

CHAPTER 4: EXTENSIONS OF MENDELIAN INHERITANCE.

Many crosses do not yield simple Mendelian ratios. Instead, the ratios are modified. These modifications reflect complexities in gene expression not complexities in inheritance of the genes. In other words, the genes (and genotypes) are still inherited according to Mendelian rules, but the phenotypes do not conform to simple Mendelian rules.

I. Variations of Dominance

A. Incomplete dominance

1. Phenotype of the heterozygote is intermediate between the phenotypes of the homozygotes

snapdragon plant with red petals (C_1C_1) x plant with white petals (C_2C_2)

1/4 red	C_1C_1
1/2 pink	C_1C_2
1/4 white	C_2C_2

B. Co-dominance

1. Phenotype of the heterozygote shows the phenotype of both homozygotes.

For example, the gene required for production of a glycoprotein on the surface of red blood cells (basis for the M and N blood groups).

$L^M L^M$	has only M antigens on the surface
$L^N L^N$	has only N antigens on the surface
$L^M L^N$	has both antigens on the surface.

C. The distinction between incomplete dominance and codominance is dependent upon the phenotypic “level” to which you are referring (i.e. sickle cell anemia example pg. 92-93 of your textbook).

II. Multiple Alleles

A. Although an individual organism (say you) can have only two alleles of a gene (because there are only two chromosomes), among a population (say the entire class), there may be multiple alleles which are said to be in an allelic series

B. For example, the genes that are responsible for the synthesis of sugars bound to a lipid on the surface of the red blood cells (basis for another type of human blood groups)

3 alleles (i or I^A or I^B) but any individual can only have two of them.

<u>Blood Group</u>	<u>Genotype</u>	<u>Phenotype of sugar on surface</u>
O	ii	no sugar on surface
A	$I^A I^A$ or $I^A i$	N-acetyl galactosamine
B	$I^B I^B$ or $I^B i$	galactose
AB	$I^A I^B$	N-acetyl galactosamine and galactose

I^A and I^B are dominant to i but codominant to each other.

C. Other allelic series

C - = full color - dark gray

c^{ch} = chinchilla - pale gray

c^h = himalayan - albino with dark extremities

c = albino

Dominance = $C > c^{ch} > c^h > c$

D. Test for Allelism

How does one know that a set of contrasting phenotypes is determined by alleles of only one gene (vs. 2 sets of genes that influence each other which is described in Section IV)

Test for allelism and simple dominance: Observation of F₂ ratios (3:1) from crosses of all pairwise combinations of pure breeding strains.

III. Lethal Alleles

A. For example,

yellow mice x normal pure breeding agouti type mouse ---→
1/2 yellow and 1/2 normal

Therefore, yellow was dominant and parent mouse was heterozygous (because agouti was pure breeding)

yellow mice x yellow mice ---→ 2/3 yellow mice and 1/3 agouti

A homozygous dominant mouse (pure breeding) could never be obtained.

Since ratio expected from heterozygous cross is 1:2:1, this suggested that homozygous dominant was being eliminated -- lethal – to alter the ratio to 2:1.

The allele causing yellow color is dominant for coat color. However, in terms of viability, the allele is recessive. This the alleles is pleiotropic (affects two or more distinct traits).

Use these symbols since it is dominant for color mutant but recessive for lethality.

$$\begin{array}{l} A^Y A \quad x \quad A^Y A \\ 1/4 A^Y A^Y \quad \text{lethal} \\ 2/4 A^Y A \quad \text{yellow} \\ 1/4 A A \quad \text{normal color} \end{array}$$

B. Can have recessive lethal alleles (as shown above) and also recessive dominant lethal alleles (where heterozygote is lethal too)

C. Lethal alleles illustrate the idea of the pleiotropic gene (gene that results in more than one phenotypic effect)

D. Can also have semilethal genes where not every individual with the lethal genotype dies.

IV. Several Genes Affecting the Same Character

The cellular functions of products encoded by more than one gene affect the phenotype of one trait. The key to determining that you have one trait controlled by more than one gene is modified (i.e. not 3:1) Mendelian ratios in a cross of 2 heterozygous individuals. Ratios are typically in 16ths if two genes are involved.

