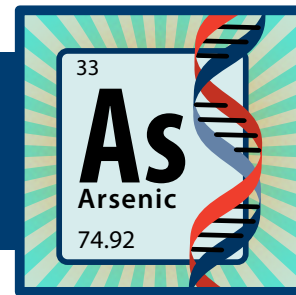


UNIT: DNA

LESSON 1: ARSENIC AND EPIGENETICS: A DNA STORY

Activity 1C: Epigenetic Word Map – Linking Vocabulary



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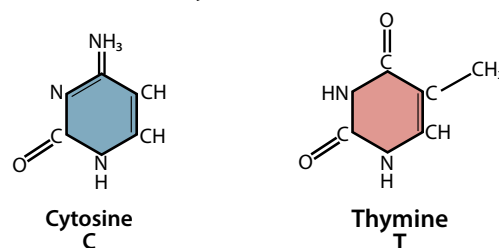
HEALTH STARTS WITH SCIENCE

DNA Structure

Individual DNA strands are made of **nucleotides**. Each nucleotide consists of three molecules: a sugar, a phosphate group, and a nitrogen base. The sugar and phosphate make up the backbone of the DNA strand. The sugar is **deoxyribose** (dee-oxee-RYE-bose) which is the D in DNA. Each nucleotide has a nitrogen base attached to it: **adenine (A)**, **thymine (T)**, **guanine (G)**, and **cytosine (C)**. There are two types of nitrogen bases: **purines** (A & G) and **pyrimidines** (T and C). Purines consist of two carbon-nitrogen rings while pyrimidines only have one carbon-nitrogen ring (Fig. 1).

Atoms within each base share electrons to make a stable, neutrally charged molecule. However, not all atoms in each base share electrons equally. This causes **polarity** within the molecule, meaning parts of the molecule have a partial negative or positive charge. These opposite charges will attract oppositely charged polar molecules forming weak but important temporary bonds between bases. These are called **hydrogen bonds** (Fig. 2).

Fig. 1
Pyrimidines



Purines

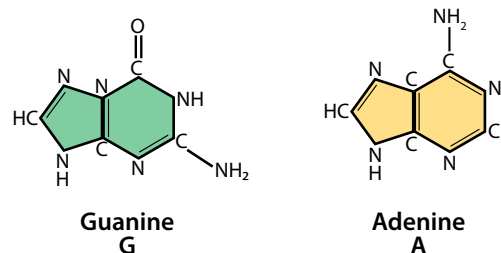
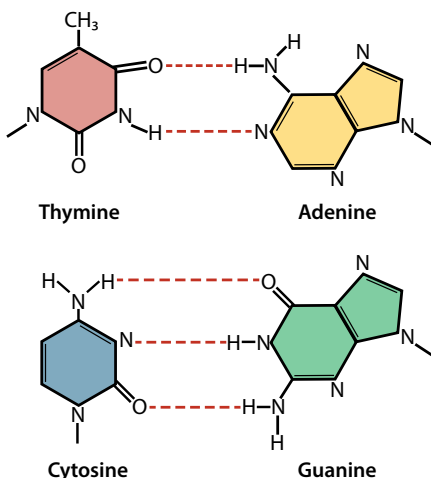


Fig. 2



The hydrogen bonds pull one DNA strand toward a complimentary DNA strand. The bonded DNA strands twist into a double helix structure (Fig. 3).

The DNA contains **genes**. Genes are formed by combinations of three nucleotides. These sets of three are referred to as **codons**. The sequence of genes on the DNA determines an organism's **genotype**. How a genotype is expressed, meaning how it shows up on a body, is known as the **phenotype**.

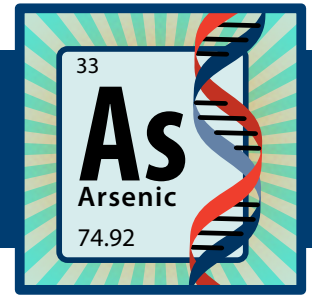
Although the DNA strands are chemically bonded to each other, chemical bonds can break. Sometimes bonds which hold the nitrogen base to the sugar-phosphate backbone break and the nitrogen base can move and attach to other sugar-phosphate groups. It isn't just bases that can move. Entire nucleotides can move to different locations on the DNA strand. When bases or nucleotides move or change position, it can affect the genetic code.

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DNA contains the genetic information, but that information needs to get from the DNA into the **cytoplasm** where cell structures interpret the information and express the gene. Sounds simple, but there is a BIG problem: DNA cannot get through the **semipermeable membrane** that surrounds the cell nucleus. How does the genetic code get out of the nucleus?

