

## INHERITANCE OF RETINAL DEGENERATIONS

**FOUNDATION** **FIGHTING**  
**BLINDNESS**

# INHERITANCE OF RETINAL DEGENERATIONS

## Table of Contents

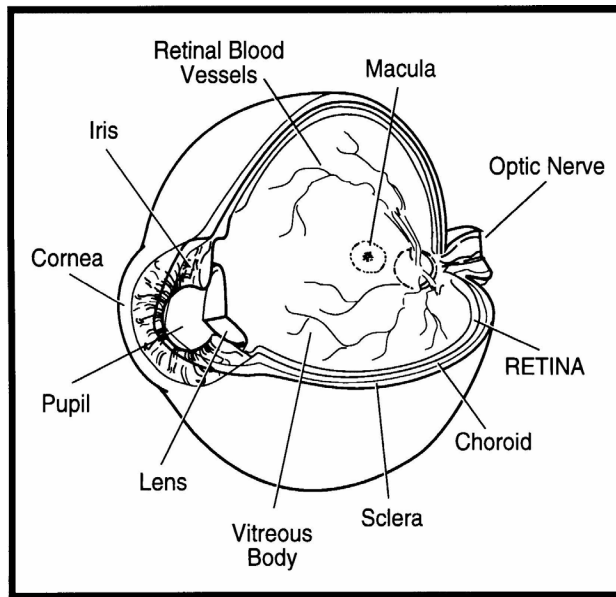
<u>Introduction</u>	<u>3</u>
<u>Basic Genetics</u>	<u>4</u>
<u>Inheritance Patterns</u>	<u>8</u>
<u>Unique Cases</u>	<u>16</u>
<u>Genetic Testing</u>	<u>20</u>
<u>Frequently Asked Questions</u>	<u>22</u>
<u>Identifying a Genetic Counselor</u>	<u>23</u>
<u>Resource List: Genetic Counseling Information</u>	<u>24</u>

## Introduction

If you or a relative have a retinal degenerative disease like retinitis pigmentosa (RP) or macular degeneration, you may, understandably, be concerned about the severity of the disease and the possible loss of sight. In addition, if it is an inherited disease, there is a risk that other family members may be affected. Now is the time to consult with an ophthalmologist trained in genetics, with a medical geneticist or with a genetic counselor. Only after a thorough review of your family history can the risk for other family members be assessed.

The information found in this booklet cannot replace genetic counseling; genetic counseling is provided only by trained professionals in a medical setting. Rather, you can use this booklet to help prepare for the counseling session, and you can refer to it after counseling to help you remember what was discussed.

Retinitis pigmentosa (RP) is the name given to a group of retinal degenerative diseases characterized by a breakdown of the retina, the thin layers of light-sensing cells in the back of the eye (Figure 1). The first symptom of RP is usually night-blindness followed by reduction in peripheral vision, which leads to tunnel vision.



**Figure 1.** Diagram of an eye. The retina forms the inner back layer.

Macular degeneration describes a group of retinal degenerative diseases that is characterized by a breakdown of the macula, the small center portion of the retina. The macula provides the sharp central vision needed for reading small print and for recognizing faces at a distance. Symptoms of macular degeneration may include seeing dark or empty areas in the center of vision, and seeing distortions of lines and shapes in every day activities.

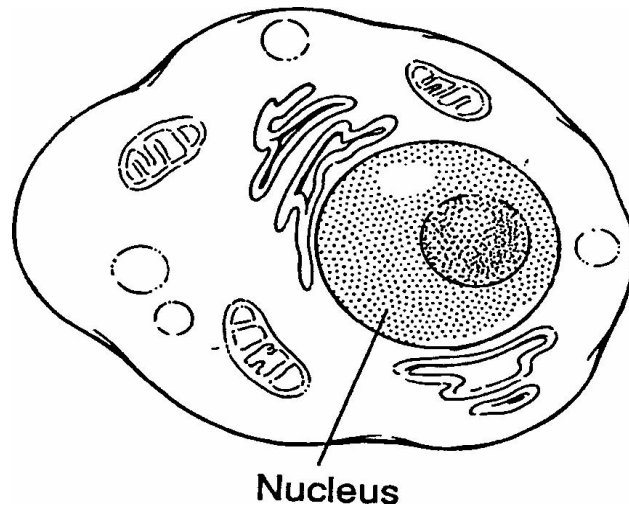
Other retinal degenerative diseases affect specific layers of the retina and may also involve other parts of the body. Retinal degenerative diseases are also referred to as retinal degenerations.

Although usually diagnosed in young adulthood, certain forms of retinal degenerations are evident in early childhood, and other forms may not appear until the fifth or sixth decade of life.

Because most retinal degenerations are inherited, they can occur in more than one individual in a family. In some families, the disease affects both parent and child. In other families, unaffected parents have one or more children with a retinal degeneration.

To understand how retinal degenerations are inherited, it is important to first review the basic facts about genetics, the science of heredity.

In most cells of the body, a structure, called the nucleus, contains the genetic material responsible for inherited traits (Figure 2). The genetic material is packaged in the form of chromosomes, rod-like structures visible only through a microscope.

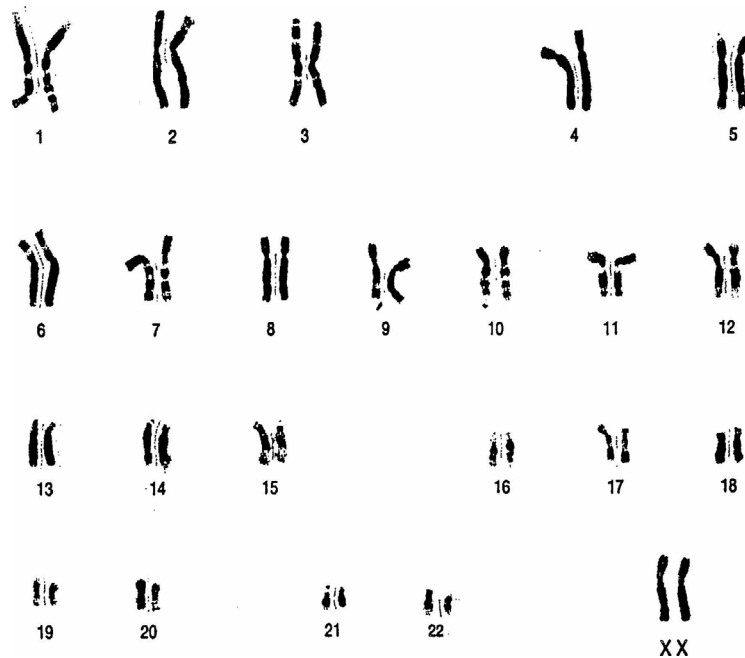


**Figure 2.** A human cell. The nucleus contains the genetic material.

Chromosomes have various sizes and come in pairs. Every cell, except eggs and sperm, contain 23 pairs, or 46 chromosomes. Twenty-two pairs are the same in both males and females and are called autosomes. The sex chromosomes make up the twenty-third pair.

