Multi-trait Inheritance

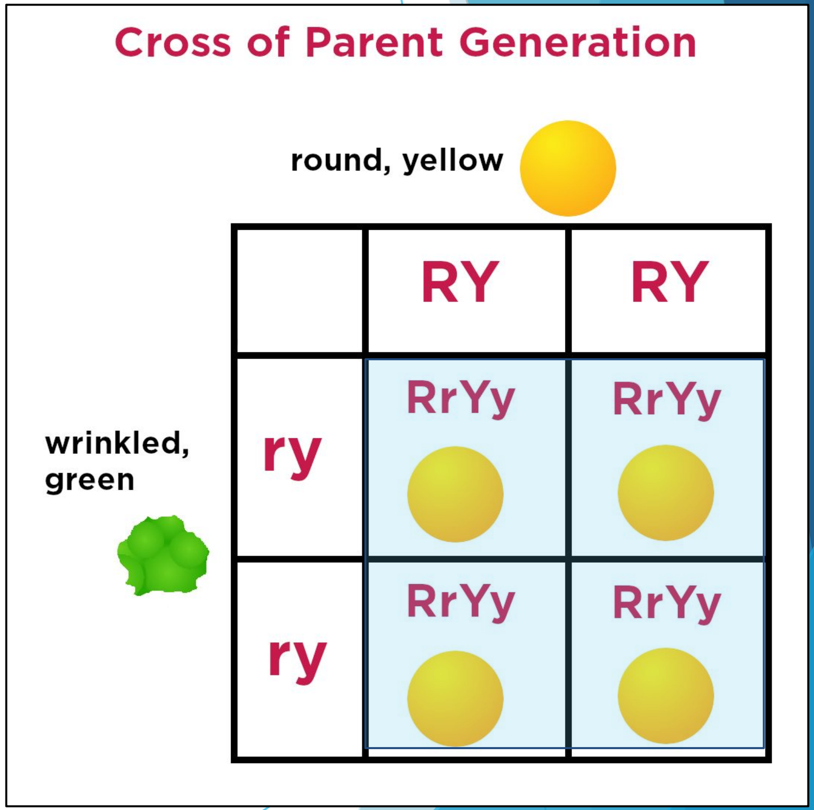
SBI3U

Unit 2, Chapter 5.7

5.7 - Multi-trait Inheritance

- ➔ A cross between two individuals for two pairs of alleles is called a dihybrid cross

- ➔ Mendel used true-breeding parent plants to produce plants (the F_1 generation) that were heterozygous for two traits



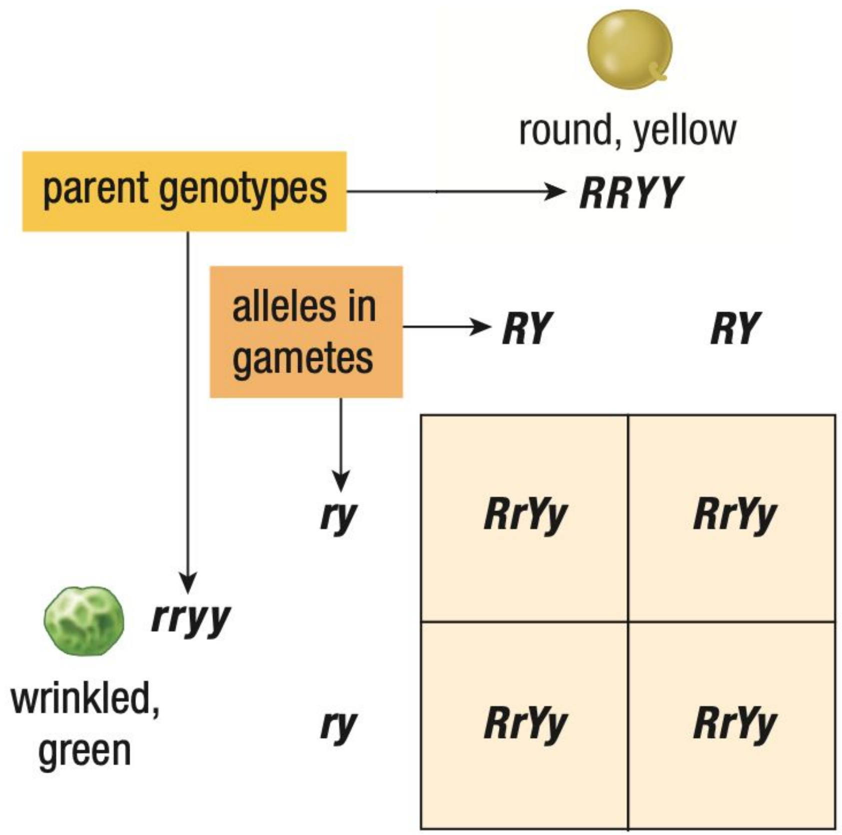
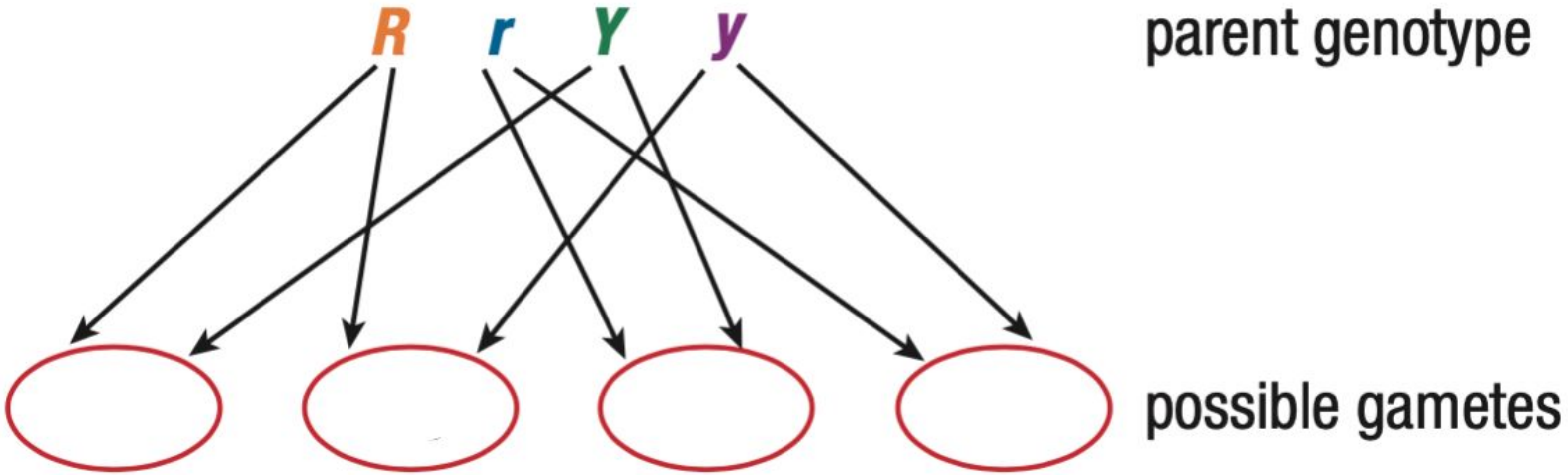


