RNA polymerase synthesizes a strand of mRNA that is complementary to the sense strand of DNA.

Termination: RNA polymerase detaches from the DNA strand when it reaches a stop signal. The mRNA strand is released and the DNA double helix re-forms.

Table 6.3 Different RNA Molecules and Their Functions

RNA	Function
Messenger RNA (mRNA)	the template for translation
Transfer RNA (tRNA)	involved in the translation of mRNA
Ribosomal RNA (rRNA)	involved in the translation of mRNA
Small nuclear RNA (snRNA)	involved in modification of mRNA molecules
Micro RNA (miRNA)	involved in regulating gene expression
Small interfering RNA (siRNA)	involved in regulating gene expression
RNA in RNaseP	RNaseP is an enzyme; the RNA is the part of the enzyme
7S RNA	involved in targeting proteins to particular regions in eukaryotic cells
Viral RNA	found in some viral genomes

10. mRNA would be transported from the nucleus to the cytoplasm for translation.
11. During the elongation phase of transcription, a second RNA polymerase complex can bind to the promoter region immediately after the previous RNA polymerase complex starts moving along the DNA. Therefore, multiple strands of mRNA can be synthesized from one gene at a time. This is advantageous for the cell since increased amounts of mRNA leads to more protein that can be produced in a given amount of time.
12. Errors in transcription would be less damaging than errors in DNA replication. An error in transcription would result in an error in one protein molecule, while an unrepaired error in DNA replication would cause a change in the genetic makeup of an organism.

mRNA Modifications in Eukaryotes

Precursor mRNA (pre mRNA) → mature mRNA

- In Prokaryotes, the transcribed mRNA can be used to create a protein right away - no modifications needed
- In Eukaryotes, modifications must occur before it is transported across the nuclear envelope

Modification steps:

1. 5' cap
2. 3' poly-A tail
3. Intron removal

mRNA Modifications in Eukaryotes

→ 5' cap

- ◆ Modified form of a G nucleotide; added to the 5' end of an mRNA

→ 3' poly-A tail

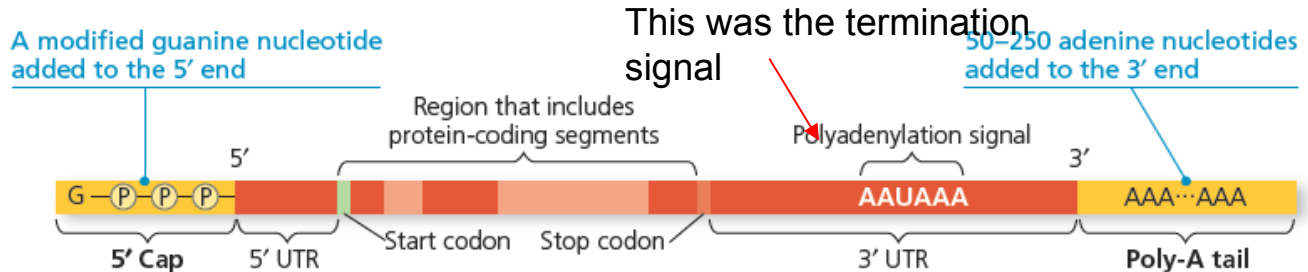
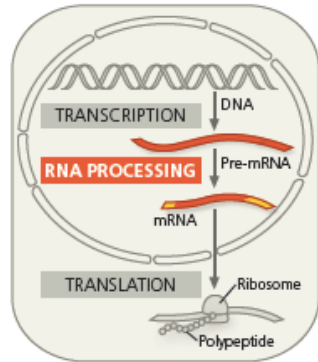
▲ A series of A nucleotides added to the 3' end of an mRNA

✓ Figure 17.11 RNA processing: addition of the 5' cap and poly-A tail.

Enzymes modify the two ends of a eukaryotic pre-mRNA molecule. The modified ends may promote the export of mRNA from the