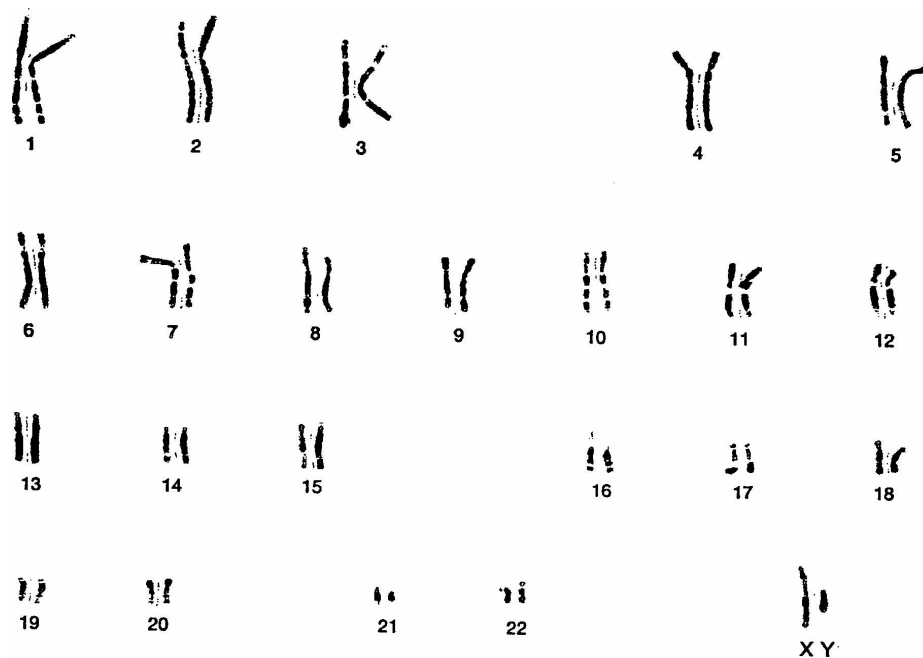
## Basic Genetics

Females have two similar chromosomes designated the X chromosomes (Figure 3), and males have one X chromosome and a different, smaller Y chromosome (Figure 4).



**Figure 3.** The 46 chromosomes of a normal female.

Each egg and sperm has only 23 chromosomes, one of each pair. Every egg has 22 autosomes and one X chromosome. Each sperm has 22 autosomes and either an X or a Y chromosome (but not both). At conception, when the egg and the sperm cells merge, the cell they form will have 46 chromosomes, half from the mother (from the egg) and half from the father (from the sperm). If the sperm carried an X chromosome, the child will have two X's and be female. If the sperm carried a Y chromosome, the child will have an X and a Y and be male.



**Figure 4.** The 46 chromosomes of a normal male.

Chromosomes are composed of genes. Genes are small pieces of hereditary material arranged along the chromosomes much like beads on a string. Genes are made of a chemical called deoxyribonucleic acid (DNA). Because chromosomes come in pairs, the genes are paired as well. It may be easiest to imagine that a pair of genes carries a set of instructions which, once read by the body, specifies an inherited trait such as blood type. Although each pair of genes specifies one trait, each gene of the pair may carry different instructions for that trait, and each will influence how the trait is actually produced in the body.

Occasionally there is a change in a gene, called a mutation, that alters the instructions for that gene. A mutated gene may cause an abnormal trait or disease. Genetic diseases are classified as dominant if only one mutated gene, when paired with a normal gene, is needed to produce the disease and recessive if a pair of mutated genes (two copies of the gene) is needed to produce the disease. Disease-causing mutated genes can lie on autosomes or sex chromosomes. Retinal degenerative diseases are caused by mutated genes that produce dominant or recessive diseases.



## Inheritance Patterns

By tracing the pattern of affected and unaffected family members, it is often possible to determine if the retinal degeneration in a family is dominant or recessive and whether the mutated gene lies on an autosome or on a sex chromosome. An **inheritance pattern** can be determined only when more than one member of a family has a retinal degeneration. Once a pattern has been identified, genetic counseling should be provided to a family member who is at risk for having the disease or who is at risk for having children with the disease. In most cases, RP and other retinal degenerative diseases are inherited in either an autosomal dominant, an autosomal recessive or an X-linked pattern. Another unusual inheritance pattern, known as digenic, has been seen in a small number of families affected by RP.

