

DNA contains the instructions for growth and development in humans and all living things. Our DNA is packaged into chromosomes that contain all of our genes.

In summary

- DNA stands for (**D**eoxyribo**N**ucleic **A**cid) which is made up of very long chains of chemical 'letters': Adenine (A), Guanine (G), Thymine (T) and Cytosine (C)
- DNA contains the instructions for our genes
- Genes are the instructions for making proteins. Proteins do the work within our cells and body
- In humans, most genes are arranged on chromosomes that are found in the nucleus of cells.

THE GENETIC BOOK OF LIFE

In humans genetic information, also known as our genome, can be described as the 'Book of Life'. This book can be thought of as being made up of two volumes, each volume of the book is given to a person by one of their parents (*Figure 1.1*).

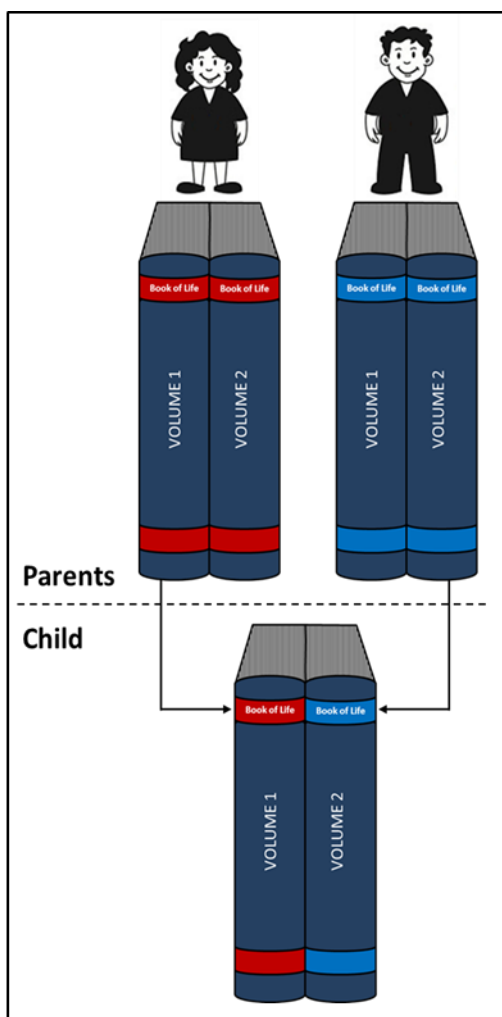


Figure 1.1: The human genome sometimes called the 'Book of Life'

Reading a person's genetic book of life (*Figure 1.2*):

- One volume of the book is inherited from the mother and the other from the father
- Both volumes contain 23 chapters each, equivalent to the 23 pairs of chromosomes in human body cells that contain genetic information
- The 23 chapters (chromosomes) are made up of a number of recipe pages (coding DNA or genes) and in-between (non-coding) pages of DNA
- Some of the chapters contain many pages while others only have a few. Some chromosomes are large and contain many thousands of genes and non-coding DNA while others are much smaller
- Genes are sections of DNA that code for the proteins our body needs to function
- In-between (non-coding) sections of DNA have various jobs, not all of which we understand
- Careful examination of the words within genes shows that all the words are made up of three letters (triplets) such as AGT, GGT, ACT, CAA etc.
- There are four letters used in the genetic book. They are A, T, C & G.

Just as reading the words on the page of a book allows an understanding of the author's message, the body is able to read the triplets in genes to make the protein needed for our cells to work.

Our cells don't need all the instructions all the time. Pages of our genetic book can be closed and then reopened when needed. Each type of cell can have different parts of the genetic book opened or shut because different cells do different jobs in our body. Which genes are turned on or off can be influenced by our diet, chemical exposure, exercise, ageing and messages from other genes in the body.

