

The Link Between Chromosomes, DNA, and Genes

How do chromosomes, DNA and genes all fit together? To figure out the puzzle let's start with the most basic piece: DNA

A DNA (deoxyribonucleic acid) double helix is the fundamental unit of our genetic material. One molecule of DNA is made up of a sugar group (deoxyribose), a phosphate group and a base. There are four bases: Adenine, Thymine, Guanine and Cytosine. The way these bases are strung together creates a 'code' that helps provide instructions for how our body grows and functions. DNA is found in every cell of our body— except red blood cells (no nucleus).

Genes are a segment of DNA. Our genes are the blueprint for our biology. They contain the instructions for things like the shape of our nose and the size of our feet. It is estimated that we have approximately 25, 000 different genes in our body.

DNA is packaged into tightly wound structures called chromosomes. Under a special microscope, the chromosomes can look like a continuous string of beads.

Each long string of DNA winds around structural protein spools called 'histones' to form a material called 'chromatin'. The chromatin further loops and coils to form the tightly condensed chromosome structure. This tight packing is important in making sure these long strings of DNA can fit inside the cell's nucleus.

We can use the analogy of a city to better understand the relationship between DNA molecules, genes and chromosomes. One DNA molecule (one DNA 'letter' - A, T, G or C) would be represented by one house on a street. A gene would equal a whole street of houses. A chromosome is all the streets in a neighbourhood. A set of chromosomes (for example all of the human chromosomes) would be represented by a city made up of all different neighbourhoods.

Human Chromosomes

Our chromosomes are found in the nucleus of each of our body cells. We have 46 of them, matched up into 23 pairs. Egg and sperm cells, however, have only 23 chromosomes; and when they come together to make a baby, he or she will get 46.

The first 22 chromosome pairs (called 'autosomes') are the same in men and women. The sex chromosomes make up the 23rd pair. Generally, females have two X chromosomes, while males have one X and one Y chromosome.

Scientists in the lab are able to look inside the nucleus and make a picture of our chromosomes called a karyotype. They match up the chromosomes into pairs and line up the pairs from biggest to smallest. The picture below shows what these matched-up chromosomes look like under the microscope.

When laboratory technicians first look at chromosomes under the microscope, the chromosomes are all jumbled together and not found neatly lined-up and paired-up in the cell as shown in figure 1. In the jumble of chromosomes, technicians must look closely at the structure of each chromosome to

figure out which ones match up. The following features of a chromosome are helpful in sorting out the chromosomes and are diagramed below:

- The centromere– part of the chromosome that pinches inwards
- The 'p' arm– the shorter part of the chromosome
- The 'q' arm– the longer section of the chromosome
- The telomeres– the ends of the chromosomes
- The banding– the pattern of light and dark stripes that run along the length of the chromosomes. It is used to distinguish chromosomes of the same size. Plus, changes in this pattern may be a clue that there is missing or extra genetic material in the chromosome.

Plant & Animal DNA

We now know humans have their DNA packaged up into chromosomes, but what about plants and animals?

It turns out that both plants and animals also have their DNA packaged into chromosomes. All normal members of a plant or animal species have the same number of chromosomes; however, the number of chromosome pairs differs among different species.

For example, in plants the number of chromosome pairs varies from just two in some flowering plants to hundreds of chromosome pairs in some ferns (1).

- The garden onion has 8 chromosome pairs
- The potato has 24 chromosome pairs
- Wheat has 21 chromosome pairs
- Rice has 12 chromosome pairs

Similarly different animal species also have different numbers of chromosome pairs.

- Dogs have 39 pairs of chromosomes
- Horses have 32 pairs
- Cats have 19 pairs
- Frogs have 13 pairs
- Mosquitos have 3 pairs

Reference

1) Griffiths et al. An Introduction to genetic analysis. 7th ed. New York: W.H. Freeman and Company. 1999. (from NCBI Books)