Unit 3: DNA and Genetics

Module 6: Molecular Basis of Heredity

NC Essential Standard
- 3.1 Explain how traits are determined by the structure and function of DNA

How much DNA is in my body?

- DNA is found in every cell (except red blood cells)
- Each cell contains roughly 2 meters of DNA containing ~3 BILLION base pairs
- The human body has ~ 10,000,000,000,0000 cells
- If you unraveled all the DNA from all of your cells and stretched it out end to end, it would stretch to the sun and back several times!
- You could fit 25,000 strands of DNA side by side in the width of a human hair!

I. What is **DNA**?

A. Importance of DNA

1. DNA stands for **deoxyribonucleic acid**. It is one of two nucleic acids found in the cell.
2. DNA is the blueprint for life. Every living thing uses DNA as a code for making proteins which determine traits. For example, DNA contains the instructions for making special proteins (called pigments) which give your eyes color.
3. DNA is packaged in **chromosomes**. Each chromosome is composed of one continuous DNA molecule. The DNA molecule is wrapped around proteins and coiled tightly for protection.
4. Remember, chromosomes are found in the nucleus of eukaryotic cells. Prokaryotic cells have a single chromosome free-floating in the cytoplasm.

DNA

What?

Where?

Used for?

B. Discovery of DNA structure

1. Many scientists worked to determine the source of heredity. **Heredity** is the passing of **traits** from parent to offspring. But how are those traits passed?
   a. First, scientists determined that chromosomes controlled heredity and are made of DNA and proteins.
   b. Then, scientists determined DNA was the chemical that controlled characteristics (traits) of the organisms.
   c. Then, the race was on to reveal the chemical structure of the DNA molecule.
2. Rosalind Franklin was the first to take a clear "picture" of DNA using a technique called X-ray crystallography. The "picture" offered a clue to the shape of DNA.
3. Watson and Crick received credit for finalizing the model of DNA by using the picture taken by Franklin (given to them by Franklin's research assistant – Maurice Wilkins), and by synthesizing work completed by other scientists.

Watch It!

C. Structure of the DNA molecule

(From small to large)

N_____ base + sugar + phosphate

↓

N_____

↓

Two strands held by _____ _____

↓

D_____H_____

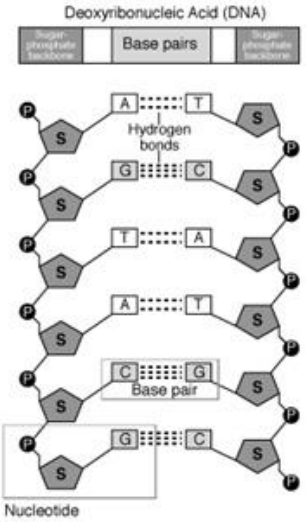
1. DNA is a **double helix**. The double helix looks like a twisted ladder.
2. The building blocks of DNA are called **nucleotides**. A nucleotide consists of three parts:
   a. A sugar (named **deoxyribose**)
   b. A **phosphate** group
   c. One of four **nitrogen bases**. The four possible nitrogen bases in a DNA molecule are named:
      i. **Adenine** (A)
      ii. **Thymine** (T)
      iii. **Guanine** (G)
      iv. **Cytosine** (C)

3. There are two strands of nucleotides in every DNA molecule held together by weak **hydrogen bonds** that occur in the middle between the nitrogen bases.
4. The nitrogen bases bond in a specific way. Adenine bonds with thymine (A–T). Guanine bonds with cytosine (G-C). This pattern is called **complementary base pairing**.

On this diagram, highlight a nucleotide.

Then write out the NAME of the sugar beside one of the sugar molecules.

Finally, draw a box around the "backbone" and label.



coris.noaa.gov/glossary/ nucleotide_186.jpg

Check Yourself!

1. How is DNA connected to your traits?

2. What larger structure is composed of DNA?

3. What two parts of the nucleotide make up the sides (backbones) of a DNA molecule?

4. What makes up one rung/ "step" of the DNA "ladder"?

5. What type of bond holds the rungs together?

II. Do all my cells have the same DNA?

Watch It!

A. **DNA replication** copies DNA for new cells

1. DNA is needed in each cell to make necessary proteins.
2. Because DNA is so important, when a cell divides, it must pass on an <u>exact</u> copy of the DNA to function correctly.
3. Therefore, DNA is copied (replicated) during the S phase of the cell cycle (part of interphase, before mitosis/meiosis).

