# X-linked Genetic Disorders

A genetic disorder is caused by one or more faulty genes.

## What are genes?

Our bodies are made up of millions of cells. Each cell contains a complete set of genes. We have thousands of genes. We each inherit two copies of most genes, one copy from our mother and one copy from our father. Genes act like a set of instructions, controlling our growth and how our bodies work. Any alteration in these instructions is called a mutation (or change). Mutations (or changes) can stop a gene from working properly. A mutation (change) in a gene can cause a genetic disorder. Genes are responsible for many of our characteristics, such as our eye colour, blood type or height.

Genes are carried on thread-like structures called chromosomes. Each of us has 46 chromosomes in every cell. We inherit our chromosomes from our parents, one set of 23 chromosomes from our mother and one set of 23 chromosomes from our father. So we have two sets of 23 chromosomes, or 23 pairs. Twenty-two of the pairs are called autosomes. Changes (mutations) in autosomal genes will affect males and females equally. The remaining pair of chromosomes are the sex chromosomes.

There are two kinds of sex chromosome, one called the X chromosome and one called the Y chromosome, and they control whether a person is male or female. Females normally have two X chromosomes (XX). A female inherits one X chromosome from her mother and one *X* chromosome from her father. Males normally have an X and a Y chromosome (XY). A male inherits an X chromosome from his mother and a Y chromosome from his father.

An X-linked genetic disorder is caused by a change (mutation) in a gene on the X chromosome.

## X-linked Inheritance

The X chromosome has many genes that are important for growth and development. The Y chromosome is much smaller and has considerably fewer genes. Girls have two X chromosomes. Boys have one X chromosome and one Y chromosome. For any gene on the X chromosome, girls have two copies and boys have one copy. If a gene on the X chromosome has a mutation (change), the effects depend on whether the person is a boy or a girl. If a girl has a gene with a change (mutation) on one X chromosome, the presence of a matching gene on her other X chromosome can usually make up for the gene with the change (mutation) (provided that the matching gene is working properly). In this case, the girl is a healthy carrier of the X-linked disorder. In some rare cases, a girl may show some signs of the disorder, but she will be much less affected than a boy.

If a boy has a gene with a mutation (change) on his single X chromosome, he does not have another copy of that gene to compensate for the changed gene, and this can cause a genetic disorder. This type of inheritance is called X-linked inheritance. Conditions that are inherited in this way are called X-linked disorders. There are many X-linked conditions. They include haemophilia, Duchenne muscular dystrophy and fragile X syndrome.

## What is the risk that a woman who is a carrier will have an affected child?

There are two possible outcomes when a woman who is a carrier of an X-linked genetic disorder has children. For each child she has, she may pass on either the X chromosome which has the gene with the mutation (change), or the X chromosome with the healthy copy of the gene. This occurs randomly, so there is a 50% or 1 in 2 chance that a child will receive the gene with the change (mutation). If the child who inherits the gene with the change is female, she will be a healthy carrier like her mother. If the child who inherits the gene with the change (mutation) is male, he will have an X-linked genetic disorder. There is a 50% or 1 in 2 chance that any baby will be a boy. A pregnant woman who is a carrier has a 1 in 2 chance of having a boy and a 1 in 2 chance of passing on the gene with the change (mutation) to any boy she does have. A woman who is a carrier thus has a 1 in 4 chance of having an affected son.

Picture 1 summarises this.

