Human Inheritance

Tracking Traits in Humans

Autosomal Inheritance

Sex-Linked Inheritance

Chromosome Changes

Genetic Testing
How Do We Study Inheritance Patterns In Humans?

- Geneticists often use historical records
- Make charts (pedigrees of genetic connections)
  - Allow geneticists to determine the probability that a trait will recur in future generations
  - Determine whether a trait is associated with dominant or recessive alleles
  - Determine whether the alleles are on autosomes or sex chromosomes
A Standard symbols used in pedigrees.

B A pedigree for polydactyly, which is characterized by extra fingers, toes, or both. The black numbers signify the number of fingers on each hand; the red numbers signify the number of toes on each foot. Though it occurs on its own, polydactyly is also one of several symptoms of Ellis–van Creveld syndrome.
Patterns of Genetic Disorders

- Autosomal dominant inheritance pattern
- Autosomal recessive inheritance pattern
- X-linked recessive inheritance pattern
- X-linked dominant inheritance pattern
- Changes in chromosome number
- Changes in chromosome structure
<table>
<thead>
<tr>
<th>Disorder or Abnormality</th>
<th>Main Symptoms</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Autosomal dominant inheritance pattern</strong></td>
<td></td>
</tr>
<tr>
<td>Achondroplasia</td>
<td>One form of dwarfism</td>
</tr>
<tr>
<td>Aniridia</td>
<td>Defects of the eyes</td>
</tr>
<tr>
<td>Camptodactyly</td>
<td>Rigid, bent fingers</td>
</tr>
<tr>
<td>Familial hypercholesterolemia</td>
<td>High cholesterol level; clogged arteries</td>
</tr>
<tr>
<td>Huntington's disease</td>
<td>Degeneration of the nervous system</td>
</tr>
<tr>
<td>Marfan syndrome</td>
<td>Abnormal or missing connective tissue</td>
</tr>
<tr>
<td>Polydactyly</td>
<td>Extra fingers, toes, or both</td>
</tr>
<tr>
<td>Progeria</td>
<td>Drastic premature aging</td>
</tr>
<tr>
<td>Neurofibromatosis</td>
<td>Tumors of nervous system, skin</td>
</tr>
<tr>
<td><strong>Autosomal recessive inheritance pattern</strong></td>
<td></td>
</tr>
<tr>
<td>Albinism</td>
<td>Absence of pigmentation</td>
</tr>
<tr>
<td>Hereditary methemoglobinemia</td>
<td>Blue skin coloration</td>
</tr>
<tr>
<td>Cystic fibrosis</td>
<td>Difficulty breathing; chronic lung infections</td>
</tr>
<tr>
<td>Ellis–van Creveld syndrome</td>
<td>Dwarfism, heart defects, polydactyly</td>
</tr>
<tr>
<td>Fanconi anemia</td>
<td>Physical abnormalities, marrow failure</td>
</tr>
<tr>
<td>Galactosemia</td>
<td>Brain, liver, eye damage</td>
</tr>
<tr>
<td>Hereditary hemochromatosis</td>
<td>Joints, organs damaged by iron overload</td>
</tr>
<tr>
<td>Phenylketonuria (PKU)</td>
<td>Mental impairment</td>
</tr>
<tr>
<td>Sickle-cell anemia</td>
<td>Anemia, pain, swelling, frequent infections</td>
</tr>
<tr>
<td>Tay–Sachs disease</td>
<td>Deterioration of mental and physical abilities; early death</td>
</tr>
<tr>
<td><strong>X-linked recessive inheritance pattern</strong></td>
<td></td>
</tr>
<tr>
<td>Androgen Insensitivity syndrome</td>
<td>XY individual but having some female traits; sterility</td>
</tr>
<tr>
<td>Red–green color blindness</td>
<td>Inability to distinguish red from green</td>
</tr>
<tr>
<td>Hemophilia</td>
<td>Impaired blood clotting ability</td>
</tr>
<tr>
<td>Muscular dystrophies</td>
<td>Progressive loss of muscle function</td>
</tr>
<tr>
<td>X-linked anhidrotic dysplasia</td>
<td>Mosaic skin (patches with or without sweat glands); other ill effects</td>
</tr>
<tr>
<td><strong>X-linked dominant inheritance pattern</strong></td>
<td></td>
</tr>
<tr>
<td>Fragile X syndrome</td>
<td>Intellectual, emotional disability</td>
</tr>
<tr>
<td>Incontinentia pigmenti</td>
<td>Abnormalities of skin, hair, teeth, nails, eyes; neurological problems</td>
</tr>
<tr>
<td><strong>Changes in chromosome number</strong></td>
<td></td>
</tr>
<tr>
<td>Down syndrome</td>
<td>Mental impairment; heart defects</td>
</tr>
<tr>
<td>Turner syndrome (XO)</td>
<td>Sterility; abnormal ovaries, sexual traits</td>
</tr>
<tr>
<td>Klinefelter syndrome</td>
<td>Sterility; mild mental impairment</td>
</tr>
<tr>
<td>XXX syndrome</td>
<td>Minimal abnormalities</td>
</tr>
<tr>
<td>XXY condition</td>
<td>Mild mental impairment or no effect</td>
</tr>
<tr>
<td><strong>Changes in chromosome structure</strong></td>
<td></td>
</tr>
<tr>
<td>Chronic myelogenous leukemia (CML)</td>
<td>Overproduction of white blood cells; organ malfunctions</td>
</tr>
<tr>
<td>Cri-du-chat syndrome</td>
<td>Mental impairment; abnormal larynx</td>
</tr>
</tbody>
</table>
How Do We Know When A Trait Is Affected By An Allele On An Autosome?