B. Process of DNA replication

1. An enzyme breaks the weak hydrogen bonds between the paired nitrogen bases. This allows DNA to "unzip" as the two strands move apart.
2. The newly unpaired nucleotides are paired (A-T and G-C) with extra nucleotides present in the nucleus. This process is catalyzed by another enzyme.
3. Enzymes then link the nucleotides along the newly constructed side of the DNA ladder by bonding sugar to phosphate.
4. The DNA is proofread by enzymes for any errors.

Enzyme Review!
What <u>are</u> enzymes?

How do enzymes work?

C. Result of DNA replication

1. Two identical DNA molecules have been produced. Each "daughter" DNA molecule is composed of one "old" strand and one "new" strand. (Here a "strand" refers to one chain of nucleotides.)
2. Each copy of DNA is packaged as a chromatid on a doubled chromosome.
3. After mitosis, each daughter cell will receive one of the two identical copies of DNA. This happens when the doubled chromosome is split, each new chromosome going to a new daughter cell.

Replication
What?

Where?

Used for?

When?

Check Yourself!

1. Why does each cell need DNA?

2. What is the name of the process which makes a copy of DNA?
3. When does DNA replication occur?
4. What catalyzes each step of DNA replication?
5. At the end of DNA replication, each molecule is composed of one _____ strand and one _____ strand.

III. How can DNA be used by the cell to make a protein?

A. Importance of **protein synthesis**

What is a trait?

How are the terms "protein" and "trait" related?

1. Every inherited trait is controlled by one or more proteins. Protein synthesis is the process that makes those proteins.
2. Each cell must produce different proteins, based on the function of that cell. For example, only blood cells need to produce the protein hemoglobin.

B. Central Dogma of Biology – the central axis around which all other biological concepts rotate

1. DNA structure controls the production of proteins.
   a. A section of DNA which is used as the blueprint or code for the production of a protein is a **gene**.
   b. Each gene is composed of a specific sequence of nucleotides. This sequence can be represented by writing the order of nitrogen bases. For example, ACGCCATGCTAC
   c. Every three bases in this sequence is called a **codon**. A codon is like a single word in a sentence. Only by putting the words (codons) in the correct order can you create a meaningful sentence (protein).

Three DNA nucleotides makes a _____.

One codon controls the placement of one _____ _____.

Many amino acids make a _____.

Rewrite the "Central Dogma" as a sentence (use all of the words!)

d. Proteins are made of amino acids. Each codon directs the cell to place a specific amino acid in a particular position as the protein is built. For example, the codon CAA in DNA codes for the amino acid "valine". If this codon was the third codon in a gene, valine would be the third amino acid in the protein.

2. Diagram of the Central Dogma

DNA ----------→ RNA ----------→ Protein
(transcription) (translation)

C. Process of protein synthesis

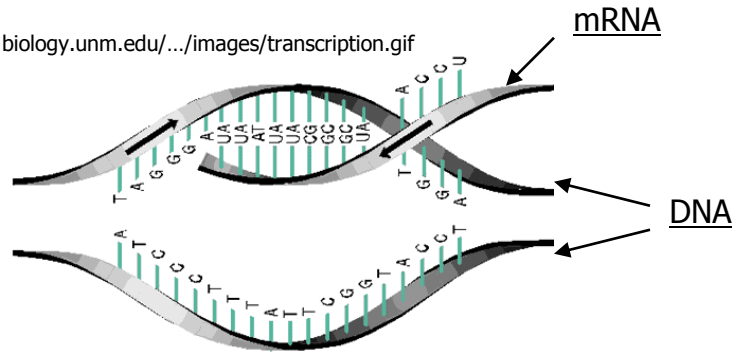
1. **Transcription** rewrites the DNA code as messenger RNA
   a. DNA cannot leave the nucleus (it is far too big) to go the ribosomes where proteins are made. Thus, it must send the instructions using RNA.
   b. **mRNA** copies the DNA when the DNA unzips one section called a gene. One gene makes one protein.
   c. **messengerRNA** is constructed one nucleotide at a time using one side of the DNA as a template.
   d. All RNA has a different sugar (**ribose**) which cannot bond to thymine. Thus, RNA must use a different nitrogen base (**uracil**) as a substitute for thymine (T). If the DNA read CTA, the mRNA would be GAU.
   e. mRNA leaves the nucleus through a small opening in the nuclear membrane called a pore.
   f. The DNA rezips the gene.

How does transcription produce a "script" based on DNA?

Highlight the mRNA.

