CHANGES TO THE GENETIC CODE

FACT SHEET 4

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Important points

- The information in the genes that are made up of DNA is in the form of a chemical code, called the genetic code
- There are small differences between every individual in their genetic information that makes each of us unique
- Some changes to the genetic information do not significantly alter the gene message so the information is still understood by the cell. These changes are common and are called neutral gene variations (*variants)* or *polymorphisms*
- Other changes to the genetic information cause the message to be changed so that it is no longer understood by the cell
  - The gene is described as broken or faulty. Changes that make the genes faulty are called *mutations*
  - Language to describe mutations needs to be sensitive but also reflect the function of the gene change
- Faulty genes (mutated genes) may
  - Cause a problem with the development and functioning of different body systems or organs and result in a genetic condition
  - Be beneficial eg. having a faulty copy of the gene that tells the body to make haemoglobin makes a person more immune to malaria
- Some gene changes
  - Are inherited from our parents
  - Occur in the egg, sperm, during or shortly after conception and are described as 'new' or 'spontaneous' gene changes
  - Build up in our body's cells during our lifetime (not inherited)
- Some faulty genes directly or indirectly cause genetic conditions that run in families (inherited)
- Everyone is born with several faulty genes that usually cause no problem

The cells in the body contain a complete copy of a person's genetic plan or blueprint contained in our genes, located on chromosomes. The chromosomes and therefore the genes are made up of DNA.

The genes contain the information necessary for our bodies to grow and work. The information in the genes is in the form of a chemical code, called the genetic code, as described in Genetics Fact Sheet 1.

Each gene contains the code to make a message to tell the cells how to make a particular product such as a protein. The message can be thought of as a recipe for a protein.

The 'Genetic Book of Life' described in Genetics Fact Sheet 1 is akin to a recipe book for our bodies. There are small differences between every individual in their genetic information that makes each of us unique – we all have a slightly different recipe.

Chromosomes can be thought of as strings of genes as shown in *Figure 4.1*. The **genes are made up of coding DNA** since they send coded messages to the body. The messages are made up of the letters A, T, C and G.

The DNA **between the genes is non-coding DNA** since the strings of letters are not made up into a message like a protein that the body uses. There is, however, increasing evidence of the importance of the non-coding DNA.

Over the centuries, changes from the original sequence of letters have built up in our non-coding DNA and have been passed down through the generations. These changes appear to have no impact on us as they are in the non-coding DNA that separates the genes. Therefore everyone, except identical twins, has a unique genetic code.

This uniqueness is used in tests to identify us from everybody else as well as identify us as part of a family. These differences in the genetic code between us all may also be used in forensic investigations by the police (see Genetics Fact Sheet 22). Studies of the non-coding DNA are increasingly being used to identify people where there is no other means to do so, such as following natural disasters.

Changes to the information in our genes

We generally all have the same number and type of genes so that the same messages are sent to the body.

- There are often small differences between individuals in the information contained in our coding DNA: that is, in our genes
- If we did not have these differences, everyone would look the same
- Members of the same family tend to be similar, as they are likely to have fewer differences in their genes than unrelated individuals

While we all have the genes which tell us to have eye colour, some people's eye colour genes will say 'make the eyes blue' and some people's will say 'make the eyes brown'. The information in the eye colour genes is different between blue and brown-eyed people.

Similarly, there may be small differences in the genes which affect how our bodies grow and develop. Generally these differences do not have any impact on our health and are called *variants* or *polymorphisms* (*poly* means many; *morphisms* means forms). They are quite common.

- We all have many different polymorphisms in our DNA that do not appear to cause a problem
- While the genetic code in a person may be slightly changed by having a variant or polymorphism, the change has not significantly altered the gene message: the information is still understood by the cell

- Some changes, however, to the genetic code cause the message to be changed so that it is no longer understood by the cell: the gene is impaired or faulty. Changes that make the genes faulty are called **mutations**
- If the message to the cell comes from a faulty gene, the cell will either not make the right protein product, make it in reduced amounts or not make it at all (see *Figure 4.1*)
- Faulty genes (mutated genes) may cause a problem with the development and functioning of different body systems or organs and result in a genetic condition (see Genetics Fact Sheet 2)
- Further information about mutations is provided in Genetics Fact Sheet 5

The language to describe a mutation

Words can be interpreted in different ways by different people. The term 'mutation' has been used to describe a change in a gene for a very long time. In some communities, there is stigma associated with this term and so we are sensitive to using an alternative term to describe these changes, while at the same time, maintaining the scientific meaning of changes to the genetic code.

Studies performed by the Centre for Genetics Education with the general community and with family members affected by particular genetic conditions, have shown that the term faulty gene is preferable to describe a mutated gene. A number of other terms are commonly used to describe a mutation such as 'altered gene' or 'changed gene'. We do not think, however, that these terms make it clear that some changes in a gene do not affect the gene function (*a polymorphism*) while other changes cause the gene not to work properly (mutation).

We believe that the term *faulty gene* describes the result of the gene change on the function of the gene in the cell.