Figure 1 Mendel crossed parents that were homozygous for two traits to produce two pairs of heterozygous alleles for his dihybrid cross experiments.

➔ He then used these F_1 plants to perform another dihybrid cross…

- A heterozygous individual for two characteristics will produce four possible gametes
- A parent that is *RrYy* can generate the possible gametes *RY, Ry, rY, and ry*



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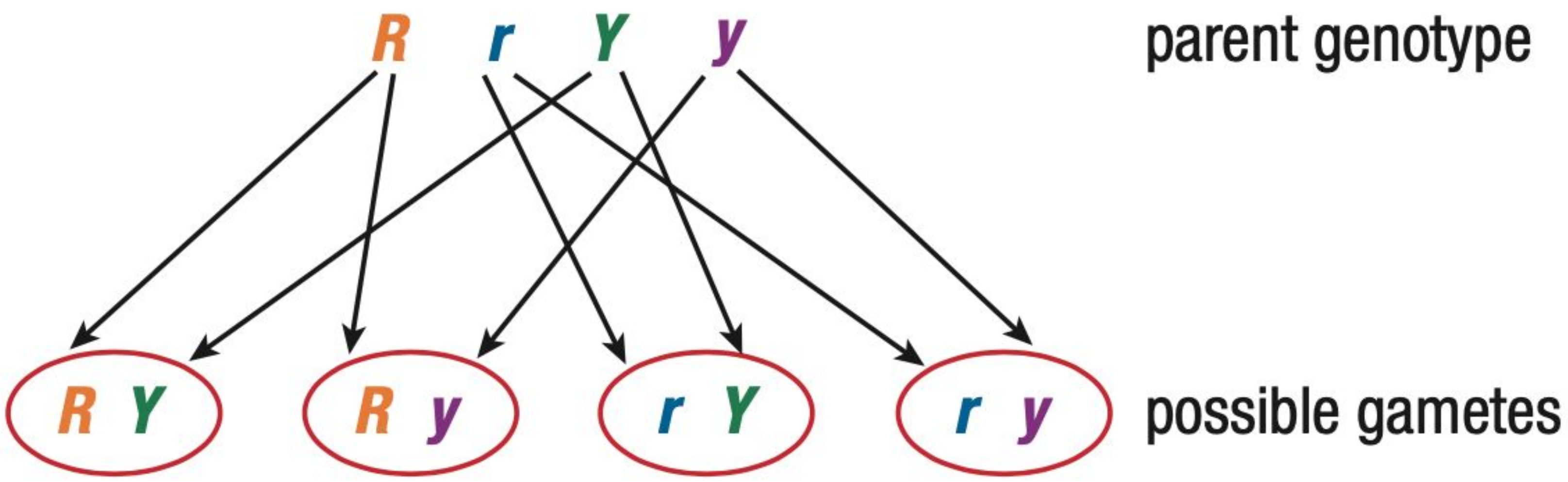
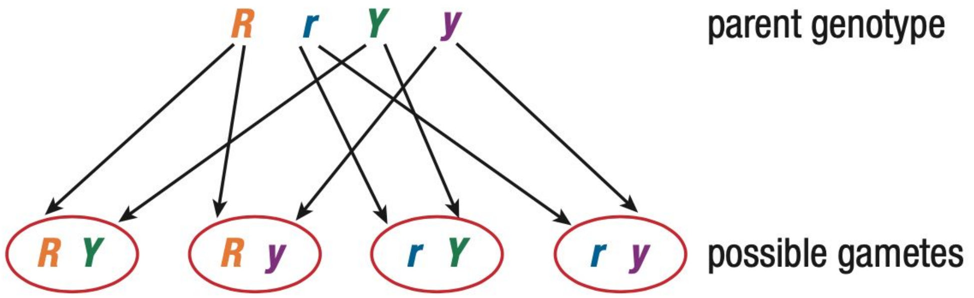
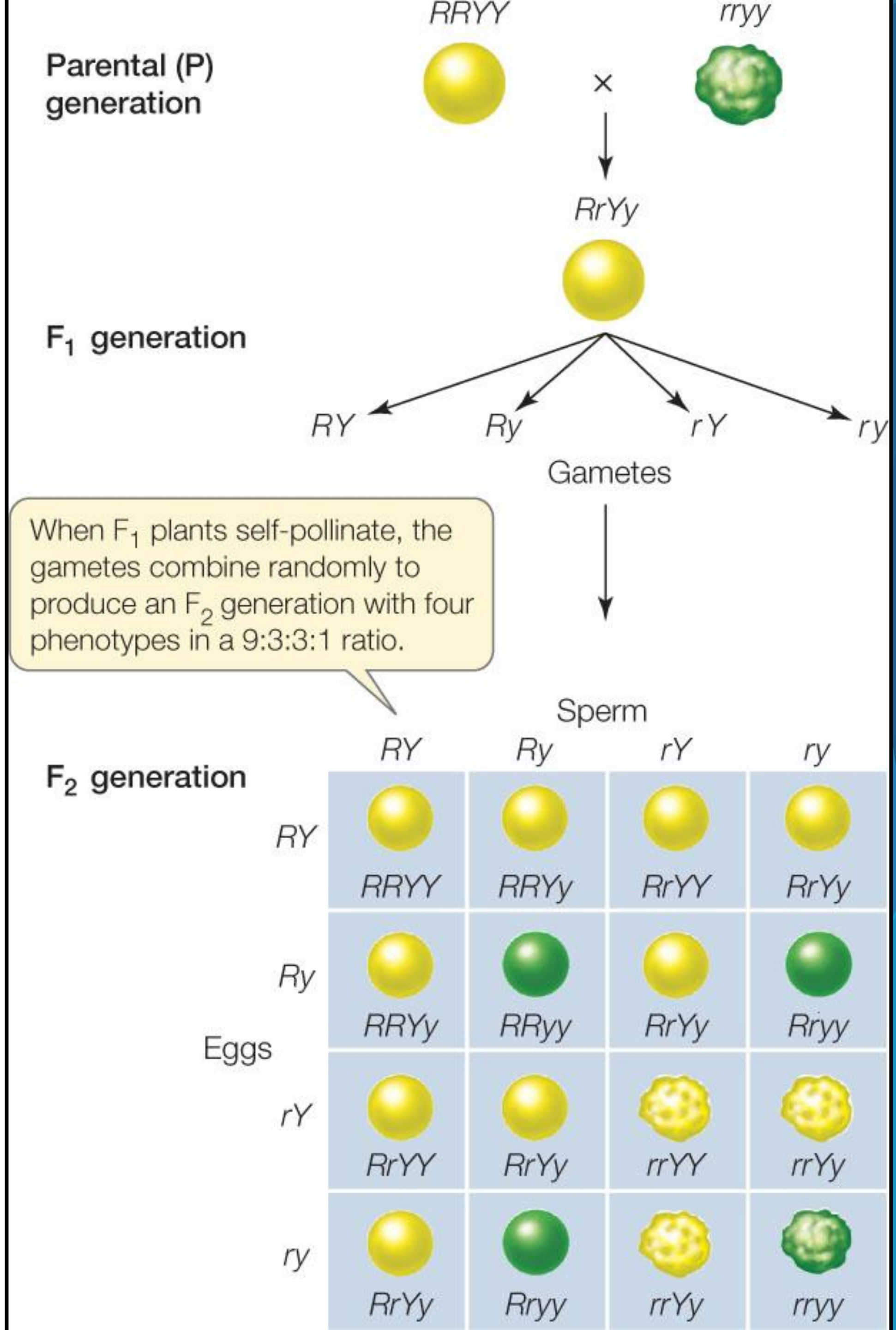


