13.1 RNA

Key Questions

- ***How does RNA differ from DNA?***
- ***How does the cell make RNA?***

Vocabulary

RNA
messenger RNA
ribosomal RNA
transfer RNA
transcription
RNA polymerase
promoter
intron
exon

Taking Notes

Preview Visuals Before you read, look at **Figure 13–3.** Write a prediction of how you think a cell makes RNA based on the figure. Then as you read, take notes on how a cell makes RNA. After you read, compare your notes and your prediction.

THINK ABOUT IT We know that DNA is the genetic material, and we know that the sequence of nucleotide bases in its strands must carry some sort of code. For that code to work, the cell must be able to understand it. What exactly do those bases code for? Where is the cell's decoding system?

The Role of RNA

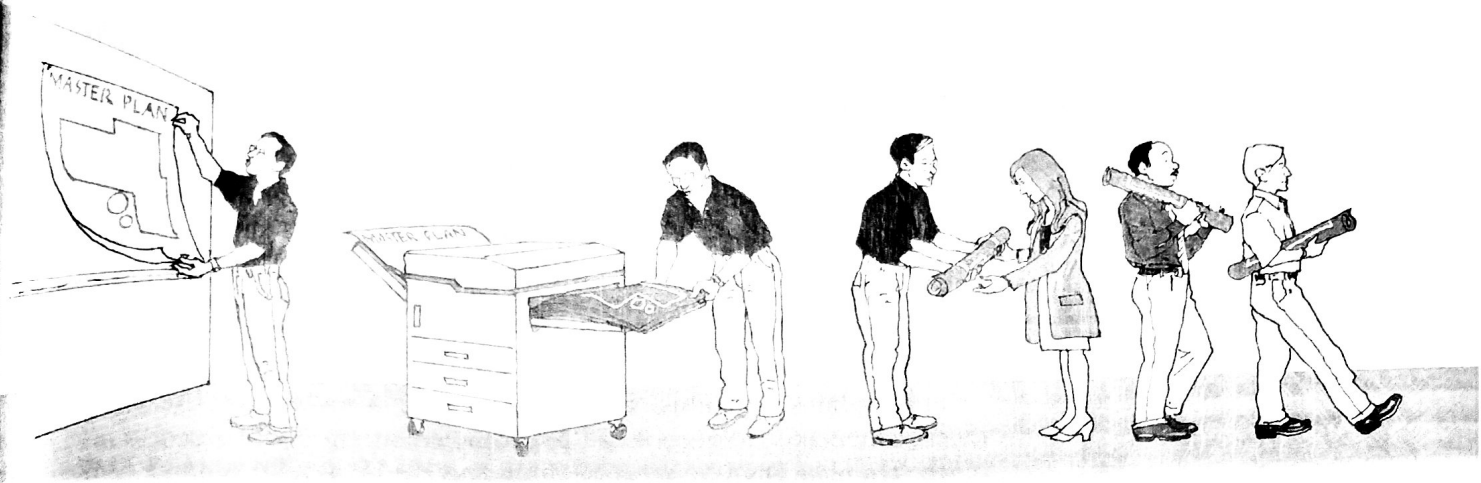
How does RNA differ from DNA?

When Watson and Crick solved the double-helix structure of DNA, they understood right away how DNA could be copied. All a cell had to do was to separate the two strands and then use base pairing to make a new complementary strand for each. But the structure of DNA by itself did not explain how a gene actually works. That question required a great deal more research. The answer came from the discovery that another nucleic acid—ribonucleic acid, or RNA—was involved in putting the genetic code into action. **RNA,** like DNA, is a nucleic acid that consists of a long chain of nucleotides.

In a general way, genes contain coded DNA instructions that tell cells how to build proteins. The first step in decoding these genetic instructions is to copy part of the base sequence from DNA into RNA. RNA then uses these instructions to direct the production of proteins, which help to determine an organisms's characteristics.

Comparing RNA and DNA Remember that each nucleotide in DNA is made up of a 5-carbon sugar, a phosphate group, and a nitrogenous base. This is true for RNA as well. **But there are three important differences between RNA and DNA: (1) the sugar in RNA is ribose instead of deoxyribose, (2) RNA is generally single-stranded and not double-stranded, and (3) RNA contains uracil in place of thymine.** These chemical differences make it easy for enzymes in the cell to tell DNA and RNA apart.

You can compare the different roles played by DNA and RNA molecules in directing the production of proteins to the two type of plans builders use. A master plan has all the information needed to construct a building. But builders never bring a valuable master plan to the job site, where it might be damaged or lost. Instead, as **Figure 13-1** shows, they work from blueprints, inexpensive, disposable copies of the master plan.



VISUAL ANALOGY

MASTER PLANS AND BLUEPRINTS

FIGURE 13–1 The different roles of DNA and RNA molecules in directing protein synthesis can be compared to the two types of plans used by builders: master plans and blueprints.