Changes that make a gene faulty (mutations) may be beneficial

Everyone is born with several faulty genes out of their 20,000 or so total number of gene pairs. Most of the time these faulty genes cause no problem because the genes come in pairs: even when one gene copy is faulty the other gene copy can still send the right message to the body (see Genetics Fact Sheet 8).

Sometimes it is essential to have both gene copies working correctly as the amount of gene product may be critical. So in these cases, even though only one copy of the gene is faulty and the other is a working copy may still occur (see Genetics Fact Sheet 9).

Other faulty genes make a person susceptible to particular conditions but they will never develop the problem unless they are exposed to particular environmental triggers (see Genetics Fact Sheet 11).

In fact, scientists know that having particular faulty genes can be beneficial to a person. For example, in regard to the condition called thalassaemia (see Genetics Fact Sheet 34):

- The severe form (*thalassaemia major*) is due to having two copies of the faulty gene involved in the production of haemoglobin, the blood protein that transfers oxygen throughout the body. People with this severe form do not produce enough working haemoglobin and have severe anaemia
- People who are carriers of the faulty gene for thalassaemia (*thalassaemia minor*) have a faulty copy of the haemoglobin gene and a working copy. They produce enough haemoglobin although they may have very mild anaemia
  - Importantly, those who are carriers of the faulty haemoglobin gene are less likely to be affected by malaria: by not producing the right amount of haemoglobin, the body is more resistant to malaria. Perhaps this is because the pale, small red blood cells that are present in those who carry the faulty haemoglobin gene provide a poor environment for the growth of the mosquito-borne malarial parasite.

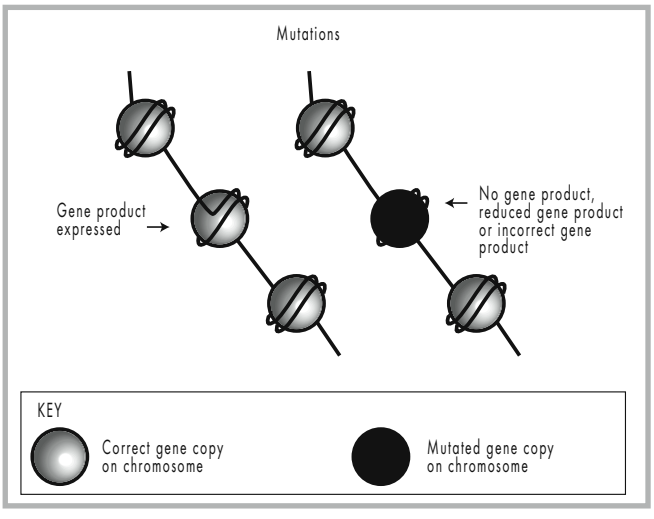

Figure 4.1 – Mutations: changes in genes that make them faulty

Everyone is born with several faulty (mutated) genes that usually cause no problem

Evolution depends on survival of the fittest. As an example, populations where malaria is common have a high frequency of people who are carriers of the faulty haemoglobin gene. More people who were resistant to malaria survived to have children and pass on their faulty genes.

Humans have evolved over the centuries by having faulty genes that increased their ability to adapt to their environment. In our cells, from birth, we all have several genes in which changes have made them faulty. Most people are unaffected by these changes in their genes.

How do changes to the genetic information occur?

Changes from the usual or correct sequence of letters in our genetic information may cause no problem (*polymorphisms*); others make the gene faulty (mutations).

These changes can be present when we are born because we have inherited them from our parents. Everyone inherits gene changes that include polymorphisms as well as mutations. Most of the time inheriting these gene changes does not cause a problem.

Other changes to the genetic information in our cells can occur during or shortly after conception occurs or during our whole lifetime. See Genetics Fact Sheet 5 for more information about changes to the genetic information.

Changes that build up in the genes in our body cells during our lifetime cannot be passed on to our children

Changes to the DNA can be due to exposure to radiation such as that produced by the sun or by certain chemicals in our diets and in our external environment. Changes may also occur in our DNA as our cells are copied to enable us to grow or repair damaged cells throughout life (as we age). Although the body has an efficient system to repair these alterations in the DNA as they occur, sometimes there is a breakdown in the cell's repair system.

If a change to the DNA occurs and is not repaired, it will be copied into all the cells arising from the cell containing the DNA change (see *Figure 4.2*). If the change causes the gene to be faulty, all the cells copied from that cell into other cells in the body during the person's life will contain the faulty gene and will receive a faulty message.

The cells containing the faulty gene may for example be in a small part of our skin; these skin cells may become cancerous because of the number of faulty genes (mutations) that have built up over time with sun exposure. In other cases, the cells containing the mutation may be in breast tissue and can lead to breast cancer (see Genetics Fact Sheet 48 and 50).