Explain this diagram.

biology.unm.edu/…/images/transcription.gif



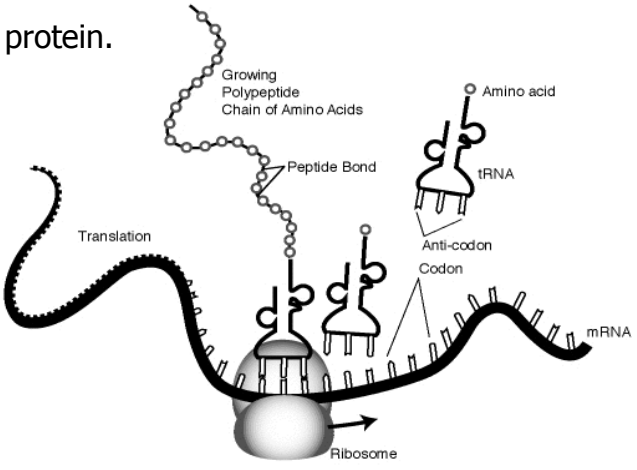
How does translation "read" the "script" produced in transcription?

Watch It!

2. **Translation** uses the mRNA to build a protein
   a. In the cytoplasm of the cell, translation occurs at the ribosome. Ribosomes are made of **rRNA** (**ribosomal RNA**) and proteins.
   b. The mRNA "start" codon (AUG) attaches to the ribosome. The ribosome holds mRNA and helps link amino acids together to make a protein.
   c. **tRNA** (**transfer RNA**) is a molecule that carries an amino acid to the ribosome. In order for the tRNA to leave the amino acid at the ribosome, the tRNA must bond with a complementary codon on the mRNA.
   d. The ribosome allows the **tRNA anticodon** (made of three bases at the bottom of each tRNA) and the complementary mRNA codon to pair.
   e. The amino acid is removed from the tRNA by an enzyme. As each new amino acid arrives on a tRNA, amino acids are bonded together IN ORDER by a **peptide bond** to form a **polypeptide**.
   f. When the ribosome reaches a "stop" codon, it releases the mRNA and the string of amino acids separately. The string of amino acids folds and coils to shape the protein.

Highlight the protein.

Explain this diagram.



www.wikipedia.org

What is the END RESULT of protein synthesis?

Watch It!

If gene regulation were not possible, would cell specialization happen?

Why/why not?

3. Result of protein synthesis
   a. Cells respond to their environments by producing different types and amounts of protein.
   b. The cell produces proteins that are structural (forming part of the cell materials) or functional (such as enzymes, hormones, or chemicals for in cell chemistry).
   c. All of an organism's cells have the same DNA, but the cells differ based on the expression of the genes.
      i. Multicellular organisms begin as undifferentiated masses of cells. Variation in DNA activity determines cell types.
      ii. Different types of cells expressing different genes leads to **differentiation**. Only specific parts of the DNA are activated in those cells. Once a cell differentiates, the process cannot be reversed. For example, we have muscle cells, nerve cells, and others.
      iii. **Gene regulation** is the process which determines which genes will be expressed (used to make a protein). This can be affected by the cell's history and/or environment. Proteins may be overproduced, underproduced or produced at incorrect times. Ex: Injury repair and cancer
   d. Each individual in a sexually reproducing population has slightly differing sequences of nucleotides in DNA when compared to other organisms of the same specie. The different sequences lead to different proteins, which produce different traits (i.e. variation). For example, two humans with different eye color.

Check Yourself!

1. What controls inherited traits?
2. What controls the production of proteins?
3. Define a gene.
4. Diagram the central dogma of biology.
5. What is the purpose of transcription?
6. What type of RNA is used in transcription?
7. What nitrogen base in RNA is used as a substitution for thymine?
8. What is the purpose of translation?
9. What two types of RNA are used only in translation?
10. What type of bond links amino acids?

Why does a change in DNA mean a change in the protein could happen?

Watch It!

IV. Whth appensw henp roteins ynthesisg oesw rong_?

A. A **mutation** is a change in the original DNA sequence, which may lead to a change in the amino acid sequence.

B. A mutation occurs when the original DNA sequence is not copied properly during replication or protein synthesis. Mutations can be spontaneous or caused by radiation and/or chemical exposure.

C. The result of a mutation is a change in the amino acid sequence. The necessary protein may not be made or is defective. This can change the traits of the cell or organism. Only mutations in sex cells (egg and sperm) or in the gamete can result in heritable changes.

D. There are two types of gene mutations:

1. **Point** (or **substitution**) mutations occur when a single base is replaced with a different base. (For example, A is replaced with C.)

   Ex. GATTACA → GAGTACA

a. A point mutation, if it occurs on a gene, may result in the change of a single amino acid within the protein.
b. Sickle cell anemia, a disease that results in misshapen red blood cells, is caused by a point mutation.