A

AF

Aa

aa

Aa

aa

normal mother

affected father

meiosis and gamete formation

A

a

Aa

A

aa

Aa

aa

affected child

normal child

disorder-causing allele (dominant)

carrier mother

carrier father

Aa × Aa

meiosis and gamete formation

A

a

AA

a

Aa

a

Aa

aa

affected child

carrier child

normal child

A Only people homozygous for a recessive allele on an autosome have the associated trait. In this example, both parents are carriers. Each of their children has a 25 percent chance of inheriting two alleles, and being affected by the trait.

B Conner Hopf was diagnosed with Tay–Sachs disease at age 7½ months. He died before his second birthday.
How Do We Know When A Trait Is Affected By An Allele On An X Chromosome?

X-linked recessive pattern

➢ An allele is inherited on the X chromosome
➢ Most are recessive, because X-linked dominant alleles tend to be lethal in male embryos
X-Linked Traits

- X-linked recessive disorders tend to appear in men more often than in women
  - Men (XY) have only one X chromosome
  - Women have two X chromosomes (XX)

- Men can transmit an X-linked allele to daughters, **but not to sons** – only a woman can pass an X-linked allele to a son
dystrophin
(muscular dystrophy)
(anhidrotic ectodermal dysplasia)
IL2RG (SCID-X1)
XIST X chromosome inactivation control
(hemophilia B)
(hemophilia A)
(red-deficient color blind)
(green-deficient color blind)
carrier mother × normal father

meiosis and gamete formation

<table>
<thead>
<tr>
<th>XX</th>
<th>XY</th>
</tr>
</thead>
<tbody>
<tr>
<td>XX</td>
<td>XY</td>
</tr>
</tbody>
</table>

normal daughter or son

carrier daughter

affected son

recessive allele on X chromosome
A In this example of X-linked inheritance, the mother carries a recessive allele on one of her two X chromosomes (red).

B A view of color blindness. The photo on the left shows how a person with red–green color blindness sees the photo on the right. The perception of blues and yellows is normal; red and green appear similar. The circles are part of a standardized test for color blindness. A set of 38 of these circles is commonly used to diagnose deficiencies in color perception.
How Does Chromosome Structure Change?

