10.2 Dihybrid Crosses & Gene Linkage

Predicting ratios in dihybrid crosses

The 9:3:3:1 ratio (seen in Mendel's Second Law) is often found when parents that are heterozygous for two different genes are crossed together (i.e crossing the F_1).

The ratio is actually the product of two independent 3:1 ratios (i.e each of the two genes would give a 3:1 ratio in a monohybrid cross between two heterozygous parents).

In a dihybrid cross, genes follow Mendel's Law of Independent Assortment because they are unlinked.

Dihybrid crosses can give other ratios (different than 9:3:3:1) if:

1) Either of the genes has codominant alleles.

2) Either of the parents is homozygous for one or both of the genes (eg. SSYy, SsYY, ssYY).

3) Either of the genes is **sex-linked** (depended on the gender). Sex-linked genes are located on sex chromosomes instead on **autosomes** (non-sex chromosomes).

Unlinked

Offspring in dihybrid crosses that are recombinants (<u>unlinked genes</u>)

Example:

Cross a tall white (Tt rr) x short red (tt Rr). Calculate all four phenotypes and identify the recombinants.

T| |t r| |r x t| | t R| |r

Gametes: Tr, Tr, tr tr tR, tr, tR, tr

F_2 generation	**Tr**	**Tr**	**tr**	**tr**
tR	TtRr	TtRr	ttRr	ttRr
tr	Ttrr	Ttrr	ttrr	ttrr
tR	TtRr	TtRr	ttRr	ttRr
tr	Ttrr	Ttrr	ttrr	ttrr

Tall red: 4 (Recombinant)

Tall white: 4

Short red: 4

Short white: 4 (Recombinant)

Offspring in dihybrid crosses between two <u>linked genes</u> (recombinants due to crossing over)

Example:

Cross a yellow flower red fruit (WW RR) x white flower yellow fruit (ww rr). Calculate all four phenotypes and identify the recombinants.

Homologous pair of chromosome at Prophase I of meiosis

W| |W x w| |w
R| |R r| |r

Crossing over occurs between one chromatid of each chromosome

W| |W x w| |w
R| |r R| |r

Gametes:

(recombinants)

W| **W|** **w|** w|
R| **r|** **R|** r|

F_2 generation	**WR**	**Wr**	**wR**	**wr**
WR	WWRR	WWRr	WwRR	WwRr
Wr	WWRr	WWrr	WwRR	Wwrr
wR	WwRR	WwRr	wwRR	wwRr
wr	WwRr	Wwrr	wwRr	wwrr

Yellow flower red fruit: 9
Yellow flower yellow fruit: 3 (Recombinant)
White flower red fruit: 3 (Recombinant)
White flower yellow fruit: 1

The new combinations are the result of the crossing over in the Prophase I of meiosis. These new combinations are called recombinants.

This cross produces 9:3:3:1 ratio, but in practice crossing over does not always occur between the two genes. In some cases it may not occur at all. In other cases it may occur in such a way that the two genes are not separated.

Possible ratios in dihybrid crosses

	3	1
3	9	3
1	3	1

	1	2	1
3	3	6	3
1	1	2	1

	1	1
3	3	3
1	1	1

	1	1
1	1	1
2	2	2
1	1	1

In the 20th century anomalous results were obtained that didn't fit Mendel's theory.

Thomas Hunt Morgan (American geneticist) developed the idea of linked genes to account for these anomalies using Drosophila melanogaster (fruit flies).

→ The inheritance pattern was different between males and females, proving sex-linkage

→ if the pattern of inheritance was the same between males and females he concluded that the genes were located together on the same non-sex chromosome (autosome)

Summary of Mendel's Hypotheses

The following summary includes terms taken from our present knowledge of the nature of genetics:

1) Each characteristic of an organism is controlled by a pair of alleles
2) If an organism has two unlike alleles for a given characteristic, one may be expressed (the dominant allele) to the total exclusion of the other (the recessive allele).

3) During meiosis each pair of alleles separates (segregates) and each gamete receives one of each pair of alleles (*the principle of segregation*).
4) During gamete formation in each sex, either one of a pair of alleles may enter the same gamete cell (combine randomly) with either one of another pair (*the principle of independent assortment*).
5) Each allele is transmitted from generation to generation as a discrete unchanging unit.
6) Each organism inherits one allele (for each characteristic) from each parent.

N.B. The mechanism of dihybrid inheritance and the typical dihybrid ratio of 9:3:3:1 only apply to characteristics controlled by genes on *different* chromosomes. Genes situated on the *same* chromosome may not show this pattern of independent assortment.

Table: A summary of the similarities between events occurring during meiosis and fertilization and Mendel's hypotheses

Meiosis and fertilization	***Mendel's hypotheses***
Diploid cells contain pairs of chromosomes (homologous chromosomes)	Characteristics are controlled by *pairs* of factors

Homologous chromosomes *separate* during meiosis	Pairs of factors separate during gamete formation
One homologous chromosome passes into each gamete cell	Each gamete receives *one* factor
Only the nucleus of the male gamete fuses with the egg cell nucleus	Factors are transmitted from generation to generation as *discrete* units
Homologous pairs of chromosomes are stored at fertilization, each gamete (♂ and ♀) contributing *one* homologous chromosome	Each organism inherits one factor from each parent