Zoo-352 Principles of genetics
Lecture 8

The Law of Independent Assortment

Outlines:

- Dihybrid vs monohybrid crosses.
- The hypotheses of gene assortment during gamete formation.
- The law of independent assortment .
- Testcross hybrid cross offsprings.
- Exercises.
- Assignment.

Introduction

- Mendel also analyzed the inheritance pattern of two traits at the same time (a dihybrid cross). For example, he examined plants that differed in both the form and color of their peas.
- He crossed homozygous plants that produced round, yellow seeds with plants that produced wrinkled, green seeds.
- In Figure 1, the letter R is assigned to the dominant allele, round, and r to the recessive allele, wrinkled; Y and y are used for yellow and green color, respectively.
- The F1 plants all had round, yellow seeds, which demonstrated that round was dominant to wrinkled and yellow was dominant to green.

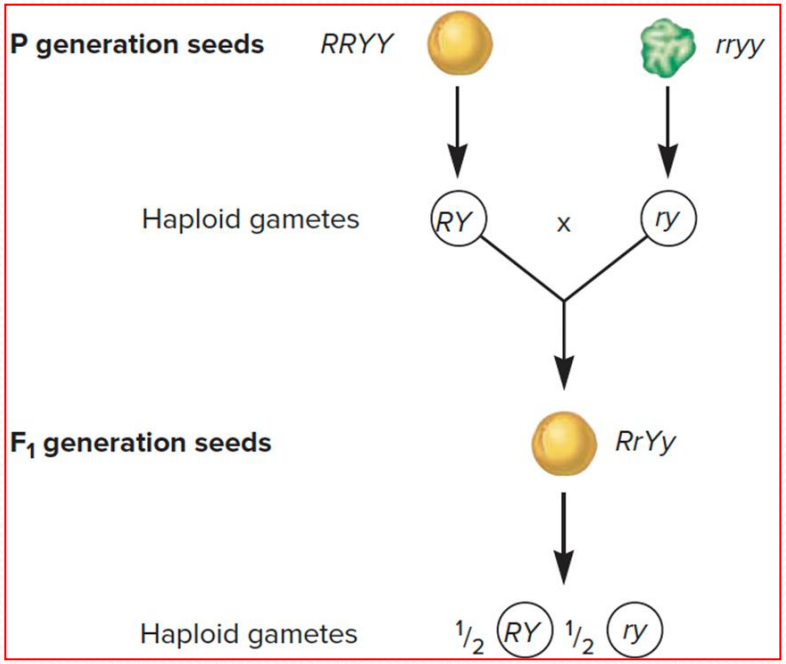


Figure 1: Independent assortment in garden peas

The hypotheses of gene assortment during gamete formation

- To illustrate **Mendel's work**, there is an experiment in which the characters were seed shape (round or wrinkled variants), and the seed color (yellow and green variants). In this two-factor cross, **Mendel** followed the inheritance pattern for both characters simultaneously.

What results are possible from a two-factor cross?

One possibility is that the genetic determinants for these two different characters are always **linked** to each other and inherited as a single unit (Figure 2a). If this was the case, **the F1 offspring could produce only two types of gametes, RY and ry**.

A second possibility is they are **not linked (independent)** and can assort themselves independently into gametes (Figure 2b). If **independent assortment occurred**, **the F1 offspring could produce four types of gametes, RY, Ry, rY, and ry**.

