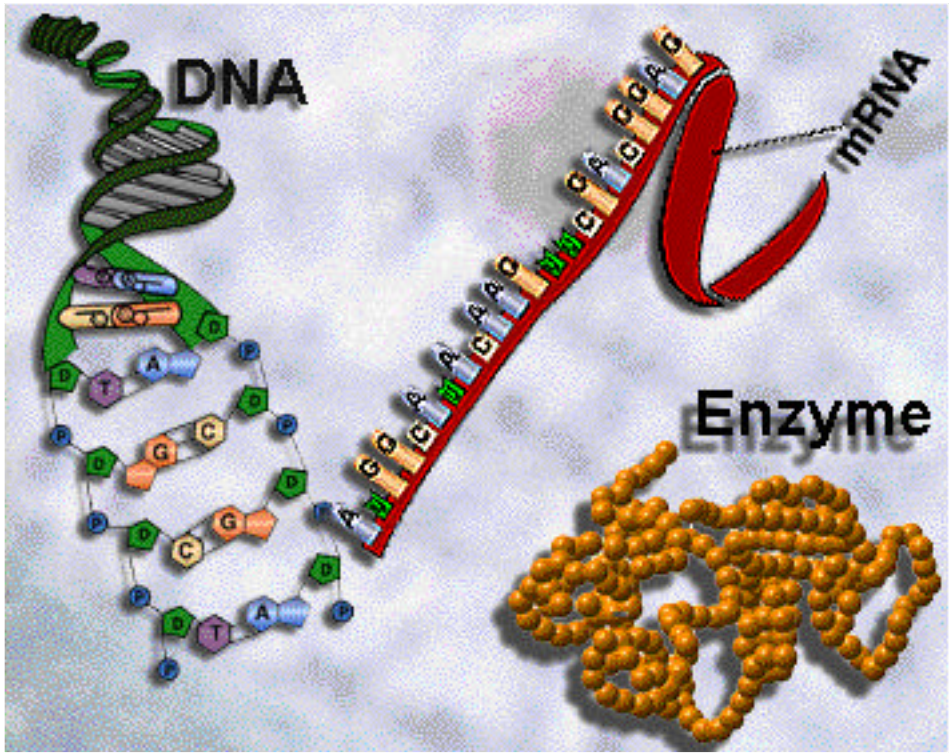
Interactive Biology™ Multimedia Courseware

# From DNA to Protein



From DNA to Protein
TEACHING OBJECTIVES

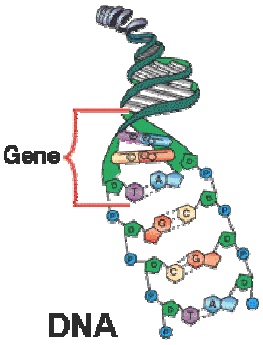
The following subject areas are illustrated throughout the Interactive Biology Multimedia Courseware program, *From DNA to Protein*. Ideally, these areas would be augmented with additional course work outside of this program.

- **An Overview of DNA as the Hereditary Molecule**: Including early experiments - such as those performed by Sir Archibald Garrod, George Beadle, and Edward Tatum.
- **The Physical Structure and Chemical Composition of DNA and RNA Molecules.**
- **Transcription of the DNA Molecule**: Including the origin of messenger RNA(mRNA), transfer RNA (tRNA), and ribosomal RNA (rRNA).
- **Translation of the mRNA Strand**: Including the roles of tRNA and rRNA, elongation of the polypeptide, and termination of translation.

Study Guide #1
GENES AND HEREDITY

What controls the way we look? In other words, why do you look like your parents and why do offspring throughout the plant and animal kingdoms tend to look like their parents? Most of you know already that the answer lies in deoxyribonucleic acid, or DNA.

Within DNA lies hereditary units known as genes.
It is these genes which get passed along from generation to generation and control an offspring's phenotype, or simply the physical traits of an individual.

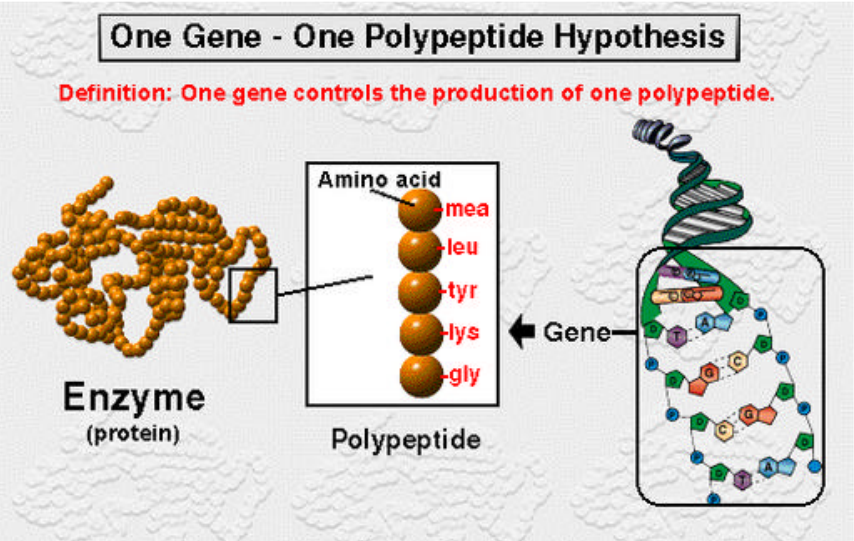



How exactly do genes release their information and direct the construction of a new individual. It took many years to unlock the answer to this question. One of the first people to investigate this was the English physician Sir Archibald Garrod.

Garrod suggested that genes controlled phenotype through enzymes, which regulate many of the biochemical reactions that take place inside our bodies. He studied patients suffering from the hereditary disease alkaptonuria, and felt that a defective gene led to this condition. This defective gene either resulted in no enzyme, or a faulty enzyme, being produced.

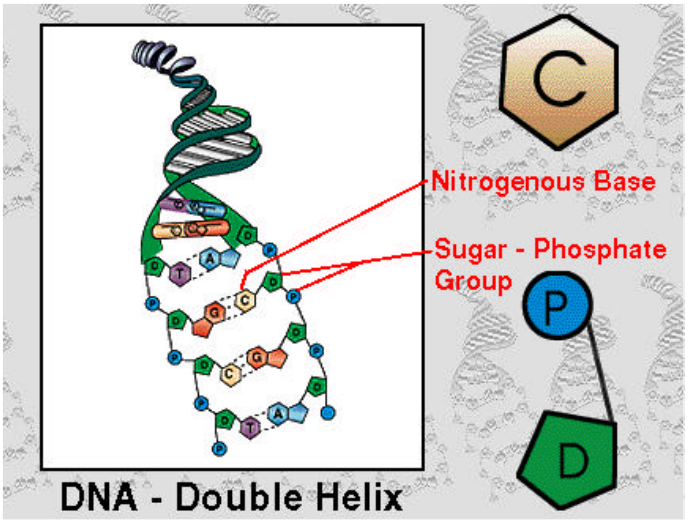
In 1941, American scientists George Beadle and Edward Tatum produced the best evidence that genes control the production of enzymes. Using bread mold for their research, these scientists were able to conclude that one gene controls the production of one enzyme. This is called the one gene-one enzyme hypothesis.

Enzymes are composed of protein. All proteins are in turn made up of amino acids connected into a long polypeptide chain. It is now known that one gene and Beadle control the construction of each polypeptide in a protein and Tatum's hypothesis has been changed to the one gene-one polypeptide hypothesis.



