Nucleic Acids: DNA

We all know that elephants only give birth to little elephants, giraffes to baby giraffes and humans to baby humans. This is so for every sexually reproducing organism. Why is this so? The answer lies in a molecule called **deoxyribonucleic acid (DNA),** which contains the biological instructions that make each species unique. DNA, along with the instructions it contains, is passed from adult organisms to their offspring during reproduction.

Researchers refer to DNA found in the cell's nucleus as nuclear DNA. An organism's complete set of nuclear DNA is called its **genome.** Besides the DNA located in the nucleus, humans and other complex organisms also have a small amount of DNA in cell structures known as **mitochondria.** Mitochondria generate the energy the cell needs to function properly (cellular respiration). In **sexual reproduction**, organisms inherit half of their nuclear DNA from the male parent and half from the female parent. However, **organisms inherit all of their mitochondrial DNA from the female parent.** This occurs because only egg cells, and not sperm cells, keep their mitochondria during fertilization.

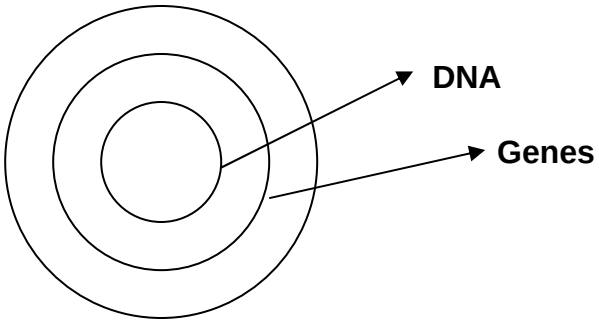
The Pioneers in the Search for Inheritable Material

1. **Griffith (1927)** discovered the natural phenomenon that bacteria have the ability to alter their genetic makeup by taking foreign DNA from another bacterial cell and incorporate it into their own DNA. This process is known as **BACTERIAL TRANSFORMATION.** At the time, Griffith did **NOT** know the material the bacteria was transferring was DNA.
2. It was not until **1944** that scientists **Avery, MacLeod, and McCarty** identified what as the first evidence that the material Griffith's bacteria was transferring was hereditary material.
3. In **1952, Alfred Hershey and Martha Chase** conducted isotope tracer experiments and found that when a bacterial virus (bacteriophage T2) infects its host cell (the bacterium Escherichia coli), it is the DNA of the T2 virus, and not its protein coat, that enters the host cell and provides the genetic information for replication of the virus.
4. **Rosalin Franklin (1950-1953**) used X-ray crystallography analysis of DNA that demonstrated that DNA to be a helix.
5. Her work was critical to James Watson and Francis Crick, who, in 1953, worked out structure of DNA and presented their now famous model of DNA.

What is the function of DNA?

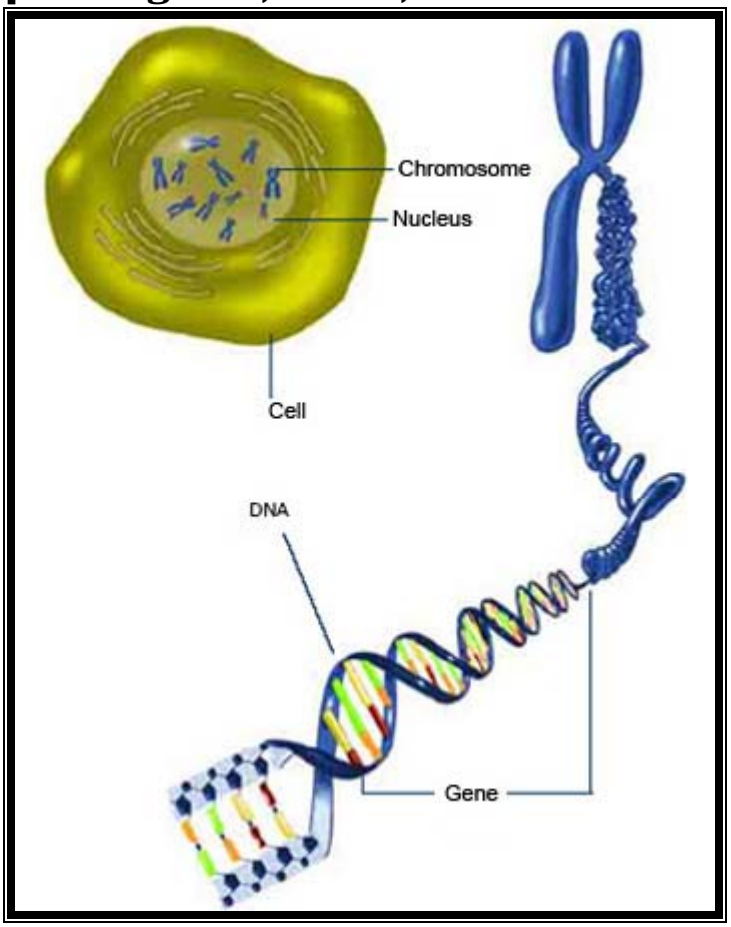
DNA **carries the genetic instructions** at are necessary for the development and functioning living organisms. DNA can be compared to a **BLUEPRINT** or **TEMPLATE**, since it contains the instructions needed to construct proteins. The segments of the DNA that carry the genetic information are called **GENES.**

