



6.1 - The Transfer of Information from DNA

Pages 244-250 (McGraw-Hill Ryerson, 2011)



Subtopics

- Overview
- Establishing a Link between Genes and Proteins
 - One-Gene/One-Enzyme Hypothesis
- Finding a Messenger between DNA and Protein
- The Genetic Code

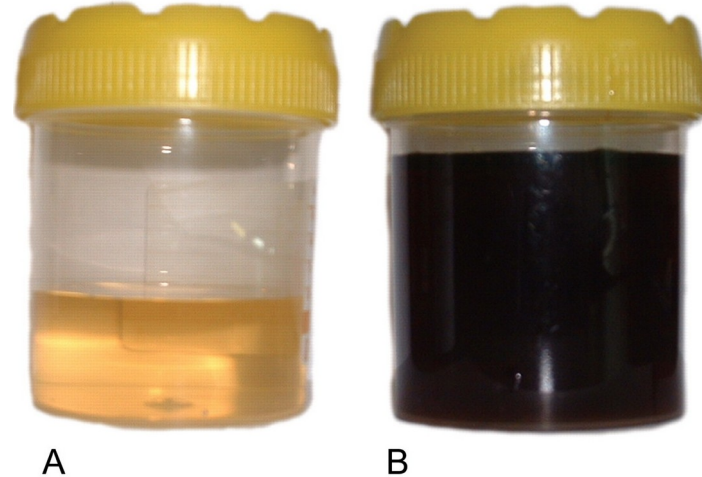
Overview

Archibald Garrod (1902)

Analyzed *alcaptonuria* - urine that turns black when exposed to air

- Identified an enzyme as the culprit
 - Disruption of phenylalanine catabolic pathway
- Identified the disease as inheritable

This is a clear connection between an inherited trait and a protein



Beadle and Tatum - One-Gene/One-Enzyme Hypothesis

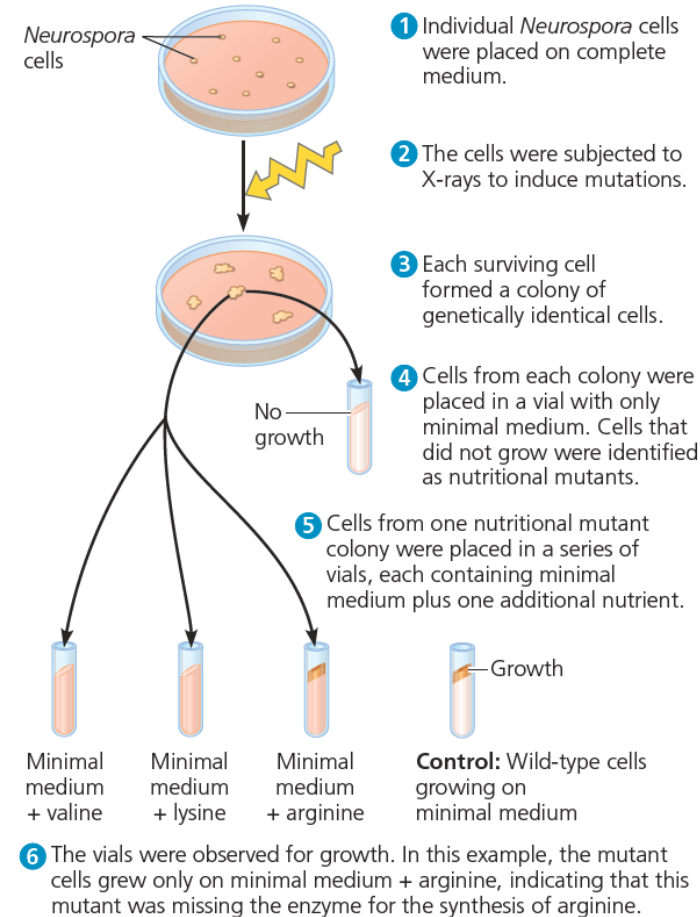
Experimental Design

Hypothesis: A defective gene will produce a defective enzyme

- Grew a mold, *Neurospora crassa*
- Exposed it to x-rays to induce mutations
- Identified *nutritional mutants* and grew them in the following environments