Study Guide #2
STRUCTURE AND COMPOSITION OF DNA

DNA exists as a double helix. Think of it as being like a ladder spiraling from end to end.




Each side of the ladder consists of a chain of sugar-phosphate groups. Each rung of the ladder consists of one pair of nitrogenous (or nitrogen containing) bases.

There are four bases found in every DNA molecule on earth - regardless of whether that molecule comes from a human, an oak tree, or a bacterium. These four bases are:

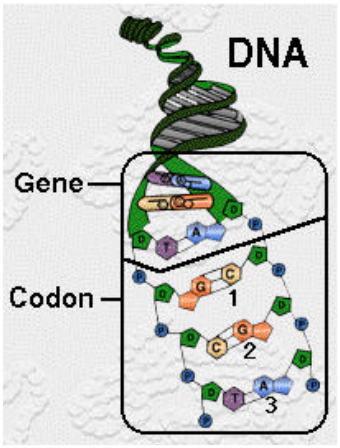
ADENINE
GUANINE
CYTOSINE
THYMINE

Adenine and Guanine are both purines.
Cytosine and Thymine are both pyrimidines.

These bases pair only in very specific ways. Adenine always pairs with thymine. Guanine always pairs with cytosine. A single base (adenine, guanine, cytosine, or thymine) together with a phosphate group and the sugar deoxyribose make up a nucleotide. A nucleotide is the basic unit of DNA and a single gene contains hundreds or thousands of nucleotides.

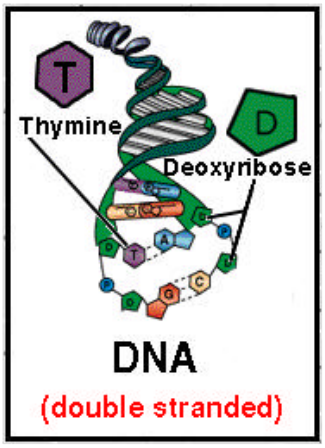
Study Guide #3
RNA

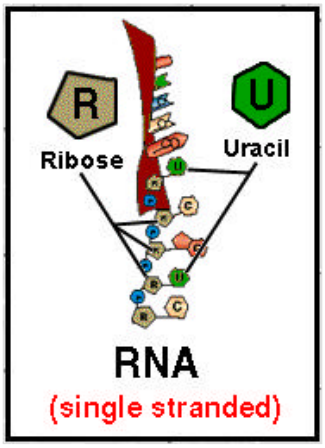
For a gene to control the production of a polypeptide, it must direct the linking of amino acids. Scientist have determined that the order of the bases in three adjacent nucleotides of a gene is the code that directs a particular amino acid be added to the growing polypeptide chain. In other words, a three-nucleotide long sequence codes for a specific amino acid. Each triplet of nucleotides is called a codon.




Amino acids are linked into polypeptides in the cytoplasm of a cell, yet the DNA in a eukaryotic cell is confined to the nucleus. How does DNA in the nucleus direct the production of polypeptides in the cytoplasm? The answer is ribonucleic acid, or RNA.

There are only two differences between the chemical makeup of RNA and the chemical makeup of DNA. In RNA, thymine is replaced by the base uracil.

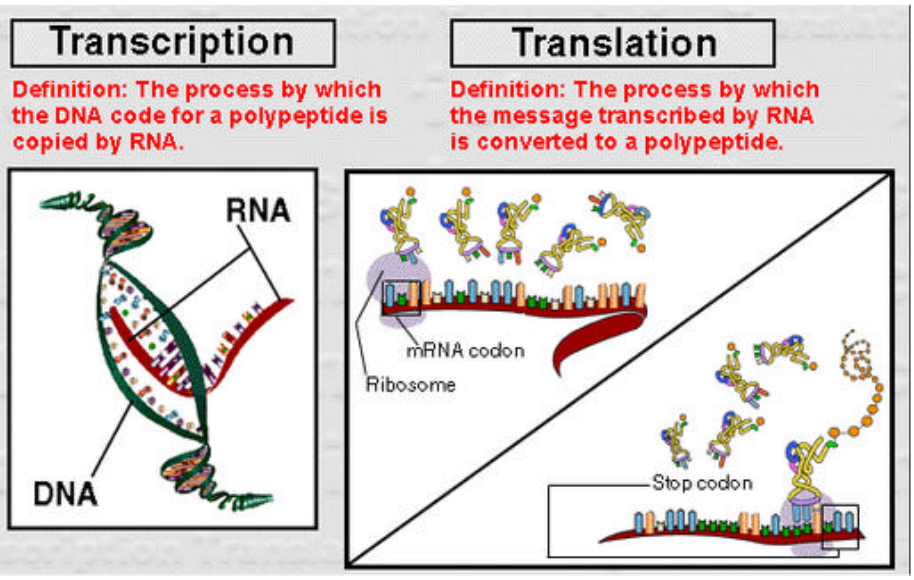



In RNA, the sugar is ribose rather than the deoxyribose found in DNA.

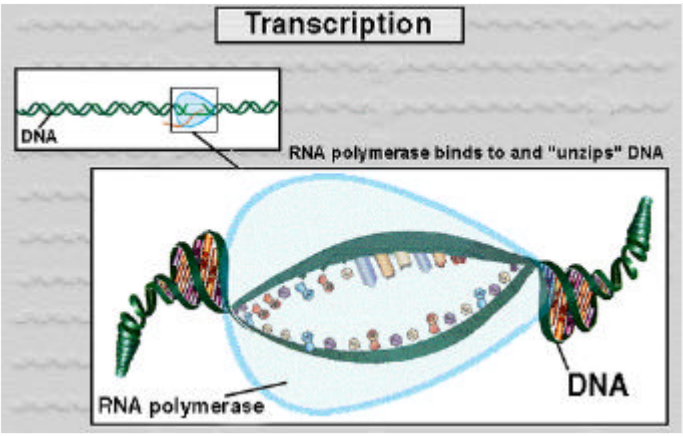
Structurally, the difference between RNA and DNA is that RNA exists as a single strand of nucleotides, whereas DNA is made up of two nucleotide strands.

To form a protein from the polypeptide directions encoded in DNA, two processes are involved: transcription and translation. Transcription occurs first and is the process by which the genetic code carried by DNA is copied by RNA. Translation is the process by which the message transcribed by RNA is converted, in the cytoplasm, into a polypeptide.



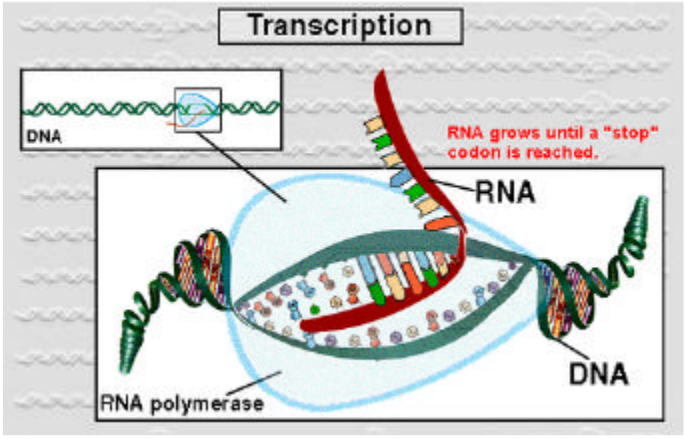
Study Guide #4
TRANSCRIPTION
MESSENGER RNA

Before RNA can make a copy of DNA, it must gain access to the code. This is done with the aid of an enzyme called RNA polymerase. RNA polymerase binds to DNA and "unzips" it - that is it separates the two strands of DNA. A single, unpaired strand of DNA now serves as the template for RNA.