- Faulty genes build up in the cells of our bodies as we age. These are called **acquired** or **new mutations**
- New faulty genes that build up in our body cells (the *somatic cells*), excluding the egg or sperm cells, over our lifetime are called **somatic** gene mutations. This type of mutation cannot be passed on to our children, as they are not in the egg or sperm. In *Figure 4.2* the mutation has arisen in a gene in a cell of the breast tissue only and so cannot be passed on to a child

Gene changes that occur in the egg or sperm cells can be passed on to children (inherited)

It is only when a mutation occurs in a gene in a man's sperm or a woman's egg cells that the faulty gene can be passed on to the next generation (inherited). As sperm and egg cells are called 'germ cells', mutations that occur in the genes of the egg or sperm are called **germ cell or germ line mutations**. Passing on the germ line faulty gene (mutation) to a child may cause the child to have or develop a genetic condition.

When the condition first appears in a family member it can be due to a 'spontaneous' or 'sporadic' gene change that makes the gene faulty that occurred in the egg or the sperm or during or shortly after conception, for unknown reasons. In those cases:

- They will have that faulty gene in every cell of their body (see *Figure 4.3*). That faulty gene may or may not cause a problem for that person
- As their egg or sperm cells will also contain the faulty gene, they in turn can pass it on to their children and their children's children. The faulty gene will now 'run in their family'
- Other blood relatives of the affected person are not usually at risk for having the same mutation that causes the genetic condition as the 'spontaneous gene change' would have occurred in the formation of the egg or sperm, during or shortly after conception of the affected family member

Faulty genes that run in families (inherited)

A parent who has inherited from his or her parents, a change that makes a particular gene faulty, has a chance of passing that faulty gene on to their children. Whether their children are affected at birth or later in life by a condition due to a change in one, or both copies of a single gene, out of the approximately 20,000 different genes, depends on the type and amount of protein that is usually produced from the working copy of the gene.

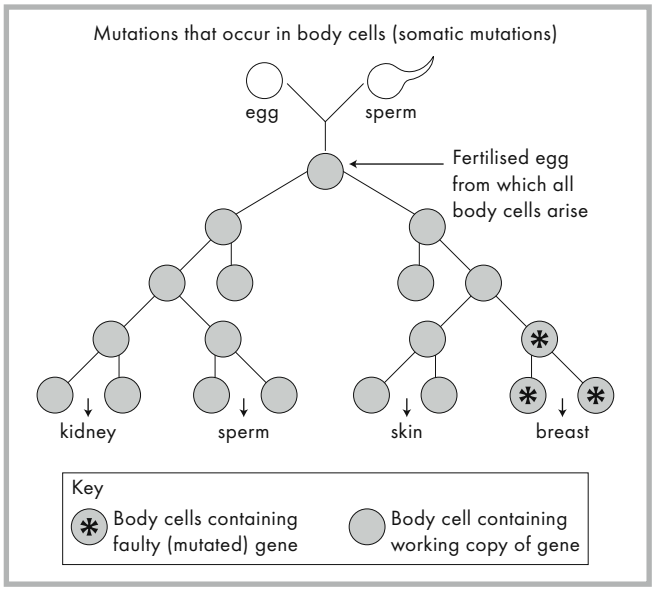

Figure 4.2. Mutations in somatic cells cannot be inherited

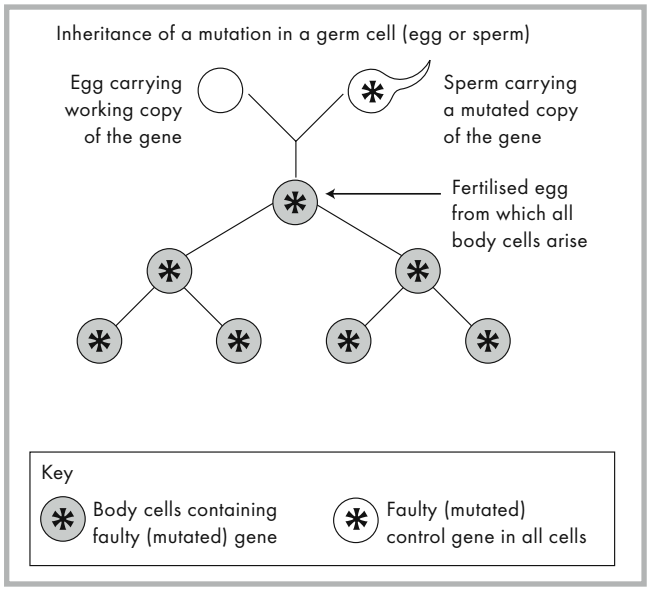

Figure 4.3. Inheritance of a mutation that is in an egg cell or sperm cell (called 'germ cells')

These factors affect the pattern of inheritance of the faulty gene (how it 'runs in the family'). A mutation in a single gene is described as recessive or dominant; this concept is explained in more detail in Genetics Fact Sheet 5.

The pattern of inheritance of the faulty gene also depends on whether it is located on one of the numbered chromosomes (*autosomes*) or on the X chromosome (*X-linked*). Patterns of inheritance of mutations in single genes are explained in Genetics Fact Sheets 8, 9 & 10.

Other Genetics Fact Sheets referred to in this Fact Sheet: 1, 2, 5, 8, 9, 10 11, 22, 34, 48, 50

Information in this Fact Sheet is sourced from:

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