- Minimal medium + valine

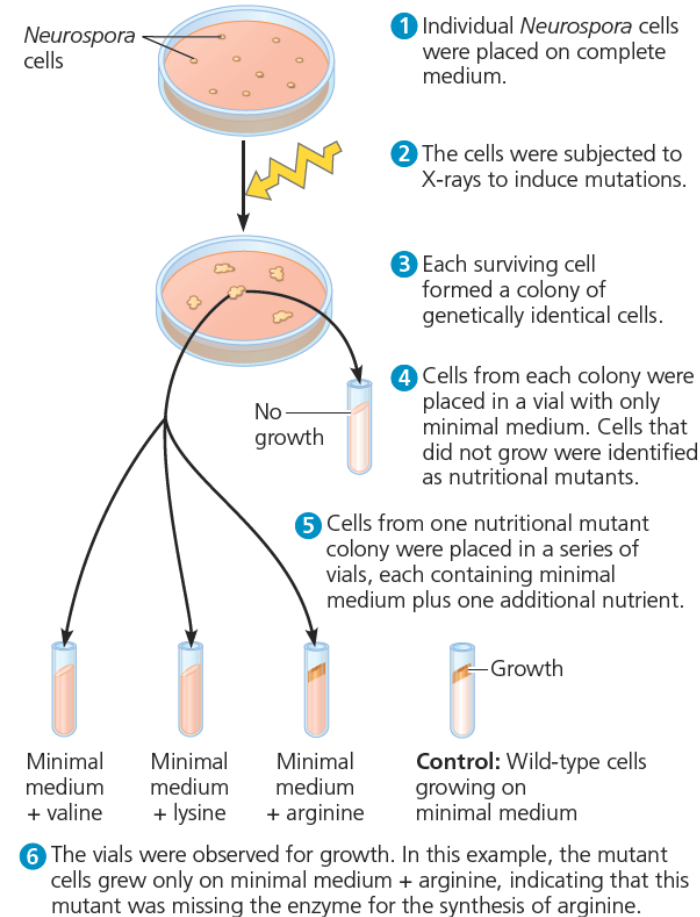
- Minimal medium + lysine



Beadle and Tatum - One-Gene/One-Enzyme Hypothesis

Findings

- *Nutritional mutants* were only able to grow in:
 - Minimal medium + arginine
- This suggests that the mutant had a defective enzyme responsible for the synthesis of arginine



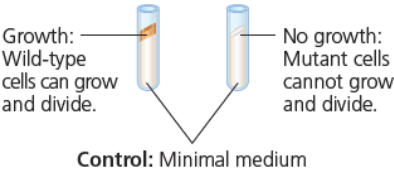
Srb & Horowitz

Experimental Design & Findings

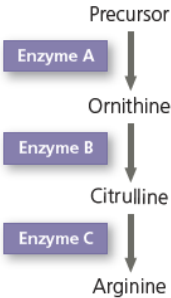
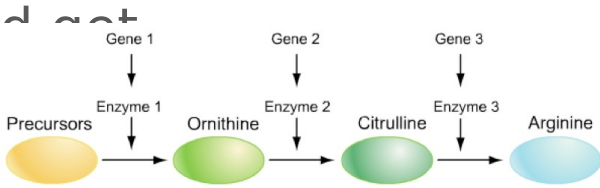
- Arginine synthesis involved multiple genes that could be disrupted by mutation

Experiment Working with the mold *Neurospora crassa*, Adrian Srb and Norman Horowitz, then at Stanford University, used Beadle and Tatum's experimental approach (see Figure 17.2) to isolate mutants that required arginine in their growth medium. The researchers showed that these mutants fell into three classes, each defective in a different gene. From studies by others on mammalian liver cells, they suspected that the metabolic pathway of arginine biosynthesis involved a precursor nutrient and the intermediate molecules ornithine and citrulline, as shown in the diagram on the right.

Their most famous experiment, shown here, tested both the *one gene-one enzyme hypothesis* and their postulated arginine-synthesizing pathway. In this experiment, they grew their three classes of mutants under the four different conditions shown in the Results Table below. They included minimal medium (MM) as a control, knowing that wild-type cells could grow on MM but mutant cells could not. (See test tubes below.)



