Inheritance:
How are traits passed from parents to offspring?

Study Guide

• Define and distinguish between the following pairs of terms: dominant allele versus recessive allele, genotype versus phenotype, and heterozygous versus homozygous.

• Explain how a testcross is performed to determine the genotype of an organism.

• Compare the frequency and method of inheritance of recessive and dominant traits.

• Define and distinguish between complete dominance, incomplete dominance, and codominance.

• Define and distinguish between pleiotropy and polygenic inheritance.

• Explain how chromosomes determine the sex of a human.

• Explain why sex-linked diseases are more common in human males.
Individuals possess observable traits
Like behavior, physical appearance or disease

Genetics study how these traits get passed on from parent to offspring

Mendel’s studies in his garden of peas provided the foundation of genetics
Why peas?

Easy to grow
Many traits could be studied
Controlled matting
Later discoveries made the connection between genes and traits.

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**Figure 14.4** Alleles, alternative versions of a gene. Shown is a pair of homologous chromosomes in an F1 hybrid pea plant, with the DNA sequence from the flower color allele of each. The paternally inherited chromosome (blue) has an allele for purple flowers, which codes for a protein that indirectly controls synthesis of purple pigment. The maternally inherited chromosome (red) has an allele for white flowers, which results in no functional protein being made.

DNA with nucleotide sequence **CTAAATCGGT**

Enzyme

Through a series of steps, this DNA sequence results in production of an enzyme that helps synthesize purple pigment.

One purple-flower allele results in sufficient pigment for purple flowers.

DNA with nucleotide sequence **ATAAATCGGT**

This DNA sequence results in the absence of the enzyme.
Genes determine traits

- **Genotype** is the genetic make up of an organism (gene)

- **Phenotype** is the appearance of an organism (trait)

Genotype determines phenotype
Closer look at Genotype: the combination of alleles an individual carries

- Chromosomes contain different genes
- Gene codes for a protein (trait)
- **Alleles** are versions of a gene
- You are a diploid organism
  You carry two chromosomes of each type
  You carry two of each type of gene

*Homozygous* individual: alleles are the *same*

*Heterozygous* individual: alleles are *different*

What is the phenotype of these individuals?
Organism’s phenotype does not always reveal its genotype

- Homozygous genotype $\rightarrow$ phenotype reflects genotype
- Heterozygous genotype $\rightarrow$ one of the alleles is fully expressed

The allele that is expressed is the *dominant allele*

The allele that does not show up is the *recessive allele*

- Three genotypes possible:
  Homozygous recessive, homozygous dominant or heterozygous
- Two phenotypes possible: dominant or recessive

Organism’s phenotype does not always reveal its genotype
Symbols used in genetics

- We assign a letter to each gene
- If gene has two alleles we use upper and lower case
  where Upper case is the dominant allele
  Lower case is the recessive allele
Determine your partner’s phenotype and **possible** genotype

**Traits**

**Earlobes:** detached is dominant over attached

\[ E \quad e \]

**Tongue:** tongue rolling is dominant over not being able to roll tongue

\[ T \quad t \]

**Hair line:** widow’s peak is dominant over straight hairline

\[ W \quad w \]

**How can two individuals with *different genotypes* for a particular trait be *identical in phenotype*?**
How are these traits (alleles) inherited?

What happens to alleles during meiosis?

What happens to alleles after fertilization?
What happens to the alleles during meiosis?

• During meiosis, If we look at one gene only:
  A gamete has only one allele

• Homozygous individual produces only one kind of gametes

• Heterozygous individual produces two kinds of gametes

<table>
<thead>
<tr>
<th>Individual (genotype)</th>
<th>Type of gametes produced</th>
</tr>
</thead>
<tbody>
<tr>
<td>AA</td>
<td>all gametes will contain an &quot;A&quot;</td>
</tr>
<tr>
<td>Aa</td>
<td>1/2 will contain &quot;A&quot; and 1/2 will contain &quot;a&quot;</td>
</tr>
<tr>
<td>aa</td>
<td>all &quot;a&quot; gametes</td>
</tr>
</tbody>
</table>
In peas, the allele for purple flowers (P) is dominant to the allele for white flowers (p).