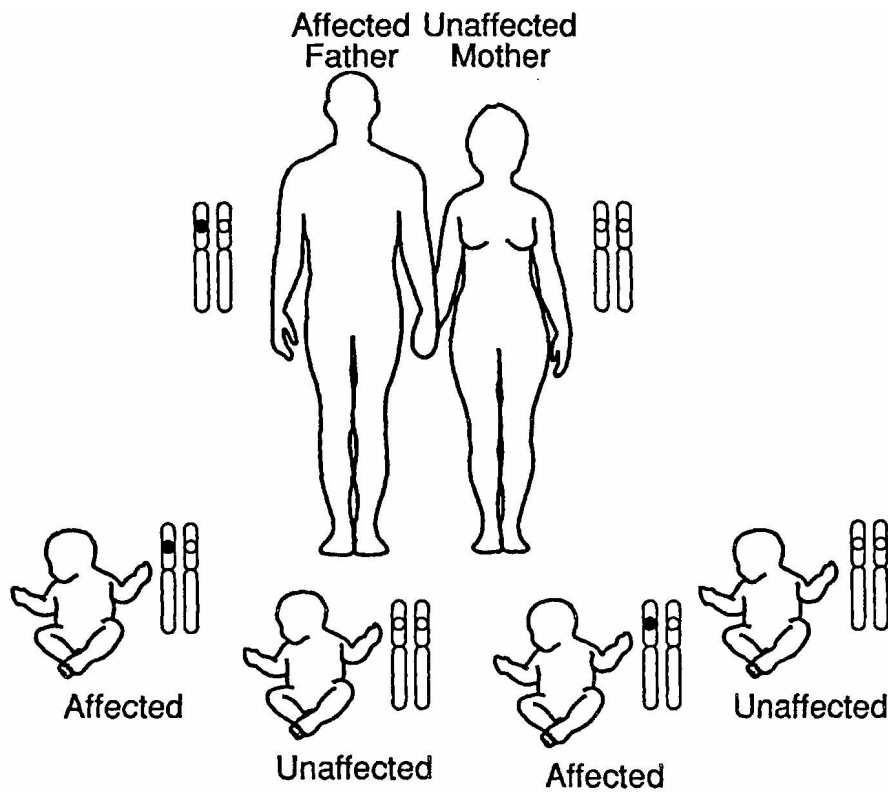
### Autosomal Dominant



In an autosomal dominant retinal degenerative disease, an affected person has one altered gene (the mutated gene) paired with one normal gene. These genes lie on one of the 22 pairs of autosomal chromosomes. About 20 percent of all families with RP have autosomal dominant RP.

When a person with an autosomal dominant retinal degeneration (whether male or female) and an unaffected partner have children, there is 1 chance in 2, or a 50 percent chance, that the affected parent will pass on the altered gene, and therefore the disease, to each child. There is also 1 chance in 2 that he (or she) will pass on the normal gene to each child. The unaffected partner will pass on one of his or her normal genes (Figure 5). A child who does not have an altered gene does not have the disease and cannot pass the gene (and the disease) on to his or her future children. Most often, families with an autosomal dominant retinal degeneration can trace the disease back through several generations. Rarely, in some of these families, the disease seems to have skipped one or more generations. In some families, it is possible for members to inherit a gene for autosomal dominant retinal degeneration but not develop the disease. This gene is said to have **reduced penetrance**, which means that the gene's effect is somehow modified, or reduced, and sometimes does not cause retinal degeneration even when present. However, in other families, the disease in affected members may be so mild that there is no, or few, symptoms.



# Inheritance Patterns



**Figure 5.** Autosomal dominant retinal degeneration.  = chromosome with retinal degeneration gene and  = chromosome with normal gene.

This gene is said to have **variable expressivity**, which means that the severity of the effect of the altered gene can vary from one affected family to another.

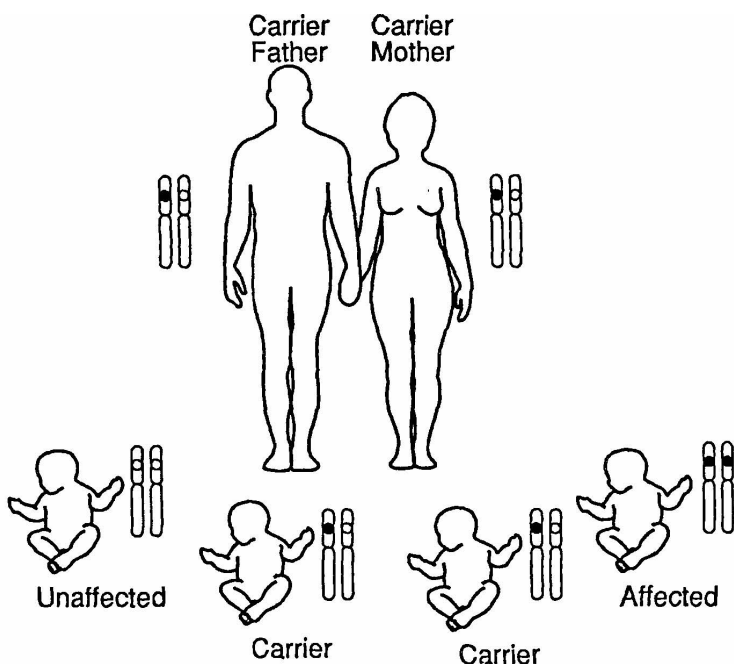
The age at which family members first show symptoms of retinal degeneration may also vary. Some family members can experience symptoms of the condition early in life, possibly in childhood, whereas other affected members in the same family may not have symptoms until they are well into middle age. When a family member dies before symptoms of retinal degeneration are discovered, but has affected children, it often seems that the disease has skipped a generation. Any person at risk for a retinal degeneration should be thoroughly examined by an ophthalmologist to detect mild or late onset cases of the disease.



# Inheritance Patterns

## Autosomal Recessive

In autosomal recessive retinal degenerative disease, the affected person has two copies of the altered gene. These genes lie on one of the 22 pairs of autosomes. Each of the affected person's parents has one altered gene paired with one normal gene and is called a carrier. Carriers do not have the disease. Autosomal recessive RP is documented in about 30 percent of all families with RP.

When two carrier parents have children, each parent will pass on either the altered gene or the normal gene. When both parents pass on the altered gene, the child will have two copies of the mutated gene and will have the disease. There is 1 chance in 4, or a 25 percent chance, that each child will have the disease. If one parent passes on the altered gene and the other parent passes on the normal gene, the child will be an unaffected carrier like the parents. There is 1 chance in 2, or a 50 percent chance, that each child will be a carrier. And if both parents pass on the normal gene, the child will not be affected and will not be a carrier. There is 1 chance in 4, or a 25 percent chance, that each child will neither have retinal degeneration nor be a carrier (Figure 6).



**Figure 6.** Autosomal recessive retinal degeneration.  = chromosome with retinal degeneration gene and  = chromosome with normal gene.