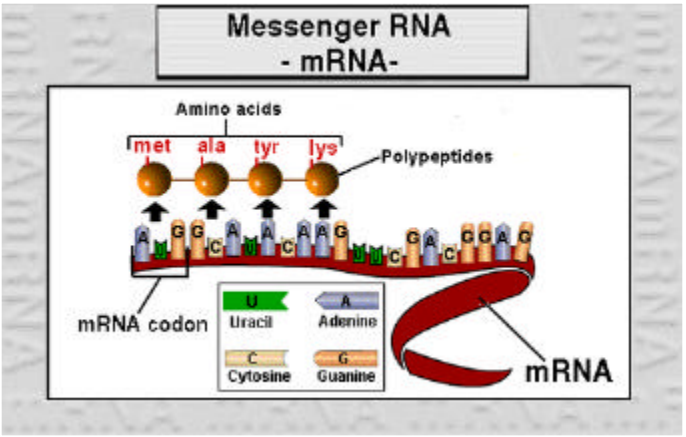

Next, free RNA nucleotides ssemble along the exposed DNA strand and line up with their complimentary bases. For instance, an RNA adenine will line up with each exposed DNA thymine. Remember though, there is no thymine in RNA. Therefore, an RNA uracil will line up with each exposed DNA adenine.

This pairing of RNA with their complementary DNA bases continues until a certain "STOP" code is reached on the DNA strand. At this point, the RNA strand stops elongating. The newly formed RNA strand then breaks away, the RNA polymerase breaks free, and the two DNA strands reconnect.



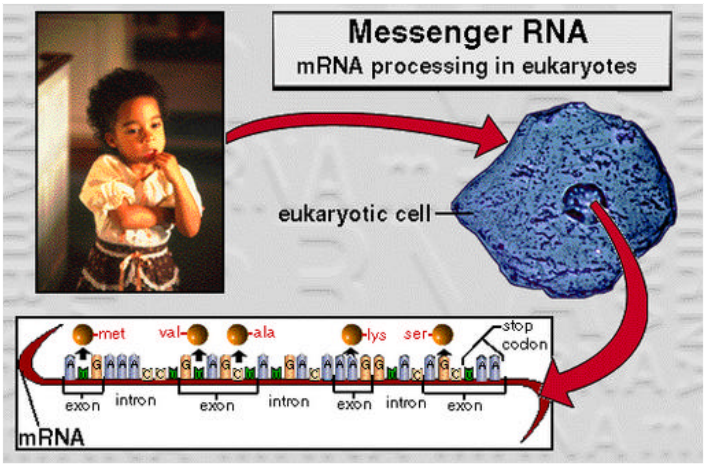

The RNA molecule that was copied from the DNA strand now carries the information to produce a polypeptide and is called messenger RNA, or mRNA. It is called this because it serves as a genetic messenger between DNA and the protein-making machinery in the cytoplasm.

Each triplet of nucleotides in the mRNA makes up a codon. Each codon codes for a specific amino acid in the polypeptide chain.

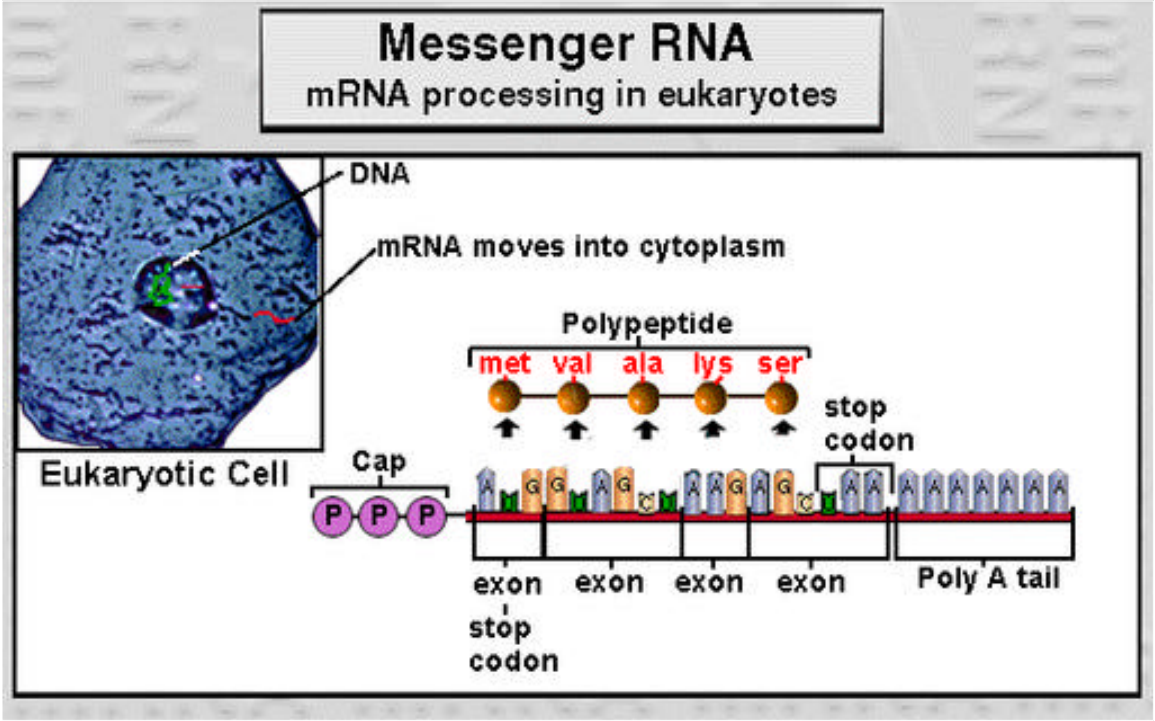



In eukaryotic organisms, such as humans, mRNA undergoes a few alterations in the nucleus before moving into the cytoplasm. In eukaryotes, the protein-coding segments of genes do not lie next to each other. Instead, they are separated by non-protein coding segment called introns. The portions that actually code for proteins (polypeptides) are called exons.

The first step in the processing of mRNA in the nucleus is the placement of a cap and tail on the mRNA strand. The tail is called a poly-a tail because it consists of about 200 adenine nucleotides. Together, the cap and tail prevent the mRNA strand from being broken down by enzymes in the cytoplasm.



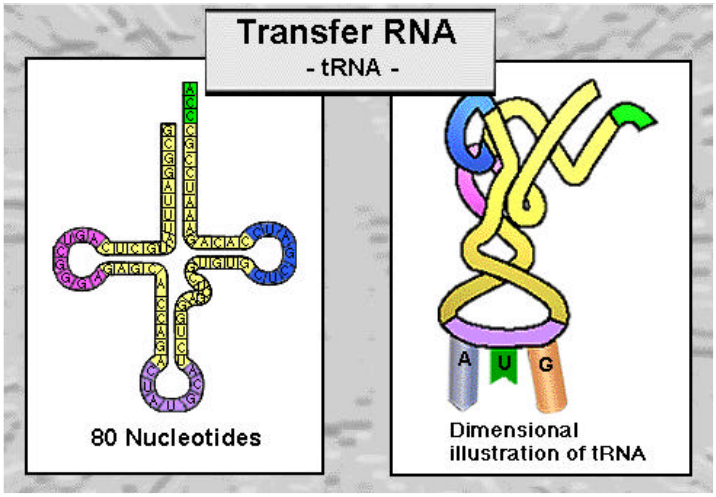

After the cap and tail are in place, the introns are cut out and the exons are spliced together. In this form, the mRNA moves into the cytoplasm where the process of translation takes place.