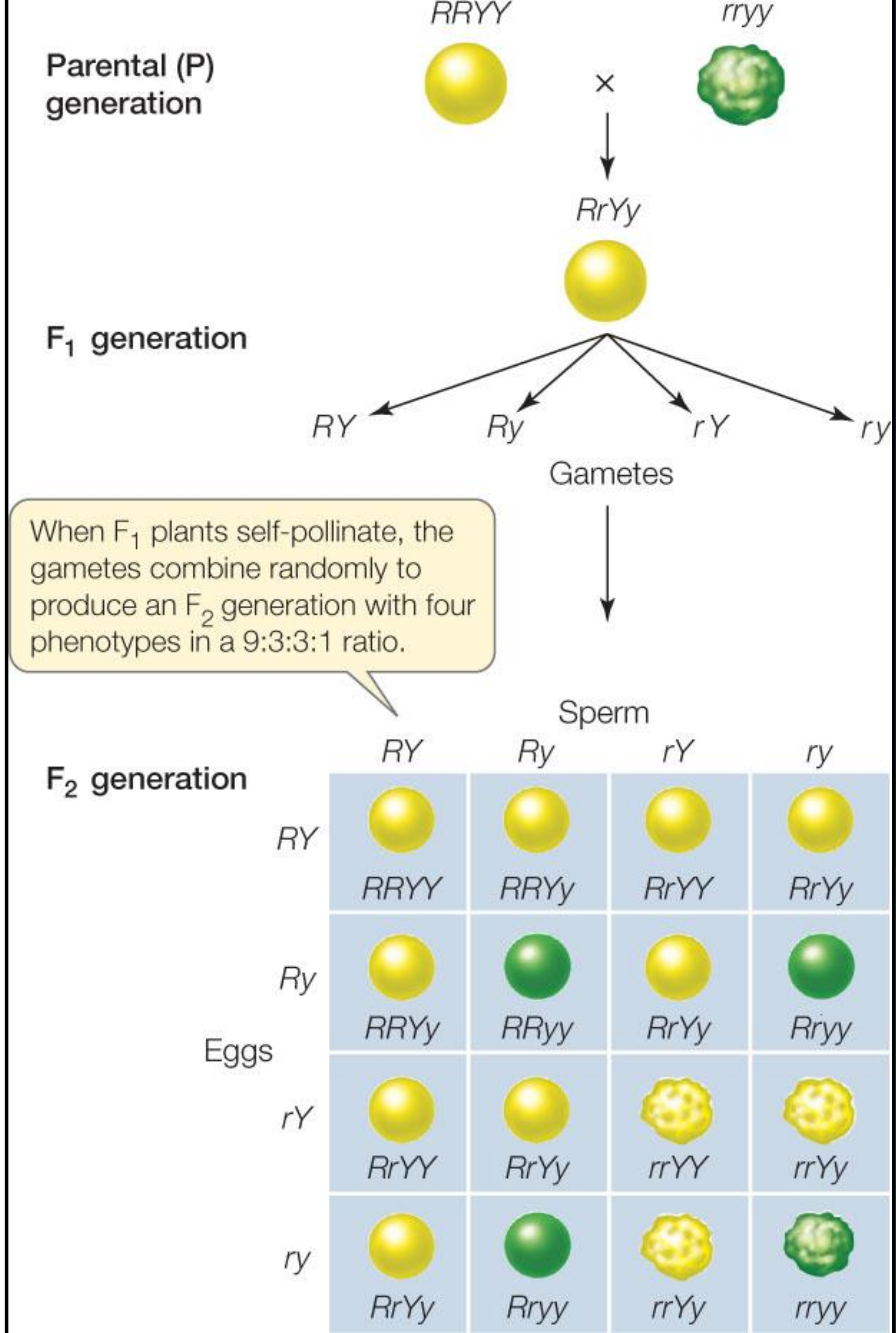
- the alleles of two genes—R and r, and Y and y—separate independently during the formation of the gametes.
- This is called Mendel's Law of Independent Assortment: Each allele is independent of the other, and no two alleles are linked to each other.
- The alleles are found on different chromosomes, creating four different gametes in different combinations of the four alleles (R, r, Y, y)



- Mendel crossed numerous heterozygous F_1 generation plants
- He noticed that the F_2 offspring characteristics were not linked
- Although the original parents (or "grandparents" of the F_2 generation) were either round yellow or wrinkled green, the F_2 offspring characteristics were of every combination possible



- ➔ the inheritance of <u>seed shape</u> had no influence over the inheritance of <u>seed colour</u>
- ➔ Four distinct combinations of seeds were produced in a <u>9:3:3:1 ratio</u>
- ➔ This ratio only shows up if both parents were heterozygous for both traits

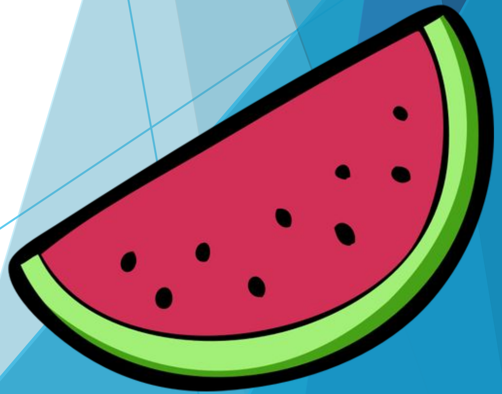


Sample Problem 1

In watermelons, the green colour gene (*G*) is dominant over the striped colour gene (*g*), and round shape (*R*) is dominant over long shape (*r*). A heterozygous round green colour (*GgRr*) watermelon plant is crossed with another heterozygous round green colour (*GgRr*) plant.

Determine the expected phenotypic ratio of the F1 generation by following these steps:

1. Determine the possible gametes from each parent
2. Draw a Punnett Square of dihybrid cross (4x4)
3. Execute the cross
4. Compile a list of plants that have the characteristics



Sample Problem 1 (steps 1-3)

Step 1:

Each parent is heterozygous for green colour and round shape (*GgRr*). The alleles assort independently of each other. Four different gametes are produced (**Figure 4**).