## Inheritance Patterns

When a person with autosomal recessive RP wants to have children, he or she is often concerned about passing on the disease. If the affected person's partner is not a blood relative (for example, a cousin), does not have the same autosomal recessive RP, and has no affected relatives, the chance that the partner will be a carrier of an autosomal recessive RP gene is about 1 in 80, and the chance that the couple will have a child with RP is less than 1 percent (1 in 100). For retinal degenerations other than RP, the chance that the partner will be a carrier of an autosomal recessive retinal degeneration gene and the chance that the couple will have a child with that retinal degeneration may vary somewhat.

### **X-linked**

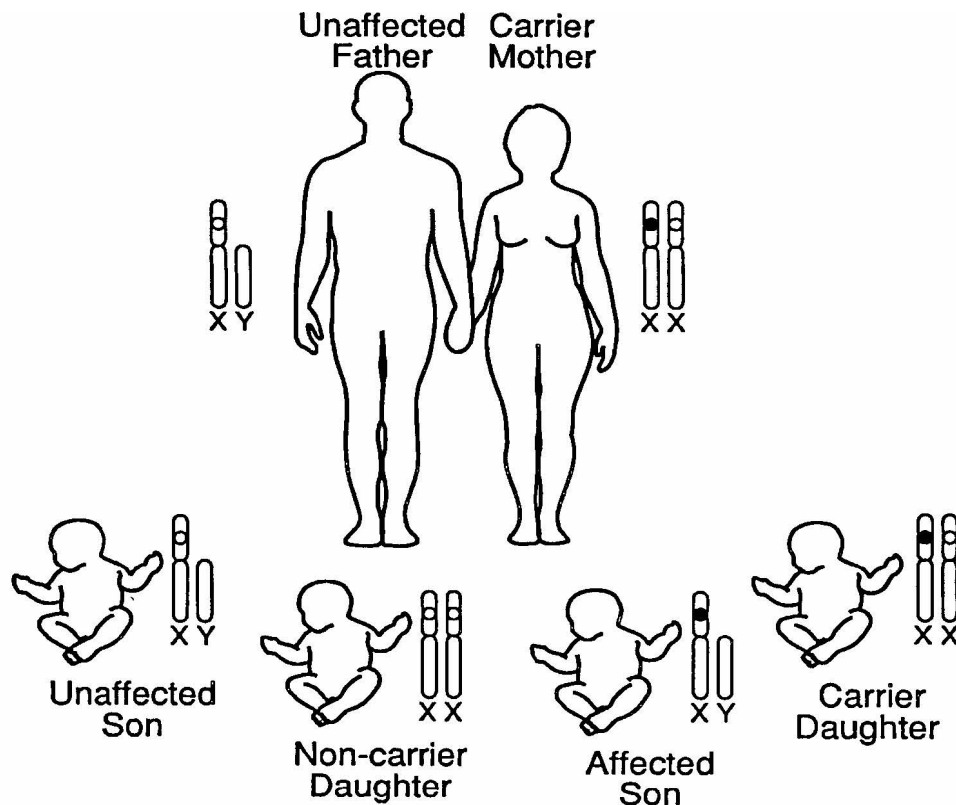
X-linked retinal degeneration (sometimes called sex-linked) is a recessive disorder caused by an altered gene on an X chromosome. With few exceptions, the disease is seen only in males. To understand X-linked inheritance, it is important to remember that females have a pair of similar sex chromosomes called X chromosomes, and males have only one X chromosome and a different, smaller Y chromosome. When a male has an altered gene on his only X chromosome, he must develop the disease because the altered gene is not paired with a normal gene and only the altered gene is needed to cause the disease. About 10 percent of families affected by RP have the X-linked form.

A female who has an altered gene on one of her X chromosomes and a normal gene on the other X chromosome is called a carrier. A carrier female usually has no symptoms of retinal degeneration. However, a female carrier can also have some vision loss associated with the X-linked retinal condition.




When a carrier female and an unaffected male have children, there is 1 chance in 2, or a 50 percent chance, that each of their sons will have retinal degeneration and also 1 chance in 2 that each of their sons will not have the disease. Remember, for each child conceived, the mother passes on one of her X chromosomes. The sex of the child is determined by the father, who passes on either a Y chromosome, for male, or an X chromosome, for female. An affected son will receive the X chromosome with the altered gene from his carrier mother and a Y chromosome with the normal gene from his carrier mother and a Y chromosome from his father. A son who receives the X chromosome with the normal gene from his carrier mother will not have retinal degeneration.

## Inheritance Patterns

There is 1 chance in 2, or a 50 percent chance, that each daughter of a carrier female and an unaffected male will be a carrier and also 1 chance in 2 that each daughter will not be a carrier (a non-carrier). The carrier mother will pass on either the X chromosome with the altered gene, for a carrier daughter, or the X chromosome with the normal gene, for a non-carrier daughter. The unaffected father will always pass on his X chromosome with a normal gene (Figure 7).



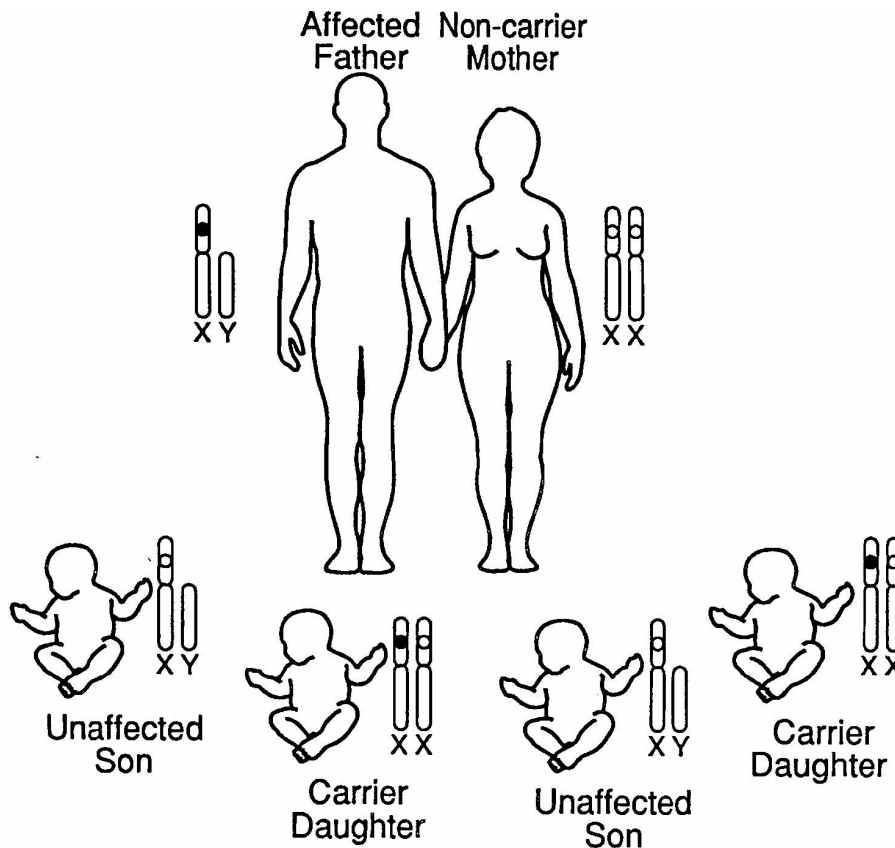
**Figure 7.** X-linked retinal degeneration with carrier mother and unaffected father.