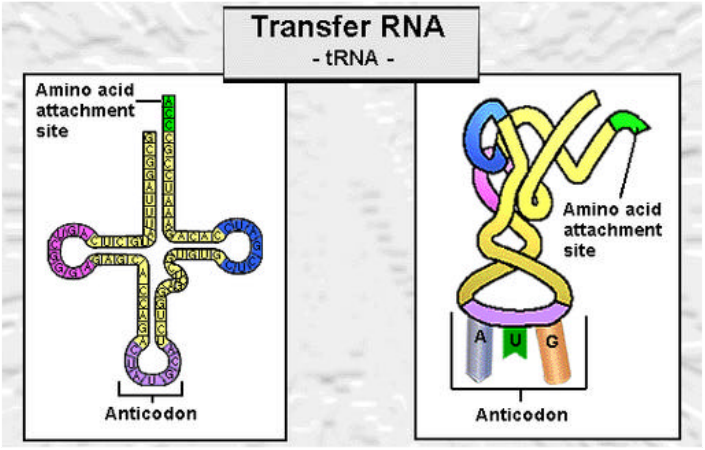
Study Guide #5
TRANSCRIPTION
TRANSFER RNA AND RIBOSOMAL RNA

In the previous study guide, you learned of messenger RNA, or, mRNA. A second type of RNA is transfer RNA, or, tRNA.

Like mRNA, tRNA is transcribed from DNA in the nucleus of the cell. tRNA is typically much smaller than is mRNA. Whereas mRNA may be several thousand nucleotides in length, tRNA has only about 80 nucleotides.




At one end of the tRNA molecule, there is a short tail. This tail serves as the amino acid attachment site. At another position on the tRNA molecule, there is a loop of nucleotides. Within this loop lies a sequence of 3 bases which make up an anticodon.



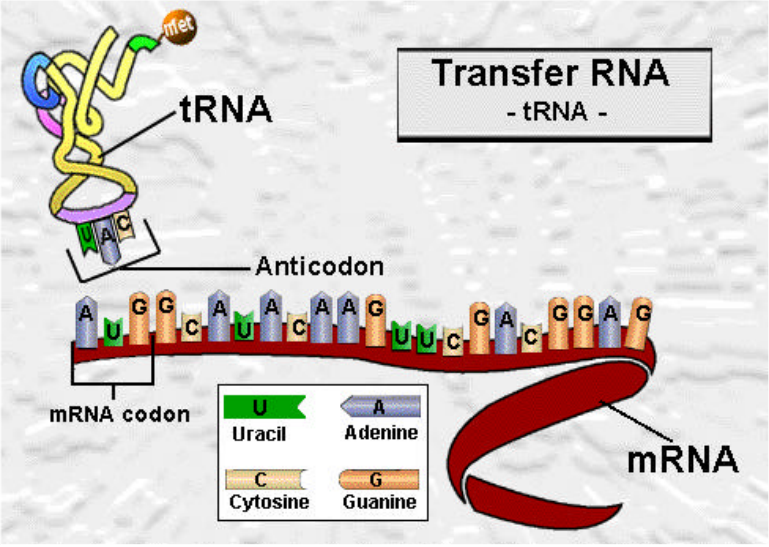

An anticodon is the complement of an mRNA codon. In other words, the anticodon of tRNA will match up with the codon on mRNA. Therefore, if you see tRNA with the sequence uracil, adenine, cytosine (UAC) you know it must match up with an mRNA sequence of adenine, uracil, guanine (AUG).

....tRNA anticodon....

uracil adenine cytosine

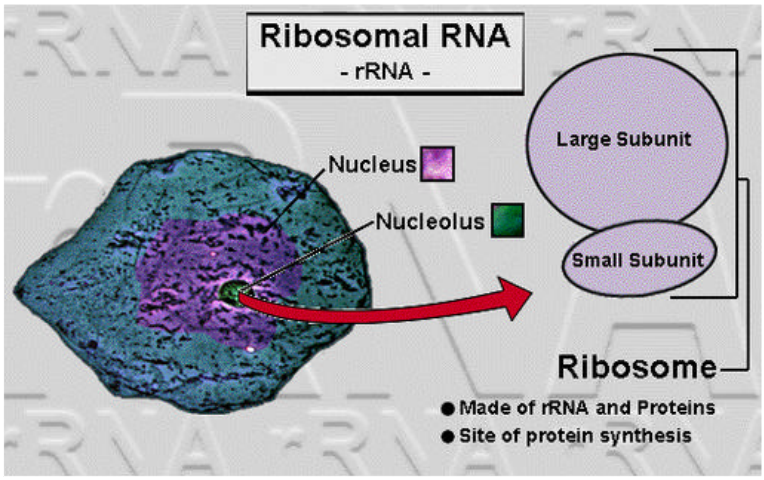
adenine uracil guanine

....mRNA codon....




Each mRNA codon calls for a specific amino acid. This amino acid will be carried by a tRNA molecule. In other words, the anticodon that binds to its codon will be found on a tRNA molecule that always carries a specific amino acid. Each specific tRNA carries a specific amino acid. Thus, tRNA acts as a vehicle for bringing up the correct amino acid at the correct time.

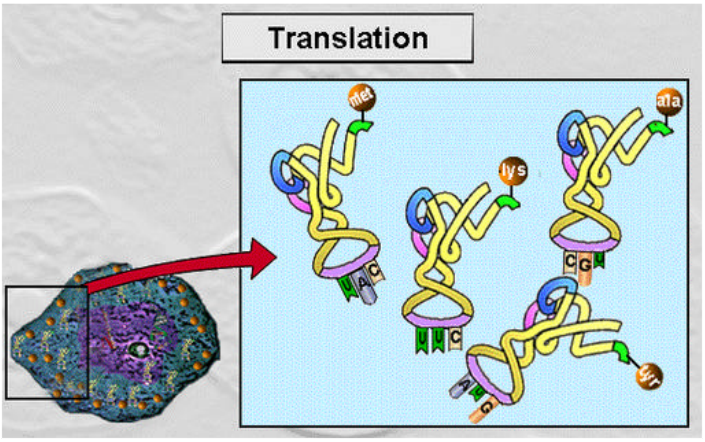
The third type of RNA is ribosomal RNA, or rRNA. Like the other two types, rRNA is transcribed from DNA.




Within the nucleus of a cell is a structure known as a nucleolus. Inside of the nucleolus, rRNA is joined with various proteins to form ribosomes. Each ribosome consists of two subunits of unequal size (a large and a small subunit). The ribosome is the site of protein synthesis.After the RNA and ribosomes have been formed, they pass from the nucleus to the cytoplasm via pores in the nuclear envelope, which is the membrane that surrounds the nucleus. Within the cytoplasm are all the amino acids needed for the next stage, translation.

