8. The reading of code in pairs of nucleotides is insufficient since only 16 different combinations ($4^2$) of the four nitrogenous bases can be made. Given that there are 20 amino acids, 16 different combinations would not suffice.
9. The start codon (AUG) signals to the ribosome that translation should commence at this point, while the stop codons (UAA, UAG, UGA) act as signals to the ribosomes to cease translation.
10. CCUAGUCCAGGUCCGUUAAAUCGUACGGGGUU
11. DNA sequence divided into codons
    5'–GGC-AUG-GGA-CAU-UAU-UUU-GCC-CGU-UGU-GGU-GGG-GCG-UGA–3'
    The start codon is the second codon, AUG; therefore, translation into protein commences with the amino acid methionine.
    Translation results in the following protein:
    Met-Gly-His-Tyr-Phe-Ala-Arg-Cys-Gly-Gly-Ala
    The last codon, UGA, is a stop codon.

### Applying Inquiry Skills

12. $4^4 = 256$, therefore the codons must comprise a minimum four ribonucleotides each. A total of 254 different amino acids could be coded for, assuming that there is one start codon and one stop codon.
13.(a) Since there are five amino acids found in this polypeptide, there must be at least five codons. Since each codon consists of three nucleotides, 15 ($5 \times 3$) nucleotides would be required to code for this peptide sequence.

### Making Connections

14. Student answers will vary. Some points that could be made are as follows. A strong piece of evidence that supports the theory of evolution is the relationship that different organisms share with respect to their DNA. The more closely related two species are, the less variation there is between their DNA. Since the same code is used by all life, it indicates that all species at some point started off more or less from one origin. If a different code were used for each species to build proteins, this would indicate that many origins of life existed, negating the theory of evolution. The biotechnology industry would also be affected if a different code were used by each species. During the process of genetic engineering, if a gene that coded for a specific protein were excised and placed into foreign DNA, it would now code for a different protein. The different protein would not act in the same manner in the new organism as it did in the parent organism.

## 5.3 TRANSCRIPTION

### Case Study: Human Immunodeficiency Virus

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### Understanding Concepts

1. No, HIV cannot attach itself to a muscle or a skin cell. HIV's antigens are not complementary to the binding sites (receptors) of skin cells and muscle cells (Figure 6, p. 245 in the Student Text).
2. You cannot obtain AIDS through shaking hands, because for the AIDS virus to be transmitted, there must be contact between two individuals via body fluids. This type of contact includes sexual contact, blood transfusions, or from mother to child during pregnancy. There is no exchange of bodily fluids through shaking hands; hence, AIDS cannot be transmitted in this manner. The antigens on HIV are not complementary to the receptor sites on skin cells; therefore, HIV cannot bind to skin cells.
3. Reverse transcriptase uses RNA as a template and builds a complementary DNA strand, thereby transcribing RNA into DNA. Reverse transcriptase is an appropriate name for the enzyme, given that conventional transcription of genetic material is in the direction of DNA to RNA. In this case, RNA is transcribed into DNA, meriting it the label of reverse transcription.
4. If a helper T cell divides and viral DNA has been incorporated into the cell's genome, it will also be replicated and be present in both of the daughter cells.
5. HIV can stay dormant for many years before symptoms are exhibited in its carrier, therefore, an individual can be infected with HIV but not necessarily show any symptoms.
6. People who are infected with HIV usually die of another infection because HIV attacks helper T cells, which are part of a human's immune system. Helper T cells act as guards against invading pathogens. Since HIV destroys helper T cells, the body cannot launch an immune response to secondary infections such as pneumonia. Therefore, a person infected with HIV is susceptible to infection.
7. Severe combined immunodeficiency (SCID) is a genetic disease. SCID has three major causes: (1) the helper T cells are absent or functioning poorly, (2) the thymus gland is absent or functions poorly, or (3) the bone marrow stem cells from which the mature T cells develop are defective or absent. In the absence of T cells, the immune system cannot function normally. The thymus gland is the organ in which immature cells from the bone marrow mature and "learn" how to become helper T cells, suppressor T cells, or killer T cells. If the thymus is not working properly, no mature T cells are

 

produced. Finally, the original source of the T cells may be defective. The mature T cells are derived from very immature cells of the bone marrow called stem cells. In some forms of SCID, bone marrow stem cells are missing. SCID differs from AIDS in that it is a genetic disease, whereas AIDS is viral based. SCID has numerous origins, whereas AIDS is solely caused by infection from HIV.