 = X chromosome with retinal degeneration gene,  = X chromosome with normal gene and  = Y chromosome.




When a male with an X-linked retinal degeneration and a non-carrier female have children, none of their sons will be affected because, for each son, the male will pass on his Y chromosome, and the non-carrier mother will pass on one of her X chromosomes with a normal gene. Each of this couple's daughters will be a carrier.

## Inheritance Patterns

Although each daughter will receive an X chromosome with a normal gene from her non-carrier mother, she will also receive her father's only X chromosome with the altered gene (Figure 8).



**Figure 8.** X-linked retinal degeneration with affected father and non-carrier

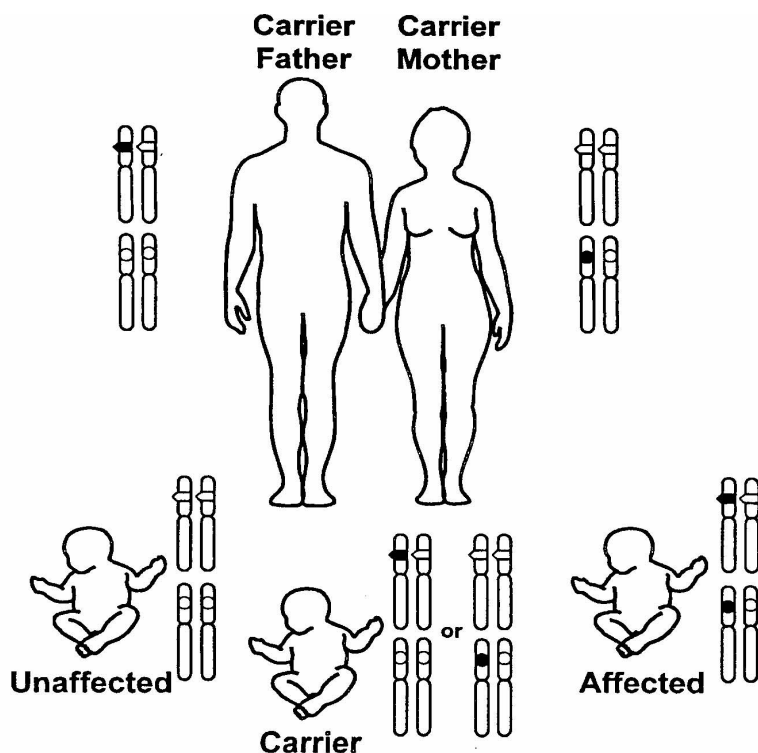
mother.  = X chromosome with retinal degeneration gene,  = X chromosome with normal gene and  = Y chromosome.

### Digenic





Recently, scientists identified a fourth inheritance pattern through which a retinal degeneration can be passed from one generation to the next, called digenic. So far, only a few females affected by RP have been identified as digenic. Remember that genes come in pairs. Although each pair of genes specifies one trait, each gene of the

## Inheritance Patterns

pair may carry different instructions for that trait and each will influence how the trait is actually produced in the body. In digenic retinal degenerative disease, an affected person has disease-causing mutations in two different gene pairs. Each of the gene pairs has one normal gene and one altered gene. The two altered genes act together to cause retinal degeneration, even though they lie on separate autosomes. Carriers, individuals who have a mutation in one of the gene pairs but not the other, will not be affected. When an affected carrier with a mutation in one gene has children with an unaffected carrier with a mutation in the other gene, the chances for having children who are affected, unaffected or carriers resembles autosomal recessive inheritance for the first two generations. There a 1 chance in 4, or 25 percent chance, that both parents will pass on their altered gene copies, and therefore the disease, to each child. There is 1 chance in 2, or a 50 percent chance, that each child will be a carrier of one of the altered genes. If both parents pass on normal genes, the child will not be affected and will not be a carrier. There is 1 chance in 4, or a 25 percent chance, that each child will neither have retinal degeneration nor be a carrier (Figure 9).



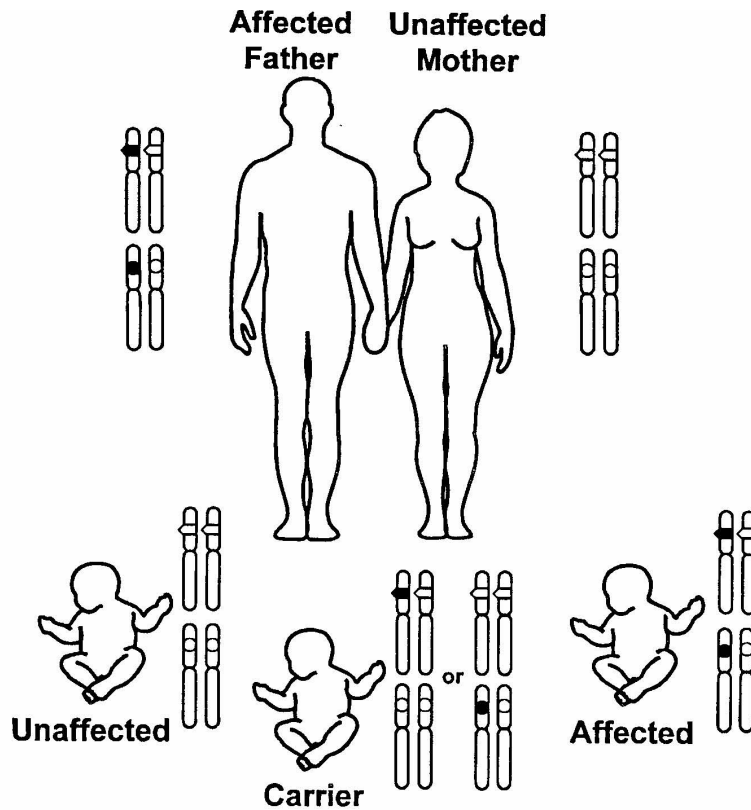
**Figure 9.** Digenic retinal degeneration with unaffected carrier parents.