2. **Frameshift** mutations occur when a single base is added (**addition** frameshift) or deleted (**deletion** frameshift) within the sequence. Because DNA and the mRNA copy are read three bases (a codon) at a time, this type of mutation "shifts" the reading frame.

Ex. GAT/TAC/ATT → GAT/TAA/CAT/T

a. The effect of a frameshift depends on the location of the addition or deletion. The earlier within the gene sequence the base is added or deleted, the more amino acids will be changed.
b. Huntington's Disease, a disease that results in the progressive loss of nervous system function, may be caused by the insertion of several bases.

Compare/Contrast point and frameshift mutations using a Venn or T-chart:

Check Yourself!

1. Define mutation.

2. What is the result of a mutation?

3. What are the two types of mutation?

4. What type of mutation is illustrated in the title of this section of notes (IV)?

5. Which type of mutation may affect a greater number of amino acids?

DNA's Two Jobs

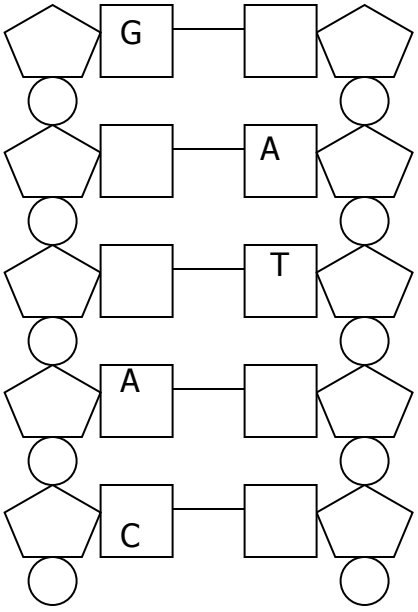
Replication	Both	Protein Synthesis
• Takes place in the _____ • Occurs before _____ _____ • Produces two _____ strands of DNA • Uses the entire _____ _____	• Uses DNA • _____ needed • Can produce _____	• Takes place in the _____ and cytoplasm (_____) • Occurs during the ____ _____ of the cell • Produces _____ • Uses a section of the DNA molecule called a _____ • Uses 3 types of _____(rRNA, mRNA, tRNA)

Word Bank:

Cell Division	Gene	Normal life	Proteins
DNA molecule	Identical	Nucleus	RNA
Enzymes	Mutations	Nucleus	Ribosome

Unit 3 / Module 6
Problem-Solving Set

1. On the DNA diagram below:
    a. Place an S in each shape that indicates sugar (deoxyribose)
    b. Place a P in each shape that indicates phosphate
    c. Complete the missing nitrogen bases
    d. Write an HB on a line that represents a hydrogen bond
    e. Draw a box around one nucleotide



2. Every living organism has DNA. ALL DNA is made of 4 types of nucleotides. What makes human DNA different from oak tree or frog DNA?

3. A molecule of DNA is analyzed for its adenine content and is found to contain 22% adenine. What is the content of the other 3 nitrogen bases?