A. Simple dominance with no epistasis and with each loci independently influencing the trait: **Phenotypic ratio is 9:3:3:1**

For example, coat color in mice.

Gene A determines the distribution of pigment in the hair in mice:

A- = agouti (yellow band on each hair)

aa = no yellow agouti band, solid color

Gene B determines the color of the pigment:

B- = black and bb = brown

Cross AABB (wildtype agouti) x aabb (brown) -----→

F1 are all AaBb (wildtype agouti)

Self the F1s (AaBb) -----→

9/16 A-B- agouti

3/16 aaB- cinnamon

3/16 A-bb black

1/16 aabb brown

In this case we have 4 different phenotypes represented for the trait of hair color.

B. Epistasis: A situation where the alleles of one gene mask the phenotype of another gene. For epistatic cases, one observes a reduction in the number of phenotypic classes expected.

1. Recessive Epistasis: **Phenotypic ratio is 9:3:4**

a) For example, mouse coat color again

C gene allows the formation of coat pigments.

C- = pigment formation cc = no pigment formation (albino)

Gene B determines the color of the pigment:

B- = black and bb = brown

Cross BBCC (black) x bbcc (albino) ----->

F1 are all BbCc (black)

Self the F1s (BbCc) ----->

9/16 B-C- black

3/16 bbC- brown

3/16 B-cc albino

1/16 bbcc albino

So overall phenotypic ratios were

9/16 B-C- black

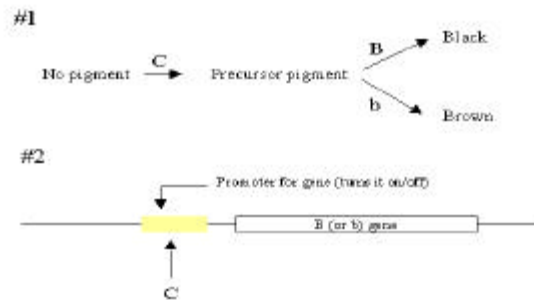
3/16 bbC- brown

4/16 --cc albino

b) Any genotype that has cc (ie either B-cc or bbcc) will be albino; the homozygous recessive cc alleles are epistatic to the alleles at the locus. This is recessive epistasis.

c)

Molecular mechanisms for recessive epistasis



2. Dominant epistasis: **Phenotypic ratio is 12:3:1**

For example, fruit color in squash

Gene a allows the formation of color.

A- = no color formation aa = color formation

Gene B determines the color

B- = yellow and bb = green

Cross AABB (white) x aabb (green) ----->
F1 are AaBb (white)

Self the F1s (AaBb) ----- ->

9/16 A-B- white
3/16 A-bb white
3/16 aaB- yellow
1/16 aabb green

Thus the total phenotypic ration is

12/16 white
3/16 yellow
1/16 green

3. Duplicate recessive epistasis (AKA complementary gene action):
Phenotypic ratio is 9:7

a) For example, flower color in sweet peas:

Gene A is required for the formation of color.
A- = purple aa = white

Gene B is also required for the formation of color.
B- = purple bb = white

Crossed 2 pure breeding plants that produced white flowers
AAbb X aaBB ----->
F1 were all unexpectedly purple (AaBb)

Self the F1s (AaBb) ----- ->
9/16 A-B- purple
3/16 A-bb white
3/16 aaB- white
1/16 aabb white

Thus the total phenotypic ration is
9/16 purple
7/16 white

b) Explanation was that white flowers in each line were a result of homozygous recessive alleles in two separate genes. Thus the F1 were all purple because the genotype was AaBb

Precursor (colorless) -A-> Intermediate (colorless) -B-> Purple

c) Complementation can be used to determine whether different variants with the same phenotype contain mutations in the same gene.