8. Antibiotics and other drugs are specifically designed to target a specific virus. The drugs must recognize the virus to be effective. Drugs recognize viruses by the protein particles that they carry on their outer membrane. If a virus mutates, it is possible that the protein found on its outer membrane will be affected and change shape. If protein conformation changes, the drug may no longer be able to recognize the virus and therefore will become ineffective.
9. Inquiring about a person's travel before their blood is accepted at a blood bank is a preventative measure. In some parts of the world there, is a greater chance of becoming infected with a specific virus as compared with other parts of the world. Canadian Blood Services screens its donors, since people may be unaware that they are carriers of the virus.
10. HIV cannot be transmitted through food or beverages. Viruses need to infect a host cell to survive. When a virus gains entry to a host cell, it uses the cell's biochemical machinery to propagate itself. A virus must come into contact with a bodily fluid to have access to human cells. Food and beverages prepared by an individual who is HIV positive are not vehicles of HIV transmission, given that food consists of dead cells and beverages are not cell based. Therefore, food and beverages cannot harbour the HIV virus.

### Making Connections

11. Student answers will vary. Medical professionals wear gloves, facemasks, and other protective clothing to keep them from being infected with HIV and any other virus. Hospitals and other care facilities are careful about properly disposing all sharp instruments, such as needles and blades, as toxic waste. Instruments are autoclaved, sterilized using high-pressure steam, to kill any viruses.
12. Student answers will vary. Some possible ways that the spread of AIDS can be prevented is through education, the wearing of condoms during sexual intercourse, and needle exchange programs for drug users.
13. The AIDS test works by screening the patient for antibodies produced against the virus by the immune system. If a person has just been recently infected with HIV, the test may not detect the virus since the concentration of antibodies in the body is small. Only when enough antibodies have been produced by the immune system will the virus be detected.

## Section 5.3 Questions

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### Understanding Concepts

1. RNA polymerase plays many roles in the process of transcription. It recognizes the promoter region upstream of a gene to be transcribed and binds to this site. Binding to the promoter region results in DNA's double helix opening up. Once bound to the DNA template strand, RNA polymerase starts to build the mRNA complementary strand using ribonucleotides. Finally, RNA polymerase recognizes the termination sequence that signals the end of a gene and ceases transcription. Poly-A polymerase plays a role in the post-translational modification of mRNA. It adds approximately 200 to 300 adenine nucleotides to the 3' end of the primary mRNA transcript. Splicesomes found in eukaryotic organisms cut introns (noncoding regions) from the primary mRNA transcript and anneal the remaining exons (coding regions) together.
2. DNA 3'–TACTACGGTAGGTATA–5'
   RNA 3'–AUGAUGCCAUCCAUAU–5'
3. (a) 3' – GGCATGCACCATAATATCGAACCTTTCGGCACGG – 5'
   The highlighted area represents the promoter region. The promoter region contains a high concentration of adenine and thymine bases. Since adenine and thymine only share two double bonds between them, RNA polymerase will expend less energy in opening up the double helix at this point.
   (b) The purpose of the promoter is twofold in the process of transcription. First, the promoter lies upstream of a DNA sequence that represents a gene. Hence, it acts as a signal for RNA polymerase to bind and transcribe the gene found downstream. Second, it also is an area where the DNA double strand is able to be unwound more easily because of its high concentration of adenine and thymine.
4. Exons are segments of DNA that code for part of a specific protein, while introns are the noncoding regions of a gene.
5. (a) The modifications that are made to the primary mRNA transcript include capping and tailing and the excision of introns. Capping involves the addition of a 7-methyl guanosine to the 5' end of the primary mRNA transcript. Tailing consists of the addition of 200 to 300 adenine nucleotides to the 3' end of the primary mRNA transcript by poly-A polymerase. The excision of introns is carried out by splicesomes, which then join the remaining exons together.
   (b) The capping and tailing of the primary mRNA transcript ensures that when the transcript exits the nucleus, it is not degraded by nucleases and phosphatases found in the cytoplasm. Capping also plays a role in the initiation of the process of translation. Introns are excised to ensure that when the mRNA transcript is translated into protein, it does not

contain amino acids that are extraneous. These extraneous amino acids would interfere with the proper folding and functioning of the protein.