Linked vs independent gene assortment in gamete formation

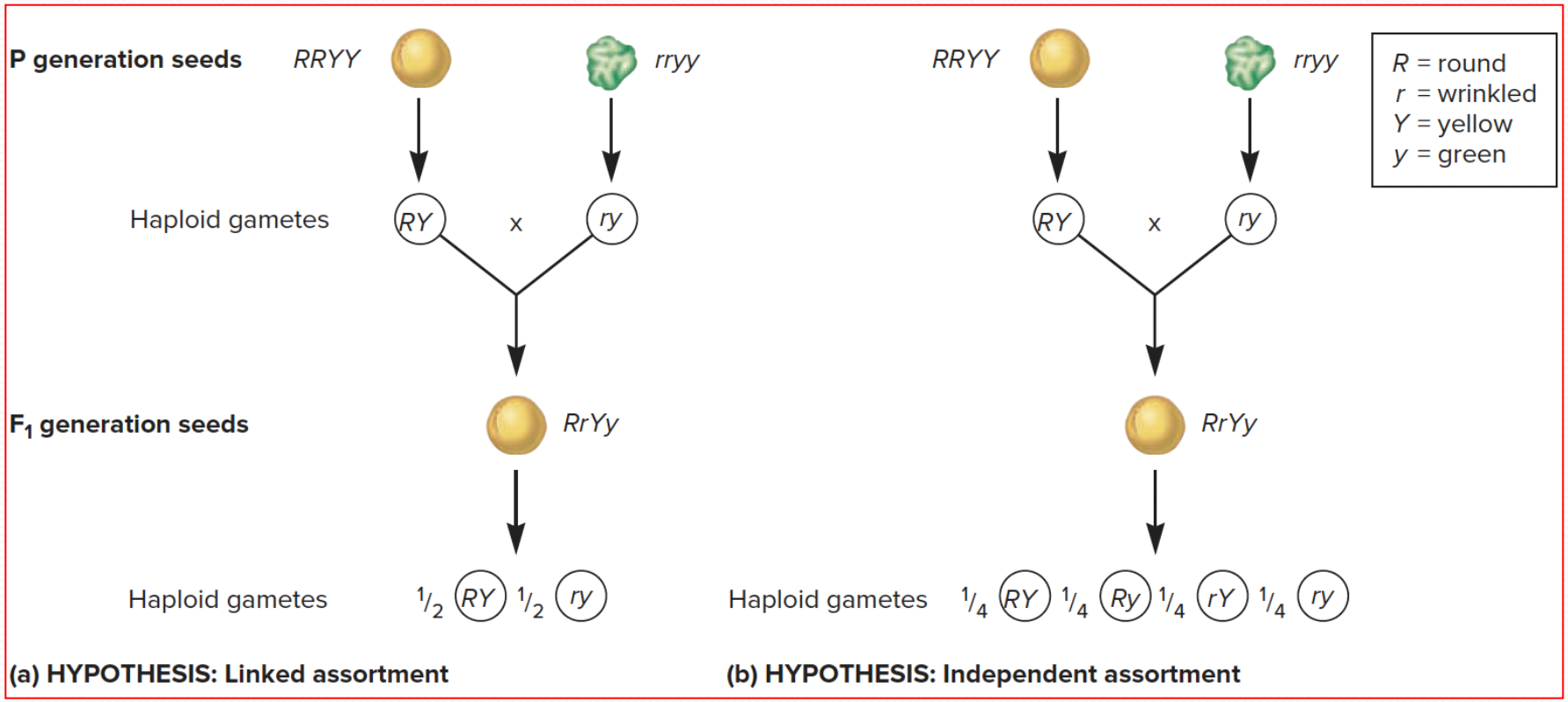
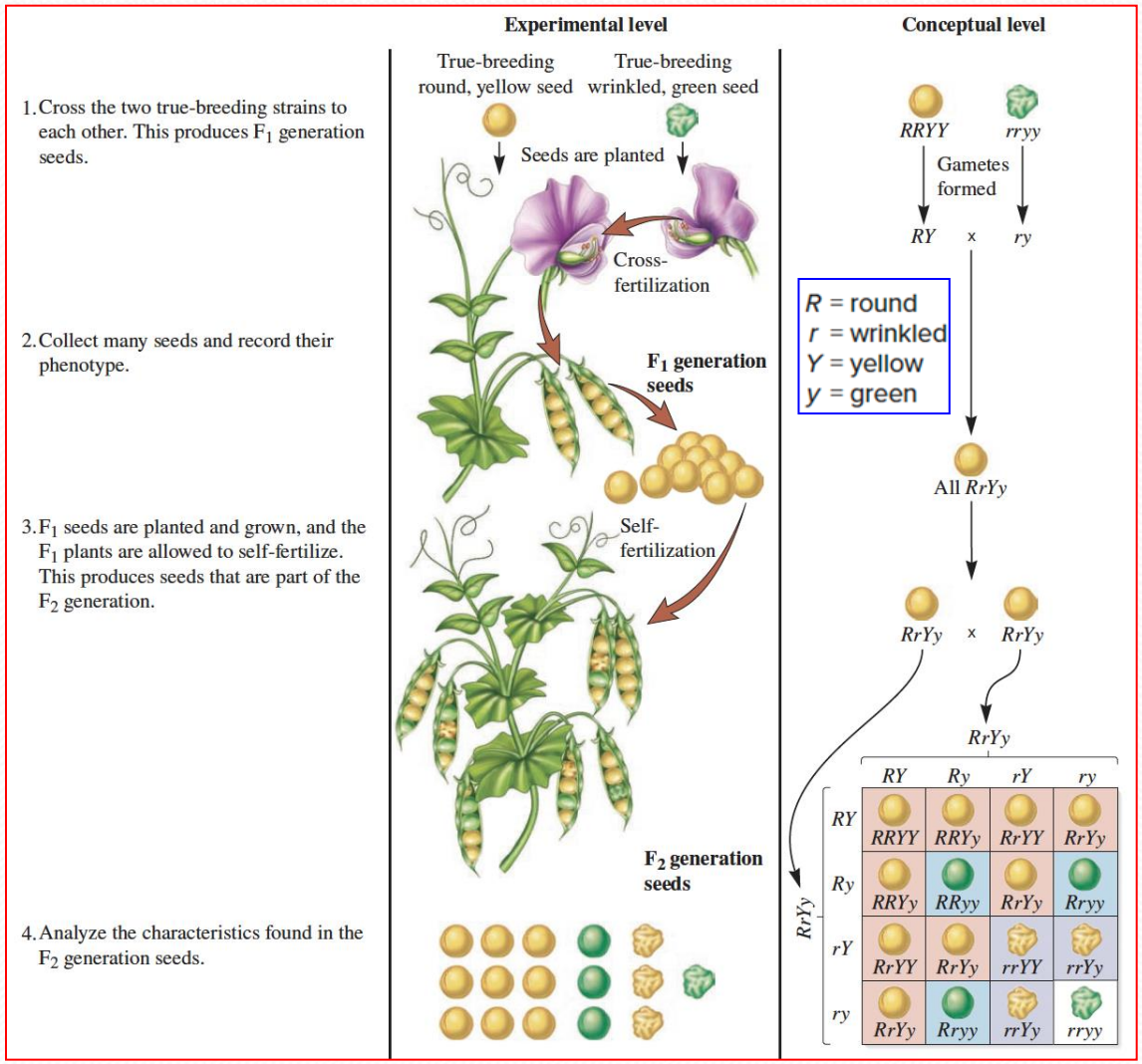