C. Suppression: One gene cancels the expression of an abnormal allele thereby RETURNING IT TO WILD TYPE PHENOTYPE.
 Please note that this is different than epistasis. The epistatic allele introduces a third phenotype (except for complementary gene action), whereas the suppressor allele simply results in a wildtype phenotype even though the genotype suggests that the phenotype should be mutant.

1. Recessive suppression of a recessive allele: **Phenotypic ratio is 13:3**

For a hypothetical gene B
 where B- = wt and bb = mutant,
 consider a recessive suppressor where
 A- = no suppression and aa = suppression of bb

Selfing heterozygotes (AaBb) ----- -->
 9/16 A-B- wt
 3/16 A-bb mutant
 3/16 aaB- wt
 1/16 aabb wt (due to suppression)

Thus the total phenotypic ratio is
 13/16 wt
 3/16 mutant

In *Drosophila*, the recessive allele pd results in purple eye color
 Purple eye color can be suppressed by the recessive allele su

pdpd SuSu X PdPd susu --> F1 were all Pdpd Susu
 Selfed the F1 -->
 9/16 Pd- Su red
 3/16 pdpd Su- purple
 3/16 Pd- susu red
 1/16 pdpd susu red (due to suppression)

Thus the overall phenotypic ratios are
 13/16 red (wt)
 3/16 purple (mutant)

2. Dominant suppression of a dominant allele: **Phenotypic ratio is 13:3**

For a hypothetical gene B
where B- = mutant and bb = wt,
consider a dominant suppressor where
A- = suppression of B- and aa = no suppression

Selfing heterozygotes (AaBb) ----- ->
9/16 A-B- wt (due to suppression)
3/16 A-bb wt
3/16 aaB- mutant
1/16 aabb wt

Thus the total phenotypic ration is
13/16 wt
3/16 mutant

3. Recessive suppression of a dominant allele: **Phenotypic ratio is 9 mutant: 7 wt**

For a hypothetical gene B
where B- = mutant and bb = wt,
consider a recessive suppressor where
A- = no suppression and aa = suppression of B-

Selfing heterozygotes (AaBb) ----- ->
9/16 A-B- mutant
3/16 A-bb wt
3/16 aaB- wt (due to suppression)
1/16 aabb wt

Thus the total phenotypic ration is
9/16 mutant
7/16 wt

4. Dominant suppression of a recessive allele (this is just another way of saying duplicate gene action): **Phenotypic ratio is 15:1**

D. Duplicate gene action: **Phenotypic ratio is 15:1**

1. For example, fruit shape in the plant shepherd's purse

Gene A determines the shape of the fruit
A- = heart shaped fruit aa = narrow fruit

Gene B also can determine the shape of the fruit
B- = heart shaped fruit bb = narrow fruit

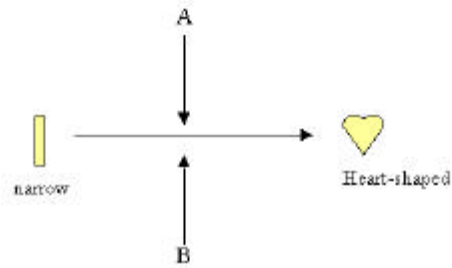
Crossed 2 pure breeding plants that produced white flowers
AABB (heart shaped) X aabb (narrow) ----->
F1 were all heart shaped (AaBb)

Self the F1s (AaBb) ----->
9/16 A-B- heart shaped
3/16 A-bb heart shaped
3/16 aaB- heart shaped
1/16 aabb narrow

Thus the total phenotypic ration is
15/16 heart shaped
1/16 narrow

2. Duplicate genes or gene function are common for genes that encode essential cellular functions.
- 3.

Molecular mechanism for duplicate gene action



V. Variations in expression

Penetrance: Looking at one gene the percent of individuals in a population with a given genotype who exhibit the phenotype associated with the genotype.

Expressivity: Looking at one gene the extent to which a particular genotype is expressed phenotypically in one individual.

Penetrance and expressivity can be affected by modifier genes, epistatic genes, and environmental effects.