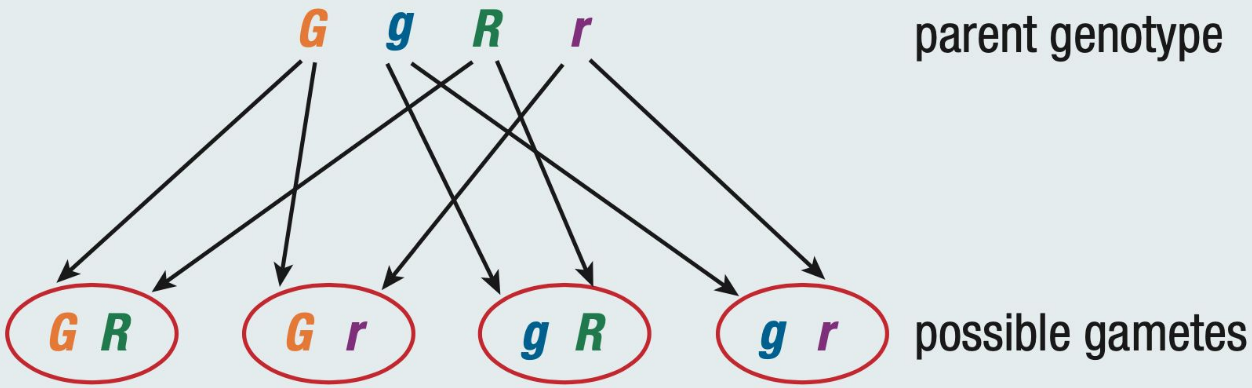


Figure 4

Step 2 and 3:

	GR	Gr	gR	gr
GR	GGRR	GGRr	GgRR	GgRr
Gr	GGRr	GGrr	GgRr	Ggrr
gR	GgRR	GgRr	ggRR	ggRr
gr	GgRr	Ggrr	ggRr	ggrr

Figure 5

Sample Problem 1 (step 4)

Compile a list of plants that have the same phenotypes (highlighters work well).

➔ Start with plants that will exhibit both dominant characteristics, followed by plants that are dominant for only one of the characteristics, and then finally with plants that are recessive for both characteristics.

- green and round: GGRR, GGRr, GgRR, GgRr, GGRr, GgRr, GgRR, GgRr, GgRr (total = 9)
- green and long: GGrr, Ggrr, Ggrr (total = 3)
- striped and round: ggRR, ggRr, ggRr (total = 3)
- Striped and long: ggrr (total = 1)

➔ Therefore, the phenotype ratio is 9 : 3 : 3 : 1 for the dihybrid cross.

Sample Problem 2

In some breeds of dogs, a dominant allele controls the characteristic of barking (*B*) while on a scent trail. The allele for non-barking trailing dogs is (*b*). In these dogs an independent gene (*E*) produces erect ears and is dominant over drooping ears (*e*). For each of the following mating situations, calculate the phenotypic ratio of the offspring:

a. A non-barking trailer with drooping ears is mated with a heterozygous barking trailer with drooping ears (*bbee* x *Bbee*).

b. A heterozygous barking trailer with heterozygous erect ears is mated with a heterozygous barking trailer with heterozygous erect ears (*BbEe* x *BbEe*).

Practice Solution (a)

B = barking while on scent trail

b = non-barking trail dogs

E = erect ears

e = drooping ears

Genotypes of Parents

Parent 1 = bbee

Parent 2 = Bbee

υ

Step 1: Possibilities Parent

Parent 1: bbee → be

Parent 2: Bbee → Be, be

Step 2: Punnett Square

υ

Parent 2 Gametes

Parent 1 Gametes	Be	be
be	Bbee	Bbee

Genotypic ratio = Bbee: bbee

= 1Bbee:1bbee

Practice Solution (b)

B = barking while on scent trail

b = non-barking trail dogs

E = erect ears

e = drooping ears

Genotypes of Parents

Parent 1 = BbEe

Parent 2 = BbEe

υ

Step 1: Possibilities Parent

Parent 1: BbEe → BE, Be, bE, be

Parent 2: BbEe → BE, Be, bE, be

Step 2: Punnett Square

Parent 1

Parent 2

	BE	Be	bE	be
BE	BBEE	BBEe	BbEE	BbEe
Be	BBEe	BBee	BbEe	Bbee
bE	BbEE	BbEe	bbEE	bbEe
be	BbEe	Bbee	bbEe	bbee

Counts:

BE = 9

Be = 3

bE = 3

be = 1

} To calculate the ratio look at the offspring possibilities (dominant/recessive)

Genetic ratio = 9 : 3 : 3 : 1

Sample Problem 2 (Answer)

In some breeds of dogs, a dominant allele controls the characteristic of barking (*B*) while on a scent trail. The allele for non-barking trailing dogs is (*b*). In these dogs an independent gene (*E*) produces erect ears and is dominant over drooping ears (*e*). For each of the following mating situations, calculate the phenotypic ratio of the offspring:

a. A non-barking trailer with drooping ears is mated with a heterozygous barking trailer with drooping ears (*bbee* 3 *Bbee*). [ans: non-barking trailers with drooping ears: barking trailer with drooping ears in a ratio of 1 : 1]

b. A heterozygous barking trailer with heterozygous erect ears is mated with a heterozygous barking trailer with heterozygous erect ears (*BbEe* 3 *BbEe*). [ans: barking trailer with erect ears: barking trailer with drooping ears: non- barking trailer with erect ears: non-barking trailer with drooping ears in a ratio of 9 : 3 : 3 : 1]

Probability: The Product Law

To figure out the probability of two or more outcomes (rather than doing a large Punnett square).

The Product Law states: the probability of two independent random events both occurring at the same time is equal to the **product (X) of the individual probabilities** of the event

Example:

Calculate the probability of getting a tall, yellow seeded, wrinkled pod, purple flower pea plant if both parents are homozygous tall, heterozygous yellow, heterozygous round pod, and homozygous purple flower.