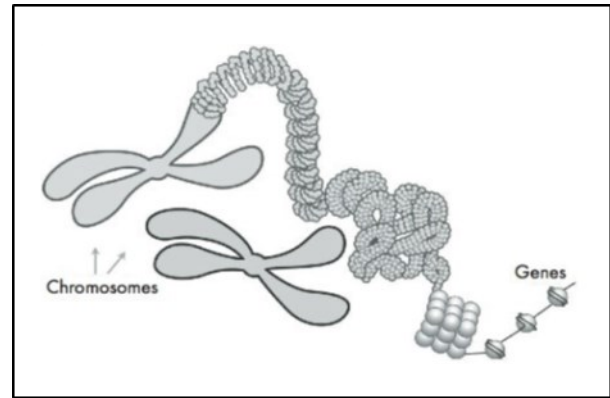


Figure 1.3: Chromosomes are like strings of genes

| The Book of Life | | Genetic Terminology |
|------------------|---|---------------------|
| Volume 1 & 2 | → | Genome |
| Chapters | → | Chromosomes |
| Pages | → | Genes |
| Words | → | Triplets |
| Letters | → | A, T, C, G |
| Spelling Mistake | → | Genetic Variant |

Figure 1.2: Genetic terminology and the 'Book of Life'

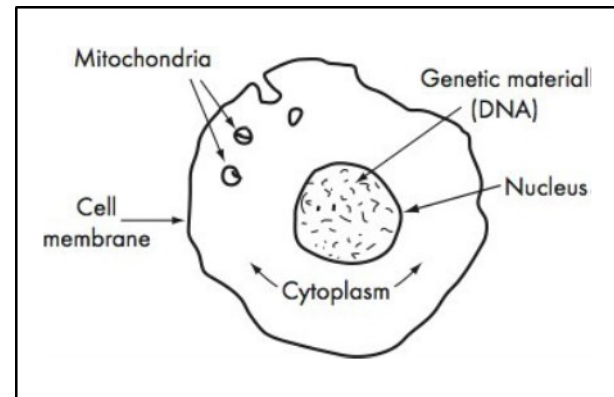


Figure 1.4: Diagram of a human cell

DNA, GENES AND CHROMOSOMES IN THE BODY

Our bodies are made up of millions of cells. Each cell contains a complete copy of a person's genetic book of life.

Chromosomes can be thought of as being made up of strings of genes (DNA that codes for proteins) with non-coding DNA between them. The chromosomes, including the genes, are made up of a chemical substance called DNA (DeoxyriboNucleic Acid).

The chromosomes are very long strands of DNA, coiled up like a ball of string as shown in Figure 1.3.

Chromosomes are found in the nucleus of all body cells except for red blood cells which have no nucleus and therefore do not contain chromosomes.

Another place in the cell where DNA is found is in very small compartments called **mitochondria** (the energy centres of the cell) that are found scattered outside the nucleus (Figure 1.4). The DNA in mitochondria is much smaller and has very little non-coding DNA.

Chromosomes

There are 46 chromosomes contained in the **nucleus** of body cells:

- Of these, 23 came from the mother's egg and 23 came from the father's sperm
- When the egg and the sperm join together at the time of conception, the first cell of the baby is formed. This cell is copied to make all of the cells of the baby
- The baby's body cells now have 46 chromosomes, made up of 23 pairs, just like the parents (Figure 1.5).

As we age and grow, our cells are continually dividing to form new cells.

During this division process, each of the long thin chromosomes coils up tightly, so that each of the 46 individual chromosomes in the nucleus become rod-shaped structures and can be seen when using a microscope.