FIGURE 2. Two hypotheses to explain how two different genes assort during gamete formation. **(a)** According to the hypothesis of linked assortment, the two genes always stay associated with each other. **(b)** In contrast, the independent assortment hypothesis proposes that the two different genes randomly segregate into haploid cells.

The law of independent assortment

- When the F1 plants were self-fertilized, they produced an F2 generation of plants that had all four possible combinations of the two seed characteristics:
  - 9 plants with round, yellow seeds.
  - 3 plants with round, green seeds.
  - 3 plants with wrinkled, yellow seeds.
  - 1 plants wrinkled, green seeds.
- Dividing the number of plants by 32 (the number in the smallest group) gives a 9.84 to 3.38 to 3.16 to 1.00 ratio, which is very close to a 9:3:3:1 ratio (Figure 3).
- One way to visualize the different gametes fusions that can occur to produce the F2 generation is to use a Punnett square.
- Mendel's second law of independent assortment states that alleles for one gene will segregate independently of the alleles at another gene.

Figure 3


Experimental level
Conceptual level
1. Cross the two true-breeding strains to each other. This produces F_1 generation seeds.
2. Collect many seeds and record their phenotype.
3. F_1 seeds are planted and grown, and the F_1 plants are allowed to self-fertilize. This produces seeds that are part of the F_2 generation.
4. Analyze the characteristics found in the F_2 generation seeds.
True-breeding round, yellow seed
True-breeding wrinkled, green seed
Seeds are planted
Cross-fertilization
F_1 generation seeds
Self-fertilization
F_2 generation seeds
RRYY
rryy
Gametes formed
RY
ry
R = round
r = wrinkled
Y = yellow
y = green
All RrYy
RrYy
RrYy
RY Ry rY ry
RRYY RRYy RrYY RrYy
RRYy RRyy RrYy Rryy
RrYY RrYy rrYY rrYy
RrYy Rryy rrYy rryy


RRYY RRYy RrYY RrYy RRYy RRyy RrYy Rryy RrYY RrYy rrYY rrYy RrYy Rryy rrYy rryy
By randomly combining male and female gametes, 16 combinations are possible.
Totals: 1 RRYY : 2 RRYy : 4 RrYy : 2 RrYY : 1 RRyy : 2 Rryy : 1 rrYY : 2 rrYy : 1 rryy
Phenotypes: 9 round, yellow seeds
3 round, green seeds
3 wrinkled, yellow seeds
1 wrinkled, green seed

Testing the law of independent assortment

- A simplest test of Mendel's law of independent assortment can be made by testcrossing the dihybrid plant (round yellow peas) with homozygous double recessive genotype..
- Mendel testcrossed a **RrYy** F1 offspring with a **rryy** individual.
- The progeny would include four phenotypes in a **1:1:1:1 ratio** as shown in Figure 4.