Results As shown in the table on the right, the wild-type strain was capable of growth under all experimental conditions, requiring only the minimal medium. The three classes of mutants each had a specific set of growth requirements. For example, class II mutants could not grow when ornithine alone was added but could grow when either citrulline or arginine was added.



Results Table		Classes of <i>Neurospora crassa</i>			
Condition		Wild type	Class I mutants	Class II mutants	Class III mutants
	Minimal medium (MM) (control)				
	MM + ornithine				
	MM + citrulline				
	MM + arginine (control)				
Summary of results		Can grow with or without any supplements	Can grow on ornithine, citrulline, or arginine	Can grow only on citrulline or arginine	Require arginine to grow

Srb and Horowitz - Building on One-Gene/One-Enzyme

Conclusion From the growth requirements of the mutants, Srb and Horowitz deduced that each class of mutant was unable to carry out one step in the pathway for synthesizing arginine, presumably because it lacked the necessary enzyme, as shown in the table on the right. Because each of their mutants was mutated in a single gene, they concluded that each mutated gene must normally dictate the production of one enzyme. Their results supported the one gene–one enzyme hypothesis, proposed by Beadle and Tatum, and also confirmed that the arginine pathway described in the mammalian liver also operates in *Neurospora*. (Notice in the Results Table that a mutant can grow only if supplied with a compound made *after* the defective step because this bypasses the defect.)

Data from A. M. Srb and N. H. Horowitz, The ornithine cycle in *Neurospora* and its genetic control, *Journal of Biological Chemistry* 154:129–139 (1944).

Gene (codes for enzyme)	Wild type	Class I mutants (mutation in gene A)	Class II mutants (mutation in gene B)	Class III mutants (mutation in gene C)
Gene A →	Precursor ↓ Enzyme A ↓ Ornithine ↓ Citrulline ↓ Arginine	Enzyme A Precursor ↓ Ornithine ↓ Citrulline ↓ Arginine	Enzyme A ↓ Enzyme B Ornithine ↓ Citrulline ↓ Arginine	Enzyme A ↓ Ornithine ↓ Citrulline Enzyme C ↓ Arginine

WHAT IF? > Suppose the experiment had shown that class I mutants could grow only in MM supplemented by ornithine or arginine and that class II mutants could grow in MM supplemented by citrulline, ornithine, or arginine. What conclusions would the researchers have drawn from those results regarding the biochemical pathway and the defect in class I and class II mutants?

One-gene/One-polypeptide hypothesis

→ A proposal that one gene codes for one polypeptide (or protein)

https://www.youtube.com/watch?v=4nXX2djQVvl&ab_channel=SusanBush

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Finding a Messenger Between DNA and Proteins

messenger RNA (mRNA)

- RNA that contains the genetic information of a gene and carries it to the protein synthesis machinery; it provides the information that determines the amino acid sequence of a protein

How do we know it does this?

- DNA is only in the nucleus - RNA is in the nucleus and in the cytoplasm
- The concentration of RNA in the cytoplasm correlates with the level of protein production