Similarly, the cell uses the vital DNA "master plan" to prepare RNA "blueprints." The DNA molecule stays safely in the cell's nucleus, while RNA molecules go to the protein-building sites in the cytoplasm—the ribosomes.

Functions of RNA You can think of an RNA molecule as a disposable copy of a segment of DNA, a working facsimile of a single gene. RNA has many functions, but most RNA molecules are involved in just one job—protein synthesis. RNA controls the assembly of amino acids into proteins. Like workers in a factory, each type of RNA molecule specializes in a different aspect of this job. **Figure 13–2** shows the three main types of RNA: messenger RNA, ribosomal RNA, and transfer RNA.

► ***Messenger RNA*** Most genes contain instructions for assembling amino acids into proteins. The RNA molecules that carry copies of these instructions are known as **messenger RNA** (mRNA). They carry information from DNA to other parts of the cell.

► ***Ribosomal RNA*** Proteins are assembled on ribosomes, small organelles composed of two subunits. These subunits are made up of several **ribosomal RNA** (rRNA) molecules and as many as 80 different proteins.

► ***Transfer RNA*** When a protein is built, a third type of RNA molecule transfers each amino acid to the ribosome as it is specified by the coded messages in mRNA. These molecules are known as **transfer RNA** (tRNA).

Messenger RNA
Carries instructions for polypeptide synthesis from nucleus to ribosomes in the cytoplasm.

Ribosomal RNA
Forms an important part of both subunits of the ribosome.

Transfer RNA
Carries amino acids to the ribosome and matches them to the coded mRNA message.

FIGURE 13–2 Types of RNA The three main types of RNA are messenger RNA, ribosomal RNA, and transfer RNA.

RNA Synthesis

How does the cell make RNA?

Cells invest large amounts of raw material and energy into making RNA molecules. Understanding how cells do this is essential to understanding how genes work.

Transcription Most of the work of making RNA takes place during **transcription. In transcription, segments of DNA serve as templates to produce complementary RNA molecules.** The base sequences of the transcribed RNA complement the base sequences of the template DNA.

In prokaryotes, RNA synthesis and protein synthesis take place in the cytoplasm. In eukaryotes, RNA is produced in the cell's nucleus and then moves to the cytoplasm to play a role in the production of protein. Our focus here is on transcription in eukaryotic cells.

Transcription requires an enzyme, known as **RNA polymerase,** that is similar to DNA polymerase. RNA polymerase binds to DNA during transcription and separates the DNA strands. It then uses one strand of DNA as a template from which to assemble nucleotides into a complementary strand of RNA, as shown in **Figure 13–3.** The ability to copy a single DNA sequence into RNA makes it possible for a single gene to produce hundreds or even thousands of RNA molecules.