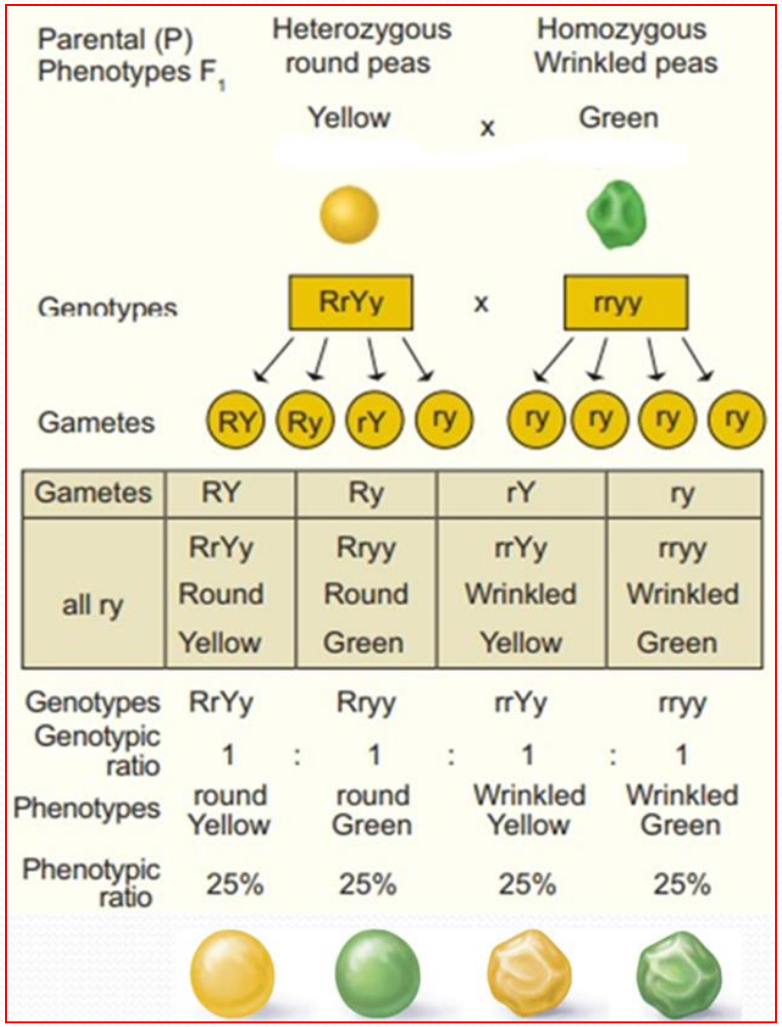


Figure 4: Testcross of a dihybrid

Dihybrid Crosses Practice Exercises

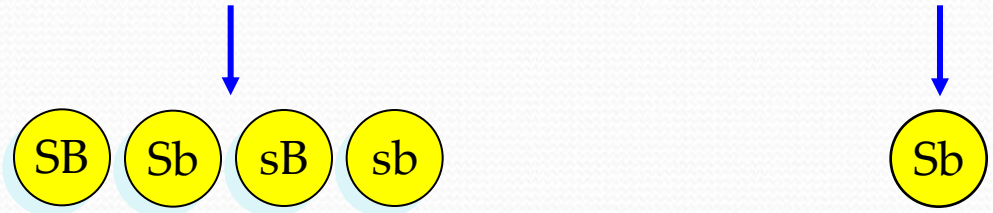
Question 1: In rabbit, short hair is controlled by a dominant allele (S) while long hair is controlled by its recessive allele (s). On the other hand, black hair is controlled by a dominant allele (B) while brown hair is controlled by a recessive allele (b). Based on the information given, answering the following questions:

A heterozygous rabbit with short black hair is cross with homozygous rabbit with short brown hair. Determine the phenotypic and genotypic ratio among the F1 progeny?