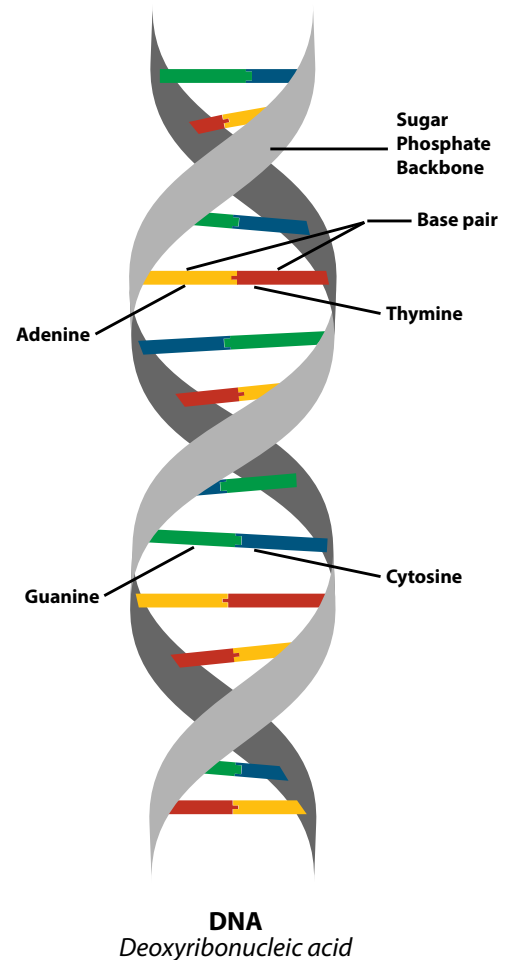
RNA to the Rescue!

Ribonucleic acid (RNA) is a single-stranded molecule made up of a sugar, phosphate group, and nitrogen base. Unlike double-stranded DNA which has deoxyribose as its sugar, the single-stranded RNA's sugar is **ribose** (RYE-bose). During the process of DNA **transcription**, small portions of the DNA molecule unwind, and hydrogen bonds between nitrogen bases are temporarily broken, exposing codons. The exposed DNA amino acids attract complementary bases, but these individual bases are attached to an RNA nucleotide. Like DNA, each individual RNA building block carries a base. Both DNA and RNA have adenine, guanine, and cytosine bases. But RNA does not have thymine. Instead, RNA has a different base: **uracil (U)**. Uracil has a similar structure to thymine, so when DNA sections unwind and expose codons, complimentary RNA nucleotides line up with the DNA bases. But, instead of thymine (T) lining up with adenine (A), uracil (U) lines up across from adenine.

The single stranded RNA molecule is assembled as bonds form between adjacent phosphate/ribose molecules. The temporary hydrogen bonds between DNA and RNA bases break and a newly assembled single stranded RNA molecule is formed. The single-stranded RNA can pass through the semipermeable nuclear membrane and carry the genetic code into the cytoplasm.

There are many types of RNA molecules, each with a specialized task. Three types of RNA are engaged with interpreting the genetic code: **transfer RNA** (tRNA), **ribosomal RNA** (rRNA) and **messenger RNA** (mRNA). The mRNA carries the complimentary codon into the cytoplasm. Once in the cytoplasm, rRNA surrounds a strand of mRNA and travels down the mRNA strand like a roller coaster car glides on the tracks. As the rRNA moves along the mRNA strand, tRNA brings in amino acids which pair up with the codon on the mRNA. The amino acids form bonds with adjacent amino acids and form a **peptide chain**. The resulting peptide chain is better known as a protein.

Fig. 3



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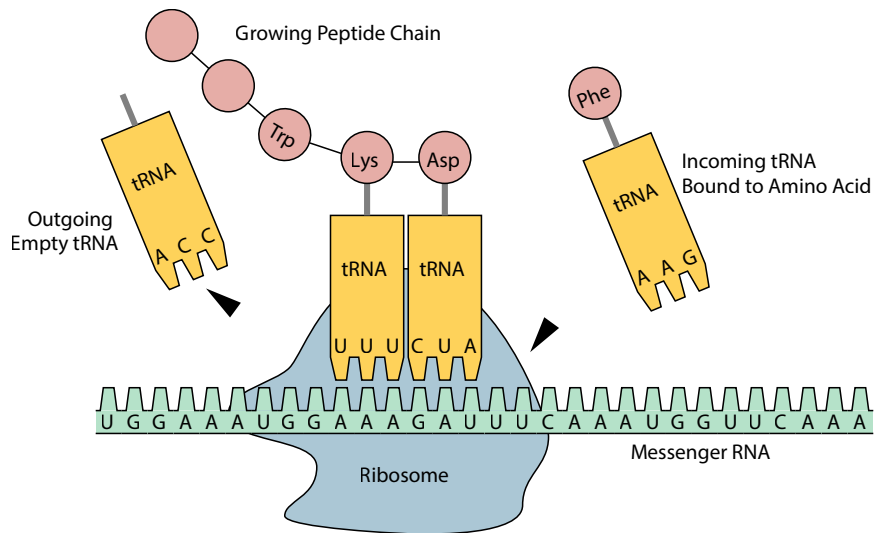
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Assembling amino acids to form a protein is called protein synthesis. This is a complex metabolic process and at any point errors can be made. When dealing with complex systems, errors can happen.