DNA is found in genes; genes are contained in chromosomes; chromosomes are found in the nucleus of cells.



Chromosome

Relationship among DNA, Genes, Chromosomes and Nucleus



What is the structure of DNA?

a. The basic building block of DNA is a nucleotide.
b. DNA is made up of two strands of repeating nucleotides attached together to form a shape called a double helix (see diagram below).

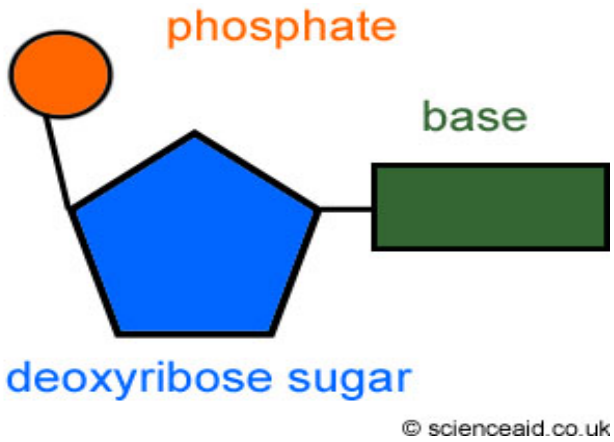
c. **NUCLEOTIDES** are made up of three parts:
   - ✓ a **phosphate group** (PO_3^{4-})
   - ✓ a **5 carbon sugar, deoxyriobose**
   - ✓ a **nitrogenous base**

d. There are **four kinds of nitrogenous bases**:
   - ✓ **Adenine (A)**
   - ✓ **Thymine (T)**
   - ✓ **Guanine (G)**
   - ✓ **Cytosine (C)**

c. Since there are two DNA strands, the nitrogenous bases are always in pairs.
   - ✓ **A and T** always pair up
   - ✓ **G and C** always pair up

✓ A good way to remember the pairing of nitrogenous bases is to remember the phrase: **AT Garden City** (A-T; C-G)

Structure of a Nucleotide

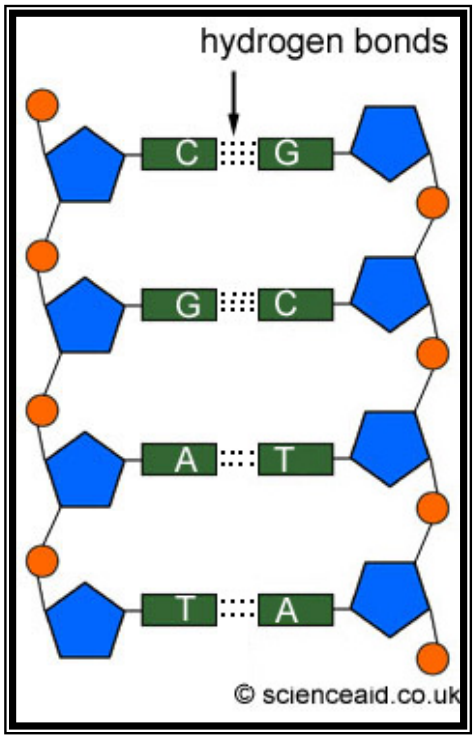


There are different nitrogenous bases, which mean there are 4 kinds of nucleotides. Each of the four nucleotides differ only in the type of nitrogenous base attached to it (A,T,G, or C).