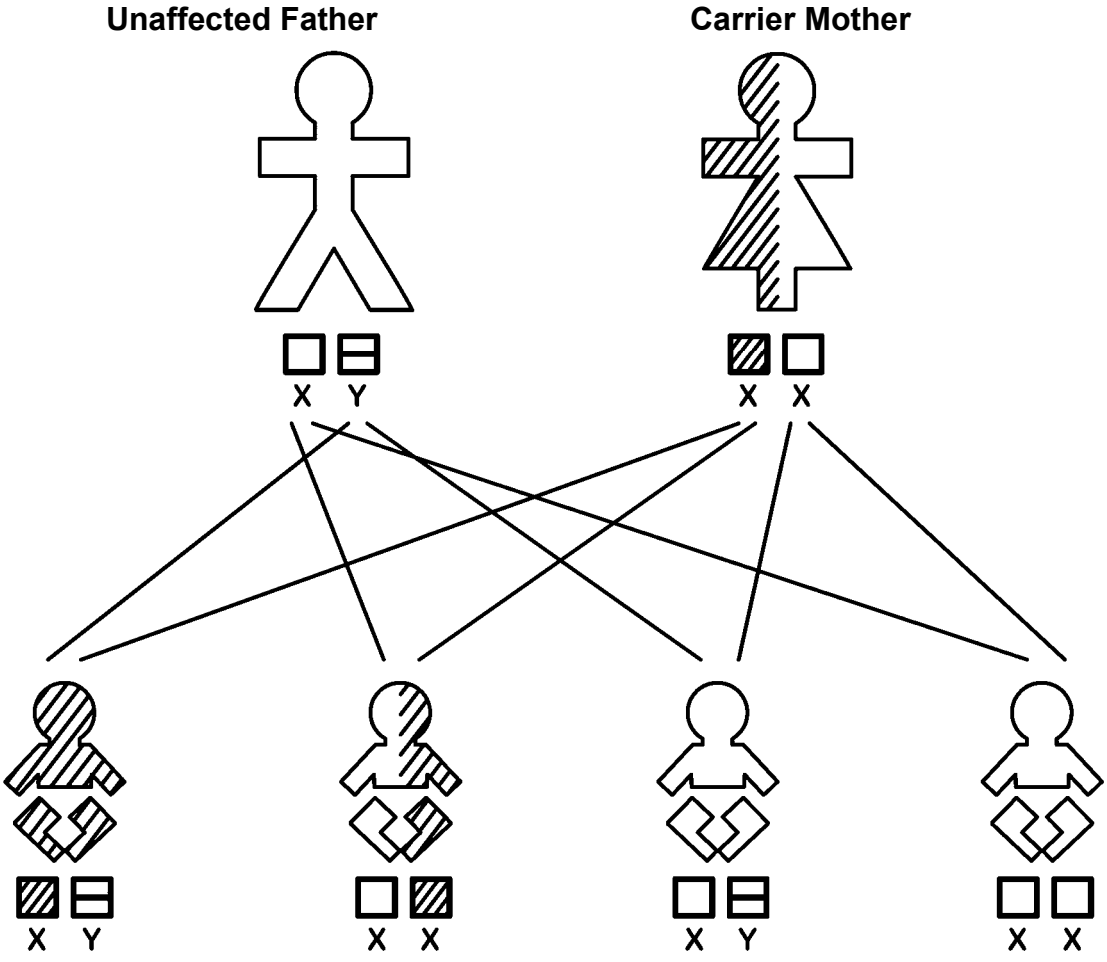
## Picture 1. How X-linked genes are passed on by carriers


These shapes represent an X chromosome and a Y chromosome


This shape represents an X chromosome with a normal copy of the gene


This shape represents an X chromosome with a gene with a mutation (change)

The mother is a carrier of an X-linked gene with a mutation (change). There are four possible ways for the parents to pass on their genes



## What is the risk that an affected man will have an affected child?

A man passes on his X chromosome to his daughters and he passes on his Y chromosome to his sons. If a man has a gene with a mutation (change) on his X chromosome, all his daughters will inherit it, but they will inherit a normal copy of the gene from their mother. His daughters will therefore be carriers. The daughters will not have the genetic disorder themselves but they are at risk of having affected sons. Sons do not inherit an X chromosome from their father, so an affected man will never pass the condition to his sons.

## Carrier Testing and Prenatal Diagnosis

Prenatal diagnosis involves testing a baby for a genetic disorder during the mother's pregnancy. Prenatal diagnosis is available for only a limited number of X-linked disorders. Carrier testing is available for some X-linked disorders. This test can establish whether a person carries a change (mutation) in a particular gene.

## In summary

- Women who carry an X-linked disorder are carriers and are usually healthy.
- A son of a carrier mother will have a 1 in 2 chance (50%) of inheriting the condition.
- A daughter of a carrier mother will have a 1 in 2 chance (50%) of being a carrier like her mother.
- A son who has not inherited an X-linked gene with a mutation (change) is unaffected and cannot pass the condition to any of his descendants.
- Any daughter who inherits a normal X chromosome from a carrier mother will not be a carrier herself and will not pass on the condition.
- An affected man will never pass the condition to his sons, as a son inherits his father's Y chromosome.
- All daughters of an affected man will inherit his X chromosome with the gene with the mutation (change), and they will all be carriers.

