Further Reading - DNA

DNA BACKGROUND

What is DNA?

DNA (short for 'deoxyribonucleic acid') is a complex molecule found in the cells of all living things. The blueprint for life, DNA contains all the information cells need to perform their vital functions. Your DNA, which remains unchanged throughout your lifetime, tells cells when to divide and multiply (a process known as 'cellular synthesis'), and it contains the genetic code that dictates your unique physical makeup.

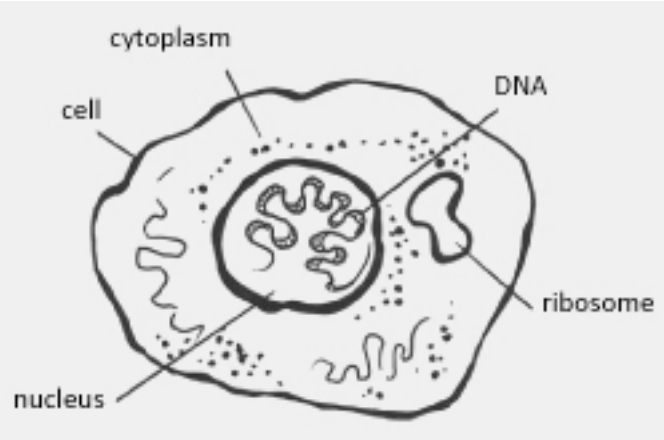
An individual's DNA information is highly variable and specific. Unless you're an identical twin or triplet, your DNA is unique. This is why DNA analysis has become so useful in solving crimes. Certain human DNA sequences—like those that produce ten fingers, ten toes, two eyes, two ears and one mouth—are very common, so they're not particularly useful for identification in police investigations. Other sequences, however, are more variable, such as those that determine hair colour, eye colour and blood type. Investigators use these sequences when comparing DNA samples from two or more people.

We can compare DNA to a reference library because it stores enormous amounts of information to be used by the body when needed. Like a book, DNA supplies the same information over and over again—information that is read and copied by other molecules in the cell. You could also say the information in each DNA molecule is 'copyrighted' because only cells of the same organism can normally copy it.

DNA is also like a computer—a 'command centre' that makes sure each of the body's functions is properly regulated, to keep the body healthy and growing normally. For example, DNA tells bone cells to keep growing at a certain rate during childhood and to stop once adulthood is reached. If a bone breaks, DNA starts the healing process by instructing the bone cells to make new cells. Although DNA from animals and plants is remarkably similar, it has different functions in different species. (For example, you'll never see a tree with eyes and a mouth, nor will you ever find a person with roots, leaves and bark!)

Where is DNA found?

DNA is a tightly coiled thread of molecules found in chromosomes within a cell's nucleus. In humans, each cell has 46 chromosomes (except for a male's sperm cells and a female's egg cells, each of which has 23 chromosomes).



When you were conceived, your father's sperm cell joined with your mother's egg cell. Twenty-three chromosomes from your father combined with 23 from your mother to produce one new cell containing 46 chromosomes and new DNA, unique to you. This single cell then copied its new DNA and divided, becoming two cells with identical DNA. These two cells then copied their DNA and divided to become four cells. This dividing process continued until there were millions of cells—all with the same DNA—making up the new you.

What does DNA look like?

If you could magnify a cell's nucleus 50 million times, you'd see that one thread of DNA (Figure 1) is really two strands. These strands wind around each other like a twisting rope ladder in a shape called a 'double helix'

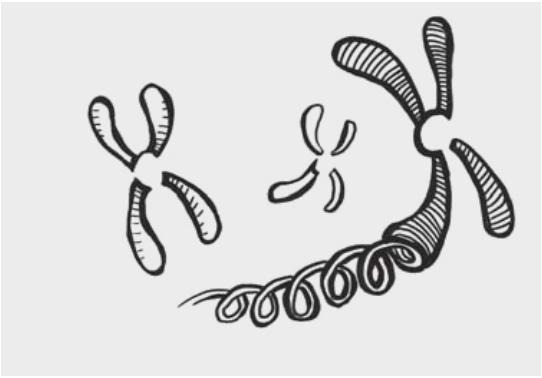


Figure1

Figure 2

What is DNA made of?