Chromosome structural changes

- Include duplications, deletions, inversions, and translocations

- Induced by: exposure to chemicals or radiation, faulty crossing over, transposable elements

- Tend to result in genetic disorders
Deletion

Loss of a part of a chromosome

Duchenne muscular dystrophy/ deletion in the X chromosome
Cri-du-chat/ deletion in the short arm of chromosome 5
Duplication

Repeated section of a chromosome

Expansion mutations

Causes genetic abnormalities or disorders

Huntington’s disease
Inversion

Part of a chromosome becomes oriented in the reverse direction

May not affect carrier’s health

May affect fertility
Translocation

two chromosomes exchange broken parts

Most translocations are reciprocal (between non-homologous chromosomes)

Can affect fertility
<table>
<thead>
<tr>
<th>Deletion</th>
<th>Inversion</th>
</tr>
</thead>
<tbody>
<tr>
<td><img src="image1" alt="Deletion Image" /></td>
<td><img src="image2" alt="Inversion Image" /></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Duplication</th>
<th>Reciprocal translocation</th>
</tr>
</thead>
<tbody>
<tr>
<td><img src="image3" alt="Duplication Image" /></td>
<td><img src="image4" alt="Reciprocal Translocation Image" /></td>
</tr>
</tbody>
</table>

*Homologous chromosomes*

*Nonhomologous chromosomes*
<table>
<thead>
<tr>
<th>Deletion</th>
<th>Inversion</th>
</tr>
</thead>
<tbody>
<tr>
<td><img src="image1" alt="Deletion Diagram" /></td>
<td><img src="image2" alt="Inversion Diagram" /></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Duplication</th>
<th>Reciprocal translocation</th>
</tr>
</thead>
<tbody>
<tr>
<td><img src="image3" alt="Duplication Diagram" /></td>
<td><img src="image4" alt="Reciprocal Translocation Diagram" /></td>
</tr>
</tbody>
</table>

- **Homologous chromosomes**
- **Nonhomologous chromosomes**
What Are The Effects of Chromosome Number Changes in Humans?

Occasionally abnormal events can occur

- Happen mostly during meiosis
- New individuals end up with the wrong chromosome number
- Consequences range from minor to lethal
Nondisjunction

- Failure of sister chromatids (*what stage?*) or homologous chromosomes (*what stage?*) to separate during nuclear division

- Causes genetic disorders among resulting offspring
Polyploidy

- Individuals have three or more of each type of chromosome
- Lethal in humans
- Many flowering plants, and some insects, fishes, and other animals, are polyploid
Aneuploidy

- An individual’s cells have too many or too few copies of a particular chromosome (result of non-disjunction)

- Most cases of autosomal aneuploidy are lethal in embryos

- Trisomy 21 (Down syndrome)
Change in number of sex chromosomes

- Usually results in some degree of impairment in learning and motor skills.
- In individuals with trisomy (XXY, XXX, and XYY), these problems can be subtle and the cause may never be diagnosed.
Sex chromosome abnormalities in females

Individuals with **Turner syndrome** have an X chromosome and no corresponding X or Y chromosome (XO) (1/2500)

- Well proportioned but short
- Ovaries do not develop properly
- Insufficient sex hormones to become sexually mature
Sex chromosome abnormalities in males

Klinefelter syndrome (XXY) (1/500)

- Tend to be overweight
- Tall
- Normal range of intelligence
- Make more estrogen and less testosterone than normal males, which has feminizing effects
How Do We Use What We Know About Human Inheritance?

Genetic screening

- Can estimate probability that a child will inherit a genetic disorder
- Pedigrees and genotypes are analyzed by a genetic counselor
- Some disorders can be detected early enough to start counter measures before symptoms develop
- More than 30 conditions detectable prenatally
Prenatal diagnosis

Testing of an embryo or fetus can reveal genetic abnormalities or disorders before birth

- Obstetric sonography (safe)
- Fetoscopy (2-10% chance of miscarriage)
- Amniocentesis (14-16 weeks, presence of certain chemicals and karyotyping)
- Chorionic villus sampling (CVS) (8-10 weeks, immediate karyotyping)

Carrier Recognition

- Sickle cell, Tay-Sachs and cystic fibrosis
Newborn screening for phenylketonuria (PKU)

- Newborns screened for mutations in the gene phenylalanine hydroxylase, a defect that can cause phenylalanine to accumulate to high levels

- Results in imbalance that inhibits protein synthesis in the brain

- Causes severe neurological symptoms characteristic of (PKU)