Lecture Series 6

Transmission Genetics: Mendel and Beyond

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A. The Foundations of Genetics

B. Mendel's Experiments and Laws of Inheritance

C. Alleles and Their Interactions

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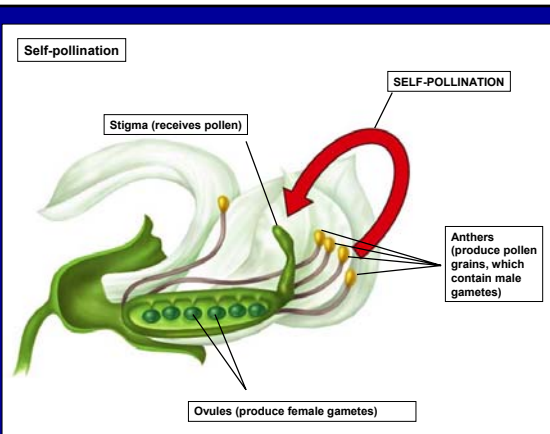
D. Gene Interactions

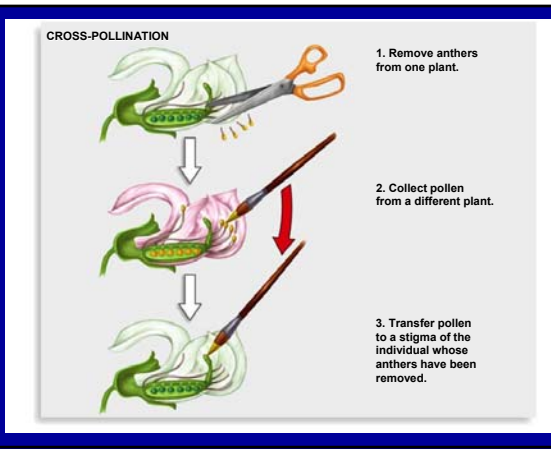
E. Genes and Chromosomes

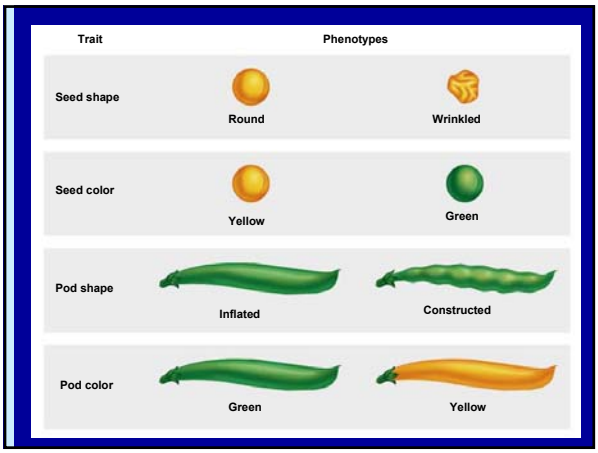
F. Cytoplasmic Inheritance

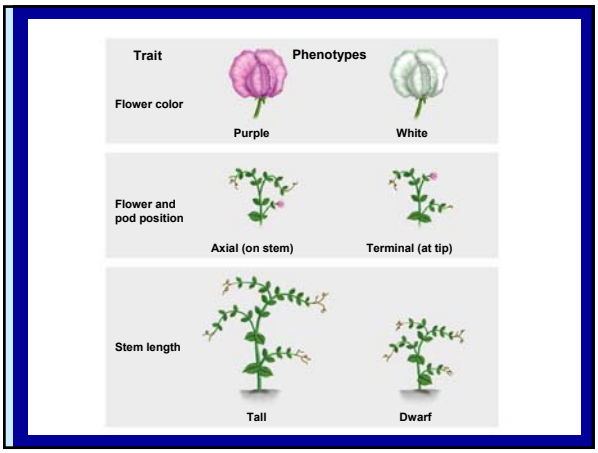
A. The Foundations of Genetics

- It has long been known that both parent plants contribute equally to character traits of offspring, but before Mendel's time it was believed that once brought together, the units of inheritance blended and could never be separated.