Each side of the ladder is a chain of alternating sugar and phosphate molecules, which are the same in all DNA. The sugar is deoxyribose, which gives DNA its name: deoxyribonucleic acid. The steps of the ladder are made from small molecules called bases. There are four different bases: thymine (T), adenine (A), cytosine (C) and guanine (G).

These bases have different chemical compositions, which determine how they pair up to form the rungs of the DNA ladder. When joining, they follow the basepairing rule: guanine pairs only with cytosine (G-C) and thymine always pairs with adenine (T-A).

The bases have different lengths. A and G have long molecules, whereas C and T molecules are shorter. To keep the ladder rungs the same length, a short base must always pair with a long base.

The bases combine with the sugar and phosphate molecules to form four basic building blocks called nucleotides. DNA strands comprise long chains of these four nucleotides. With only four basic building blocks, how can everyone be so different? You're different from everyone else because there are approximately six billion complementary pairs in your DNA, and the sequence of these pairs is different from everyone else's.

What are DNA sequences?

'DNA sequence' refers to the order in which base pairs appear along the DNA strand. They contain the genetic code that dictates how you look and how you

function and grow. A length of coded DNA is known as a gene. Genes contain the special characteristics you inherited from your parents as well as your unique characteristics. Unique sequences of base pairs are the foundation for DNA fingerprinting. DNA strands are broken down into smaller lengths of 100 to 10,000 pairs, and scientists look for lengths that repeat sequences of particular interest. To see these extremely small repeating pairs, radioactive material is used to produce dark images on X-ray film.

How long are DNA strands?

If you could unravel all the DNA in one cell, it would stretch two metres. If you took the DNA in all your cells (approximately three billion cells), it would stretch from the Earth to the Moon and back 8,000 times!

How does DNA copy itself?

When DNA is ready to copy itself (immediately before cell division), it ‘unzips’ down the middle of the ladder at the sites where bases connect together (Figure 3). The two unzipped strands act as a pattern for the formation of new, complementary strands. In the cell nucleus, many unlinked bases float around like loose beads. These unlinked bases attach to the unzipped DNA according to the base-pairing rule (G with C and T with A). In this way, cells use one strand of DNA to build another.

The same process allows scientists to make more DNA for analysis if they only have a tiny sample to work with.

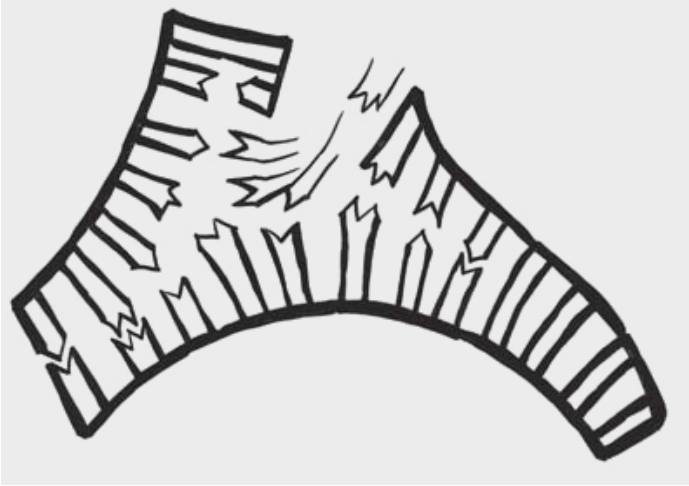


FIGURE 3

Using DNA in police investigations

'DNA fingerprinting' has made it possible to identify a perpetrator from a very small amount of physical evidence. Biologist Alec Jeffreys introduced DNA fingerprinting in the early 1980s. In 1986, the RCMP hired a forensic serologist to study the new technique. In November 1988, the RCMP lab in Ottawa began accepting evidence from select cases for DNA typing. Finally, in 1989, the RCMP's Molecular Genetics Section was formed.