6. Some possible reasons that RNA is single stranded are as follows. RNA is single-stranded for reasons of efficiency. It would not be energetically advantageous to a cell to have double-stranded RNA. Due to the complementary nature of genetic sequences, it is possible to encode within a single strand the information required to build a protein. Also, it is easier for a ribosome to read a single strand of RNA. If the mRNA transcript were double stranded, energy would have to be expended by the ribosome to unwind the mRNA to translate it. Again, this would be an inefficient use of energy. DNA is double stranded because it encodes all the genes required by a cell to function. The complementary nature of DNA ensures that there is more than one copy of the genes.
7. Transcription is initiated with the binding of RNA polymerase to the promoter region. The promoter region is found upstream of a gene and contains a high number of adenine and thymine bases. The binding of RNA polymerase to the promoter region opens up the DNA double helix so it can be transcribed.

   The next step in the transcription process is elongation. RNA polymerase starts building the primary mRNA transcript in the 5' to 3' direction using the 3' to 5' strand of DNA as the template strand. Elongation does not start until RNA polymerase encounters the target gene. The promoter itself is not transcribed and a primer is not required. The primary mRNA transcript consists of the same base complementarity, as does DNA, except that thymine is replaced by uracil.

   Transcription is terminated when RNA polymerase encounters a terminator sequence at the end of the gene. This sequence signals to the RNA polymerase to cease transcription and to disassociate from the DNA template strand. The mRNA primary transcript is released, and posttranscriptional modifications are made to prepare the mRNA for exit from the nucleus.
8. (a) If the termination sequence of a gene is removed, RNA polymerase will continue to transcribe and build a primary mRNA transcript beyond the gene.
   (b) If poly-A polymerase is inactivated, the 200 to 300 protective adenine nucleotides that are added at the end of a primary mRNA transcript will no longer be added. This will leave the mRNA susceptible to degradation on exiting the nucleus.
   (c) If the enzyme that adds the 5' cap is dysfunctional, then the 7-methyl-guanosine molecule will not be added to the 5' end of the primary mRNA transcript. This will leave the mRNA susceptible to degradation on exiting the nucleus.
   (d) If splicesomes excise exons and join introns together, then the mRNA transcript will consist of noncoding sequences. When the mRNA is translated, it will produce a nonfunctional protein.
   (e) If the RNA polymerase fails to recognize the promoter region, then the process of transcription will not take place since the RNA polymerase cannot transcribe DNA unless it is bound to it. The promoter region acts as the initial binding site.
9.

| Transcription | DNA Replication |
|---|---|
| RNA polymerase binds to the DNA region known as the promoter; DNA strands unwind | The enzyme helicase unwinds DNA strands by breaking hydrogen bonds |
| RNA polymerase uses DNA as a template and synthesizes a complementary mRNA strand using ribonucleotides | DNA polymerase III uses a DNA strand as a template and synthesizes a complementary DNA strand using deoxyribonucleotides |

## Applying Inquiry Skills

10. To determine whether the DNA molecule is eukaryotic or prokaryotic, the following characteristics can be explored. Eukaryotic DNA consists of introns and exons, whereas prokaryotic DNA consists of only exons. Therefore, a comparison can be made between the primary mRNA transcript and the mRNA transcript. If the primary mRNA transcript is longer than the mRNA transcript, then it is eukaryotic DNA. An additional difference between DNA from a prokaryotic source versus a eukaryotic source would be the termination sequence. The sequence can be determined using the nucleotide sequencer and the origin of the molecule determined based on the results.
11. The promoter region of a DNA sequence is high in adenine and thymine nucleotides. Adenine and thymine bond to each other via two hydrogen bonds. Guanine and cytosine bond to each other via three hydrogen bonds. A larger amount of energy is required to break three hydrogen bonds compared with two hydrogen bonds. DNA helix B represents the promoter region because it unwinds at a lower temperature of 65ºC, indicating a higher incidence of adenine and thymine nitrogenous bases.
12. A human heart cell is eukaryotic, whereas a bacterium is prokaryotic. Eukaryotic DNA comprises introns and exons. Eukaryotic cells contain the enzyme splicesome, which excises the exons and splices the remaining introns. Bacterial cells are prokaryotic and lack the enzyme splicesome. If eukaryotic DNA is placed into a prokaryotic system to be expressed, the exons will remain intact within the mRNA. When the mRNA is translated into protein, it will contain extraneous amino acids, rendering the protein dysfunctional. If the biotechnologist wants to use the bacterium as a host cell, she must first excise the exons from the source DNA or use a eukaryotic cell system to express the DNA.