

# Blood Types and Genetic Disorders

## Human Genes

The human genome includes tens of thousands of genes.

In 2003, the DNA sequence of the human genome was published.

In a few cases, biologists were able to identify genes that directly control a single human trait such as blood type.

## Blood Group Genes

Human blood comes in a variety of genetically determined blood groups.

A number of genes are responsible for human blood groups.

The best known are the ABO blood groups and the Rh blood groups.

The Rh blood group is determined by a single gene with two alleles—positive and negative.

The positive (Rh+) allele is dominant, so individuals who are Rh+/Rh+ or Rh+/Rh are said to be Rh-positive.

Individuals with two Rh- alleles are said to be Rh-negative.

### ABO blood group

- There are three alleles for this gene,  $I^A$ ,  $I^B$ , and  $i$ .
- Alleles  $I^A$  and  $I^B$  are codominant.

Individuals with alleles  $I^A$  and  $I^B$  produce both A and B antigens, making them blood type AB.

Phenotype (Blood Type)	Genotype	Antigen on Red Blood Cell	Safe Transfusions	
			To	From
AB	$I^A I^B$	A and B	AB	A, B, AB, O

The  $i$  allele is recessive.

Individuals with alleles  $I^A I^A$  or  $I^A i$  produce only the A antigen, making them blood type A.

Individuals with  $I^B I^B$  or  $I^B i$  alleles are type B.

Phenotype (Blood Type)	Genotype	Antigen on Red Blood Cell	Safe Transfusions	
			To	From
A	$I^A I^A$ or $I^A i$	A	A, AB	A, O
Phenotype (Blood Type)	Genotype	Antigen on Red Blood Cell	Safe Transfusions	
B	$I^B I^B$ or $I^B i$	B	B, AB	B, O

Individuals who are homozygous for the  $i$  allele ( $ii$ ) produce no antigen and are said to have blood type O.

Phenotype (Blood Type)	Genotype	Antigen on Red Blood Cell	Safe Transfusions	
			To	From
O	$ii$	none	A, B, AB, O	O

## Recessive Alleles

The presence of a normal, functioning gene is revealed only when an abnormal or nonfunctioning allele affects the phenotype.

Many disorders are caused by autosomal recessive alleles.

Disorder	Major Symptoms
Albinism	Lack of pigment in skin, hair, and eyes
Cystic fibrosis	Excess mucus in lungs, digestive tract, liver; increased susceptibility to infections
Galactosemia	Accumulation of galactose (a sugar) in tissues; mental retardation; eye and liver damage
Phenylketonuria (PKU)	Accumulation of phenylalanine in tissues; lack of normal skin pigment; mental retardation
Tay-Sachs disease	Lipid accumulation in brain cells; mental deficiency; blindness; death in early childhood

## Dominant Alleles

The effects of a dominant allele are expressed even when the recessive allele is present.

Two examples of genetic disorders caused by autosomal dominant alleles are achondroplasia and Huntington disease.

Disorder	Major Symptoms
Achondroplasia	Dwarfism (one form)
Huntington disease	Mental deterioration and uncontrollable movements; symptoms usually appear in middle age
Hypercholesterolemia	Excess cholesterol in blood; heart disease

## Codominant Alleles

Sickle cell disease is a serious disorder caused by a codominant allele.

Sickle cell is found in about 1 out of 500 African Americans.

Disorder	Major Symptoms
Sickle cell disease	Misshapen, or sickled, red blood cells; damage to many tissues

**In both cystic fibrosis and sickle cell disease, a small change in the DNA of a single gene affects the structure of a protein, causing a serious genetic disorder.**

## Cystic Fibrosis

Cystic fibrosis is caused by a recessive allele.

Sufferers of cystic fibrosis produce a thick, heavy mucus that clogs their lungs and breathing passageways.

The most common allele that causes cystic fibrosis is missing 3 DNA bases.

As a result, the amino acid phenylalanine is missing from the CFTR protein.

Normal CFTR is a chloride ion channel in cell membranes.

Abnormal CFTR cannot be transported to the cell membrane.

The cells in the person's airways are unable to transport chloride ions.

As a result, the airways become clogged with a thick mucus.

## **Sickle Cell Disease**

Sickle cell disease is a common genetic disorder found in African Americans.

It is characterized by the bent and twisted shape of the red blood cells.

Hemoglobin is the protein in red blood cells that carries oxygen.

In the sickle cell allele, just one DNA base is changed.

As a result, the abnormal hemoglobin is less soluble than normal hemoglobin.

Low oxygen levels cause some red blood cells to become sickle shaped.

There are three phenotypes associated with the sickle cell gene.

An individual with both normal and sickle cell alleles has a different phenotype—resistance to malaria—from someone with only normal alleles.

Sickle cell alleles are thought to be codominant.

People who are heterozygous for the sickle cell allele are generally healthy and they are resistant to malaria.