DNA typing can be done on blood, hair, semen, skin and bone marrow. In crimes of violence against persons, blood, hair and semen are found more often than fingerprints.

Police detectives have the authority to search the crime scene and to seize any evidence they may find. Usually the victim or the victim's family will have no objections to the police searching the victim's belongings for any further clues. Searching and seizing evidence from a suspect is a different matter and becomes more complicated when detectives are looking for DNA evidence.

In order to search a suspect's home or belongings, police must first convince a judge that there is enough evidence to warrant a search. A blood sample can be taken without the suspect's consent if the crime is serious. Hair samples are more easily obtained but these cannot be obtained by violence or threat of violence. The suspect's home is searched instead and the police must prove that the hair sample originated from the suspect.

Making a DNA fingerprint

Traditionally, investigators have used the RFLP (Restriction Fragment Length Polymorphism) method to analyze and compare DNA samples.

The first step in RFLP DNA fingerprinting involves exposing the DNA to 'restriction enzymes' that split the DNA strands at specific points called restriction sites. In a process known as gel electrophoresis, the small segments of DNA are forced through a gel using an electric current, which pulls the segments through the gel according to size. Larger segments move slowly; smaller ones move more quickly. The segments are then exposed to a radioactive solution and X-ray film to produce a picture that reveals bands of different widths. The picture, known as an autorad, is the DNA fingerprint. It's similar to the barcode on a product for sale at a grocery store: it is unique for the individual, just as a barcode is unique for a specific product.

Matching DNA fingerprints

Using autorads, police investigators can make visual comparisons between a suspect's DNA sample and samples recovered from the crime scene. They compare autorad patterns of known samples (usually blood samples from the suspect and victim) with patterns of samples in question (for example, blood stains from the crime scene). If the sample profiles don't match, the person did not contribute the DNA at the crime scene.

If the patterns match—that is, when bands on the X-ray film line up—the suspect may have contributed the evidence sample. While there is a chance that someone else has the same DNA profile for a particular probe set, the odds are exceedingly slim.

The Latest Advancement in DNA Typing: The PCR Method

Although it is effective, the RFLP DNA typing method requires long, intact pieces of DNA. A new method called PCR (Polymerase Chain Reaction) DNA typing analysis can also make use of DNA that is 'degraded', in other words, DNA that has been broken down into small fragments through environmental, bacterial or chemical exposure. 20
This is possible because the PCR method starts out by targeting a small, specific region 100–350 base pairs long (compared to lengths of 600–12,000 base pairs required for the RFLP method). Then, using an enzyme similar to the one that splits DNA strands for RFLP analysis, it amplifies this small region by making millions of copies of it. With the PCR method, several different, specific areas can be targeted at once (a process called 'multiplexing'), while RFLP can target only one control area at a time. To separate the amplified fragments, the PCR method uses a different gel than RFLP, resulting in a much sharper separation. And the actual visualization in PCR uses fluorescence rather than radioactivity.

What are the advantages to DNA evidence?

Because it offers several distinct advantages, DNA fingerprinting has replaced traditional blood grouping technology in forensic science:

1. Scientists need only small samples for analysis. A DNA autorad can be produced from a few drops of blood. If a sample is too small to be analyzed, they can replicate the DNA to produce a larger sample.
2. DNA is relatively stable, does not deteriorate with age and can survive adverse environmental conditions. As such, if physical evidence (like blood stains on clothing) still exists, DNA fingerprints can be made many years after a crime was committed.

3 DNA typing is highly accurate and precise. For this reason, it is used frequently not only in forensic studies but in parentage testing, population studies, medical analysis, and agricultural and animal genetics.

4 DNA fingerprinting gives much more individualized results than traditional blood typing. While any number of people can have a certain blood type (e.g., A+), only one person can belong to a certain DNA sample.