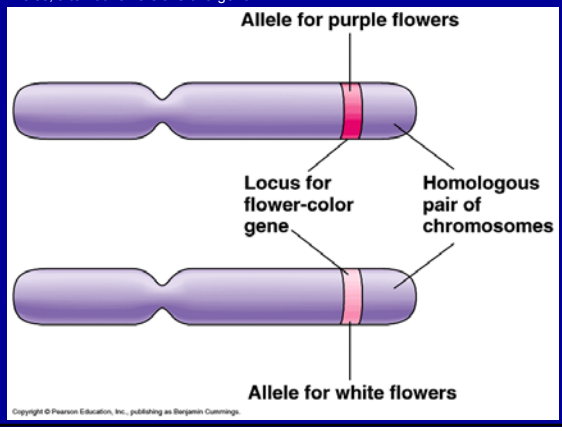




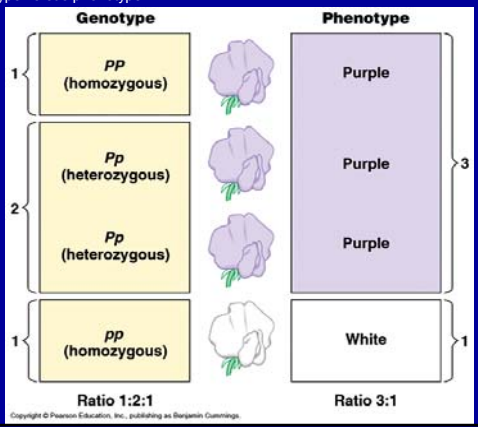
A. The Foundations of Genetics

- Although Gregor Mendel's work was meticulous and well documented, his discoveries, reported in the 1860s, lay dormant until decades later.

Alleles, alternative versions of a gene



Genotype versus phenotype



B. Mendel's Experiments and Laws of Inheritance

- Mendel used garden pea plants for his studies because they were easily cultivated and crossed, and showed numerous characters with clearly different traits.
- Initially, Mendel performed crosses between true breeding lines of garden peas that differed in a single trait.

10.1 Mendel's Results from Monohybrid Crosses

DOMINANT × RECESSIVE	DOMINANT	RECESSIVE	TOTAL	RATIO
Spherical seeds × Wrinkled seeds	5,474	1,850	7,324	2.96:1
Yellow seeds × Green seeds	6,022	2,001	8,023	3.01:1
Purple flowers × White flowers	705	224	929	3.15:1
Inflated pods × Constricted pods	882	299	1,181	2.95:1
Green pods × Yellow pods	428	152	580	2.82:1
Axial flowers × Terminal flowers	651	207	858	3.14:1
Tall stems × Dwarf stems	787	277	1,064	2.84:1

Table 10.1

B. Mendel's Experiments and Laws of Inheritance

- In a monohybrid cross (exp #1), the offspring showed one of the two traits. Mendel proposed that the trait observed in the first generation (F_1) was dominant and the other was recessive.
- Dominant traits "mask" recessive traits in the F_1 generation.

B. Mendel's Experiments and Laws of Inheritance

- When the F_1 offspring were self-pollinated, the F_2 generation showed a 3:1 phenotypic ratio, with the recessive phenotype present in one-fourth of the offspring.
- Reappearance of the recessive phenotype refuted the blending hypothesis.

Exp. #1

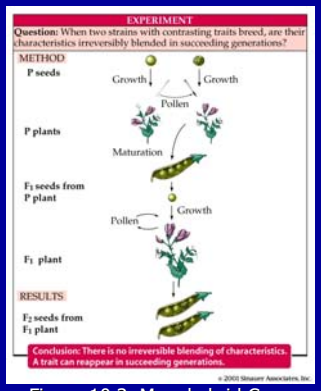


Figure 10.3 Monohybrid Cross

B. Mendel's Experiments and Laws of Inheritance

- Because some alleles are dominant and some are recessive, the same phenotype can result from different genotypes.
- Homozygous genotypes have two copies of the same allele; heterozygous genotypes have two different alleles.
- Heterozygous genotypes yield phenotypes showing the dominant trait.

B. Mendel's Experiments and Laws of Inheritance

- On the basis of many crosses using different characters, Mendel proposed his first law: the units of inheritance (genes) are particulate, there are two copies (alleles) of each gene in every parent, and during gamete formation the two alleles for a character segregate from each other.

Mendel's Interpretation of Exp #1

F = "filial" or a sequence of generations.

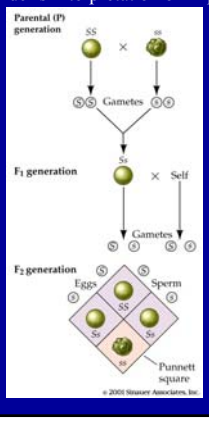


Figure 10.4

B. Mendel's Experiments and Laws of Inheritance

- Geneticists who followed Mendel showed that genes are carried on chromosomes and that alleles are "segregated" during meiosis I.

