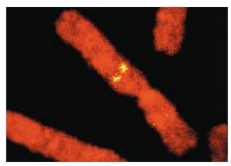
CH 12: Chromosomal Basis of Inheritance

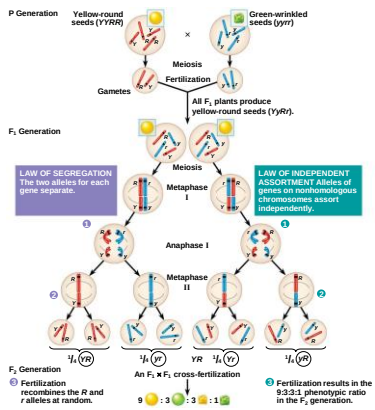
- Mendel's "hereditary factors" were genes
- Today we know that genes are located on chromosomes
- The location of a particular gene can be seen by tagging isolated chromosomes with a fluorescent dye that highlights the gene



Concept 12.1: Mendelian inheritance has its physical basis in the behavior of chromosomes

- Mitosis and meiosis were first described in the late 1800s
- The **chromosome theory of inheritance** states
  - Mendelian genes have specific loci (positions) on chromosomes
  - Chromosomes undergo segregation and independent assortment
- The behavior of chromosomes during meiosis accounts for Mendel's laws of segregation and independent assortment

Figure 12.2



Morgan's Experimental Evidence: *Scientific Inquiry*

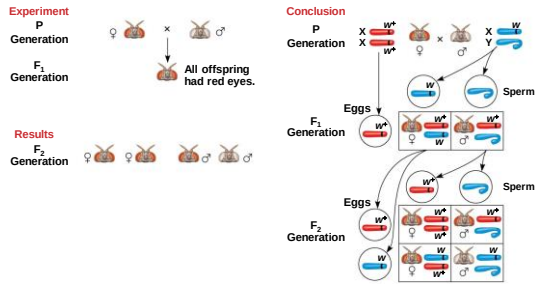
- Thomas Hunt Morgan and his students began studying the genetics of the fruit fly, *Drosophila melanogaster*, in 1907
- Fruit flies were/are a convenient organism for genetic studies
  - They produce many offspring
  - A generation can be bred every two weeks
  - They have only four pairs of chromosomes

- Morgan noted **wild-type**, or normal, phenotypes that were common in the fly populations
- Traits alternative to the wild type are called mutant phenotypes
- The first mutant phenotype they discovered was a fly with white eyes instead of the wild type, red

Correlating Behavior of a Gene's Alleles with Behavior of a Chromosome Pair

- In one experiment, Morgan mated male flies with white eyes (mutant) with female flies with red eyes (wild type)
  - The F_1 generation all had red eyes
  - The F_2 generation showed the classical 3:1 red:white ratio, but only males had white eyes
- Morgan concluded that the eye color was related to the sex of the fly (on the X chromsome)

- Morgan determined that the white-eyed mutant allele must be located on the X chromosome
  - Morgan's finding supported the chromosome theory of inheritance



Concept 12.2: Sex-linked genes exhibit unique patterns of inheritance

- In humans and some other animals, there is a chromosomal basis of sex determination
- In humans/mammals: Two varieties of sex chromosomes: a larger X chromosome and a smaller Y chromosome
  - Only the ends of the Y chromosome have regions that are homologous with corresponding regions of the X chromosome (homologs?)
  - The *SRY* gene on the Y chromosome is required for the development of testes

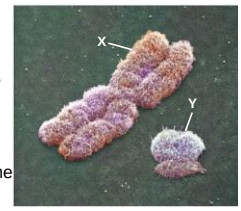
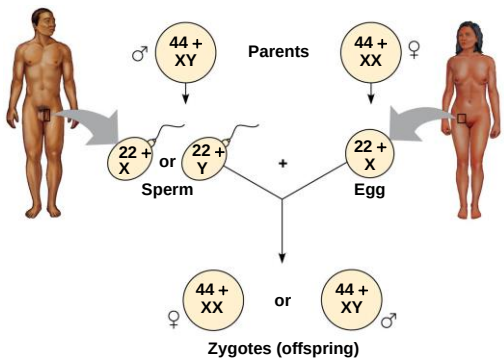


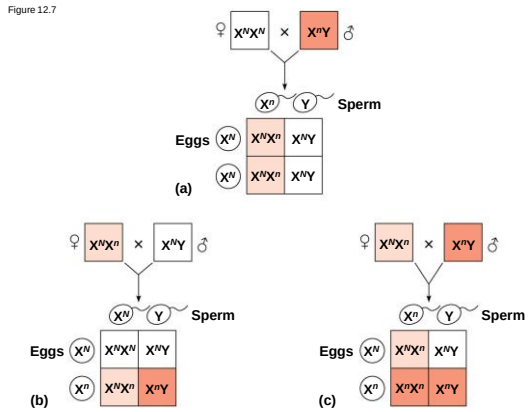
Figure 12.6



- A gene that is located on either sex chromosome is called a **sex-linked gene**
  - Genes on the Y chromosome are called Y-linked genes; there are few of these
  - Genes on the X chromosome are called **X-linked genes**
- X chromosomes have genes for many characters unrelated to sex, whereas the Y chromosome mainly encodes genes related to sex determination