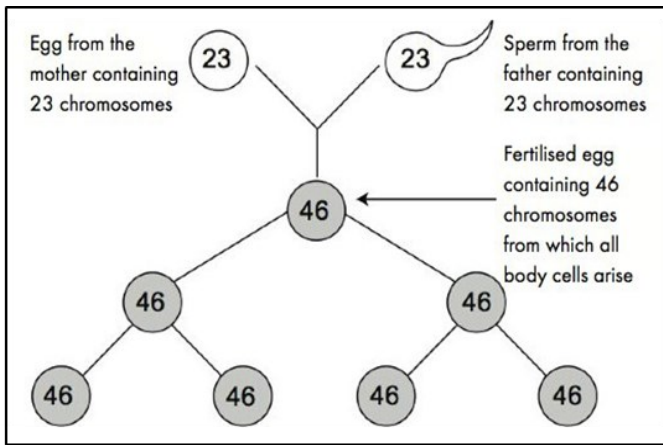


Figure 1.5: At conception the sperm and egg combine

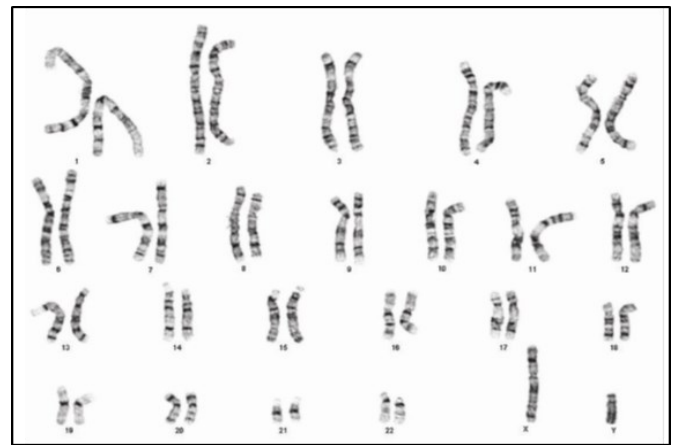


Figure 1.6: Chromosome picture (karyotype) from a male 46,XY.

In a genetic testing laboratory the chromosomes may be coloured (stained) with special dyes to produce distinctive banding patterns and lined up in size order. This produces what we call a **karyotype**. These patterns allow the laboratory to check the size and structure of each chromosome.

Figure 1.6 shows a banded chromosome karyotype where each chromosome has been numbered from the largest (chromosome number 1) to the smallest (chromosome number 22) and arranged in pairs in order of size. These numbered chromosomes are called **autosomes**.

There are two chromosomes that have been given the labels X and Y. These are the **sex chromosomes**. It is these sex chromosomes that determine whether the chromosomes have come from a male or a female.

In females, cells in the body have 46 chromosomes (44 autosomes plus two copies of the X chromosome). They are said to have a **46,XX karyotype**. Eggs (female reproductive cells) are different as they only contain half of the chromosomes (23 made up of 22 numbered chromosomes and an X chromosome).

In males, cells in the body have 46 chromosomes (44 autosomes plus an X and a Y chromosome). They are said to have a **46,XY karyotype**. Sperm (male reproductive cells) are different as they only contain half of the chromosomes (23 made up of 22 numbered chromosomes and an X chromosome or a Y chromosome).

Genes

The DNA making up each chromosome is usually coiled up tightly. If we imagine it stretched out, it would look like beads on a string (*Figure 1.3*):

- Each of these beads is called a **gene**
- Each gene is an instruction for a specific protein
- Thousands of genes make up each chromosome
- Between the genes are segments of non-coding DNA.

Since the chromosomes come in pairs, there are also two copies of each of the genes. The exception to this rule applies to the genes carried on the sex chromosomes, X and Y.

Since men have only one copy of the X chromosome, they have only one copy of all the genes carried on the X chromosome. Women have two copies of the X chromosome in their cells and so they have two copies of all the genes carried on the X chromosome.

To adjust for the fact that women have two X chromosomes with lots of genes while men have only one, one of the woman's X chromosomes is **switched off** or inactivated in each of their cells.

There are very few genes on the Y chromosome and their role is mainly to make a person male, so they are not needed in female cells.

DNA

There are over 20,000 genes found in the DNA of each person. Each gene has its own specific location on a chromosome or on the mitochondrial DNA and the genes (coding DNA) plus the non-coding DNA make up that person's **genome**.