Meiosis Accounts for the Segregation of Alleles

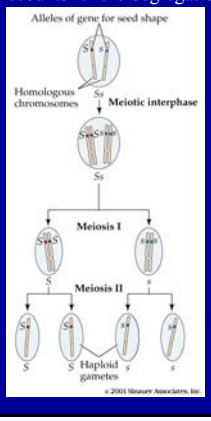


Figure 10.5

B. Mendel's Experiments and Laws of Inheritance

- Using a test cross (exp #2), Mendel was able to determine whether a plant showing the dominant phenotype was homozygous or heterozygous. The appearance of the recessive phenotype in half of the offspring indicates that the parent is heterozygous.

Exp. #2

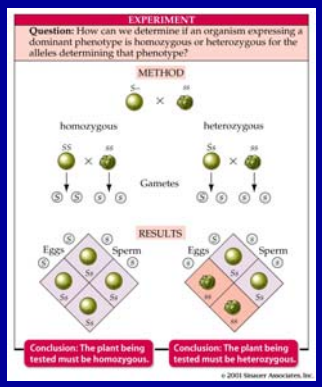


Figure 10.6 Test Cross

B. Mendel's Experiments and Laws of Inheritance

- From studies of the simultaneous inheritance of two characters, Mendel concluded that alleles of different genes assort independently.
- Rem: Independent Assortment!

Mendel's Interpretation of Exp #2

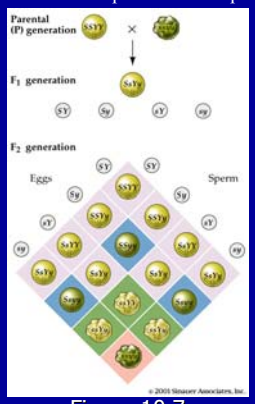


Figure 10.7

Independent Assortment:

9 Genotypes

4 Phenotypes in 9:3:3:1

Meiosis Accounts for the Independent Assortment of Alleles

Homologs line up during Metaphase I

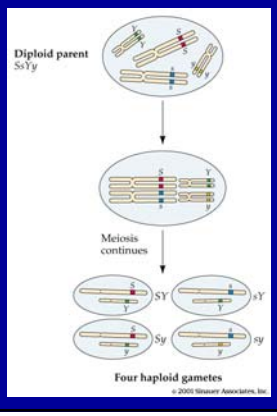


Figure 10.8

B. Mendel's Experiments and Laws of Inheritance

- We can predict the results of hybrid crosses by using a Punnett square or by calculating probabilities.
- To determine the joint probability of independent events, individual probabilities are multiplied.
- To determine the probability of an event that can occur in two or more different ways, they are are added.

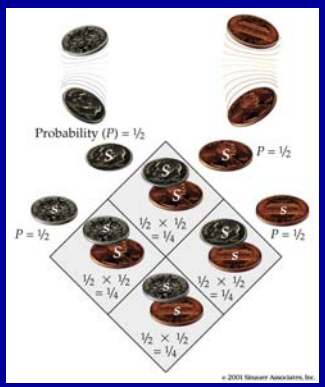
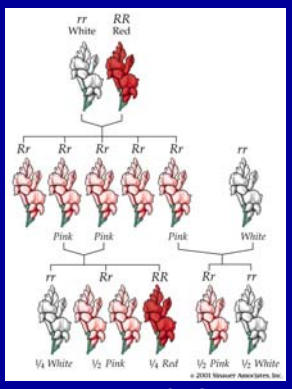


Figure 10.9

C. Alleles and Their Interactions

- New alleles arise by mutation and many genes have multiple alleles.
- Dominance is usually not complete, since both alleles in a heterozygous organism may be expressed in the phenotype.
- Some alleles may have multiple phenotypic effects.



Incomplete Dominance: Snapdragons still follow Mendel's laws even though appear to become blended.