What gametes would be produced by a plant that has white flowers?
What happens during fertilization?
Fertilization creates allele pairs again in the offspring

Parent 1:
Genotype Aa

Parent 2:
Genotype Aa

Gamete types

A
a

During fertilization

Offspring:
Genotype aa

Chance determines which alleles the offspring receives from each parent
We need to consider all possible combinations and estimate probabilities for each offspring phenotype and genotype.

**Parent 1:** Aa

- Gametes from parent 1: A, a

**Parent 2:** Aa

- Gametes from parent 2: A, a

Probabilities of offspring being:

- AA:
- Aa:
- aa:

**Dominant phenotype:**

**Recessive phenotype:**
Assume tall (T) is dominant to dwarf (t). If a homozygous dominant individual is crossed with a dwarf. What will the offspring look like?
Fill in the blanks:
allele, recessive, homozygous, dominant, chromosomes
Pea plants are tall if they have the genotype $TT$ or $Tt$, and they are short if they have genotype $tt$.

A tall plant is mated with a short plant. Half the offspring are tall, and half are short.

What do you know about the tall plant?
Diseases that show complete dominance

EXAMPLE:
*Huntington’s disease* is a dominant trait
H = allele for Huntington’s disease
h = normal allele

Genotypes and phenotypes

EXAMPLE:
*Cystic fibrosis disease* is a recessive trait
C = normal allele
c = allele for cystic fibrosis

Genotypes and phenotypes
So far we have seen genes that show complete dominance

The type of inheritance in which both heterozygote and dominant homozygote have the same phenotype.

<table>
<thead>
<tr>
<th>Genotypes</th>
<th>Phenotypes</th>
</tr>
</thead>
<tbody>
<tr>
<td>AA homozygous dominant</td>
<td>dominant</td>
</tr>
<tr>
<td>Aa heterozygous</td>
<td>dominant</td>
</tr>
<tr>
<td>aa homozygous recessive</td>
<td>recessive</td>
</tr>
</tbody>
</table>

3 genotypes                 2 phenotypes
Complete dominance is rare

One gene → one trait

COMPLETE DOMINANT GENES  3 genotypes : 2 phenotypes

INCOMPLETE DOMINANT GENES

CODOMINANT GENES

SEX-LINKED GENES (genes found in the X or Y chromosomes)

One gene → many traits

PLEIOTROPY

Many genes → one trait

POLYGENIC INHERITANCE
A gene with Incomplete Dominance results in in the heterozygous individual expressing an intermediate phenotype

EXAMPLE: gene for color of flowers in carnations

<table>
<thead>
<tr>
<th>Genotypes</th>
<th>Phenotypes</th>
</tr>
</thead>
<tbody>
<tr>
<td>RR</td>
<td>White</td>
</tr>
<tr>
<td>rr</td>
<td>Red</td>
</tr>
<tr>
<td>Rr</td>
<td>Pink</td>
</tr>
</tbody>
</table>

3 genotypes and 3 phenotypes
3rd phenotype is an intermediate of the recessive and dominant
Disease that shows incomplete dominance

Hypercholesterolemia:
high blood cholesterol because liver cells can not remove it

**Genotypes**

<table>
<thead>
<tr>
<th>Genotype</th>
<th>Phenotype</th>
</tr>
</thead>
<tbody>
<tr>
<td>HH</td>
<td></td>
</tr>
<tr>
<td>Hh</td>
<td></td>
</tr>
<tr>
<td>hh</td>
<td></td>
</tr>
</tbody>
</table>

**Diagram:**

- **Normal (HH):**
  - LDL (carries cholesterol)
  - LDL receptor (mops up LDL)
  - Cell

- **Mild disease (Hh):**
  - LDL (carries cholesterol)
  - LDL receptor (mops up LDL)
  - Cell

- **Severe disease (hh):**
  - LDL (carries cholesterol)
  - LDL receptor (mops up LDL)
  - Cell

- **Genotypes:**
  - Normal (HH): Homozygous for ability to make LDL receptors
  - Mild disease (Hh): Heterozygous
  - Severe disease (hh): Homozygous for inability to make LDL receptors
Practice # 4

Flower color in snapdragons is an example of incomplete dominance.