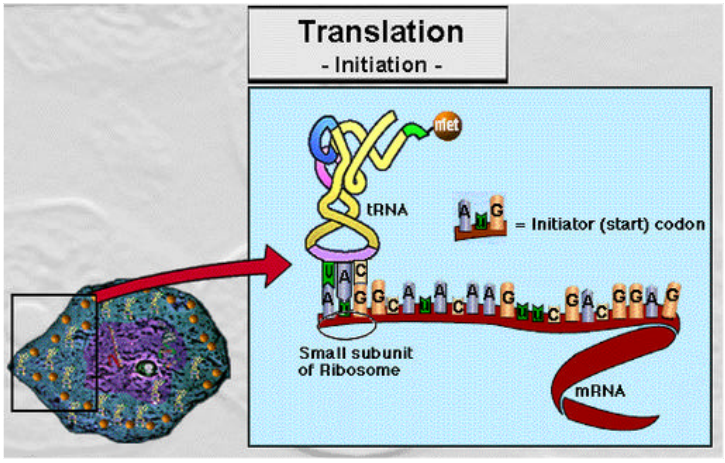
Study Guide #6
TRANSLATION

Whereas transcription takes place inside the nucleus, translation occurs outside of the nucleus in the cytoplasm. During translation, the information held within mRNA is used to form a polypeptide.



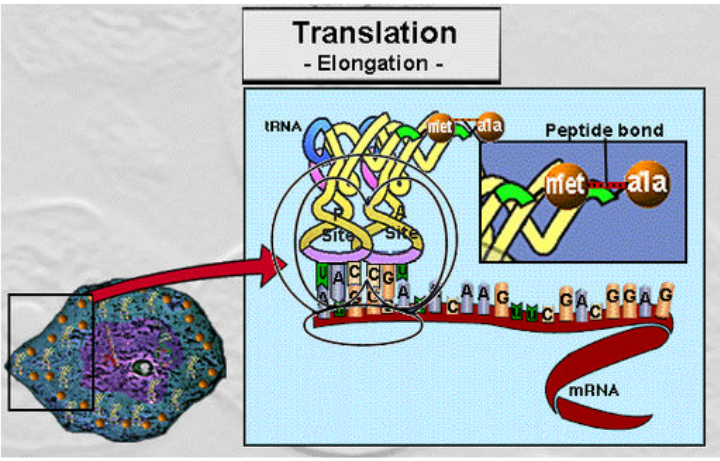

Once they reach the cytoplasm, tRNA molecules become attached to their specific amino acids. This creates a pool of tRNA molecules with amino acids in tow.

Also in the cytoplasm, ribosomes become attached to mRNA at various sites along the strand. The small ribosomal subunit is the first unit of the ribosome to attach to the mRNA strand. At the same time, tRNA with the anticodon AUC attaches to mRNA at the site of its complementary codon AUG. AUG is an initiator codon. That is, it is AUG codons at which translation starts.




Once tRNA has attached to mRNA at the initiator codons, the large ribosomal subunits join the complex. In the large subunit are two groove-like sites known as the P site and the A site. Into these two grooves fit the tRNA molecules carrying amino acids. When the large subunit joins the complex, it attaches so that the initiator codon is in the P site. This leaves the A site open. Another tRNA with an anticodon corresponding to the

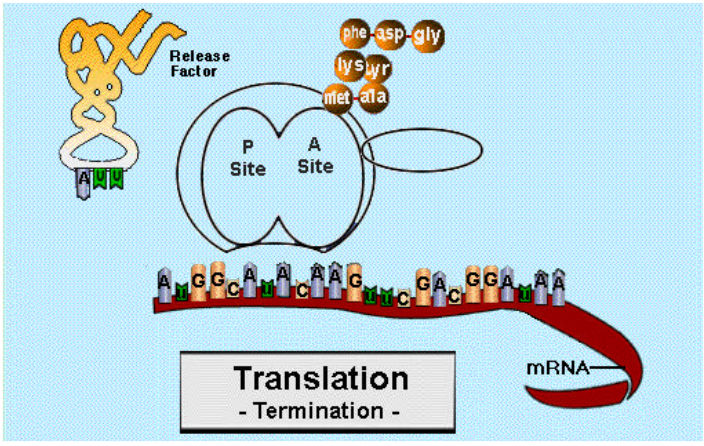
next codon in the line fills in the A site. As this new tRNA molecule fills in the A site, a peptide bond links the amino acid in the P site with that in the A site. This forms a two peptide long chain, known as a dipeptide.




Once the dipeptide bond forms, three things happen. First, the bond linking the amino acid in the P site to the tRNA that carried it there breaks. The peptide bond remains intact though, so the dipeptide still exists. Second, the tRNA in the P site breaks free from the mRNA strand. This leaves an open P site. Third, the ribosome slides one codon down the mRNA strand. The tRNA that was filling the A site now fills the P site. The A site is once again free to receive a tRNA carrying an amino acid.

Molecules of amino acid carrying tRNA continue to enter and leave the ribosomal sites as the ribosome moves along the mRNA strand. Thus, the dipeptide quickly becomes a polypeptide (many peptides).

The polypeptide continues to grow until a special stop codon on the mRNA strand is reached. At this point, the A site accepts a protein known as a release factor instead of a tRNA molecule. The release factor causes the last tRNA in the P site to exit the ribosome. At the



same time, the bond is broken between the polypeptide and the tRNA. The polypeptide is now free and coils itself into a functional protein. Finally, the two ribosomal subunits detach from the mRNA.

From DNA to Protein

QUIZ PAC

The following quizzes are meant to test student understanding of specific topic areas covered in the Interactive Biology Multimedia Courseware program, *From DNA to Protein*. Many, but not all, of these questions have been addressed directly in the study guides designed to strengthen student understanding of these topics.

| | |
|---|---|
| QUIZ #1 | DNA and Heredity |
| QUIZ #2 | Structure & Composition of DNA |
| QUIZ #3 | RNA |
| QUIZ #4 | Transcription |
| QUIZ #5 | Transcription |
| QUIZ #6 | Translation |
| EXAM | Comprehensive Exam |

Quiz #1

DNA AND HEREDITY

1. The basic unit of heredity is the gene.

    A. True
    B. False

2. _____ is the physical traits of an individual.

    A. Genotype
    B. Physique
    C. Phenotype
    D. Genome

3. Sir Archibald Garrod studied the hereditary disease _____.

    A. alkaptonuria
    B. breast cancer
    C. cystic fibrosis
    D. down syndrome

4. Garrod felt that _____ lead to the condition he studied.

    A. exposure to chemicals
    B. non-disjunction
    C. UV radiation
    D. a faulty gene

5. Working with bread mold, George Beadle and Edward Tatum came up with the _____ hypothesis.

    A. one chemical-one mutation
    B. one gene-one mutation
    C. one mutation-one enzyme
    D. one gene-one enzyme

6. Beadle and Tatum's hypothesis was later changed to the _____.

    A. one chemical mutation-one enzyme hypothesis
    B. one gene-one enzyme theory
    C. one mutation-one enzyme theory

D. one gene-one polypeptide hypothesis

7. Enzymes area composed of _____, which are in turn composed of _____.

A. genes, proteins
B. genes, amino acids linked to form polypeptides
C. amino acids, polypeptides linked to form proteins
D. proteins, amino acids linked to form polypeptides

