What is a DNA fingerprint?

DNA fingerprinting is a molecular biological method used to identify an individual from a DNA sample by looking at unique patterns in his/her DNA.

Background

- Humans have their DNA in almost every cell in the body. The DNA is identical in all cells and tissues in an individual.
- On average, about 99.9 per cent of the DNA between two humans is the same.
- The remaining percentage is what makes everyone unique (except in identical twins).
- It means that there are around three million base pairs that are different between two people. These differences can be compared and used to help distinguish one man from someone else.
- Minisatellites are short sequences (10-60 base pairs long) of repetitive DNA that show greater variation from one person to the next than other parts of the genome. This variation is exhibited in the number of repeated units or 'stutters' in the minisatellite sequence. The first minisatellite was discovered in 1980.

DNA fingerprinting

- DNA fingerprinting was invented in 1984 by Prof. Alec Jeffreys after he realised that one could detect variations in human DNA, in the form of these minisatellites.
- DNA fingerprinting is a technique that simultaneously detects lots of minisatellites in the genome to produce a pattern unique to an individual. This is a **DNA fingerprint**.
- The probability of having two people with the same DNA fingerprint that are not identical twins is extremely small. Thus it can be effectively used to establish identity.
- Just like the actual fingerprint, DNA fingerprint is something one is born with and is unique to everyone.

How was the first DNA fingerprint produced?

1. The first step of DNA fingerprinting was to extract DNA from a sample of human material, usually blood.
2. Molecular scissors called restriction enzymes were used to cut the DNA. This restriction digestion resulted in generation of pieces of DNA with a variety of different lengths.
3. These pieces of DNA were then separated according to size by agarose gel electrophoresis:
    - The DNA was loaded into wells at one end of a porous gel, which acted like a sieve.
    - An electric current was applied which pulled the negatively-charged DNA through the gel.
    - The shorter pieces of DNA moved through the gel fastest. It was more difficult for the longer pieces of DNA to move through the gel so they travelled slower.
    - As a result, by the time the electric current was switched off, the DNA pieces had been separated in order of size. The smallest DNA molecules were furthest away from where the original sample was loaded on to the gel.

4. Once the DNA had been sorted, the pieces of DNA were transferred or 'blotted' out of the fragile gel on to a nylon membrane and then denatured to produce single strands of DNA.
5. Next the nylon membrane was incubated with radioactive probes.
    - Probes are small fragments of minisatellite DNA tagged with radioactive P^{32}.
    - The probes only attach to the pieces of DNA that they are complementary to – in this case they attach to the minisatellites in the genome.
6. The minisatellites that the probes have attached to were then visualised by exposing the nylon membrane to X-ray film.
    - When exposed to radioactivity a pattern of more than 30 dark bands appeared on the film where the labelled DNA was. This pattern was the DNA fingerprint.
    - To compare two or more different DNA fingerprints the different DNA samples were run side-by-side on the same electrophoresis gel.