♂ ♀

P phenotype: A heterozygous short black A homozygous short brown

P genotype: SsBb X SSbb



Gametes:

F1:

	SB	**Sb**	**sB**	**sb**
Sb	**SSBb** Short black	**SSbb** Short brown	**SsBb** Short black	**Ssbb** Short brown

- Phenotypic ratio = 2 (short black) : 2 (short brown)
- Genotypic ratio = 1 (SSBb) : 1 (SSbb) : 1 (SsBb) : 1 (Ssbb)

Question 2: How many different types of gametes can be produced from the following genotypes?

a) AAbb b) Aabb c) AaBbCc d) AaBbCcDd

The number of gamete produced = $\mathbf{2^n}$

n= The number of heterozygous gene pairs from one parent

a) AAbb = $\mathbf{2^n} = 2^0 = 1$

b) Aabb = $\mathbf{2^n} = 2^1 = 2$

c) AaBbCc = $\mathbf{2^n} = 2^3 = 8$

d) AaBbCcDd = $\mathbf{2^n} = 2^4 = 16$

Question 3: Suppose that black hair (B) is dominant over blonde hair and brown eyes (E) are dominant over blue eyes. The father has black hair (homozygous) and brown eyes (heterozygous) and the mother has blonde hair and blue eyes. Answer the following questions:

a) Draw a Punnett square to show all possible offspring.

b) What percent of the offspring will be totally heterozygous?

c) What is the phenotypic ratio?

d) What percent of the offspring will have blonde hair and blue eyes?

	♂		♀
P phenotype:	black hair (homo) and brown eyes (hetero)		Blonde hair and brown eyes
P genotype:	BBEe	X	bbee
Gametes:	BE Be		be

F1 (a):

	BE	**Be**
be	**BbEe** Black hair brown eyes	**Bbee** Black hair blue eyes

b) What percent of the offspring will be totally heterozygous? 50%

c) What is the phenotypic ratio? 1 : 1

d) What percent of the offspring will have blonde hair and blue eyes? 0%

Question 4: In Horses, being clumsy (C) is dominant to being cool (c) and being dazzling (D) is dominant to being docile (d). If female that is heterozygous for both C and D is mated with a male that is also heterozygous for both traits. What is the probability they will have an offspring that is clumsy and dazzling?

a) 1/16 b) 9/16 c) 3/16 d) 1/4

Genotypes of parents:
Female: CcDd
Male: CcDd

Gametes:
Female: (CD, Cd, cD, cd)
Male: (CD, Cd, cD, cd)

Clumsy & dazzling possible genotypes are:
CCDD, CCDd, CcDD, or CcDd

	CD	Cd	cD	cd
CD	CCDD	CCDd	CcDD	CcDd
Cd	CCDd	CCdd	CcDd	Ccdd
cD	CcDD	CcDd	ccDD	ccDd
cd	CcDd	Ccdd	ccDd	ccdd

In-class assignment

In rabbits, brown fur (B) is dominant to white fur (b) and short fur (H) is dominant to long fur (h). A brown, long-furred rabbit (Bbhh) is crossed with a white, short-furred rabbit (bbHh).

What percentage of the offspring will be brown with long fur?

a) 25% b) 50% c) 75% d) 100%:

P genotype: Bbhh X bbHh

Gametes: Bh bh bH bh

F1:

	Bh	**bh**
bH	**BbHh** Brown short fur	**bbHh** White short fur
bh	**Bbhh** Brown long fur	**bbhh** White long fur

Second Assignment (Due: 13/4/2025)

Question 1: Suppose that black hair (B) is dominant over blonde hair and brown eyes (E) are dominant over blue eyes. The father has black hair (heterozygous) and brown eyes (heterozygous) and the mother has blonde hair and blue eyes. Answer the following questions:

a) Draw a Punnett square to show all possible offspring.

b) What percent of the offspring will be totally heterozygous?

c) What is the phenotype ratio?

d) What percent of the offspring will have blonde hair and blue eyes?

Question 2: If 2 black mice are crossed, the offspring consist of 10 black and 3 white mice.

Which allele is dominant?

Which allele is recessive?

What are the genotypes of the parents?

Question 3: In rabbits, grey hair is dominant to white hair, and black eyes are dominant to red eyes. A male rabbit homozygous dominant for hair and homozygous recessive for eyes is crossed with a female rabbit heterozygous for both traits. Use a Punnett square to determine the phenotypic ratio of their offspring.

Quiz: The law of independent assortment

1. A pea plant has the genotype (rrYy). How many different types of gametes can it produce, and in what proportions?

- 1 rr : 1 Yy
- 1 rY : 1 ry
- 3 rY : 1 ry
- 1 RY : 1 rY : 1 Ry : 1 ry

2. A cross is made between a pea plant with the genotype (RrYy) and another with the genotype (rrYy). What is the predicted outcome of the seed phenotypes?

- 9 round yellow : 3 round green : 3 wrinkled yellow : 1 wrinkled green
- 3 round yellow : 3 round green : 1 wrinkled yellow : 1 wrinkled green
- 3 round yellow : 1 round green : 3 wrinkled yellow : 1 wrinkled green
- 1 round yellow : 1 round green : 1 wrinkled yellow : 1 wrinkled green