Quiz #2

STRUCTURE AND COMPOSITION OF DNA

1. DNA exists as a double helix.

    A. True
    B. False

2. A nucleotide is the basic unit of DNA.

    A. True
    B. False

3. Each "rung" in the DNA "ladder" consists of _____.

    A. a single nitrogenous base
    B. a pair of nitrogenous bases
    C. three nitrogenous bases
    D. two pairs of nitrogenous bases

4. Which of the following is NOT a base found in DNA?

    A. Adenine
    B. Guanine
    C. Phenylalanine
    D. All of the above ARE bases found in DNA.

5. Which of the following is NOT a base found in DNA?

    A. Uranine
    B. Cytosine
    C. Thymine
    D. All of the above ARE bases found in DNA.

6. Adenine ALWAYS pairs with what base?

    A. Thymine
    B. Guanine
    C. Phenylalanine
    D. Adenine

7. Cytosine ALWAYS pairs with what base?

A. Uranine
B. Guanine
C. Adenine
D. Cytosine

8. A nucleotide of DNA consists of _____.

A. a phosphate group
B. a single base
C. the sugar deoxyribose
D. All of the above.

Quiz #3

RNA

1. RNA has the exact structure and composition of DNA.

   A. True
   B. False

2. For a gene to control the production of a polypeptide, it must direct the linking of _____.

   A. polypeptides
   B. proteins
   C. amino acids
   D. nucleotides

3. _____ adjacent nucleotides in a gene code for _____.

   A. Two, a specific polypeptide
   B. Two, a specific amino acid
   C. Three, a specific polypeptide
   D. Three, a specific amino acid

4. This _____ of nucleotides is known as _____.

   A. doublet, a codon
   B. doublet, a conduit
   C. triplet, a codon
   D. triplet, a conduit

5. RNA allows DNA, which remains in the nucleus, to _____.

   A. become much less critical to the survival of the cell
   B. direct the production of polypeptides in the cytoplasm
   C. leave the nucleus for a short time
   D. lay dormant for long periods of time

6. A difference between the CHEMICAL makeup of RNA and DNA is _____.

   A. in RNA, the base THYMINE is replaced by the base URACIL
   B. in RNA, the sugar DEOXYRIBOSE is replace by RIBOSE
   C. Both A and B
   D. Neither A nor B

7. A difference between the STRUCTURAL makeup of RNA and DNA is _____.

A. RNA exists as a single strand
B. RNA exists as a double helix
C. RNA exists as a triple helix
D. RNA exists as a pair of double helixes

Quiz #4

TRANSCRIPTION

1. The enzyme RNA polymerase helps break down DNA.

   A. True
   B. False

2. _____ serves as the template for making a strand of RNA.

   A. A single strand of DNA
   B. Two strands of DNA
   C. Three strands of DNA
   D. Two strands of RNA

3. The RNA base _____ pairs up with the DNA base GUANINE.

   A. thymine
   B. guanine
   C. cytosine
   D. uracil

4. The RNA base _____ pairs up with the DNA base ADENINE.

   A. adenine
   B. thymine
   C. cytosine
   D. uracil

5. The RNA strand elongates until _____.

   A. the entire chromosome has been transcribed
   B. the cell runs out of RNA bases
   C. a specific "stop" code is reached on the DNA strand
   D. the DNA strand is completely degraded

6. After elongation of the RNA strand is complete, _____ and _____.

   A. the RNA becomes a part of the chromosome, the DNA completely degrades
   B. the RNA strand breaks free, the DNA strands reconnect
   C. the RNA strand breaks free, the cell divides
   D. the RNA becomes a part of the chromosome, the cell divides

7. The RNA strand made from transcription of DNA is _____.

   A. messenger RNA
   B. mobile RNA
   C. micro RNA
   D. message RNA

8. Each triplet of nucleotides on mRNA make up _____.

   A. a tripod
   B. a genetic code
   C. a codon
   D. an mRNA base

9. In _____ organisms, mRNA undergoes a few alterations.

   A. all
   B. eukaryotic
   C. prokaryotic

10. After these alterations, mRNA moves _____.

    A. into the nucleus
    B. out of the cell
    C. into the chromosome
    D. into the cytoplasm

11. The segments of mRNA which code for proteins are known as _____ and the non-protein coding segments that are removed are known as _____.

    A. introns, exons
    B. exons, introns

12. In processing of mRNA, _____ to help prevent the mRNA strand from being broken down by enzymes.

    A. a cap is added to the strand
    B. a poly-A tail is added to the strand
    C. Both A and B.
    D. Always A and sometimes B.

Quiz #5

TRANSCRIPTION

1. The type of RNA that makes a direct copy of a gene sequence is known as messenger RNA, or mRNA.

   A. True
   B. False

2. Typically, tRNA is much larger than is mRNA.

   A. True
   B. False

3. tRNA stands for _____.

   A. transcription RNA
   B. translocation RNA
   C. transduction RNA
   D. transfer RNA

4. At one end of a tRNA molecule is a tail that serves as what?

   A. An amino acid attachment site.
   B. A device to prevent the tRNA from being degraded.
   C. A means of movement for the tRNA.

5. At another point on a tRNA molecule is a sequence of three bases that make up _____.

   A. a codon
   B. a genetic code
   C. an anticodon

6. The purpose of the _____ on tRNA is to match up with its complementary _____ on mRNA.

   A. anticodon, codon
   B. codon, anticodon
   C. codon, codon
   D. genetic code, genetic code

7. The tRNA sequence UAC (uracil, adenine, cytosine) will match up with the sequence _____ on mRNA.

   A. ATG (adenine, thymine, guanine)
   B. UAC (uracil, adenine, cytosine)
   C. AUG (adenine, uracil, guanine)
   D. CAU (cytosine, adenine, uracil)

8. Each sequence of three bases on an mRNA molecule codes for _____ which is brought to the mRNA by _____.

   A. a specific amino acid, a tRNA molecule carrying the exact amino acid needed
   B. a specific tRNA molecule, a specific amino acid
   C. a specific protein, a tRNA molecule carrying the exact protein needed
   D. a tail that prevents mRNA from being degraded in the cytoplasm, tRNA

9. rRNA stands for _____.

   A. reverse RNA
   B. restricted RNA
   C. regulation RNA
   D. ribosomal RNA

10. rRNA is produced _____.

    A. in the cytoplasm
    B. in the nucleolus
    C. only once during the life of the cell
    D. only immediately before the cell divides

11. rRNA is joined with various proteins to form _____.