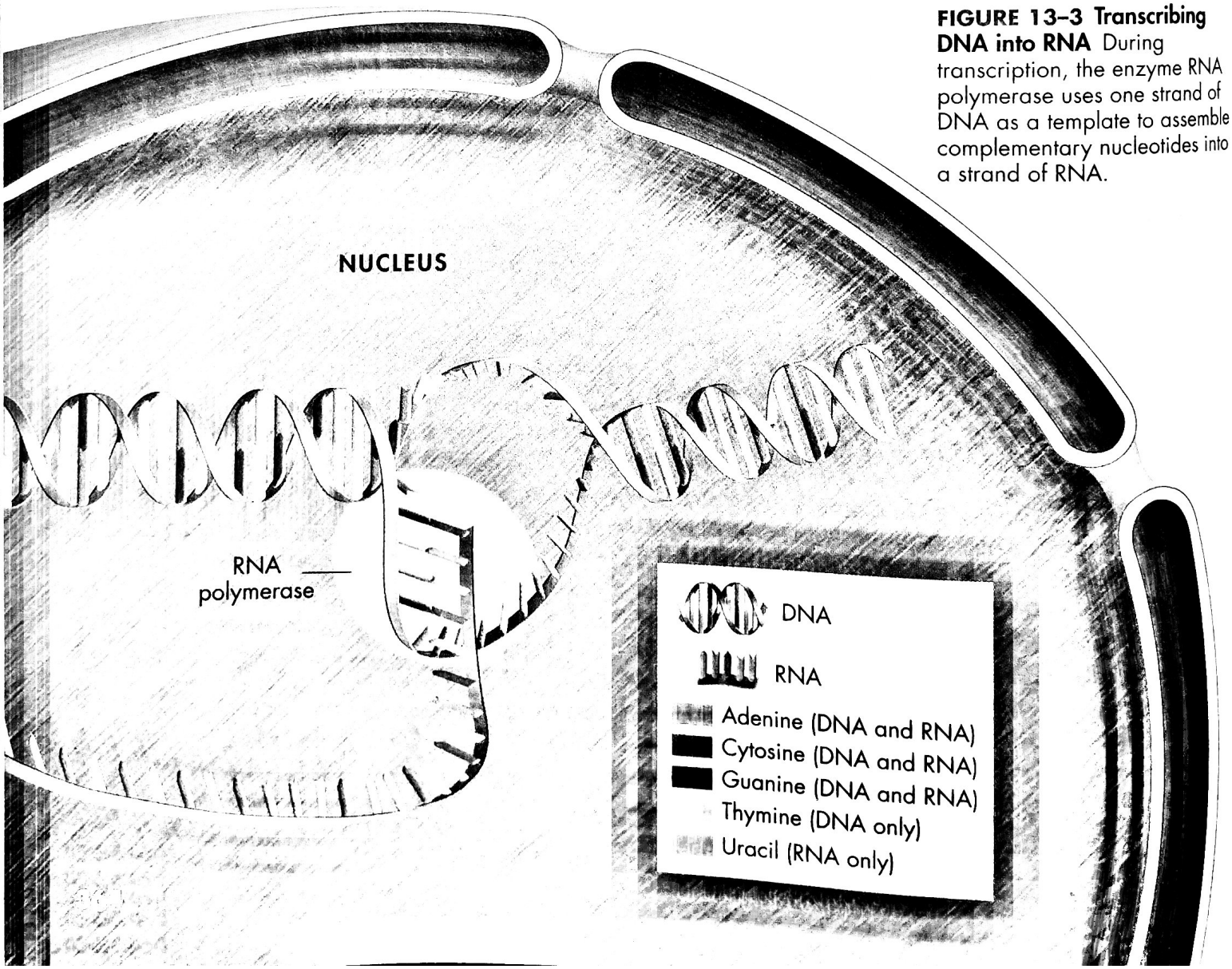


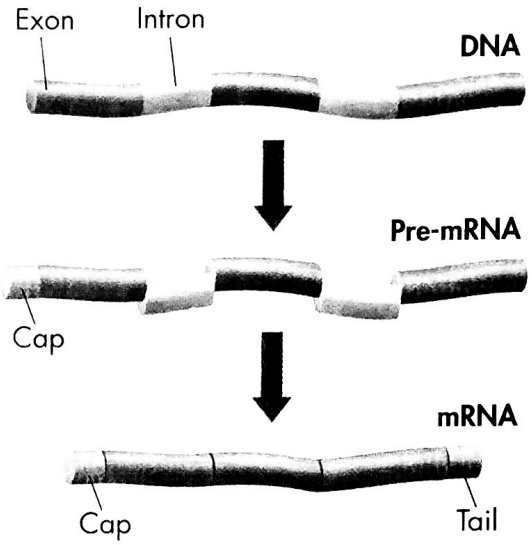
FIGURE 13–3 Transcribing DNA into RNA During transcription, the enzyme RNA polymerase uses one strand of DNA as a template to assemble complementary nucleotides into a strand of RNA.

Promoters How does RNA polymerase know where to start and stop making a strand of RNA? The answer is that RNA polymerase doesn't bind to DNA just anywhere. The enzyme binds only to **promoters,** regions of DNA that have specific base sequences. Promoters are signals in the DNA molecule that show RNA polymerase exactly where to begin making RNA. Similar signals in DNA cause transcription to stop when a new RNA molecule is completed.

RNA Editing Like a writer's first draft, RNA molecules sometimes require a bit of editing before they are ready to be read. These pre-mRNA molecules have bits and pieces cut out of them before they can go into action. The portions that are cut out and discarded are called **introns.** In eukaryotes, introns are taken out of pre-mRNA molecules while they are still in the nucleus. The remaining pieces, known as **exons,** are then spliced back together to form the final mRNA, as shown in **Figure 13–4.**

Why do cells use energy to make a large RNA molecule and then throw parts of that molecule away? That's a good question, and biologists still don't have a complete answer. Some pre-mRNA molecules may be cut and spliced in different ways in different tissues, making it possible for a single gene to produce several different forms of RNA. Introns and exons may also play a role in evolution, making it possible for very small changes in DNA sequences to have dramatic effects on how genes affect cellular function.

FIGURE 13–4 Introns and Exons Before many mRNA molecules can be read, sections called introns are "edited out." The remaining pieces, called exons, are spliced together. Then, an RNA cap and tail are added to form the final mRNA molecule.



13.1 Assessment

Review Key Concepts

1. a. Review Describe three main differences between RNA and DNA.

b. Explain List the three main types of RNA, and explain what they do.

c. Infer Why is it important for a single gene to be able to produce hundreds or thousands of the same RNA molecules?

2. a. Review Describe what happens during transcription.

b. Predict What do you think would happen if introns were not removed from pre-mRNA?

WRITE ABOUT SCIENCE

Creative Writing

3. An RNA molecule is looking for a job in a protein synthesis factory. It asks you to write its résumé. This RNA molecule is not yet specialized and could, with some structural changes, function as mRNA, rRNA, or tRNA. Write a résumé for this molecule that reflects the capabilities of each type of RNA.