POLYMER is any compound that is made up of repeating base units to form a chainlike molecule. DNA is an example of a polymer.

If we untwist the double helix, it looks like a ladder.

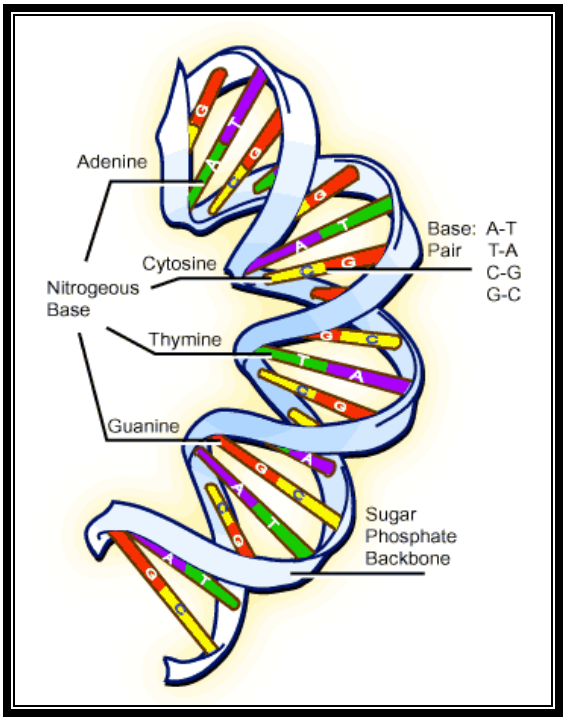
- ✓ The **sides of the ladder** are made up of **alternating phosphates and 5 carbon sugars** (deoxyribose).
- ✓ The **rungs of the ladder** are made up of the **pairs of nitrogenous bases** (A-T; G-C)
- ✓ The two strands are held together between the bases by **weak hydrogen bonds.**



DNA "Ladder"

The sides of the ladder are alternating phosphates (circles) and sugars (pentagons). The rungs of the ladder are the pairs of nitrogenous bases
(A-T; C-G). The two strands of DNA are held together by weak hydrogen bonds.

DNA Double Helix



How are nucleotides chemically attached to each other?

Each strand of DNA is made up of repeating nucleotides linked together by **COVALENT BONDS** (sharing of electrons) in a chain. The process of linking each nucleotide to the next one is called **DEHYDRATION SYNTHESIS**. A water molecule is removed to chemically attach each nucleotide to the next to form the covalent bonds. Dehydration synthesis is the way all living organisms build large complex molecules from smaller, simpler ones.

To break down a DNA strand into its building blocks (nucleic acid) the chemical reaction is reversed. The adding of water to break the covalent bonds between nucleic acids is called **HYDROLYSIS** (hydro – water, lysis – to break of cleave).

Nucleotide + Nucleotide + Nucleotide $\xrightarrow{\text{dehydration synthesis}}$ **DNA + water**