 and  = chromosomes with altered genes;  and  = chromosomes with normal genes.

# Inheritance Patterns

From the second to third generations of digenic inheritance, there can be direct parent-to-child transmission, similar to autosomal dominant inheritance. When a person (whether male or female) with retinal degeneration due to these two altered genes has children with an unaffected non-carrier partner, there is 1 chance in 4, or 25 percent chance, that the affected parent will pass on both altered gene copies, and therefore the disease, to each child. There is 1 chance in 2, or a 50 percent chance, that each child will be the carrier of one of the altered genes. And if both parents pass on normal genes, the child will not be affected and will not be a carrier.

There is 1 chance in 4, or a 25 percent chance, that each child will neither have retinal degeneration nor be a carrier (Figure 10).



**Figure 10.** Digenic retinal degeneration with affected parent and unaffected parent.  and  = chromosomes with altered genes;  and  = chromosomes with normal genes.



## Unique Cases

Other combinations are more complicated to describe. Genetic counseling will be needed.

### Isolated Cases

When only one member of a family has a retinal degeneration, as we see in about 40 percent of families affected by RP, it is impossible to determine how the disease is inherited in that family. Nevertheless, to assess the risk of retinal degeneration occurring in other family members, it must be assumed that the disease is following one of the known inheritance patterns.

Isolated cases of retinal degeneration most often represent autosomal recessive disease. Even though carrier parents have a 25 percent chance of having an affected child, there is still a 75 percent chance of having an unaffected child. So, it is often the case that there is only one child with a retinal degeneration in the family.

Rarely, isolated cases of retinal degenerations represent new gene mutations. Retinal degenerations are caused by mutated genes that can pass through generations of a family. Occasionally, even when neither parent is affected nor carries an altered gene, one of the genes, usually in the egg or sperm, changes spontaneously from normal and becomes an altered gene, causing the disease in the child. New gene mutations most often represent the start of an autosomal dominant retinal degeneration; or, when a male is affected, either an autosomal dominant or X-linked retinal degeneration. Because an X-linked carrier female often shows mild effects of the altered gene, any mother of a male with an isolated case of retinal degeneration should be examined by an ophthalmologist to determine if she is a carrier.

Retinitis pigmentosa is just one of a number of inherited diseases that cause the retina to degenerate. There are many other retinal degenerations similar to RP but with their own distinct characteristics. Some of these diseases are described below. Most of these diseases are genetic and follow either an autosomal dominant, an autosomal recessive, or an X-linked inheritance pattern. The risk of any one of these diseases occurring in other family members is based in its inheritance pattern and is the same as described in the "Inheritance Patterns" section.

### **Bardet-Biedl (Laurence-Moon) Syndrome**

Multiple physical problems are usually found in a person with Bardet-Biedl syndrome. The most common are RP, extra fingers and/or toes, obesity, mental retardation and kidney disease. Not all of these occur in every person with this disease. Bardet-Biedl syndrome is an autosomal recessive disease.

### **Bassen-Kornzweig Syndrome (Abetalipoproteinemia)**

RP and progressive neurologic problems are symptoms of this disease. Patients also have oddly shaped red blood cells. Bassen-Kornzweig syndrome is an autosomal recessive disease.

### **Best Disease (Vitelliform Dystrophy)**

This disease is characterized by a lesion in the macula, which leads to impaired central vision in one or both eyes. It is an autosomal dominant disease.

### **Choroideremia**

Choroideremia has symptoms similar to RP, including night blindness followed by loss of peripheral vision. It is characterized by degeneration of the retina and of the choroid. It has an X-linked inheritance pattern and affects males. Female carriers may experience mild symptoms of the disease.

### **Gyrate Atrophy**

This retinal degenerative disease is associated with a deficiency in the enzyme ornithine aminotransferase. Myopia, night blindness, reduction in peripheral vision and cataracts are characteristic of this syndrome. Gyrate atrophy is an autosomal recessive disease.

### **Leber Congenital Amaurosis**

Leber congenital amaurosis is characterized by severe visual impairment from birth or very early childhood. It is an autosomal recessive disease. Leber congenital amaurosis causes visual problems that are different from those of Leber optic neuropathy, a condition that is not caused by primary degeneration of the retina.

### **Macular Degeneration**

Macular degeneration is divided into two broad categories: early onset and age-related. Early onset forms are inherited macular degenerations that include Best disease, Stargardt disease and other rare macular dystrophies, like Sorsby macular dystrophy and North Carolina macular dystrophy. Age-related macular degeneration is the leading cause of central vision loss in people over the age of 60. The first symptom is usually a blank spot in the center of the visual field or a distortion of normal central vision. Although it can be found in more than one member of a family, its inheritance pattern is usually unknown. It is sometimes seen as an autosomal dominant disease in some families.

### **Refsum Syndrome**

Refsum syndrome is a complex disease. It is believed to be caused by the absence of phytanic acid hydroxylase, an enzyme found normally in circulating blood. In addition to having RP, patients may have hearing loss, neurologic problems and dry and/or flaky skin. It is an autosomal recessive disease.