Probability of tall plant:

	T	T
T		
T		

Probability of purple flower:

	P	P
P		
P		

Probability of yellow seeded plant:

	Y	y
Y		
y		

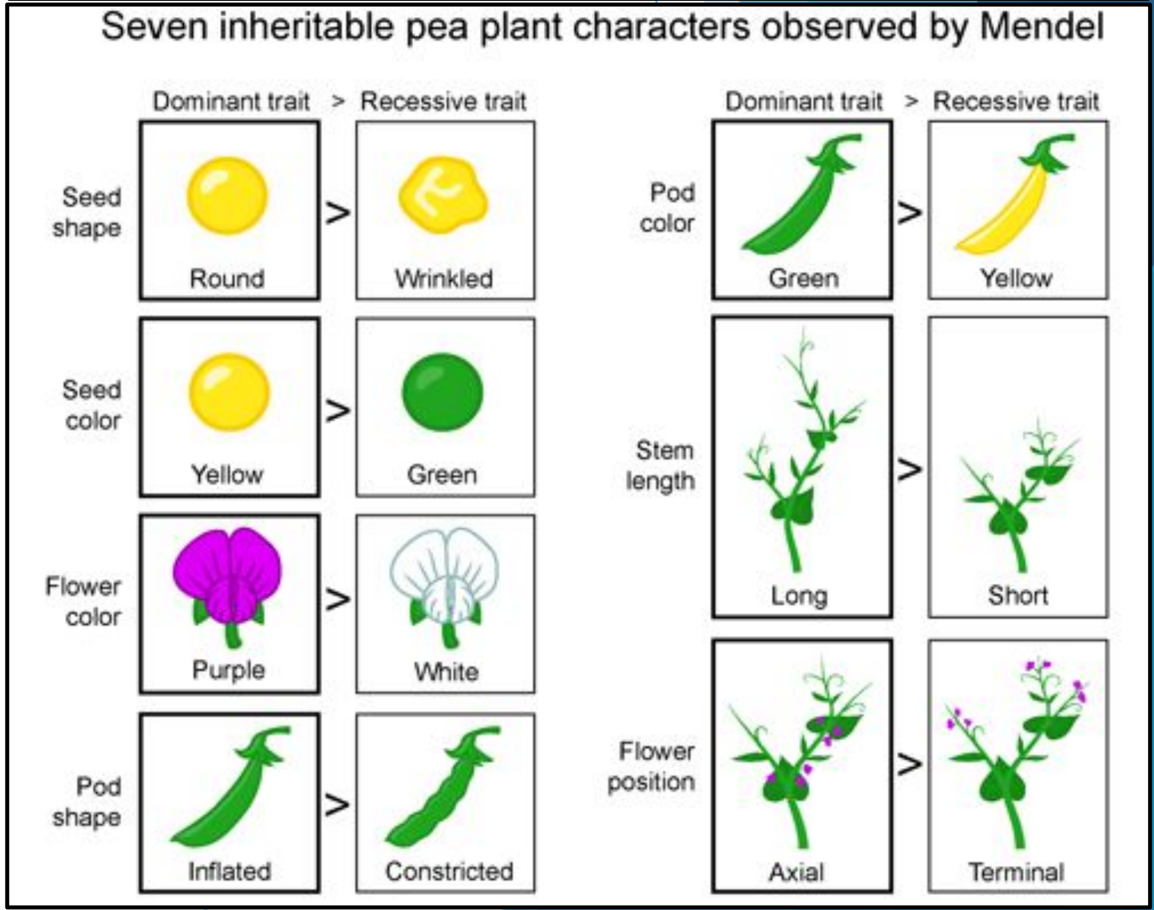
Probability of wrinkled plant:

	R	r
R		
r		

Probability = ____ X ____ X ____ X _____

Example:

Calculate the probability of getting a tall, yellow seeded, wrinkled pod, purple flower pea plant if both parents are homozygous tall, heterozygous yellow, heterozygous round pod, and homozygous purple flower.