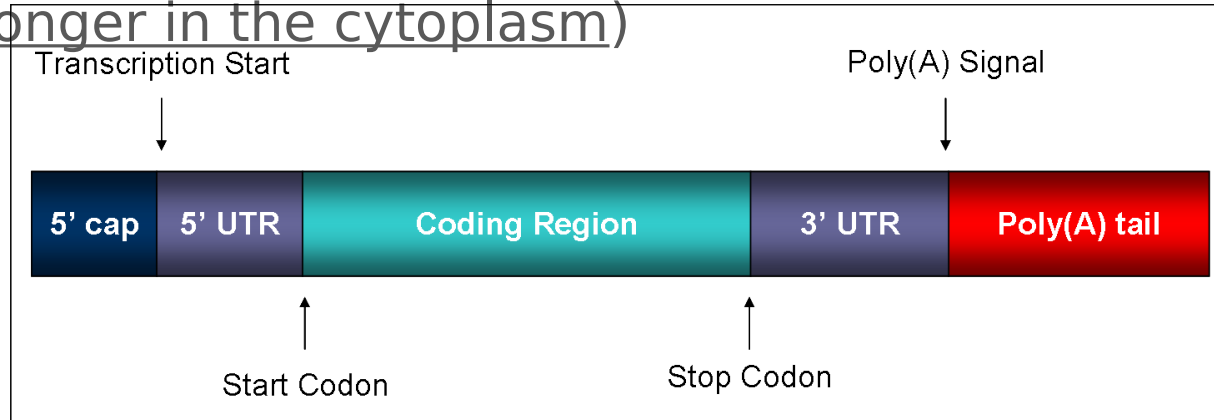
nucleus, and they help protect the mRNA from degradation. When the mRNA reaches the cytoplasm, the modified ends, in conjunction with certain cytoplasmic proteins, facilitate ribosome attachment. The 5' cap and poly-A

tail are not translated into protein, nor are the regions called the 5' untranslated region (5' UTR) and 3' untranslated region (3' UTR). The pink segments are introns, which will be described shortly (see Figure 17.12).



mRNA modification

- **Addition of 5' cap:** involves covalent linkage of a modified G nucleotide (To let the mRNA be recognizable by the protein synthesis machinery)
- **Addition of 3' poly-A tail:** involves covalent linkage of a series of A nucleotides (To make the mRNA more stable and exist longer in the cytoplasm)



mRNA Modifications in Eukaryotes

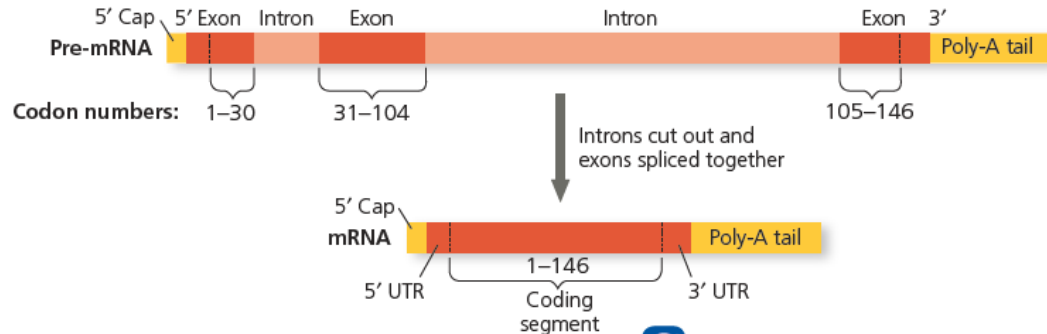
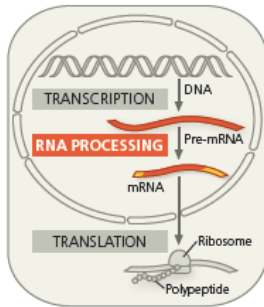
➤ Intron Removal

- ◆ **Introns** - non coding regions; **exons** - coding regions
- ◆ Exons get joined together
- ◆ **Splicing** - in mRNA, a process of excising out the introns and combining the exons

✓ **Figure 17.12 RNA processing: RNA splicing.** The RNA molecule shown here codes for β -globin, one of the polypeptides of hemoglobin. The numbers under the RNA refer to codons; β -globin is 146 amino acids

long. The β -globin gene and its pre-mRNA transcript have three exons, corresponding to sequences that will leave the nucleus as mRNA. (The 5' UTR and 3' UTR are parts of exons because they are included in the mRNA;

however, they do not code for protein.) During RNA processing, the introns are cut out and the exons spliced together. In many genes, the introns are much longer than the exons.



DRAW IT ➤ On the mRNA, indicate the sites of the start and stop codons.