- The DNA code is made up of very long chains of four basic building blocks (*nucleotide bases*) called **Adenine (A)**, **Guanine (G)**, **Thymine (T)** and **Cytosine (C)**
- A chromosome consists of two of these DNA chains running in opposite directions. The bases pair up to form the rungs of a ladder twisted to form a double helix (*Figures 1.7 & 1.8*)
- Pairing of the bases follows a pattern where base A can only pair with base T and base G can only pair with base C. Roughly three billion of these base pairs of DNA make up the human genome
- Our DNA code is made up of a combination of three of these four chemical 'letters' called a triplet.
 - ◇ Each three-letter word (*triplet*) tells the cell to produce a particular amino acid, the building blocks of proteins
 - ◇ The sequence of three-letter words in the gene enables the cells to assemble the amino acids in the correct order to make up a protein
 - ◇ Only about 2% of the entire DNA in the human cell is made up of genes that contain the information codes for making proteins
 - ◇ The remaining 98% of DNA does not contain the information for proteins and used to be called **junk DNA**. This non-coding DNA separates genes from each other along the chromosomes and there is increasing evidence that it has a role in turning genes **on** and **off**. This non-coding DNA therefore has a control function within the genome.

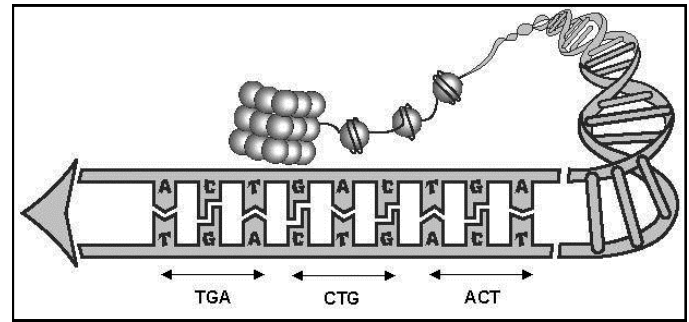


Figure 1.7: The DNA bases pair up to make genes

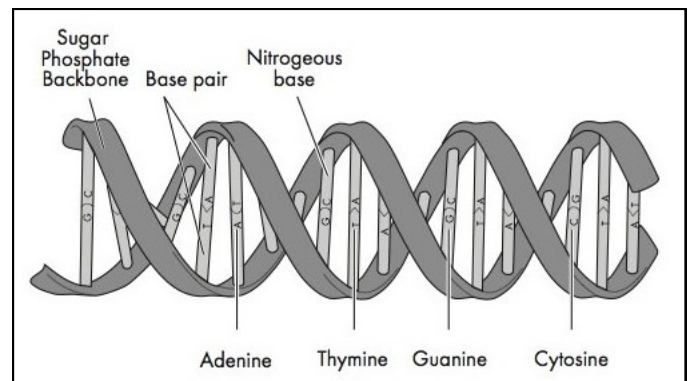


Figure 1.8: The DNA helix

DNA VARIATIONS

We all have small variations in our genetic code. That is why we are all unique. Even identical twins have some variations in their DNA by the time they are born. Because we inherit our genes from our parents, members of the same family share their DNA including its variations.

There may be changes in the sequence of letters in the gene message; nucleotide base/s (A, G, T or C) can be missing (called a deletion) or base/s can be added (called an insertion) and these can be of one or many DNA bases.

Variations in the code can occur during our life for a variety of reasons including exposure to radiation, certain chemicals or by chance. Ageing is a common cause of genetic variation. Throughout our lives, our cells are continually being replaced.

Some variations in the genetic information do not seem to make any difference to the function of our cells. These types of DNA variations are quite common.

Other DNA variations can be associated with an increased chance of a health condition, for example diabetes or cancer.

Some DNA variations can mean the gene instruction is incorrect so a faulty protein is made or the control switch is changed. A variation in a gene that creates a fault is called a **pathogenic variant** or **mutation**.

A DNA mutation can cause a problem for one cell type but not another, since not all cells use all of the possible proteins.

When a DNA change causes a faulty protein in cells that need that protein, it usually results in disease symptoms that can sometimes be recognised as a genetic condition.

Since we have two copies of each gene, if one copy has a mutation and the other copy is working, then we may not develop any problems.

We are all born with DNA mutations and sometimes these can be beneficial or cause no problem.

When a gene variation is present in egg or sperm cells, it can be passed on to children (inherited).

In other cases, a new gene variation can arise in an egg or sperm cell. This is called a **de novo** change.

The person arising from that egg or sperm cell will be the first in the family to have the DNA change which may then be passed down to his or her children and future generations.

Genes contain recipes for the body to make proteins - the Book of Life is like a recipe book for our bodies