    A. various regulatory molecules
    B. structures important in reverse transcription
    C. restricted proteins used only inside of the cell
    D. structures known as ribosomes, which are needed for transcription

12. All three types of RNA (mRNA, tRNA, and rRNA) move _____ after they are manufactured.

    A. into the nucleus
    B. into the nucleolus
    C. outside of the cell
    D. into the cytoplasm

Quiz #6

TRANSLATION

1. Translation occurs inside of the nucleus.

   A. True
   B. False

2. Translation is the mechanism by which information held within mRNA is used to form a polypeptide.

   A. True
   B. False

3. Once reaching the cytoplasm, tRNA molecules become attached to _____.

   A. each other
   B. single strands of DNA
   C. their specific amino acids
   D. None of the above.

4. The _____ ribosomal subunit is the first unit of the ribosome to attach to the mRNA strand.

   A. top
   B. bottom
   C. small
   D. large

5. In translation, the sequence _____ serves as an initiator codon all along the mRNA strand.

   A. AUC
   B. GCG
   C. UAG

6. The first anticodon that attaches to the mRNA strand is what?

   A. AUC
   B. CGC
   C. UAG

7. The second ribosomal subunit that attaches and completes the complex is the _____ ribosomal subunit.

   A. top
   B. bottom
   C. small
   D. large

8. The two groove-like sites in the ribosomal complex into which tRNA molecules fit are _____.

   A. the GCG and the CGC site
   B. the front and the back site
   C. the A and the P site
   D. the A and the B site

9. As the ribosomes slide along the mRNA strand, _____ link the amino acids together.

   A. peptide bonds
   B. hydrogen bonds
   C. double bonds
   D. polypeptide bonds.

10. What is formed after the first bond in question #9 is made?

   A. A dipeptide
   B. A dihydro amino acid
   C. double stranded amino acid
   D. None of the above.

11. As the ribosomes slide along the mRNA strand, tRNA molecules exit the _____ and enter the _____.

   A. cytoplasm, nucleus
   B. inactive stage, active stage
   C. P site, A site
   D. A site, P site

12. As the ribosomes slide along the mRNA strand, _____ is formed.

A. DNA
B. RNA
C. a polyhydro amino acid
D. a double stranded amino acid chains
E. a polypeptide

13. The structure in question #12 continues to elongate until _____.

A. the cell exhausts its supply of tRNA
B. the ribosomes reach a special stop codon
C. the ribosomes accept a release factor protein
D. All of the above.
E. B and C only.

14. The end product of translation is _____.

A. single stranded DNA
B. double stranded DNA
C. single stranded RNA
D. a functional protein

From DNA to Protein
COMPREHENSIVE EXAM

The following exam is based on the Interactive Biology Multimedia Courseware program, *From DNA to Protein*. Most, but not all, of these questions have been addressed directly in the study guides. All of the questions on this exam, however, are based on information put forthin the program.

Please determine if the following statements are true or false.

1. The basic unit of heredity is the chromosome.

   A. True
   B. False

2. A genotype consists of all the physical characteristics that an organism possesses.

   A. True
   B. False

3. DNA exists as a double helix.

   A. True
   B. False

4. DNA and RNA have identical structure and composition.

   A. True
   B. False

5. The enzyme RNA polymerase "unzips" DNA molecules.

   A. True
   B. False

6. For a gene to control the production of a polypeptide, it must direct the linking of amino acids.

   A. True
   B. False

7. The type of RNA that makes a direct copy of a gene sequence is known as messenger RNA, or mRNA.

   A. True
   B. False

8. Typically, tRNA is much larger than mRNA.

   A. True
   B. False

9. Translation occurs in the cytoplasm.

   A. True
   B. False

In the following portion of the exam, please choose the letter beside the word, words, or phrase that best completes each sentence.

10. Sir Archibald Garrod studied the hereditary disease _____.

   A. alkaptonuria
   B. breast cancer
   C. cystic fibrosis
   D. Down syndrome

11. George Beadle and Edward Tatum came up the _____ hypothesis.

   A. one chemical - one mutation
   B. one gene - one mutation
   C. one mutation - one enzyme
   D. one gene - one enzyme

12. Their hypothesis was later changed to the _____.

   A. one chemical mutation - one enzyme hypothesis
   B. one gene - one enzyme theory
   C. one mutation - one enzyme theory
   D. one gene - one polypeptide hypothesis

13. Enzymes are composed of _____, which are in turn composed of _____.

A. genes, proteins
B. genes, amino acids linked to form polypeptides
C. amino acids, polypeptides linked to form proteins
D. proteins, amino acids linked to form polypeptides

14. Each "rung" in the DNA "ladder" consists of _____.

A. a single nitrogenous base
B. a pair of nitrogenous bases
C. three nitrogenous bases
D. two pairs of nitrogenous bases

15. Which of the following is NOT a base found in DNA?

A. Adenine
B. Guanine
C. Phenylalanine
D. All of the above ARE bases found in DNA.

16. Cytosine ALWAYS pairs with what base?

A. Adenine
B. Guanine
C. Phenylalanine
D. Cytosine

17. A nucleotide of DNA consists of _____.

A. a phosphate group
B. a single base
C. the sugar deoxyribose
D. All of the above make up a nucleotide.

18. _____ adjacent nucleotides in a gene code for _____.

A. Two, a specific polypeptide
B. Two, a specific amino acid
C. Three, a specific polypeptide
D. Three, a specific amino acid

19. A _____ of nucleotides is known as _____.

A. pair, a gene
B. triplet, a codon
C. chain, an enzyme
D. polypeptide, a protein

20. RNA allows DNA, which remains in the nucleus, to _____.

A. become much less critical to cellular survival
B. direct the production of polypeptides in the cytoplasm
C. leave the nucleus for a short time
D. lay dormant for long periods of time

21. A difference between the CHEMICAL makeup of RNA and DNA is _____.

A. in RNA, the base THYMINE is replaced by the base URACIL
B. In RNA, the sugar DEOXYRIBOSE is replaced by RIBOSE
C. Both A and B.
D. Neither A nor B.

22. A difference between the STRUCTURAL makeup of RNA and DNA is _____.

A. RNA exists as a single strand
B. RNA exists as a double helix
C. RNA exists as a triple helix
D. RNA exists as a pair of helixes

23. The RNA base _____ pairs up with the DNA base ADENINE.

A. THYMINE
B. GUANINE
C. CYTOSINE
D. URACIL

24. The RNA strand elongates until _____.

A. the entire chromosome has been transcribed
B. the cell runs out of RNA bases
C. a specific "stop" code is reached on the DNA strand
D. the DNA strand is completely degraded

25. After elongation of the RNA strand is complete, _____ and _____.

A. the RNA becomes a part of the chromosome, the DNA completely degrades
B. the RNA strand breaks free, the DNA strands reconnect
C. the RNA strand breaks free, the cell divides
D. the RNA becomes a part of the chromosome, the cell divides

26. In _____ organisms, mRNA undergoes a few alterations.

A. all
B. eukaryotic
C. prokaryotic

27. The segments of mRNA which code for proteins are known as _____ and the non-protein coding segments that are removed are known as _____.

A. introns, exons
B. exons, introns

28. In processing mRNA, _____ to help prevent the mRNA strand from being broken down by enzymes.

A. a cap is added to the strand
B. a poly-A tail is added to the strand
C. Both A and B.
D. Always A and sometimes B.

29. At one end of a tRNA molecule is a tail that serves as what?

A. An amino acid attachment site.
B. A means of attaching tRNA to DNA.
C. A means of movement for the tRNA, like a tadpole's tail.

30. At another point on a tRNA molecule is a sequence of three bases that make up _____.

A. a genetic code
B. a codon
C. an anticodon

31. The purpose of the _____ on tRNA is to match up with its complementary _____ on mRNA.

A. anticodon, codon
B. codon, anticodon
C. codon, codon
D. genetic code, genetic code

32. Each sequence of three bases on an mRNA molecule codes for _____ which is brought to the mRNA by _____.

A. a specific amino acid, a tRNA molecule carrying the exact amino acid needed
B. a specific tRNA molecule, a specific amino acid
C. a specific protein, a tRNA molecule carrying the exact protein needed
D. a tail that prevents mRNA degradation, tRNA

33. rRNA is joined with various proteins to form _____.