Probability of tall plant: 1/1

	T	T
T	TT	TT
T	TT	TT

Probability of purple flower: 1/1

	P	P
P	PP	PP
P	PP	PP

Probability of yellow seeded plant: 3/4

	Y	y
Y	YY	Yy
y	Yy	yy

Probability of wrinkled plant: 1/4

	R	r
R	RR	Rr
r	Rr	rr

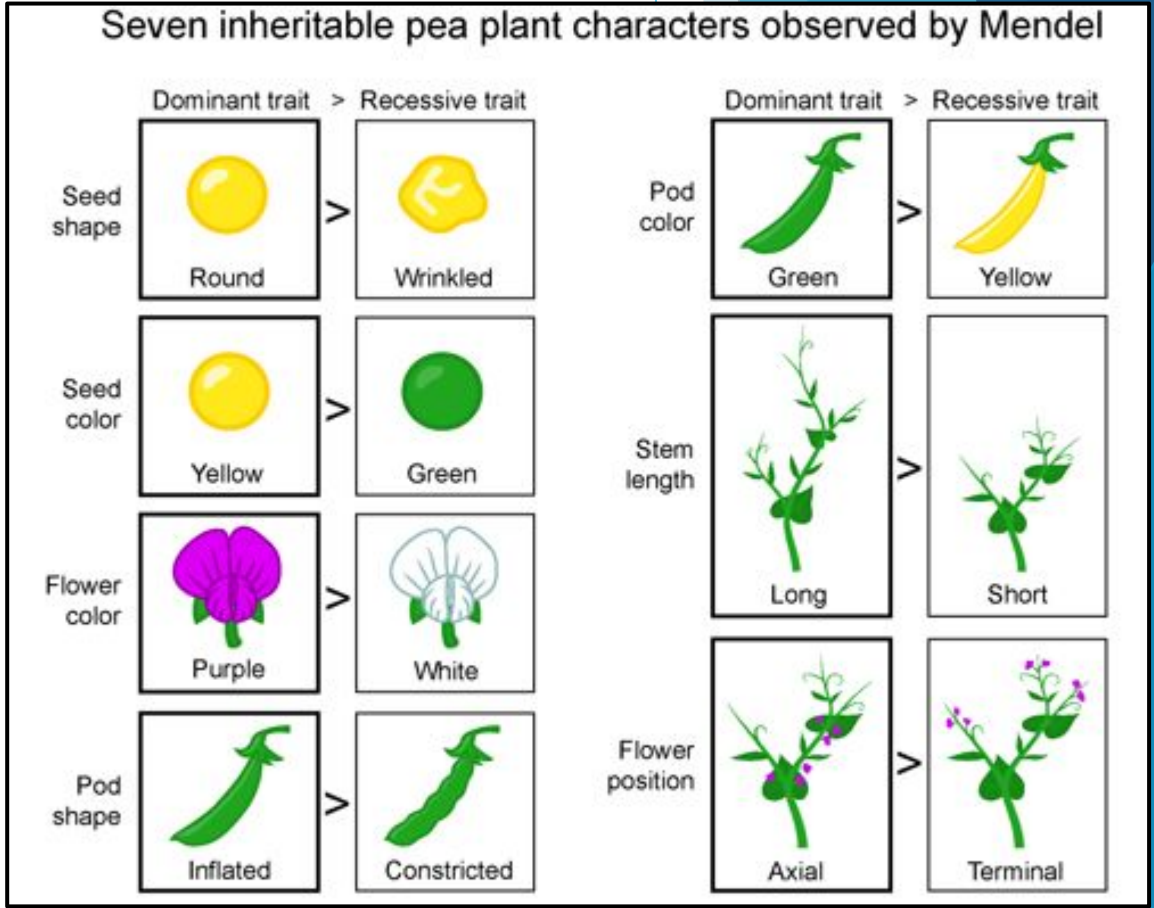
Probability = 1 X ¾ X ¼ X 1

= 3/16

= 19%

Example:

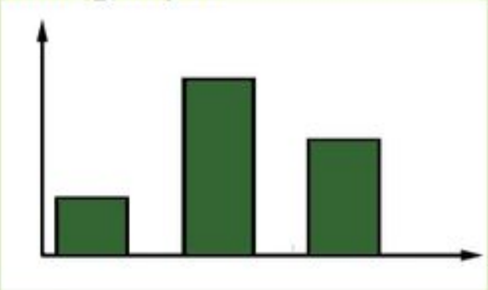
Calculate the probability of getting a tall, yellow seeded, wrinkled pod, purple flower pea plant if both parents are homozygous tall, heterozygous yellow, heterozygous round pod, and homozygous purple flower.



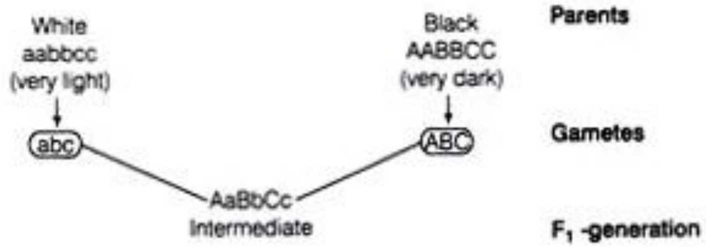
Continuous Variation and Additive Alleles

Continuous variation is when the phenotypic variation is <u>not clear cut.</u>

- Example, in the general population there are many variations of skin colour, from pale white to dark black
- This is because skin colour is not controlled by <u>one gene</u>, but rather by three or more separately inherited genes from the father and mother
- The genes are on different <u>autosomal</u> chromosomes and their interaction is <u>additive</u>
- An additive allele contributes a set amount to a <u>phenotype</u> and is an example of continuous variation.

	Continuous variation	Discontinuous variation
Properties	- No distinct categories - No limit on the value - Tends to be quantitative	- Distinct categories. - No in-between categories - Tends to be qualitative
Examples	• height • weight • heart rate • finger length • leaf length	• tongue rolling • finger prints • eye colour • blood groups
Representation	Line graph 	Bar graph 
Controlled by	A lot of Gene and environment → range of phenotypes between 2 extremes, e.g. height in humans.	A few genes → limited number of phenotypes with no intermediates e.g. A, B, AB and O blood groups in humans