Learning Check

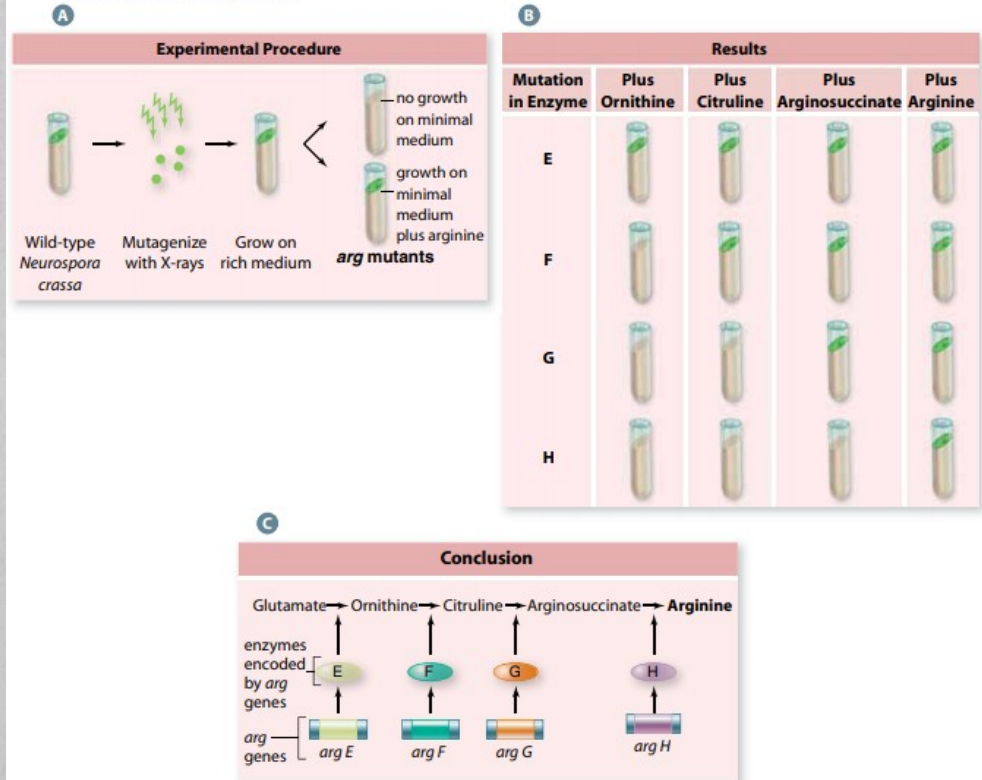
Learning Check

1. How did Garrod's findings demonstrate a link between genes and proteins?
2. Using a flowchart, outline the procedure and results of the experiment performed by Beadle and Tatum on *Neurospora crassa*. What was the significance of their results?
3. What evidence supported the idea that RNA acts as an intermediate molecule between DNA and proteins?
4. How did Jacob and colleagues show that RNA acts as a "genetic messenger"?
5. Explain why it is advantageous for cells to synthesize an mRNA messenger.
6. Predict the sequence of bases in a strand of mRNA that is synthesized from the following strand of DNA.
5'-CCGTTAATC-3'

- Garrod's studies on alcaptonuria showed that having the black urine phenotype was due to a recessive inheritance factor that caused that production of a defective enzyme.
- Answers could use **Figure 6.1** on page 245 of the student textbook as a guideline. The results of the Beadle and Tatum experiment showed that a single gene produces one enzyme (one-gene/one-enzyme hypothesis). This was later modified to the one-gene/one-polypeptide hypothesis since not all proteins are enzymes.
- The evidence that supported RNA as an intermediate molecule included the following: RNA is found in the nucleus and cytoplasm; the concentration of RNA in the cytoplasm is correlated with protein production; RNA is synthesized in the nucleus and transported to the cytoplasm.
- Jacob and colleagues saw that bacteria infected with a virus had a newly synthesized virus-specific RNA molecule. This RNA molecule associated with bacterial ribosomes, which are the sites of protein production. Therefore, the RNA molecule carried the genetic information for the production of a viral protein.
- Having RNA as an intermediate molecule that can transport from the nucleus to the cytoplasm is preferred over DNA having to continually transport itself, which could increase the likelihood of damage to the DNA. Multiple steps in gene expression provide many opportunities for regulation. This allows the cell to have increased control over protein synthesis.
- 5'-GAUUAACGG-3'

Figure 6.1 Beadle and Tatum's experiment showed that a single gene determines the production of one enzyme.

Predict whether growth would occur after each addition of the intermediates for a mutant strain that does not produce glutamate.



The Genetic Code

So we know that mRNA codes for the polypeptide, but what's the genetic code?