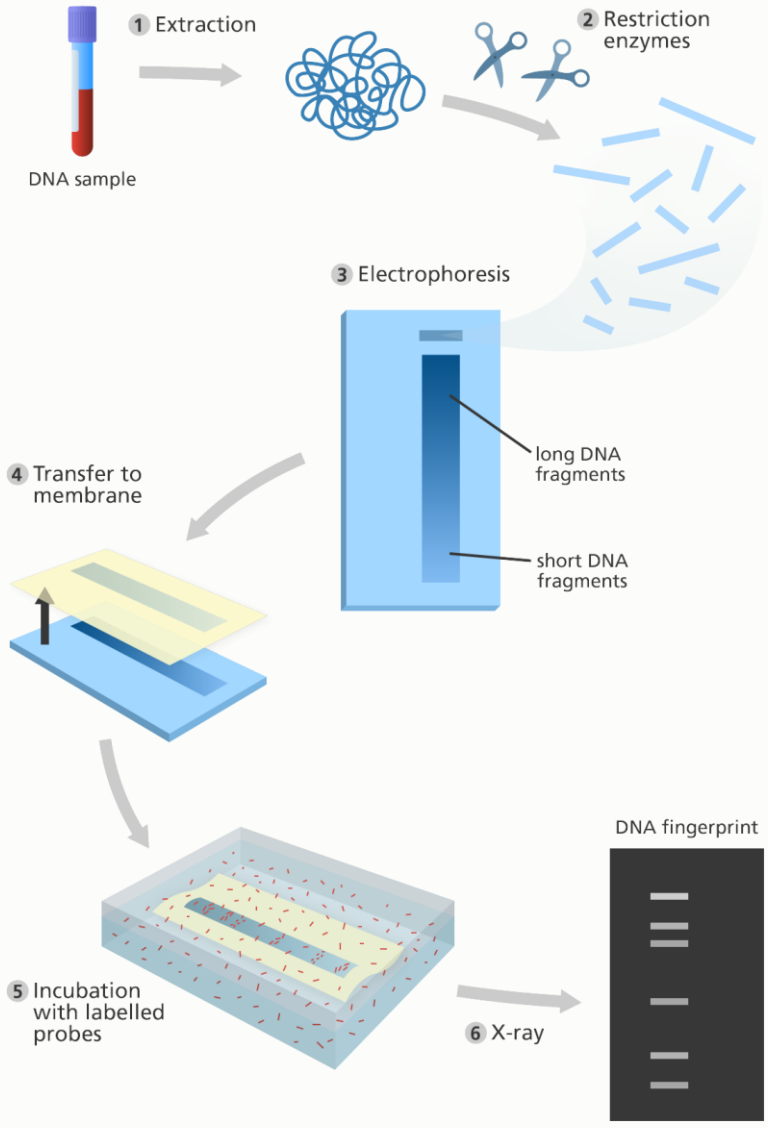


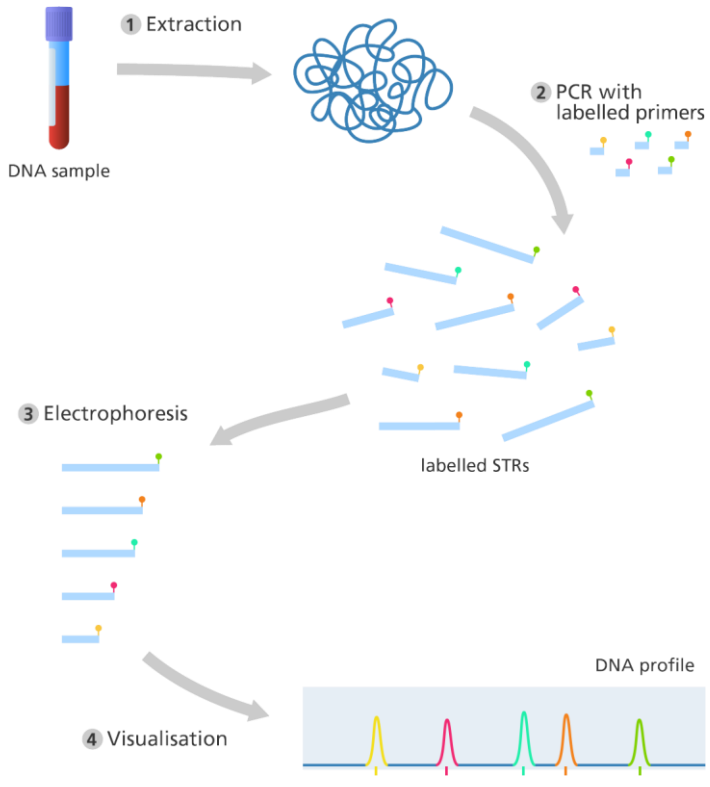
Illustration showing the steps in DNA fingerprinting. Image credit: Genome Research Limited

DNA profiling

- **Modern-day DNA profiling is also called STR analysis and relies on microsatellites** rather than the minisatellites used in DNA fingerprinting.
- Microsatellites, or short tandem repeats (STRs), are the shorter relatives of minisatellites usually two to five base pairs long. Like minisatellites they are repeated many times throughout the human genome, for example 'TATATATATATA'.

How is a DNA profile produced today?

1. DNA is extracted from a biological sample. STR analysis is incredibly sensitive and it only needs a tiny amount of someone's DNA to produce an accurate result. As a result the DNA can be extracted from a wider range of biological samples, including blood, saliva and hair.
2. Unlike the original DNA fingerprinting method, DNA profiling does not use restriction enzymes to cut the DNA. Instead it uses the polymerase chain reaction (PCR) to produce many copies of specific STR sequences.
    - PCR is an automated procedure that generates lots of copies of a specific sequence of DNA. It only requires small amounts of DNA to start with and can even make copies from a DNA sample that is partially degraded.
    - In PCR small bits of DNA called primers bind to complementary sequences of the DNA of interest and mark the starting point for the copying of the DNA of interest.
    - In STR analysis the primers used in the PCR are designed to attach to either end of the STR sequence of interest.
    - The primers for each STR is labelled with a specific fluorescent tag. This makes it easier to identify and record the STR sequences after PCR.



3. Once enough copies of the sequence have been produced by PCR, electrophoresis is used to separate the fragments according to size.
4. Each fragment passes by a laser which causes the fragments with fluorescent tags to glow with a specific colour. The output is displayed as a series of coloured peaks (as shown in the image) highlighting the colour and length of each STR sequence.

Illustration showing the steps in DNA profiling. Image credit: Genome Research Limited

- The more STR sequences that are tested, the more accurate the test is at identifying someone.
- Other STRs used for forensic purposes are called Y-STRs, which are derived solely from the male Y chromosome. This is useful for identifying a male perpetrator from mixed DNA samples.
- Only one person in every 10 million million (10,000,000,000,000) will have a particular STR profile. With the world human population estimated at only 7,100 million (7,100,000,000) it is therefore extremely unlikely that someone will share the same profile as someone else, unless they are identical twins.