A. various regulatory molecules
B. structures important in reverse transcription
C. restricted proteins used only inside of the cell
D. structures known as ribosomes, which are needed for transcription

34. _____ is the mechanism by which information held in mRNA is used to manufacture a polypeptide.

A. Transcription
B. Translation
C. Reverse transcription
D. Reverse translation

35. Once reaching the cytoplasm, tRNA molecules become attached to _____.

A. each other
B. DNA strands
C. specific amino acids
D. specific polypeptides

36. The _____ ribosomal subunit is the first subunit to attach to the mRNA strand, followed by the _____.

A. small, large ribosomal subunit
B. large, small ribosomal subunit
C. top, bottom ribosomal subunit
D. bottom, top ribosomal subunit

37. As ribosomes slide along the mRNA strand, _____ bonds link _____ together.

A. hydrogen, amino acids
B. peptide, tRNA molecules
C. hydrogen, tRNA molecules
D. peptide, amino acids

38. Ribosomes continue to slide along the mRNA strand until _____.

A. reaching a stop codon
B. reaching the end of the mRNA strand
C. all the tRNA molecules have been used up
D. reaching a stop anticodon

In the following portion of the exam, please fill in the word or phrase that best completes each sentence.

39. _____ are the basic units of DNA.

40. The DNA bases _____ and _____ are both purines.

41. The RNA base _____ pairs with the DNA base ADENINE.

42. The RNA strand made from the transcription of DNA is _____.

43. The "t" in tRNA stands for _____.

44. On mRNA, the sequence UAG serves as _____.

45. The final substance accepted by a ribosome prior to the polypeptide breaking free is a protein known as a _____.

From DNA to Protein
ANSWER GUIDE

## QUIZ PAC

| QUIZ #1 | QUIZ #2 | QUIZ #3 | QUIZ #4 | QUIZ #5 | QUIZ #6 |
|---|---|---|---|---|---|
| 1. A | 1. A | 1. B | 1. B | 1. A | 1. B |
| 2. C | 2. A | 2. C | 2. A | 2. B | 2. A |
| 3. A | 3. B | 3. D | 3. C | 3. D | 3. C |
| 4. D | 4. C | 4. C | 4. D | 4. A | 4. C |
| 5. D | 5. A | 5. B | 5. C | 5. C | 5. C |
| 6. D | 6. A | 6. C | 6. B | 6. A | 6. A |
| 7. D | 7. B | 7. A | 7. A | 7. C | 7. D |
| 8. D | | 8. C | 8. A | 8. C | |
| | | 9. B | 9. D | 9. A | |
| | | 10. D | 10. B | 10. A | |
| | | 11. B | 11. D | 11. C | |
| | | 12. C | 12. D | 12. E | |
| | | | | 13. E | |
| | | | | 14. D | |

## COMPREHENSIVE EXAM

| | | | | | |
|---|---|---|---|---|---|
| 1. B | 9. A | 17. B | 25. B | 33. D | 41. uracil |
| 2. B | 10. A | 18. D | 26. B | 34. B | 42. messenger RNA (or mRNA) |
| 3. A | 11. D | 19. B | 27. B | 35. C | 43. transcription |
| 4. B | 12. D | 20. B | 28. C | 36. A | 44. an initiator codon |
| 5. A | 13. D | 21. C | 29. A | 37. D | 45. release factor |
| 6. A | 14. B | 22. A | 30. C | 38. A | |
| 7. A | 15. C | 23. D | 31. A | 39. genes | |
| 8. B | 16. B | 24. C | 32. A | 40. adenine, guanine (or guanine, adenine) | |

From DNA to Protein
GLOSSARY

**adenine**: a nitrogen-containing (nitrogenous) base of the purine class; complementary to the pyrimidine thymine in the DNA double helix.

**alkaptonuria**: a hereditary disease which prevents its victim from breaking down the chemical alkapton, causing the victim's urine to appear black.

**amino acid**: the structural unit of proteins consisting of a carboxyl group (COOH), an amino group ($NH_2$) and a side chain.

**Beadle, George**: an American scientist who, along with Edward Tatum, conducted experiments with the red bread mold *Neurospora crassato* show that one gene controls the production of one protein.

**codon**: a sequence of three consecutive nucleotides that codes for a single polypeptide.

**cytosine**: a nitrogenous base of the pyrimidine class; complementary to guanine in the DNA double helix.

**deoxyribonucleic acid** (DNA): a nucleic acid, mainly found in chromosomes, which contains the hereditary information of an organism.

**enzyme**: a protein which speeds up (catalyzes) biochemical reactions.

**eukaryote**: an organism whose DNA is enclosed in a membrane-bound nucleus within each cell.

**exon**: any segment of a gene that codes for a protein.

**Garrod, Sir Archibald**: an English physician who first proposed the idea that genes determine phenotype through enzymes.

**guanine**: a nitrogenous base of the purine class; complementary to cytosine in the DNA double helix

**intron**: any segment of a gene that does not code for a protein messenger RNA (mRNA): a type of ribonucleic acid that is transcribed into genetic information from DNA, and then carries this information from the nucleus to the cytoplasm.

***neurospora crassa***: a red bread mold used by George Beadle and Edward Tatum to demonstrate that one gene codes for one enzyme.

**nitrogenous base**: a nitrogen-containing purine (adenine, guanine) or pyrimidine (thymine, cytosine), which combines with a five-carbon sugar and a phosphate group to form a nucleotide one gene-one enzyme hypothesis: the idea that one gene codes for the synthesis of a single enzyme.

**one gene-one polypeptide hypothesis**: the idea that one gene codes for the synthesis of a single polypeptide of an enzyme or a structural protein.

**phenotype**: the physical characteristics of an organism which are the result of an organism's genetic inheritance.

**polypeptide**: a chain of amino acids linked by peptide bonds prokaryote: a single-celled organism that lacks a membrane-bound nucleus, organelles, and nucleoproteins.

**protein**: a large molecule constructed of one or more polypeptide chains.

**purine**: a nitrogenous base with a double ring structure, such as adenine or guanine.

**pyrimidine**: a nitrogenous base with a single ring, such as cytosine, thymine and uracil.

**ribonucleic acid** (RNA): a nucleic acid consisting of a single strand of linked nucleotides similar in composition to those of DNA with the substitution of the sugar ribose for deoxyribose and the pyrimidine uracil for thymine.

**ribosome**: an organelle found in the cytoplasm, but assembled in the nucleolus, that serves as the site of protein synthesis. Each ribosome consists of ribosomal RNA and proteins, which make up two subunits: one large and one small.

**ribosomal RNA** (rRNA): the ribonucleic acid that combines with proteins in the nucleolus of a cell to form ribosomes.

**RNA polymerase**: an enzyme that binds to DNA to initiate transcription of a gene.

**structural gene**: a segment of DNA that codes for a polypeptide.

**Tatum, Edward**: an American scientist who, along with George Beadle, conducted experiments with the red bread mold *Neurospora crassa* to show that one gene controls the production of one protein.

**transcription**: the process whereby the information encoded in DNA is copied into messenger RNA.

**transfer RNA** (tRNA): A type of ribonucleic acid that binds an amino acid and transports it to sites of polypeptide elongation on a ribosome-mRNA complex

**translation**: the process whereby the genetic information carried by an mRNA transcript is converted to a protein.

**thymine**: a nitrogenous base of the pyrimidine class; complementary to the purine adenine in the DNA double helix.

**uracil**: a nitrogenous base of the pyrimidine class that is substituted for thymine in RNA.