Genetic Code

- A set of rules for determining how genetic information in the form of a nucleotide sequence is converted to an amino acid sequence of a protein; a code specifying the relationship between a nucleotide codon and an amino acid

The Genetic Code

1 to 1 scenario

A	Amino acid 1
T	Amino acid 2
C	Amino acid 3
G	Amino acid 4

The Genetic Code

2 to 1 one scenario

	A	T	C	G
A	Amino acid 1	Amino acid 5	Amino acid 9	Amino acid 13
T	Amino acid 2	Amino acid 6	Amino acid 10	Amino acid 14
C	Amino acid 3	Amino acid 7	Amino acid 11	Amino acid 15
G	Amino acid 4	Amino acid 8	Amino acid 12	Amino acid 16

The Genetic Code

Triplet hypothesis

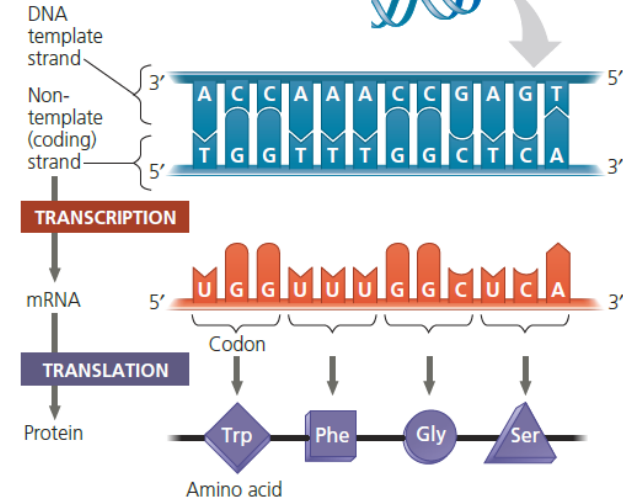
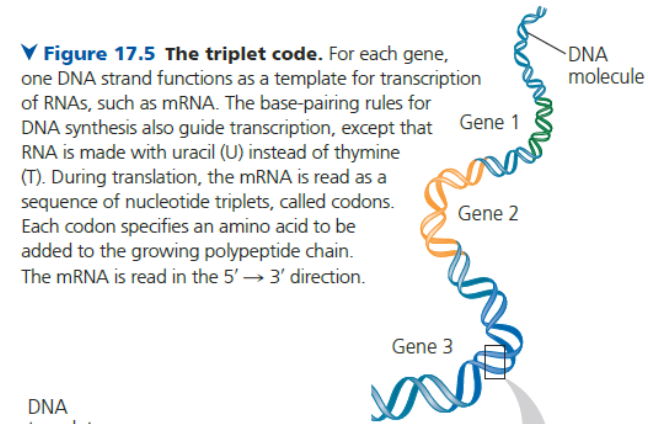
- A proposal that the genetic code is read three nucleotide bases at a time
- This provides enough complexity to account for up to 20 amino acids
- We call this triplet of bases a **codon**

		Second letter				
		U	C	A	G	
First letter	U	UUU Phenylalanine UUC Phenylalanine UUA Leucine UUG Leucine	UCU Serine UCC Serine UCA Serine UCG Serine	UAU Tyrosine UAC Tyrosine UAA Stop codon UAG Stop codon	UGU Cysteine UGC Cysteine UGA Stop codon UGG Tryptophan	U C A G
	C	CUU Leucine CUC Leucine CUA Leucine CUG Leucine	CCU Proline CCC Proline CCA Proline CCG Proline	CAU Histidine CAC Histidine CAA Glutamine CAG Glutamine	CGU Arginine CGC Arginine CGA Arginine CGG Arginine	U C A G
	A	AUU Isoleucine AUC Isoleucine AUA Isoleucine AUG Methionine; start codon	ACU Threonine ACC Threonine ACA Threonine ACG Threonine	AAU Asparagine AAC Asparagine AAA Lysine AAG Lysine	AGU Serine AGC Serine AGA Arginine AGG Arginine	U C A G
	G	GUU Valine GUC Valine GUA Valine GUG Valine	GCU Alanine GCC Alanine GCA Alanine GCG Alanine	GAU Aspartic acid GAC Aspartic acid GAA Glutamic acid GAG Glutamic acid	GGU Glycine GGC Glycine GGA Glycine GGG Glycine	U C A G

FIGURE 10.11 The Genetic Code Genetic information is encoded in three-letter units—codons—that are read in the 5'-to-3' direction on the mRNA. To decode a codon, find its first letter in the left column, then read across the top to its second letter, then read down the right column to its third letter. The amino acid the codon specifies is given in the corresponding row. For example, AUG codes for methionine, and GUA codes for valine.