### **Retinoschisis (Juvenile)**

Juvenile retinoschisis is characterized by vision loss that is usually diagnosed in childhood. In this disease, the layers of the retina separate, and the macula may also be affected. Juvenile retinoschisis has the X-linked inheritance pattern and affects males. A non-inherited form of retinoschisis may occur in some individuals as the result of aging and may not affect vision.

### **Stargardt Disease/Fundus Flavimaculatus**

This form of macular degeneration usually appears before the age of 20. It is characterized by a reduction of central vision with a preservation of peripheral vision. The symptoms and progression of fundus flavimaculatus are very similar to that of Stargardt disease. Many researchers believe that these two conditions may be the same. In most affected families, Stargardt and fundus flavimaculatus are autosomal recessive diseases, although autosomal dominant families have been identified.

### **Usher Syndrome**

The combination of RP and congenital hearing impairment in a person is known as Usher syndrome, which is divided into three types. Type I is characterized by profound hearing impairment, problems with balance and typical RP. Type II is characterized by moderate hearing impairment and typical RP. Type III is characterized by progressive hearing impairment and typical RP. All types of Usher syndrome are autosomal recessive diseases.

The science of genetics is expanding rapidly. New technologies are available to locate disease-causing genes on each of the 23 pairs of chromosomes, to isolate and study these genes and to determine their mutations. Retinal degeneration researchers have already located and characterized some of the genes that cause these diseases and continually search for others.

In medicine, genetic research has the greatest impact so far in testing for retinal degenerations. As more retinal degeneration genes are identified, new gene-based tests are being developed. Genetic tests allow for faster and more accurate diagnoses.

Early discovery of a retinal degeneration can lead to earlier use of treatments that may slow the diagnosis. For example, if a doctor knows that a patient has an altered gene, he or she may suggest that the patient start taking vitamin A palmitate. If a child were at significant risk for a retinal degeneration, earlier diagnosis of the condition could mean earlier interventions, such as evaluation of the benefit of low vision aids, school adaptations, or orientation and mobility training.

Although the use of genetic testing allows the diagnosis of these diseases, treatments that cure retinal degenerations are still not available. Continued genetic research will lead the way to future treatments, especially in the development of gene therapy for retinal diseases. Discovering the genetic causes of a disease is a crucial first step in developing means for prevention and cure.

Many people affected by retinal degenerative diseases ask about genetic testing for themselves or their families. In some cases it is now possible to diagnose retinal degeneration through a gene test. Genes can be obtained from a blood or tissue sample. Researchers can separate DNA from the rest of the sample and test for the presence of disease-causing genes.

## Genetic Testing

Once a gene has been located, it is possible, in certain families, to perform tests on the genetic material found in blood and other cells to determine which members of the family have a retinal degeneration gene. Two categories of tests are available for retinal degenerative diseases: direct testing and indirect testing. The results of these tests can be used to determine if an individual carries a gene (carrier detection), to predict the presence of disease before symptoms appear (presymptomatic diagnosis), or to find out if an unborn child will be affected later in life (prenatal testing).

### Direct Testing

Direct tests are much like any other medical blood tests in that they show whether or not a certain disease is present. A direct test requires that the gene and the specific mutation, the change that caused the disease, are known. Researchers can then look for the disease-causing mutation. If it is present, then the individual has the genetic disorder.

For example, mutations can be directed in any of 3 genes that cause autosomal dominant RP (ADRP) known to date. If an individual with ADRP has a mutation, other family members can be tested for that mutation. Family members who are found to have the same mutation are likely to have ADRP also. If the individual with ADRP does not have any of the known mutations, the individual and his or her family might want to pursue indirect gene testing.

Unaffected individuals with a family history of retinal degeneration and individuals who are affected but do not have a family history can also undergo direct tests for all of the known gene mutations. However, if their test results are negative, this does not guarantee that they do not carry an infection, or will not pass it on to children. The genes known to date do not cover all cases. Scientists are still searching for more genes and mutations. In many cases, direct testing is possible for ADRP, Usher syndrome type 1B, some macular dystrophies, choroideremia and gyrate atrophy. Direct testing may take a period of weeks to be completed by the laboratory service.

### Indirect Testing

Indirect tests take advantage of the fact that genes and other DNA regions that lie close together on the same chromosome are usually inherited together. In other words, these genes are “linked.” To find the links between genes, scientists perform a specific type of study using markers. Markers are DNA fragments with harmless variations that are unique to families. Markers are not involved in causing disease themselves but might have a disease gene next to or sandwiched between them; they can act as flags for the area that contains a disease gene. If the disease gene is linked to a marker, scientists can detect where that gene is located.

Because all individuals inherit markers from both parents, researchers must compare markers from affected and unaffected individuals to sort out which ones are associated with the disease. Therefore, several family members are needed from more than one generation. The certainty of indirect testing results depends on how close the disease gene is linked to markers. Sometimes, markers cannot be readily identified and a disease gene cannot be traced through a family. Continued research and identification of new markers may be helpful in genetic diagnosis at a later time for these families. While direct testing may take a few weeks, indirect testing might take much longer. Most of the known retinal degeneration genes were found by linkage analysis.

### Who Does Genetic Testing, and Is Genetic Testing Available?

There are several fee-for-service diagnostic laboratories.

For a list of clinical laboratories that are CLIA-approved (federally regulated) for the commercial testing of DNA for inherited retinal degenerations, and for information on genetics, genetic testing, and inherited retinal disease, refer to the Foundation’s publication, *Genetic Testing Information Packet*.

For the physician’s office, there is another publication that lists the same CLIA-approved labs and cites their requirements and procedures for submitting samples: *Information for Clinicians – Procedures for Genetic Testing for Retinal Degenerative Disease*. Both publications are available on request or can be downloaded from FFB’s website.

## Frequently Asked Questions

Another important aspect of commercial labs is that there are costs involved. Fees vary greatly and are dependent on a number of factors. For the latest information on available tests and associated fees, the clinical labs should be contacted directly. Contact information is available in the *Genetic Testing Information Packet*.