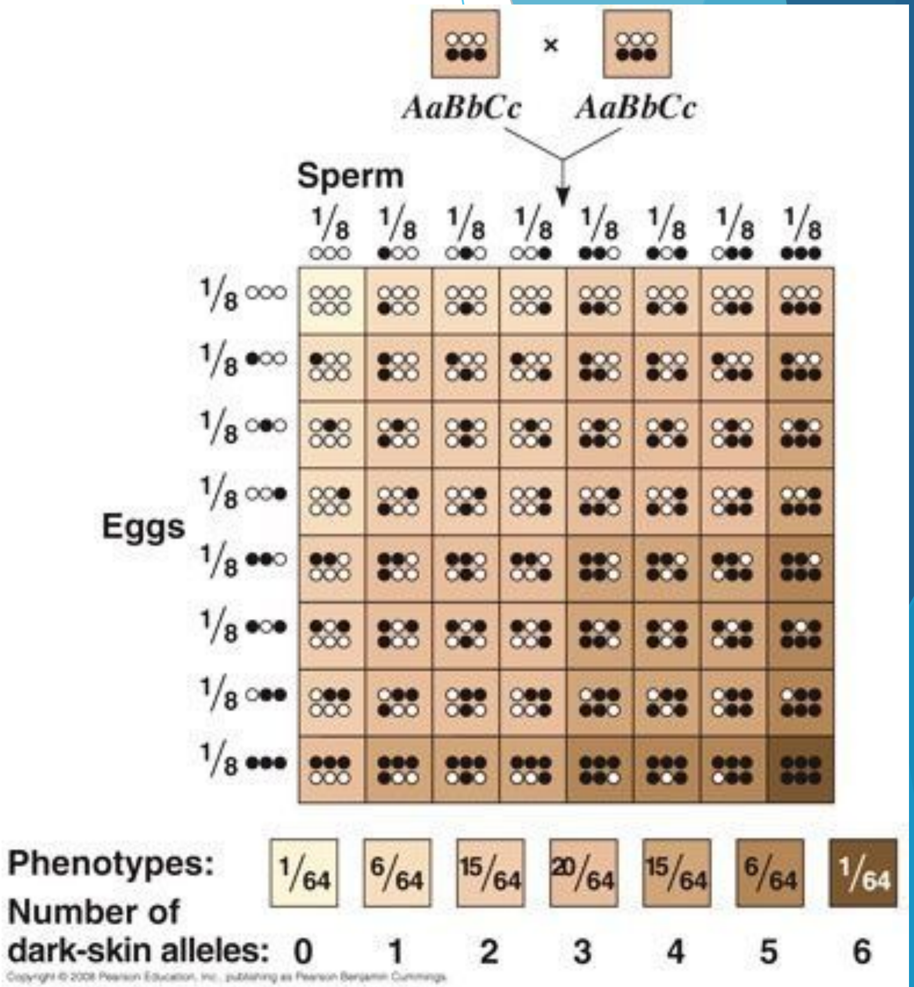
Polygenic Example in Humans - Skin Pigmentation



Gametes ♀ ↓ / ♂ →	ABC	aBC	AbC	ABc	abC	Abc	aBc	abc
ABC	AABBCC very dark	AaBBCC dark	AABbCC dark	AABBCc dark	AaBbCC fairly dark	AaBbCc fairly dark	AaBBCc fairly dark	AaBbCc intermediate
aBC	AaBBCC dark	aaBBCC fairly dark	AaBbCC fairly dark	AaBBCc fairly dark	aaBbCC intermediate	AaBbCc intermediate	aaBBCc intermediate	aaBbCc fairly light
AbC	AABbCC dark	AaBbCC fairly dark	AAbbCC fairly dark	AABbCc fairly dark	AabbCC intermediate	AAbbCc intermediate	AaBbCc intermediate	AabbCc fairly light
ABc	AABBCc dark	AaBbCc fairly dark	AABbCc fairly dark	AABBcc fairly dark	AaBbCc intermediate	AABbcc intermediate	AaBBcc intermediate	AaBbcc fairly light
abC	AaBbCc fairly dark	aaBbCC intermediate	AabbCC intermediate	AaBbCc intermediate	aabbCC fairly light	AabbCc fairly light	aaBbCc fairly light	aabbCc light
Abc	AABbCc fairly dark	AaBbCc intermediate	AAbbCc intermediate	AABbcc intermediate	AabbCc fairly light	AAbbcc fairly light	AaBbcc fairly light	Aabbcc light
aBc	AaBBCc fairly dark	aaBBCc intermediate	AaBbCc intermediate	AaBBcc intermediate	aaBbCc fairly light	aaBbcc fairly light	aaBBcc fairly light	aaBbcc light
abc	AaBbCc intermediate	aaBbCc fairly light	AabbCc fairly light	AaBbcc fairly light	aabbCc light	Aabbcc light	aaBbcc light	aabbcc very light

Phenotypes : Very Dark (Black)-1, Dark-6, Fairly Dark-15, Intermediate-20, Fairly Light-15, Light-6, Very Light (White)-1.

Fig. 5.6 Quantitative inheritance of skin colour in human beings



5.7 Summary

- Dihybrid crosses are crosses between individuals who differ in two pairs of alleles; if individuals are heterozygous for both alleles, the phenotype ratio of the offspring is 9:3:3:1.
- Mendel's law of independent assortment states that alleles of different genes separate into gametes independently of each other.
- The probability of two independent events both occurring may be calculated using the product law.
- Punnett square ratios are one way to show probability.
- Discontinous variation occurs when a trait is either expressed or not. There is no in-between trait.
- Continuous variation occurs in nature when the expression of a characteristic is the sum of the expression of all alleles involved.

Homework

- → 5.7: page 212 #1a, 1d
- → 5.7: Page 214 #1, 2, 4