## Where can I find out more?

More information can be obtained from your local regional genetics centre or from these addresses:

### The Genetic Interest Group

*Unit 4D, Leroy House,*
*436 Essex Rd.,*
*London N1 3QP*
Telephone: 020 7704 3141
Email: *mail@gig.org.uk* Web: *www.gig.org.uk*

### Contact a Family

*209-211 City Rd.,*
*London EC1V 1JN*
Telephone: 020 7608 8700 Fax: 020 7608 8701
Helpline 0808 808 3555 or Textphone 0808 808 3556
(Freephone for parents and families, 10am-4pm, Mon-Fri)
Email: *info@cafamily.org.uk* *Web: cafamily.org.uk*

*This edition prepared in July 2005* *Ref 23*

# Glossary (difficult words and their meanings): X-linked Genetic Disorders

This glossary is intended only to explain terms used in the information: X-linked Genetic Disorders. Words shown in **bold** are defined elsewhere in the glossary.

**autosomal.** Involving the **autosomes.**

**autosomes.** The 44 **chromosomes** (22 pairs) which are not **sex chromosomes**.

**carrier.** A woman who has one normal copy of a **gene** on the **X chromosome** and who has a change (**mutation**) in the other copy of that **gene** on her other **X chromosome**. The presence of the normal **gene** usually ensures that she will not be affected. Carriers are not usually affected by the corresponding **X-linked genetic** disorder.

**cell.** The human body is made up of millions of cells, which are like building blocks. There are many specialised types of cells. These include skin cells, brain cells, and blood cells. Cells in different parts of the body look different and do different things. Every cell (except for eggs in women and sperm in men) contains all the body's **genes.**

**chromosomes.** Thread-like structures which can be seen under the microscope and contain the **genes**. Usually people have 46 chromosomes in every **cell**. There are two **sex chromosomes.** The other 22 pairs of chromosomes (numbered 1 to 22) are called **autosomes**. Twenty-three chromosomes come from the mother, and twenty-three come from the father. One chromosome of each pair comes from each parent. (As an analogy: a chromosome is like a book; a **gene** is like a story in the book).

**gene.** Information needed for the body to work, stored in a chemical form on **chromosomes**. Changes or **mutations** in genes alter the information and this can change how the body works. **Autosomal genes** are in pairs: one from the mother, one from the father. The two genes of a pair are at matching places on a pair of **chromosomes**. (As an analogy: a **chromosome** is like a book, a **gene** is like a story in the book, a change or **mutation** in a **gene** is like a missing or extra letter in a word in the story).

**genetic.** Caused by **genes**, concerning **genes.**

**mutation**. A change in a **gene**. Some mutations are not harmful. Sometimes when a **gene** is changed, its information is altered so it does not work properly. (As an analogy: a change or mutation in a **gene** is like a missing or extra letter in a word in a story).

**prenatal diagnosis.** Test during a pregnancy for the presence or absence of a **genetic** disorder in the baby.

**sex chromosomes.** The X **chromosome** and the Y **chromosome.** The sex chromosomes control whether a person is male or female. Females have two X **chromosomes**. Males have one **X** and one **Y chromosome**.

**X chromosome.** One of the **sex chromosomes**. Females have two X **chromosomes** Males have one X **chromosome** and one **Y chromosome**.

**X-linked**. Describes a gene on the **X chromosome**. An X-linked **genetic** disorder is one caused by a **mutation** (change) in a **gene** on the **X chromosome**.

**XX.** This represents the **sex chromosomes** of a female. Females have two **X chromosomes**. One **X chromosome** is inherited from each parent

**XY**. This represents the **sex chromosomes** of a male. Males have one **X chromosome** and one **Y chromosome**. A male inherits his **X chromosome** from his mother and his **Y chromosome** from his father.

**Y chromosome.** One of the **sex chromosomes**. Males have one Y **chromosome** and one **X chromosome**. Females have two **X chromosomes**.

This glossary is intended only for use by patients and families, with the genetic information to which it refers.

*This edition prepared in July 2005* *Ref Glossary 23*