

Chapter 7 Course Companion

From DNA to mRNA: Transcribing the Code of Life

Use this course guide as you work through this chapter in Achieve. As you read, pay close attention to the questions in this guide and answer them as you work through the notes. Also pay close attention to the terms that are underlined: these are key terms that you should know the definitions of and be able to apply in new situations. Be sure to complete the assessment items throughout the assignments to give you practice using this information.

Chapter Learning Objectives

- a. Compare and contrast bacterial and eukaryotic transcription.
- b. Describe the process of transcription.
- c. Produce an mRNA transcript from a DNA template.

Chapter Outline:

Module 7.1 An Overview of Transcription

- Lesson 1. Setting the Stage for Transcription and Translation
- Lesson 2. RNA Polymerase Binding and Transcription Bubble Formation
- Lesson 3. mRNA Polymerization
- Lesson 4. The mRNA Product

Module 7.2 Transcription in Bacteria

- Lesson 1. Transcription Initiation
- Lesson 2. Open Complex Formation
- Lesson 3. Transcription Elongation
- Lesson 4. Intrinsic Termination
- Lesson 5. Rho-Dependent Termination

Module 7.3 Differences Between Bacterial, Archaeal, and Eukaryotic Transcription

- Lesson 1. RNA Polymerases
- Lesson 2. Initiation Factors
- Lesson 3. DNA Packaging
- Lesson 4. Polycistronic mRNA and Intron Splicing
- Lesson 5. Termination and mRNA Processing

Module 7.4 Transcription in Eukaryotes

- Lesson 1. Promoters Recruit General Transcription Factors
- Lesson 2. TFIID, TFIIA, and TFIIB
- Lesson 3. RNA Polymerase II, TFIIF, TFIIE, TFIIH, and Mediator
- Lesson 4. Open Complex Formation and Phosphorylation of the C-terminal Tail of RNA Polymerase II
- Lesson 5. Polymerase Escape and the NELF/DSIF Checkpoint
- Lesson 6. Releasing Checkpoint Inhibition

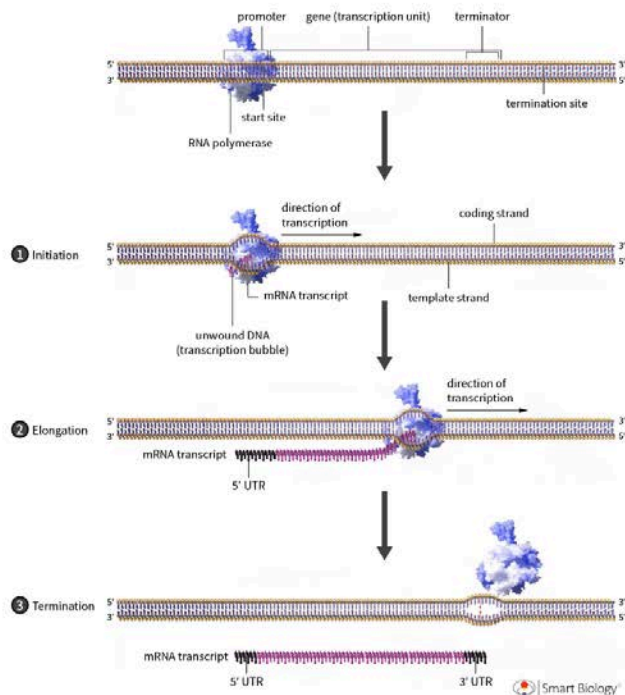
THE HUMAN CONNECTION Drug Inhibitors of RNA Polymerase II

Module 7.1 An Overview of Transcription

Module Learning Objectives:

- Compare the basic procedure of transcriptional initiation, elongation, and termination that are common to both prokaryotes and eukaryotes.
- Correctly transcribe (and later translate) from a given DNA template.
- Describe the structural and functional differences between DNA and RNA.
- Summarize the general structure of a gene, including control regions such as promoter(s).
- Distinguish between the coding strand, noncoding strand, and template strand of DNA during transcription.

In this module, we set the stage for the rest of the chapter by learning about transcription at a conceptual level. We will look at the three stages of transcription: initiation, elongation, and termination. The topics covered in this module apply to transcription in bacteria, archaea, and eukaryotes.