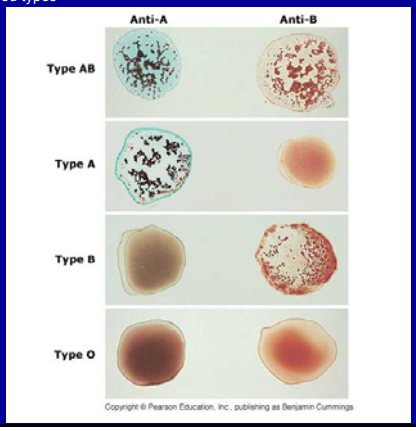
Figure 10.13

Incomplete dominance in carnations

Multiple alleles for the ABO blood groups: Example of Codominance

(a) Phenotype (blood group)	(b) Genotypes (see p.258)	(c) Antibodies present in blood serum	(d) Results from adding red blood cells from groups below to serum from groups at left			
			A	B	AB	O
A	$I^A I^A$ or $I^A i$	Anti-B				
B	$I^B I^B$ or $I^B i$	Anti-A				
AB	$I^A I^B$	—				
O	ii	Anti-A Anti-B				

ABO blood types



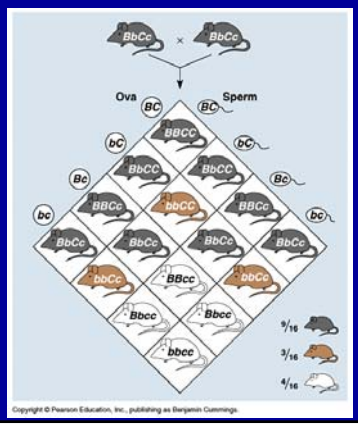
C. Alleles and Their Interactions

Complete Dominance	Incomplete Dominance	Codominance
AA & Aa are same phenotype	Aa = intermediate phenotype	Aa are both equally expressed
Eg., Peas	Eg., Snapdragons	Eg., Blood Type

D. Gene Interactions

- In epistasis, the products of different genes interact to produce a phenotype.
- In some cases, the phenotype is the result of the additive effects of several genes (polygenes), and inheritance is quantitative.
- Environmental variables such as temperature, nutrition, and light affect gene action.

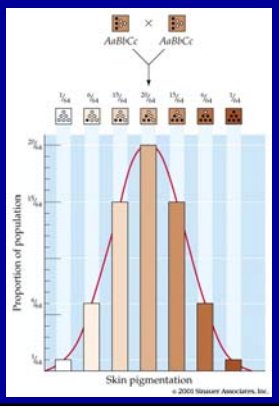
An example of epistasis



Epistasis: Where a gene at one locus alters the expression of a gene at a second locus.

Still follows Mendel's laws.

A simplified model for polygenic inheritance of skin color



Polygenic Inheritance: Where there is an additive effect of two or more genes on a single phenotype.

Figure 10.17

E. Genes and Chromosomes

- Each chromosome carries many genes.
- Genes located on the same chromosome are said to be linked, and are often inherited together.

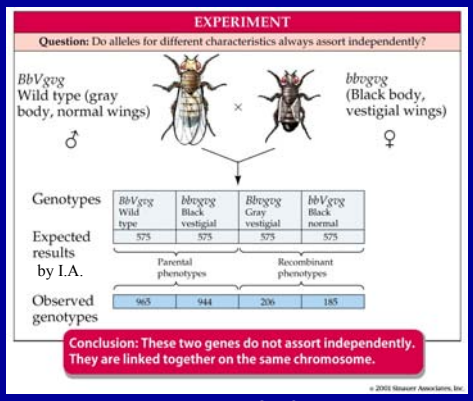


Figure 10.19

If Linkage Were Absolute: Like a Single Gene

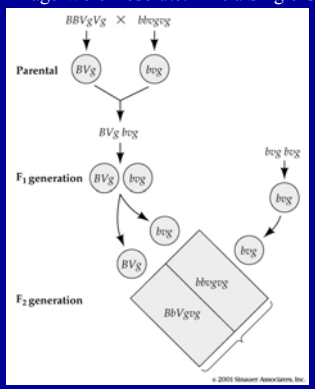


Figure 10.20

E. Genes and Chromosomes

- Linked genes recombine by "**crossing over**" in prophase I of meiosis, resulting in recombinant gametes, which have new combinations of linked genes.
- Recombination frequency can be calculated as the total recombinants divided by the total number of offspring.