Solving crime

- DNA profiles are very useful in forensics because only a tiny sample of human material left behind after a crime may be sufficient to identify someone.
- In the UK, a complete DNA profile consists of 11 STR sequences plus a sex determiner to confirm if the profile is from a man or a woman. Now all new profiles include an additional five STR sequences to provide consistency across borders in Europe.
- In the USA, the Federal Bureau of Investigation (FBI) recommends that 13 STR sequences are tested. Many states are increasing the number of STR sequences tested to enable more efficient investigations across state borders.
- A match made between a crime scene profile and an individual profile identifies a possible suspect.
- A match made between different crime scene profiles indicates a repeat offender at work.
- The police may use this DNA evidence to support other evidence to help prosecute someone for a crime. Complete DNA profiles give very reliable matches and may provide strong evidence that a suspect is guilty or innocent of a crime.

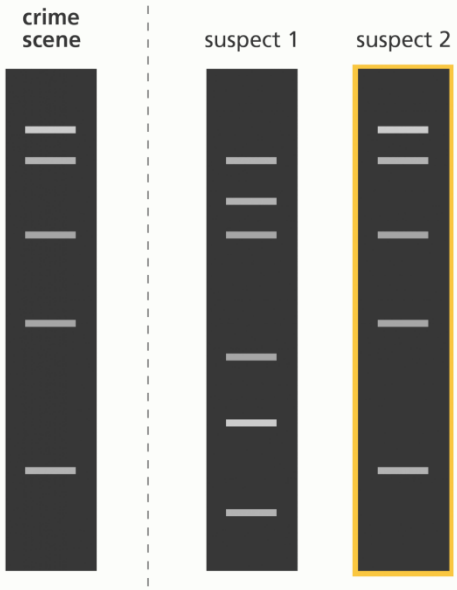


Illustration showing a comparison of a DNA fingerprint from a crime scene and DNA fingerprints from two suspects. The DNA fingerprint from suspect 2 matches that taken from the crime scene. Image credit: Genome Research Limited

How are DNA profiles stored by countries?

- The UK was the first country to set up a national database of DNA profiles in 1995.
- The UK National DNA Database holds the DNA profiles from a select number of UK individuals, most of which are linked to serious crimes.
- The Protection of Freedom Act 2013 ensured that 1,766,000 DNA profiles taken from innocent adults and children were deleted from the UK National DNA Database.
- Most countries now have a national DNA database.

Linking blood relatives

- One gets half of the DNA from the mother and half, from the father. STRs are therefore passed down from parents to their children.
- DNA profiling can be used to help confirm whether two people are related to one another and is commonly used to provide evidence that someone is, or is not, the biological parent of a child.
- DNA profiling can also be used to identify victims of crime or major disasters and help bring separated families back together.
- DNA profiling has a high success rate and very low false-positive rate.

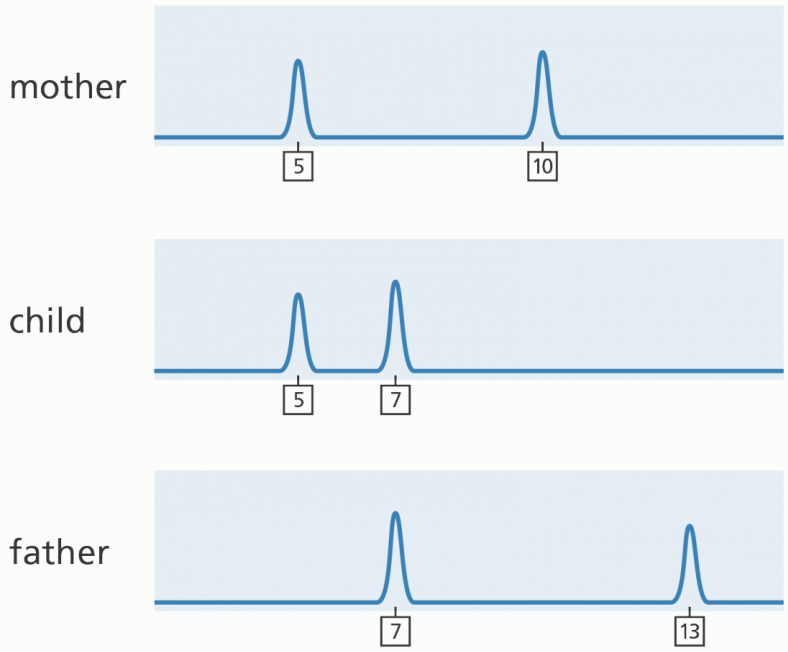


Illustration comparing the DNA profiles of two parents and their child. You can see which STRs in the child have been inherited from which parent.
Image credit: Genome Research Limited

https://www.yourgenome.org/facts/what-is-a-dna-fingerprint