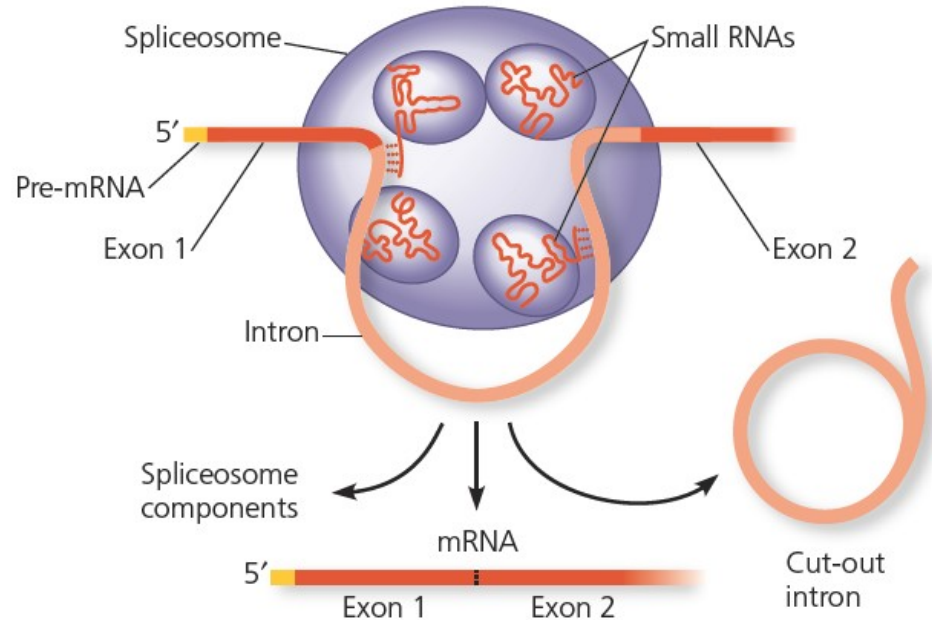
BioFlix® Animation: RNA Processing

mRNA Modifications in Eukaryotes

➤ Spliceosome

- ◆ Comprised of snRNA & proteins (snRNPs) and other proteins in a complex
- ◆ Can join all exons, or certain exons (*alternative splicing*) - can lead to different versions of the

✓ **Figure 17.13 A spliceosome splicing a pre-mRNA.** The diagram shows a portion of a pre-mRNA transcript, with an intron (pink) flanked by two exons (red). Small RNAs within the spliceosome base-pair with nucleotides at specific sites along the intron. Next, small spliceosome RNAs catalyze cutting of the pre-mRNA and the splicing together of the exons, releasing the intron for rapid degradation.



[HHMI Animation](#)

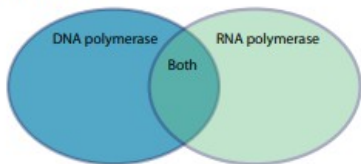
[Hillis Animation](#)



2, 3, 4, 5, 6, 7, 8, 9, 10, 11, 12, 13

Topic Review Question

2. **C** Use a flowchart to summarize the three stages of transcription.
3. **K/U** How does transcription differ from DNA replication?
4. **K/U** Distinguish between the following terms: sense strand and antisense strand.
5. **K/U** What is a promoter region? Why are promoter regions necessary for transcription?
6. **K/U** Copy and complete the Venn diagram below to organize information about DNA polymerase and RNA polymerase.



7. **T/I** The following DNA sequence is a fragment from the antisense strand that codes for a protein involved in cell cycle regulation:
3' - ATACTAGTG - 5'
 - a. Write the complementary sense strand.
 - b. Which strand will RNA polymerase use in transcription?
 - c. What is the nucleotide sequence of the mRNA strand transcribed?
 - d. What is the amino acid sequence of the polypeptide produced from the mRNA strand?

8. **A** As you have learned, gene expression involves transcribing information from only one strand of the DNA molecule. What could be some of the biological advantages of double-stranded DNA?
9. **K/U** In prokaryotes, protein synthesis can occur at the same time as transcription. Why is this not the case for eukaryotes?
10. **C** Below is a graphical representation of eukaryotic precursor mRNA.



- a. Draw the corresponding mature mRNA.
 - b. Label and explain each modification.
11. **A** One of the goals of the Human Genome Project was to identify the number of genes present in the human genome. Before the project, it was estimated that the human genome had 100 000 genes, since it was thought that humans produce approximately 100 000 proteins. The project has since revealed that the human genome contains approximately 25 000 genes, despite estimates for proteins remaining at 100 000–150 000. Use an illustration and a brief paragraph to explain how this is possible.
12. **T/I** How does alternative splicing provide evidence that the one-gene/one-polypeptide hypothesis is not an accurate description of the relationship between genes and proteins?
13. **T/I** Introns are non-coding regions in eukaryotic genes.
 - a) Why do introns exist in eukaryotic genes?
 - b) How does the absence of introns in prokaryotic genes affect prokaryotic gene expression?



References

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