Which strand of DNA does RNA match up with?

- The Non-template (coding) strand sequence is nearly identical to the mRNA sequence
- Thymine bases in the DNA are represented by Uracil bases in the mRNA



VISUAL SKILLS ▶ By convention, the nontemplate strand, also called the coding strand, is used to represent a DNA sequence. Write the sequence of the mRNA strand and the nontemplate strand—in both cases reading from 5' to 3'—and compare them. Why do you think this convention was adopted? (Hint: Why is this called the coding strand?)

Three characteristics

1. The genetic code is redundant
 - More than one codon for an amino acid (61 codons for just 20 amino acids)
 - Only 3 codons code for nothing (stop signals)
2. The genetic code is continuous
 - No spaces, punctuations or overlap
 - A small shift can disrupt the entire base pair sequence and thus the amino acid sequence
3. The genetic code is nearly universal
 - Nearly all organisms use the same code
 - A gene taken from one kind of organism and inserted into another organism will produce the same protein

The Genetic Code

Gene expression - the transfer of genetic information from DNA to RNA to protein

- This is referred to as the *central dogma* of genetics

Transcription

The synthesis of RNA from a DNA template

Translation

The synthesis of protein from an mRNA template

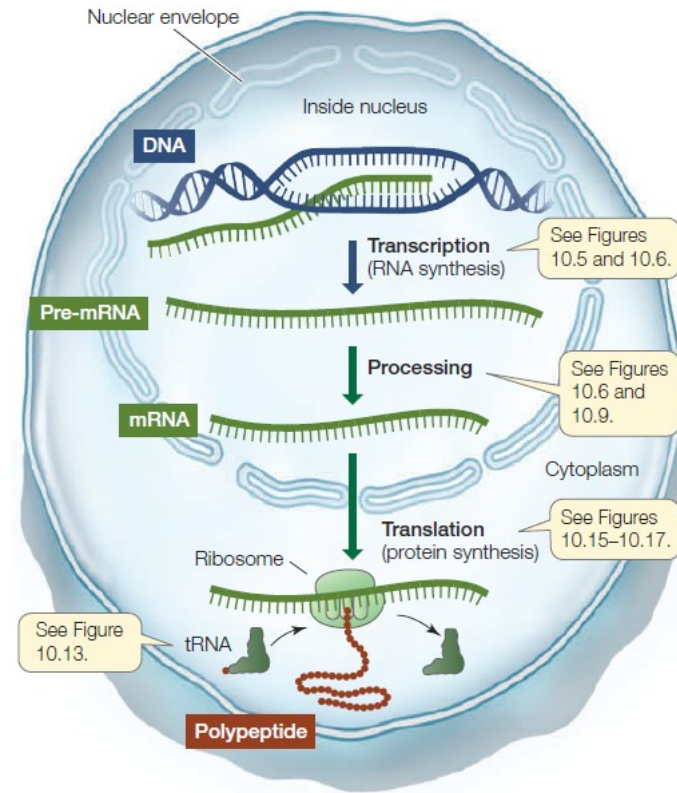
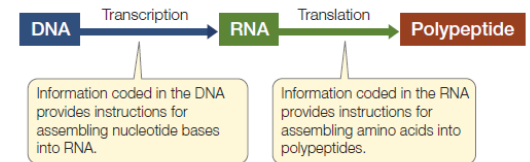


FIGURE 10.3 From Gene to Protein This diagram summarizes the processes of gene expression in eukaryotes.



