

Chem Factsheet

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Number 181

Genetic Fingerprinting

Try looking at the statements below and choose the ones which are true.

Statement	True	False
Genetic fingerprints may be used to aid security, for example when accessing bank accounts		
Your genetic fingerprint is the unique pattern on the tip of a finger		
The genetic fingerprints of those arrested are taken and stored on a database		
Genetic fingerprints can be taken from various parts of the human body		
Your genetic fingerprint is your unique DNA		

If you decided that the last three are true then congratulations, you can probably write out an excellent definition of genetic fingerprinting. The examiners will expect you to understand not only genetic fingerprinting and how it works, but also how it is used in society and to be able to enter the general debate about how and when it should be used.

Background

Knowledge of DNA (deoxyribonucleic acid) Structure


DNA consists of two strands in a helical arrangement (rather like two slinky springs) winding around each other in opposite directions. Each strand consists of the bases adenine, cytosine, guanine and thymine, stacked one above the other, and the order of the bases determines the DNA code or sequence. The strands are hydrogen bonded together via these bases. In the Watson Crick structure, adenine pairs with thymine, and cytosine pairs with guanine. This means that given the sequence of bases for one strand, the sequence for the other strand is determined. For example if one strand is A T T C A G then the other strand must be C T G A A T (winding in the *opposite direction*).


Model of DNA Showing Individual Atoms



Schematic Diagram Showing DNA Coils and the Bases



 Our DNA code is unique to each of us, which means we can be identified by the sequence of our bases in our DNA.

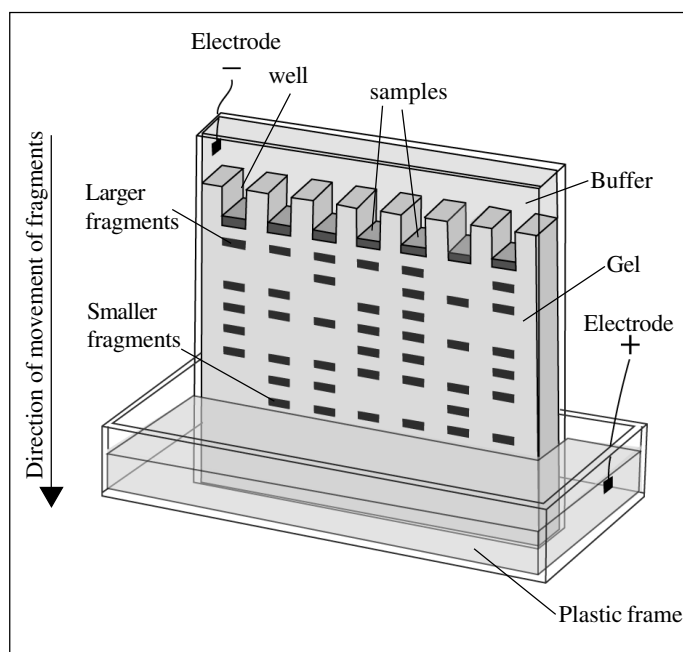
 “Genetic Fingerprinting” is the name of the actual procedure of analysing DNA samples from a person’s body. Body tissue, body fluids or both of these can be used to aid with identifying the person.

The Process of Genetic Fingerprinting

Often, only tiny samples are available. This requires the DNA to be first copied to increase the amount present. This is done using the polymerase chain reaction.

Enzymes are then used to hydrolyse (‘cut’) the DNA at certain specific base sequences, to give short fragments of DNA. For example, an enzyme called EcoRI will cut DNA only when the base sequence GAATTC occurs.

Gel electrophoresis is then used to separate the DNA fragments. An electric potential is used to cause like-charged fragments of similar mass to come together. The fragments move through buffered agarose gel (a jelly-like product made from seaweed) when subjected to an electrical field because they are negatively charged and so move to the positive electrode. They are separated on the basis of mass to charge ratio – in effect, by mass, since the charges are fixed. Smaller fragments move faster; heavier particles move slower.



The distribution of DNA pieces is transferred to a nylon sheet by placing the sheet on the gel and soaking them overnight.