An overview of transcription. Transcription is the process of producing an mRNA transcript that is complementary to a DNA template. It involves three stages—initiation, elongation, and termination—and is catalyzed by the enzyme RNA polymerase, which moves along the gene from its promoter to its terminator. (1) **Initiation.** Once bound to the promoter, RNA polymerase separates a portion of double-stranded DNA into two single strands to form a transcription bubble, thereby exposing the nucleotide bases on each strand. RNA polymerase can then polymerize RNA nucleotides beginning at the start site on the template strand. (2) **Elongation.** RNA polymerase can travel along the DNA template strand only in the 3' to 5' direction, which means that it can polymerize complementary RNA nucleotides only in the 5' to 3' direction. As RNA polymerase moves along the template strand, the transcription bubble moves like a wave, opening into two single strands in front of the polymerase and closing back into double-stranded DNA behind. (3) **Termination.** Transcription termination occurs when RNA polymerase encounters a stop sequence, or terminator sequence, at which point the mRNA is released and the polymerase dissociates from the DNA. In prokaryotes, the mRNA transcript can be translated immediately, while in eukaryotes it must first undergo processing.

Module Lessons:

Lesson 1. Setting the Stage for Transcription and Translation

Lesson 2. RNA Polymerase Binding and Transcription Bubble Formation

Lesson 3. mRNA Polymerization

Lesson 4. The mRNA Product

Study Questions:

Summarize the process of bacterial transcription initiation in your own words. See Figure 7.8 and use the following terms in your summary: sigma factor, promoter element.

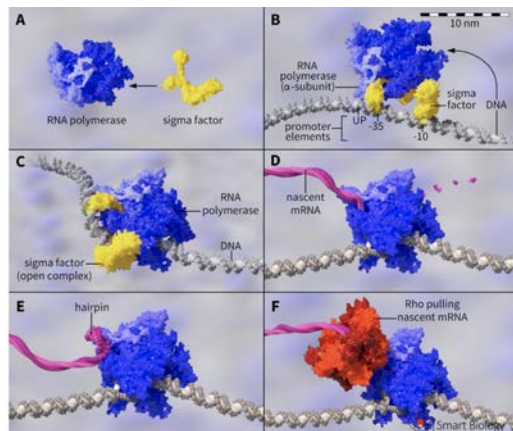
Explain the significance of the transition from the closed complex to the open complex. What triggers this change to occur? See Figure 7.9.

Module 7.2 Transcription in Bacteria

Module Objectives:

- Describe the process of bacterial initiation, elongation, and termination of transcription.
- Distinguish between the two mechanisms of bacterial termination of transcription.
- Explain how the beginning of a gene is recognized by the transcriptional machinery in bacteria

Now that we've covered the process of transcription at the conceptual level, we're going to learn how it actually occurs in cells. In this module, we'll learn how transcription initiation, elongation, and termination occur in bacteria because the bacterial transcriptional system is the most basic of the three domains of life. Learning about bacterial transcription will therefore serve as a foundation when we examine eukaryotic transcription in Module 7.4.



Modules Lessons

Lesson 1. Transcription Initiation

Lesson 2. Open Complex Formation

Lesson 3. Transcription Elongation

Lesson 4. Intrinsic Termination

Lesson 5. Rho-Dependent Termination

Study Questions:

Summarize the process of bacterial transcription initiation in your own words. See Figure 7.8 and use the following terms in your summary: sigma factor, promoter element.

What is the major difference between intrinsic termination and Rho-dependent termination? Briefly describe the role of the terminator sequence in these processes. See Figure 7.15.

Module 7.3 Differences Between Bacterial, Archaeal, and Eukaryotic Transcription

Module 7.3 Objectives:

- List and briefly describe the eight main differences between transcription in prokaryotes and eukaryotes.
- Describe the differences between mRNA made by bacteria and eukaryotes.
- Explain the role of DNA packaging as chromatin in gene activation.
- Briefly summarize the differences between bacterial and eukaryotic RNA polymerases.

Module Lessons

Lesson 1. RNA Polymerases

Lesson 2. Initiation Factors

Lesson 3. DNA Packaging

Lesson 4. Polycistronic mRNA and Intron Splicing

Lesson 5. Termination and mRNA Processing

Study Questions:

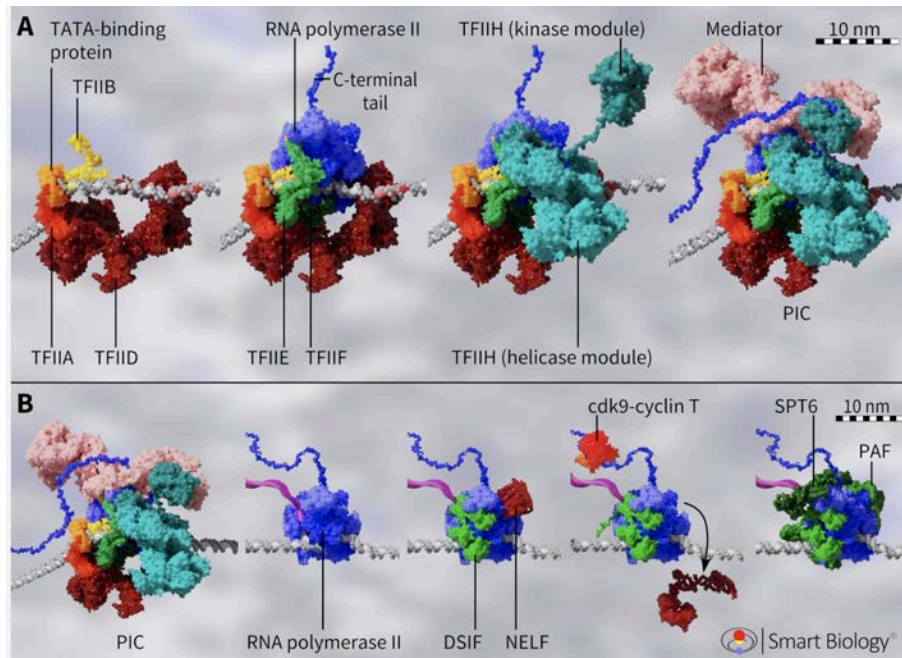
How do the relationships between sigma factor, transcription factor B (TFB), and transcription initiation factor II B (TFIIB) provide evidence on the evolutionary histories between bacteria, archaea, and eukaryotes? See Figure 7.23.

How does mRNA processing differ between bacteria, archaea, and eukaryotes? See Figure 7.27.

Module 7.4 | Transcription in Eukaryotes

Module 7.4 Objectives:

- Describe the process of initiation for eukaryotic transcription.
- Sketch and describe the gene structure in the promoter region of a eukaryotic gene.



Module Lessons

Lesson 1. Promoters Recruit General Transcription Factors

Lesson 2. TFIID, TFIIA, and TFIIB

Lesson 3. RNA Polymerase II, TFIIF, TFIIE, TFIIH, and Mediator

Lesson 4. Open Complex Formation and Phosphorylation of the C-terminal Tail of RNA Polymerase II

Lesson 5. Polymerase Escape and the NELF/DSIF Checkpoint

Lesson 6. Releasing Checkpoint Inhibition

Study Questions

Make a diagram or sketch of the six different promoter elements named above in how they are aligned within a promoter. See Figure 7.30.

Explain how transcription factor II D (TFIID), the TATA-binding subunit/protein of TFIID, transcription factor II A (TFIIA), and transcription factor II B (TFIIB) together bind to the promoter and to each other to form the PIC. See Figures 7.31 and 7.32.

Explain how transcription factor II H (TFIIH) contributes to the transition from the closed to the open PIC complex formation. See Figure 7.35.

Explain how negative elongation factor (NELF) and DRB sensitivity-inducing factor (DSIF) act as negative regulators of transcription. See Figure 7.37.

Explain how elongation factors PAF and SPT6 bind to RNA polymerase II to allow transcription elongation to continue. See Figures 7.38 and 7.39.

Chapter Key Terms

Transcription initiation factor

Promoter

Upstream

Downstream

dsDNA

ssDNA

Transcription bubble

Template strand

RNA transcript

Coding strand

DNA-RNA hybrid (or RNA-DNA hybrid)

5' untranslated region (5' UTR)

3' untranslated region (3' UTR)

Sigma factor

Element (promoter element)

Closed complex

Open complex

Terminator sequence (or termination stop site)

Intrinsic termination (or Rho-independent termination)

Rho-dependent termination

RNA hairpin

Helicase

Rho utilization site (RUT)

Homologous proteins

Archaeal transcription factor B (TFB)

Transcription initiation factor II B (TFIIB)

Monocistronic

Polycistronic

Exon

Intron

TATA box element

Transcription factor II B (TFIIB)-recognition element (BRE)

Initiator (INR)

Motif ten element (MTE)

Downstream core promoter element (DPE)

Pre-initiation complex (PIC).

Transcription factor II D (TFIID)

TATA-binding protein

Transcription factor II A (TFIIA)

Transcription factor II F (TFIIF)

Transcription factor II E (TFIIE)

Transcription factor II H (TFIIH)

Mediator

Polymerase escape

Negative elongation factor (NELF)

DRB sensitivity-inducing factor (DSIF)

Cyclin-dependent kinase 9-cyclin T (Cdk9-cyclin T)

PAF

SPT6