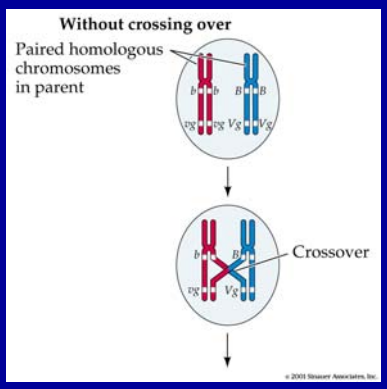


Figure 10.21 – Part 1

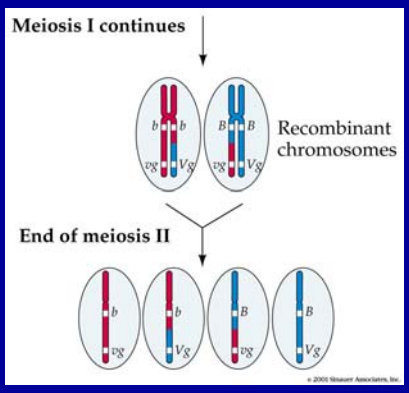


Figure 10.21 – Part 2

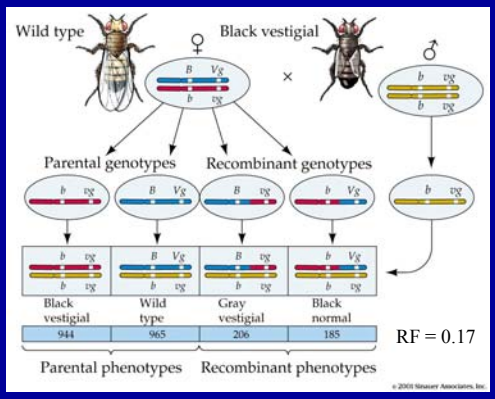
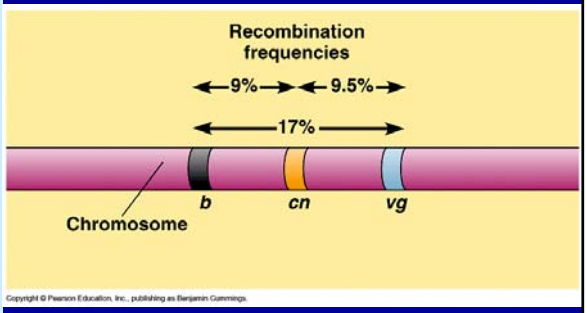


Figure 10.22

E. Genes and Chromosomes

- The distance between genes on a chromosome is proportional to the frequency of crossing over. Genetic maps are based on recombinant frequencies.

Using recombination frequencies to construct a genetic map



Units = cM or centimorgans = RF of 0.01

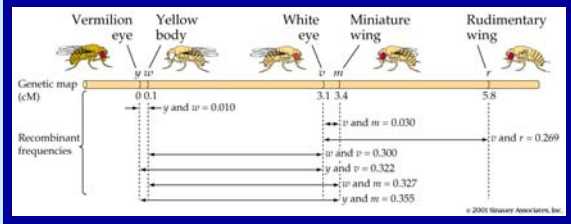
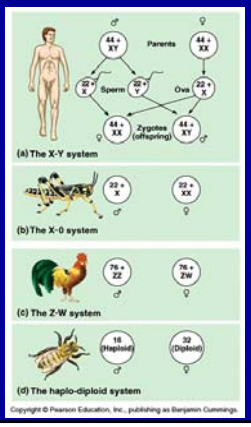


Figure 10.23

E. Genes and Chromosomes

- Sex chromosomes carry genes that determine whether male or female gametes are produced.
- Specific functions of X and Y chromosomes differ among species.

Some chromosomal systems of sex determination



E. Genes and Chromosomes

- In fruit flies and mammals, the X chromosome carries many genes, but the Y chromosome has only a few.
- Males have only one allele for most X-linked genes, so rare alleles appear phenotypically more often in males.

Eye Color is a Sex-Linked Trait in Fruitflys: Males are "Hemizygous"

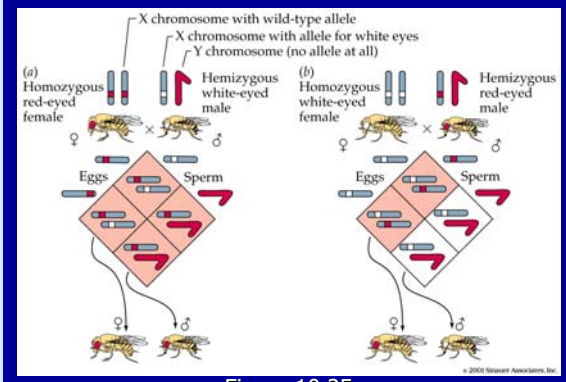


Figure 10.25

F. Cytoplasmic Inheritance

- Cytoplasmic organelles such as plastids and mitochondria contain some heritable genes.
- Cytoplasmic inheritance is generally by way of the egg, because male gametes contribute only their nucleus to the zygote at fertilization.

Cytoplasmic inheritance in tomato leaves