Questions about your family's risks for developing a genetic disorder like a retinal degeneration are best answered in a genetic counseling session. Genetic counseling can provide practical information to you and your family about the inheritance of genetic conditions. The process includes discussion of family history (and construction of a pedigree), available tests, treatments and research options, examination of medical records and assessment of the chances that the disease might occur again in your family. Such counseling can be provided by an ophthalmologist or family doctor with special training in genetics. However, most certified genetic counselors are masters degree-level health care professionals who have followed a specific educational course.

### **Who should consider genetic counseling and why should you participate?**

Any person with an inherited retinal degenerative disease or with a family history of one of these diseases is a candidate for genetic counseling to:

1. learn how the disease is inherited in your family and to learn about the chance of passing it to your children
2. learn more about presymptomatic diagnosis or carrier detection
3. learn more about prenatal diagnosis
4. learn about the latest advances in research and testing, and to determine if they are useful to your family

### **When should I consider genetic counseling?**

You should consider genetic counseling immediately after you, or a family member, are diagnosed with a retinal degenerative disease, before you marry or before you have children. If you intend to use this information to plan a family, it is best to plan long in advance of any pregnancy.



## Finding a Genetic Counselor

If you are interested in genetic counseling, the following can help you to identify an appropriate professional.

1. Ask your ophthalmologist to refer you to an ophthalmologist trained in retinal diseases and/or genetics, to a medical geneticist or to a genetic counselor.
2. Contact the departments of ophthalmology, genetics, obstetrics or pediatrics at the nearest university medical school or major hospital.
3. Contact your state department of health and ask for genetic counseling referrals.
4. Contact your local March of Dimes chapter (see the Resource List below).
5. Contact the National Society of Genetic Counselors (see Resource List below).
6. Consult one of the Foundation Research Centers.

## Resource List: Genetic Counseling Information

Reports obtained from genetic testing can often be difficult to interpret. Consequently, most testing facilities require that a genetic counselor, geneticist or physician arrange for the testing, explain results and address concerns before and after testing.

Genetic Alliance, Inc.  
4301 Connecticut Avenue, NW, Suite 404  
Washington, DC 20008-2369  
202-966-5557  
info@geneticalliance.org  
www.geneticalliance.org

March of Dimes  
1275 Mamaroneck Avenue  
White Plains, NY 10605  
800-367-6630  
914-997-4488  
www.marchofdimes.com

National Center for Education in Maternal & Child Health  
Georgetown University  
Box 571272  
Washington, DC 20057-1272  
877-624-1935  
202-784-9770  
www.ncemch.org

National Organization for Rare Disorders (NORD)  
55 Kenosia Avenue  
P. O. Box 1968  
Danbury, CT 06813-1968  
800-999-6673  
203-744-0100  
www.rarediseases.org

## Resource List: Genetic Counseling Information

National Society of Genetic Counselors  
401 N. Michigan Avenue, 22nd Floor  
Chicago, IL 60611  
312-321-6834  
nsgc@nsgc.org  
www.nsgc.org

FFB also maintains a physician referral list to help you find a retinal specialist in your area. It is available on request or through our website.

## Glossary of Terms

*affected*: having the disease

*autosomal dominant*: a trait (or a disease) that is produced when only one copy of a gene is present

*autosomal recessive*: a trait (or disease) that is produced only when two copies of a gene are present

*autosome*: one of the non-sex chromosomes; there are 22 pairs of autosomes

*carrier*: an individual with one mutated gene paired with one normal gene; a carrier of a gene for a recessive disease does not have the disease

*carrier detection*: using tests to determine who carries a mutated gene for a recessive disease

*cell*: the smallest unit of living matter; the human body is made up of about 10 trillion cells

*choroid*: the layer of the eye behind the retina that contains major blood vessels

*chromosome*: a microscopic, rod-like structure in the cell's nucleus that carries the genetic material

*conception*: the union of an egg and a sperm that forms a cell capable of surviving and maturing, resulting in pregnancy

*congenital*: present at birth

*DNA*: deoxyribonucleic acid, the molecule that holds genetic information; it is the biochemical molecule that makes chromosomes and genes

*enzyme*: a protein involved in an important biochemical reaction in the body; a defective enzyme can be the result of a mutated gene

## Glossary of Terms

*family history*: information about an individual's family concerning its medical background and usually concentrating on the history of the disease, both defects and reproduction

*gene*: a unit of heredity; composed of deoxyribonucleic acid (DNA)

*gene therapy*: the administration of genetic material into cells of a patient to correct or replace a specific gene that is not working properly

*genetics*: the science concerning genes and heredity

*genetic counselor*: a professional trained to evaluate a family's medical history to determine the presence of genetic diseases or other inherited traits and to assess the risk of these occurring in other family members

*inheritance pattern*: the way in which a gene or trait is passed through generations of a family

*inherited*: passed through generations of a family, from parents to children

*isolated*: occurring in only one individual in a family

*linked*: two or more markers that are close enough together on a chromosome to be inherited together

*macula*: the central area of the retina

*marker*: a gene or DNA fragment with a known location on a chromosome that is associated with a certain disease; it can be used as a point of reference when looking for disease-causing mutations

*medical geneticist*: a medical doctor who specializes in the diagnosis and treatment of inherited diseases

*mutation*: a change in a gene

*myopia*: nearsightedness

## Glossary of Terms

*neurologic*: concerning the nervous system

*night blindness*: inability to see at night or in areas with low lighting

*nucleus*: a structure within the cell containing genetic material

*ophthalmologist*: a medical doctor who specializes in the diagnosis and treatment of eye diseases

*pedigree*: a multigenerational family tree using symbols to denote lineage and genetic information

*peripheral*: side

*prenatal diagnosis*: the diagnosis of a disease before the onset of clinical symptoms

*presymptomatic diagnosis*: the diagnosis of a disease before the onset of clinical symptoms

*retina*: the layers of cells in the back of the eye that are responsible for sensing light and transmitting light-induced signals to the brain

*reduced penetrance*: when the effect of a mutated gene for a dominant disease is somehow modified or reduces and does not always cause disease when present

*sex chromosome*: an X or Y chromosome; the XX pair determines female and the XY pair determines male

*trait*: a distinguishing characteristic

*unaffected*: not having the disease

*variable expressivity*: when the effect of a mutated gene for a dominant disease may be severe in one member of the family and mild in another

## Notes