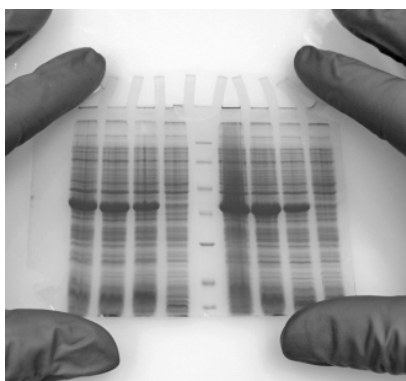
The resultant pattern can be made visible by various “probe” techniques using dyes or radioactive tracers. Each probe “sticks” to only one or two specific DNA fragments on the nylon sheet. For example, when radioactive probes (e.g. ^{32}P) are used, these attach themselves to certain DNA sequences and the nylon sheet bearing the probed-DNA is then left in contact with photographic film (similar to that used for taking X-rays) which is darkened in specific positions by the radioactive emissions.

Note: typically, 5-10 different probes are used simultaneously to produce the full DNA fingerprint

The exposed film is then developed.

The results can be seen as a series of dark bands which are of varying width and darkness.

Results of DNA Sequence Analysis



Extract from Examiners Report: Many candidates drew diagrams with the sample in the middle of the agarose gel and movement to both electrodes, suggested a confused understanding of genetic fingerprinting. Many also referred to the DNA samples being X-rayed or exposed to X-rays.

Applications of Genetic Fingerprinting

In general, the technique has the advantage of being able to be used on very small samples, such as blood spots or tiny pieces of preserved tissue from extinct animals. Some of the many applications include:

1. Forensic scientists take samples of DNA from suspects and use genetic fingerprinting to compare these with the samples taken from the crime scene. For example small amounts of blood, body cells or semen may be found at the crime scene.
2. Proving or disproving paternity, linked to financial responsibility and provision for a baby/child. It may also be used to prove or disprove whether potential immigrants are actually part of a closely related family, when deciding whether to allow applications to enter and remain in Britain.
3. It may be used to find the amount of interbreeding between parent and offspring and siblings in an animal population. Both wild and zoo populations of a specific species are examined. This is particularly important for small populations where the lower the amount of inbreeding, the greater the chance of their survival.
4. Genetic fingerprinting has also been used to verify whether a clone such as Dolly the sheep is genuine or not.
5. Archaeologists investigate materials originating from living creatures. It has, for example, been used to match the goatskin fragments of the Dead Sea Scrolls.
6. In biological classification (taxonomy) it can help to show evolutionary change and relationships between species at a molecular level.

The Debate Surrounding Genetic Fingerprinting

How accurate are the conclusions drawn from genetic evidence of this type?

- When genetic fingerprinting first began to be used, the likelihood of a match occurring by chance was estimated to be 1 in 5 million. Current day estimates vary and may claim 1 in a hundred billion. However, these estimates are theoretical and unlikely to be achieved in practice.
- As identical twins (monozygotic twins) constitute about 1 in 500 of the population the theoretical risk of a match occurring by chance becomes 1 in a thousand.
- There is the risk of an error occurring in the laboratory. It may be difficult to ascertain whether there is an exact match between two bands on the photograph. In addition the medium (agarose gel) in which the DNA is examined may not be perfect, and experiments have shown that identical samples may not appear identical. This has resulted in a need to expand the criteria for stating that there is a match between two samples.
- The samples taken from the scene of the crime are normally tiny and often contaminated with other material. Which makes it difficult to analyse and obtain reliable results.
- DNA of an innocent individual may just happen to occur (or be ‘planted’) at a scene of a crime.

Is it acceptable to keep a data base of genetic evidence taken from suspects even after they have been found not guilty?

- One argument against keeping such data is that it is likely to be skewed socio-economically and ethnically.
- Others may argue in favour of keeping a data base in that the data may be of use subsequently and help to solve other crimes, especially given that those initially arrested may be linked to known criminal activity although proven innocent of the actual crime in question.
- Another argument against keeping such data is that it constitutes an invasion of the privacy and civil rights of an individual.
- In America the development of the use of genetic fingerprinting evidence has actually been used to free some convicted criminals, because their DNA did not match that of the person who must have committed the crime. Should we do this in Britain?