    Adenine – 22%

    Thymine - _____

    Guanine - _____

    Cytosine - _____

4. Put the steps of DNA replication in the correct sequence:

   _____ Free nucleotides pair with newly unpaired nucleotides

   _____ The DNA molecule "unzips"

   _____ Enzymes break hydrogen bonds

   _____ Enzymes "re-zip" the DNA molecule

   _____ Two identical molecules of DNA are complete

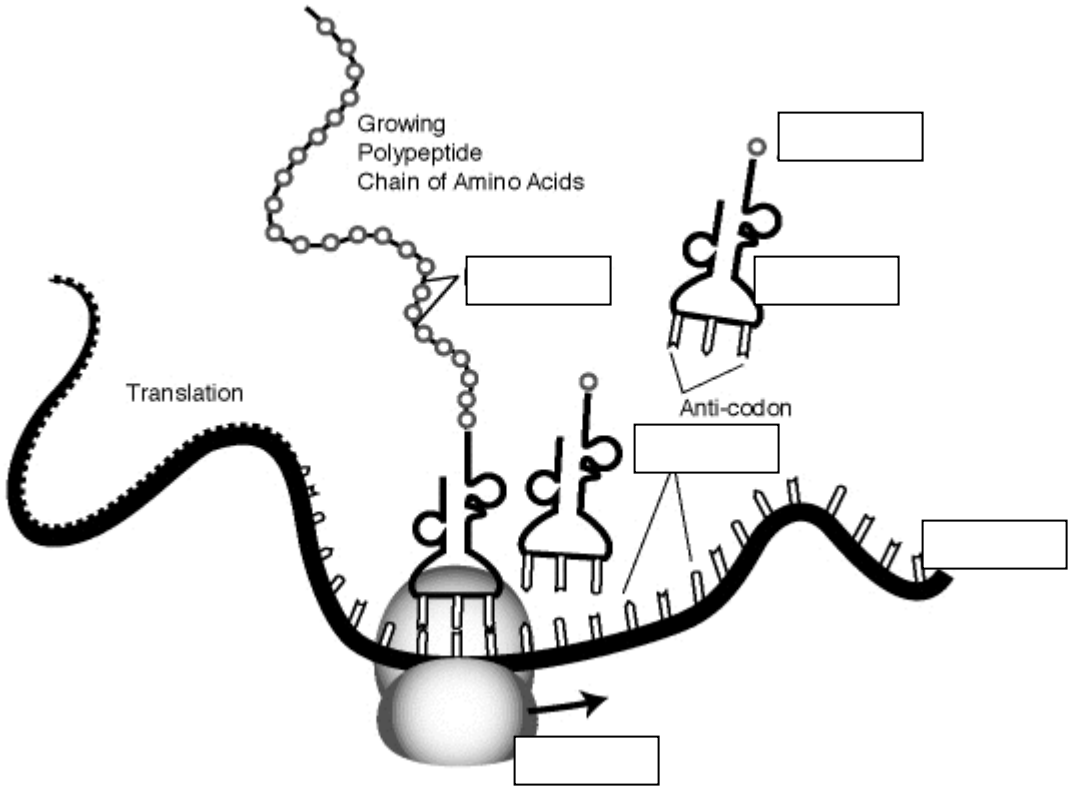
5. In the sequence below, what is the molecule labeled "A"? The molecule labeled "B"?

   A ----------→ B ----------→ Protein
   (transcription) (translation)

   A = _____ B = _____

6. Label the diagram of Protein Synthesis using the following terms:

   Ribosome mRNA tRNA Codon Amino acid Peptide bond



mRNA codon chart:

First Letter	Second Letter				Third Letter
	U	C	A	G	
U	phenylalanine	serine	tyrosine	cysteine	U
	phenylalanine	serine	tyrosine	cysteine	C
	leucine	serine	stop	stop	A
	leucine	serine	stop	tryptophan	G
C	leucine	proline	histidine	arginine	U
	leucine	proline	histidine	arginine	C
	leucine	proline	glutamine	arginine	A
	leucine	proline	glutamine	arginine	G
A	isoleucine	threonine	asparagine	serine	U
	isoleucine	threonine	asparagine	serine	C
	isoleucine	threonine	lysine	arginine	A
	(start) methionine	threonine	lysine	arginine	G
G	valine	alanine	aspartate	glycine	U
	valine	alanine	aspartate	glycine	C
	valine	alanine	glutamate	glycine	A
	valine	alanine	glutamate	glycine	G

7. Use the mRNA codon chart to determine the amino acid sequence for the DNA sequence below.

   DNA – TAC GCT CAC AAA CGC ATC

   mRNA - _____ _____ _____ _____ _____ _____

   tRNA - _____ _____ _____ _____ _____ _____

   amino acids - _____ _____ _____ _____ _____ _____

8. Use the mRNA codon chart to determine the codons that would code for the amino acid tyrosine.

   _____ or _____

9. If the mRNA sequence reads UCACCUACGGUG, what is the sequence of DNA that it was transcribed from?

   DNA - _____

An original gene sequence in DNA reads TACGTTCCCGAT.

10. Transcribe the above sequence to mRNA:

    ____

    Use the mRNA codon chart to determine the amino acid sequence coded for:

    __________ __________ __________ __________

11. Re-write the DNA sequence assuming that a point mutation has occurred and the first G in the sequence is replaced with a T:

    ____

    Transcribe the DNA sequence into mRNA:

    ____

    Use the mRNA codon chart to determine the amino acid sequence coded for:

    __________ __________ __________ __________

    How did the point mutation affect the polypeptide chain?

12. Rewrite the DNA sequence assuming that a frameshift mutation has occurred and the first C in the sequence is deleted.

    ____

    Transcribe the DNA sequence into mRNA:

    ____

    Use the mRNA codon chart to determine the amino acid sequence coded for:

    __________ __________ __________

    How did the frameshift mutation affect the polypeptide chain?

13. ABCDE → ABFDE illustrates a _______________ mutation.

14. ABCDE → ABCFDE illustrates a _________________ mutation.