MUTATIONS

Although *microscopic* or *nanoscopic*, the processes which take place inside cells are extremely complex. The more complex a system, the higher the chance that mistakes can happen. Sometimes a nucleotide moves to another section of a DNA strand or is eliminated entirely from the strand. When these types of changes occur on DNA, a mutation results. During DNA transcription, mRNA transcribes the mutation and carries this “misinformation” out of the nucleus and into the cytoplasm. Most mutations are harmless, but some can have devastating results.

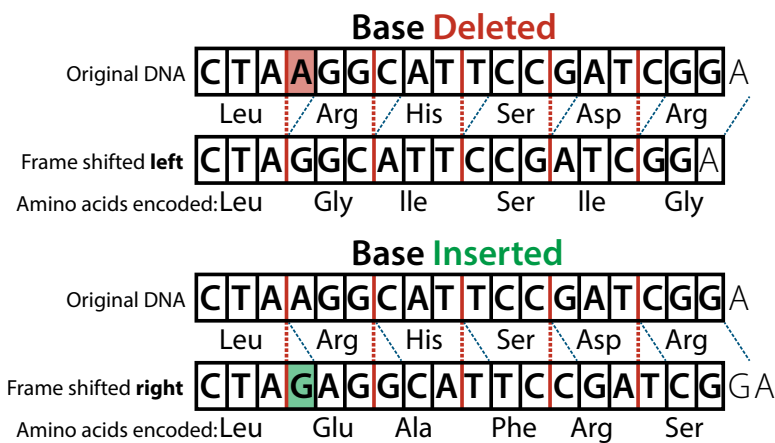


Peptide Synthesis

Source: [Wikipedia](https://en.wikipedia.org/wiki/Peptide_synthesis), based on work by Boumphreyfr.

Fig. 4

Frameshift (InDel) Mutations



Source: Based on a graphic by Henry K. O'Norman.

mRNA reads an incorrect code and carries this incorrect code to rRNA. As rRNA “reads” the code, tRNA brings in the wrong amino acid, creating the wrong protein.

Types of Mutations

Point mutation: a change to a single nitrogen base. Generally, a point mutation is harmless. An example of a point mutation would be an error in pairing. Instead of an A-T pairing, an A-G pairing may result.

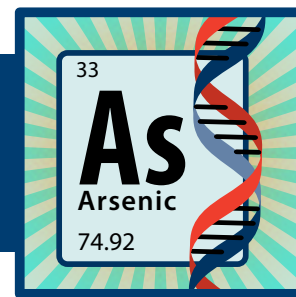
Frameshift mutation: These mutations are more serious and can even lead to deadly consequences. In a frameshift mutation, a single base is either deleted from a gene or an extra base is inserted into a gene. This causes a shift to the codon which impacts how the gene is interpreted by the single-stranded mRNA. The entire DNA codon is shifted and every codon from that point on is incorrect. When the mRNA reads the codon,

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There are two types of frameshift mutations: **insertions** and **deletions** (Fig. 4). Each DNA codon codes for a specific amino acid. For example, DNA codon AGG (adenine, guanine, guanine) codes for the amino acid arginine. However, if the A is deleted, the DNA codon is read as GGC by mRNA. GGC is the code for glycine. This is an example of a **deletion frameshift**. Using the same DNA codon, if a guanine base (G) is inserted into the DNA strand before the AGG, the codon changes. The mRNA now reads GAG (guanine, adenine, guanine) which is the code for the amino acid glutamine. This is an example of an insertion frameshift.

EPIGENETICS

Epigenetics is the study of how changes in gene expression affects the phenotype which is the physical appearance of an individual, but does not change the DNA sequence. **Gene expression** refers to when genes are active or not active. Unlike genetic mutations where genes are rearranged, epigenetic changes affect when genes are “on” and “off”. This changes how and when genes are expressed. When genes are turned off, necessary proteins may not be produced or when genes are turned on at the wrong time, proteins are produced not needed. Although the DNA itself is not changed, epigenetic changes in gene expression can be inherited from one generation to the next. Epigenetic changes can also be influenced by environmental factors such as diet, stress, and exposure to toxins, such as arsenic.

Because behaviors (diet, exercise) and environmental factors influence epigenetic changes, epigenetic changes can occur throughout your life. Sometimes epigenetic changes can be reversed as behaviors are modified (quit smoking, increase exercise) or detrimental environmental factors (toxins, infectious diseases) are removed. Epigenetic changes are passed on from one generation to another, affecting the health of offspring later in life, and can be passed down through multiple generations.