It has been proposed that a database including the entire population could be kept, but this raises the questions of cost and also civil liberty.

- DNA samples from the scenes of bombings have been used to help identify victims by comparing them with samples taken from items such as toothbrushes supplied by anxious relatives. Therefore it could be argued that each person should have a copy of their own genetic fingerprint or profile as part of their identity, kept on a database independent of the police. However, some people might be worried about criminals managing to deliberately change the database, and this raises the question of which organisation could be used to actually be sure that the database remained secure and accurate.
- Personal data would have to be kept and even if this were on a database separate from the genetic fingerprint database there is still the possibility of someone managing to obtain data. This is especially relevant given the number of cases involving people illegally obtaining information on the internet for example, and criminals obtaining bank account details etc.
- Another argument against this type of data collection and storage is that it would constitute an invasion of privacy, and people might refuse to allow themselves to be included.
- The cost to the nation would be excessive and there is actually no need for such a database. If people feel they would like to have their own genetic fingerprint file then they can do this and store the results themselves. There are private genetic fingerprint databases in existence all over the World.

Practice Questions

- The UK has one of the largest databases in the world containing the genetic fingerprint data of all those individuals who have been arrested by the police. The DNA data remains on the database even if the person is later found to be innocent. Whereas some people believe that the genetic fingerprint data should be kept, others believe that the data of those not convicted should be removed.
Give and explain clearly your own opinion.
Why do you think other people may disagree with your ideas? (2 marks)
- Gel electrophoresis may be used as a technique in genetic fingerprint analysis. Describe and explain how samples of DNA from a crime scene which have been prepared may be used together with this technique to produce a 'genetic fingerprint'. (6 marks + 1 for quality of communication.)
- Blood other than that of the victim was found at the scene of a crime. How might genetic fingerprinting be used to prove that a suspect is probably innocent? (2 marks)
- It is sometimes claimed that the accuracy of genetic fingerprinting is so good that the chance of a match between two samples occurring by chance is less than 1 in a hundred billion. Explain why in practice this sort of accuracy may not be achieved. (4 marks)
- It has been proposed that a database be kept with genetic fingerprint data for the entire population of Britain. Give and explain your own opinion on this idea. Give one argument which someone of the opposite viewpoint might use. (2 marks)

- The data should be kept because it might help to solve subsequent crimes. There would have been some reason to suspect the person and so they may be involved in the same type of activity again. If they are completely innocent then it will not matter if their data is kept. Fingerprint data is retained and no one objects to that. (valid point = 1 mark)
- The data should be deleted. The person is innocent and keeping it infringes their civil rights. (valid point = 1 mark)
- DNA fragments diffuse through the agarose gel because they are attracted to the positive electrode (due to their negative charge). They are separated on the basis of their size. A buffer solution is used. The pattern bands are transferred to a membrane. They are then heat treated to form single stranded DNA. They are labelled with phosphorus-32. They are used to expose X-ray film so that an image is formed on the film. (6 marks for six from the above)
- Plus a 'quality of communication' mark for using four of the following terms: agarose; gel; positive electrode; negative electrode; diffuse
- The genetic fingerprint of blood taken from the crime scene is prepared and this is compared with the genetic fingerprint of blood from the suspect. If the two do not match, then the blood at the scene of the crime cannot be from the suspect. (2 marks)
- Monozygotic twins constitute about 0.2% of the world population and so there is a much greater probability of a match occurring by chance. There is the possibility of small errors in laboratory methods, especially with small samples where the results cannot be repeated to improve reliability. It may be difficult to ascertain if two bands match, and so the practical accuracy is much less than the theoretical accuracy. The agarose gel may not be perfect and so even the same sample repeated may not give precisely the same bands. (1 mark for each point = 4 marks)
- For a genetic database: It would enable victims of accidents, bombings etc. to be identified more easily. OR It would enable many crimes to be solved more easily, because genetic fingerprinting would locate possible suspects more easily. (1 mark)
- Against a genetic database: It would constitute an infringement of the civil rights of individuals. OR Criminal groups may add false information or swap data to hide their activities. (1 mark)

Answers

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