The Genetic Code

Gene expression - the transfer of genetic information from DNA to RN to protein

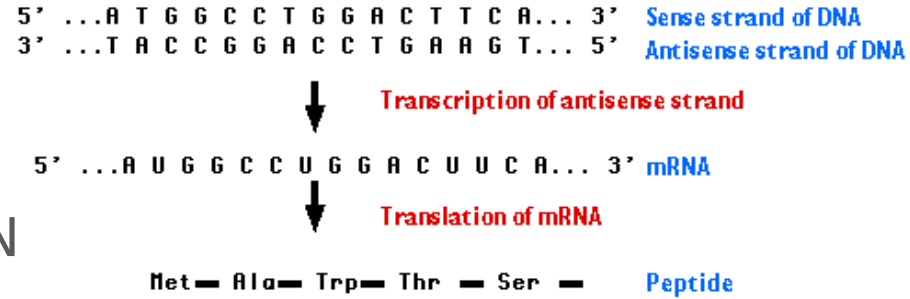
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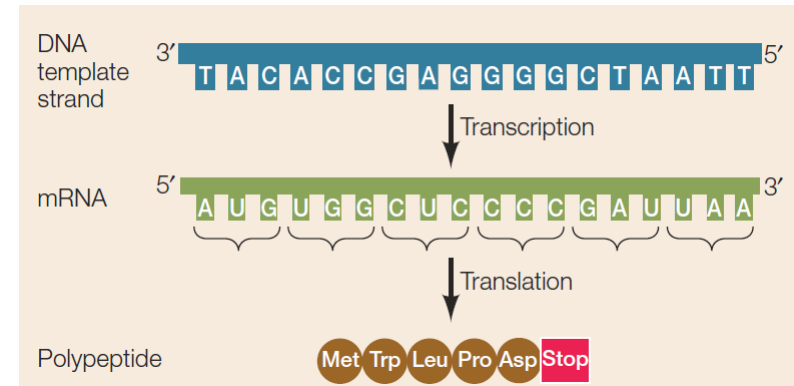
The synthesis of RNA from a DNA template

Translation

The synthesis of protein from an mRNA template



https://www.youtube.com/watch?v=-L0rikDOX5s&ab_channel=biologyexams4u

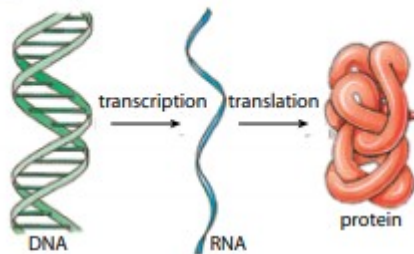


1, 5, 7, 8, 9, 11, 12, 13, **14**, 15

Topic Review Questions

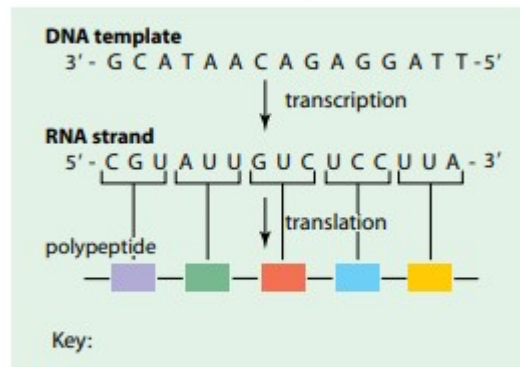
1. **T/I** "The link between genes and proteins was determined experimentally by Archibald Garrod." Explain why you agree or disagree with this statement.
5. **K/U** Describe the triplet hypothesis.
7. **T/I** Suggest another genetic code system that could code for 20 different amino acids.
8. **K/U** List and explain the three characteristics of the genetic code.
9. **T/I** Infer why growing polypeptides begin with methionine.
11. **T/I** Suppose that during replication of a gene, one nucleotide is copied incorrectly. However, the protein coded for by this "new" gene is the same as that coded for by the normal gene. How can this be explained?

12. **K/U** Study the illustration below.



- a. What theory does the illustration represent?
 - b. What does this theory explain?
13. **A** "Each person has a unique genetic code." Do you think this is an accurate statement? Explain your answer.

14. **A** Use **Table 6.1** and the information in the diagram below to determine the amino acids that would make up the portion of the polypeptide shown. Include information for a key as well.



15. **A** Discuss the significance of the universality of the genetic code with respect to the following fields:
 - a. evolutionary science
 - b. medical science

<https://www.explorellearning.com/index.cfm?method=cResource.dspView&ResourceID=442>



References

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