If a pink-flowered plant is crossed with a pink-flowered plant, what will the progeny of plants look like?
A gene with Codominance results in a heterozygous individual expressing both recessive AND dominant phenotypes

**EXAMPLE:** gene for color of hair in dogs

<table>
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<th>Phenotypes</th>
</tr>
</thead>
<tbody>
<tr>
<td>HH</td>
<td>hh</td>
</tr>
<tr>
<td>hh</td>
<td>HH</td>
</tr>
<tr>
<td>Hh</td>
<td>HH</td>
</tr>
</tbody>
</table>
AOB blood type

AOB blood gene codes for the type of antigen found in the membrane of red blood cells.

AOB blood gene is a codominant gene.

AOB blood gene has more than two alleles (multiple alleles)

**Genotypes**  **Phenotypes**

<table>
<thead>
<tr>
<th>Genotypes</th>
<th>Phenotypes</th>
</tr>
</thead>
<tbody>
<tr>
<td>A, B, O</td>
<td></td>
</tr>
</tbody>
</table>
Practice # 5

A man who has type B blood
And
a woman who has type A blood
have a child with type O blood.

How is this possible?
Blood types can be used to determine paternity

Which of the following matings can NOT produce a child with blood type O?

- O x AB
- A x B
- O x O
- A x A

Blood types can rule a out possible parenthood but can NOT confirm a parenthood.
A single characteristic may be influenced by many genes

Polygenic inheritance

Additive effect of 2 or more genes on a single trait

Example:
Height, skin or eye color
A single gene may affect many phenotypic characteristics

Pleiotropy (pleion, more)
One gene → Many traits

Sickle Cell Disease has a pleiotropic inheritance
Sickle Cell Disease is also codominant trait

Heterozygous individual (carrier) has normal and abnormal hemoglobin

Only in rare cases does the heterozygous person develop symptoms.
Sex chromosomes determine sex in many species

In some cultures, The mother is blamed for not bearing a boy, is this justified?

Diagram:

- Female: XX
- Male: XY

Gametes:

- Female: X
- Male: X, Y

Children:

- XX Female
- XY Male

1 Female: 1 Male
Genes carried in the sex chromosomes exhibit a unique pattern of inheritance

- Some genes are present on the X-chromosome but missing on the shorter Y-chromosome.

- In the non-homologous region of the X-chromosome a male will only have one allele for any gene in this region.
Hemophilia is a X-linked recessive disease

Possible alleles

\[ X^H \]
\[ X^h \]
\[ Y \]

Possible genotypes and phenotypes

<table>
<thead>
<tr>
<th>Genotype:</th>
<th>[ X^H X^h ]</th>
<th>[ X^H Y ]</th>
</tr>
</thead>
<tbody>
<tr>
<td>Fertilisation</td>
<td>[ X^H ] [ X^H Y ] [ X^H X^h ] [ X^h Y ]</td>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Offspring Genotype</th>
<th>[ X^H X^H ]</th>
<th>[ X^H X^h ]</th>
<th>[ X^H Y ]</th>
<th>[ X^h Y ]</th>
</tr>
</thead>
</table>

| Offspring Phenotypic Ratio: | 1 Normal Female: 1 Carrier Female: 1 Normal Male: 1 Haemophiliac male |
Solving genetic problems for X linked genes

Problem should state that it is a sex linked gene

Allele is attached to the X chromosome

Need to determine gender of offspring in order to determine phenotype

Color blindness is a recessive trait

Parents' Phenotypes:

Normal Vision Father X Colorblind Mother

Parents' Genotypes:

\[ \begin{align*}
X^C Y^o & \quad x \quad X^C X^c \\
X^C & \quad X^C X^c \quad X^C Y^o \\
X^C & \quad X^C X^c \quad X^C Y^o
\end{align*} \]

Phenotypes of Offspring:

100% Normal Vision Daughters
100% Colorblind Sons
Practice # 6

A couple are both normal, but their son suffers from hemophilia.

What fraction of the couple’s children are likely to suffer from hemophilia?

What fraction are likely to be carries?