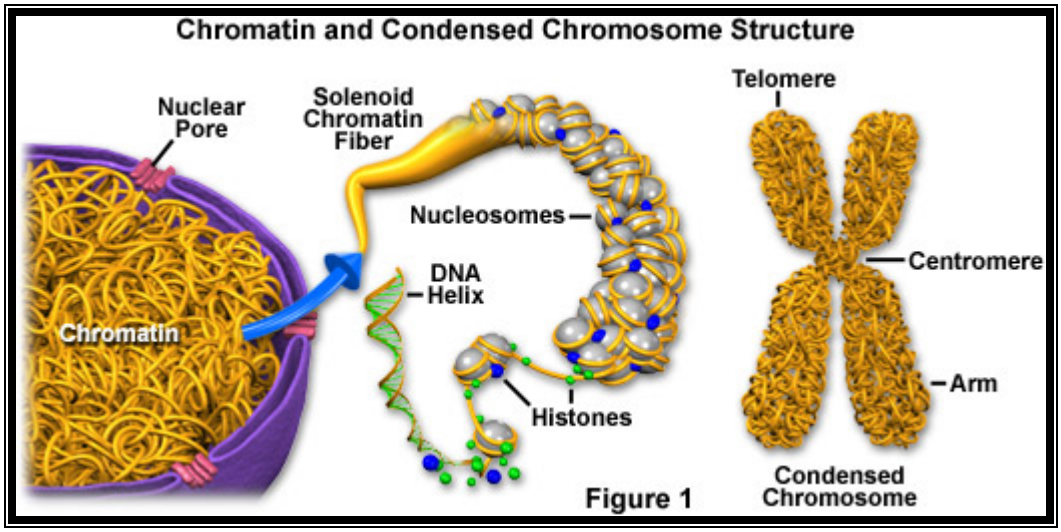
enzymes

$\xleftarrow{\text{hydrolysis}}$

The Structure of Chromosomes

Except when the cell is getting ready for cell division or to "reading" genes to make synthesize proteins, chromosomes exist as **CHROMATIN** – which appears to look like a mass of "spaghetti" or string. However, chromatin is far from just a jumble of string. For example, packed inside the

nucleus of every human cell is nearly 6 feet of DNA, which is subdivided into 46 individual molecules, one for each chromosome and each about 1.5 inches long. Collecting all this material into a microscopic cell nucleus is an extraordinary feat of packaging. In order to accomplish such an orderly and compact arrangement, each DNA strand wraps around groups of small protein molecules called **histones**, forming a series of bead-like structures, called **nucleosomes**, connected by the DNA strand. The string of nucleosomes, already compacted by a factor of six, is then coiled into an even denser structure known as a **solenoid** that compacts the DNA by a factor of 40. The solenoid structure then coils to form a hollow tube. This complex compression and structuring of DNA serves several functions. **The overall negative charge of the DNA is neutralized by the positive charge of the histone molecules**, the DNA takes up much less space, and inactive DNA can be folded into inaccessible locations until it is needed.



DNA Facts:

- ✓ DNA is found in every living organism
- ✓ Most DNA exists in the form of chromosomes in the nucleus of each cell
- ✓ Offspring inherit one half of their DNA from each parent in sexually reproducing organisms
- ✓ In asexually reproducing organisms, DNA is inherited from the parent cell.
- ✓ The number of chromosomes varies from species to species. For example, humans have 23 pairs of chromosomes found in the nucleus of every cell
- ✓ A DNA profile is unique to each living creature; only identical twins have identical DNA profiles.
- ✓ DNA can be used to identify people and establish paternity of children.
- ✓ **DNA is made up of 2 strands that twist to form a <u>DOUBLE HELIX</u>.** (picture a A twisted ladder).
- ✓ Basic building block is a nucleotide
- ✓ When untwisted, DNA resembles a ladder.
- ✓ Sides of the ladder are made up of alternating phosphates and sugars (deoxyribose)
- ✓ Rungs of the ladder are made up of nitrogenous bases (A-T, C-G)

Questions:

1. Why is DNA considered to be a blueprint or template?

2. Where is DNA found in the cell?
3. Describe the shape of DNA.
4. Define the term gene.
5. Describe the relationship among DNA, genes, and chromosomes.
6. Draw a nucleotide and label its three parts.
7. How many different nucleotides are there? Explain.
8. What is the base pairing rule among the nitrogenous bases adenine, guanine, cytosine, and thymine?
9. Why is DNA considered to be a polymer?
10. When DNA is untwisted, it looks like a ladder. **What makes up the sides of the ladder? What makes up the rungs of the ladder?**
11. How are the two strands of DNA held together?
12. Describe the shape of DNA in nature.
13. Discuss the process by which building blocks such as nucleotides are combined to form larger, more complex molecules such as DNA.
14. Describe how larger, more complex molecules such as DNA are broken down into smaller, simpler ones.
15. What is chromatin?
16. Describe the structure of chromatin.

Bonus:

17. Humans have 46 chromosomes in every cell of their body. Can you think of any cell in the human body that has half this amount?
18. When DNA is synthesized sometimes the base pair matches are wrong. For example, an A joins with a C or a T joins with a G. What do you think may occur as a result of this mistake in base pairing?