- Sex-linked genes - patterns of inheritance
- For a recessive X-linked trait to be expressed
  - A female needs two copies of the allele (homozygous)
  - A male needs only one copy of the allele (hemizygous)
- X-linked recessive disorders are much more common in males than in females

Figure 12.7

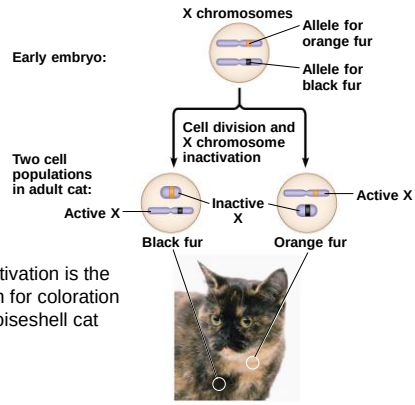


- Some disorders caused by recessive alleles on the X chromosome in humans
  - Color blindness (mostly X-linked)
  - **Duchenne muscular dystrophy**
  - **Hemophilia**

X Inactivation in Female Mammals

- In mammalian females, one of the two X chromosomes in each cell is randomly inactivated during embryonic development
  - The inactive X condenses into a **Barr body**
  - If a female is heterozygous for a particular gene located on the X chromosome, she will be a mosaic for that character

Figure 12.8



X inactivation is the reason for coloration in tortoiseshell cat

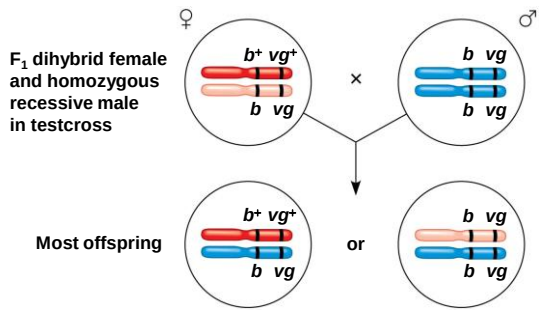
Concept 12.3: Linked genes tend to be inherited together because they are located near each other on the same chromosome

- Chromosomes have hundreds or thousands of genes
  - Y: 200 ish genes (~60 mbp)
  - Ch 21: 500 ish genes (~50 mbp)
  - Ch 1: 5000 ish genes (~250 mbp)
- Genes located on the same chromosome that tend to be inherited together are called **linked genes**

How Linkage Affects Inheritance

- Morgan did experiments with fruit flies that show how linkage affects inheritance of two characters
  - Morgan crossed flies that differed in traits of body color and wing size
  - Morgan found that body color and wing size are usually inherited together in specific combinations (parental phenotypes)
  - He reasoned that since these genes did not assort independently, they were on the same chromosome

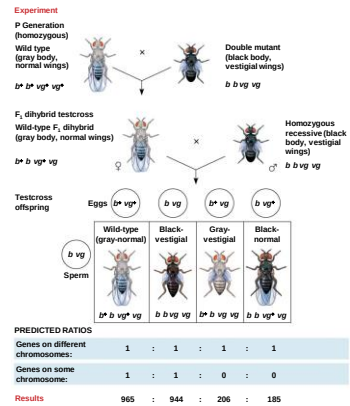
Figure 12.UN01



Genetic Recombination and Linkage

- However, nonparental phenotypes were also produced
  - Understanding this result involves exploring **genetic recombination**, the production of offspring with combinations of traits differing from either parent

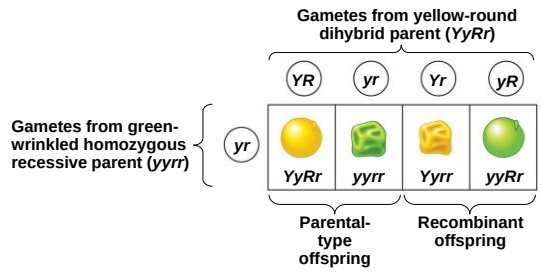
Figure 12.9



Recombination of Unlinked Genes: Independent Assortment of Chromosomes

- Mendel observed that combinations of traits in some offspring differ from either parent
  - Offspring with a phenotype matching one of the parental phenotypes are called **parental types**
  - Offspring with nonparental phenotypes (new combinations of traits) are called **recombinant types**, or **recombinants**
  - A 50% frequency of recombination is observed for any two genes on different chromosomes

Figure 12.UN02



Recombination of Linked Genes: Crossing Over

- Morgan discovered that even when two genes were on the same chromosome, some recombinant phenotypes were observed
  - He proposed that some process must occasionally break the physical connection between genes on the same chromosome
  - That mechanism was the **crossing over** between homologous chromosomes

Figure 12.10a

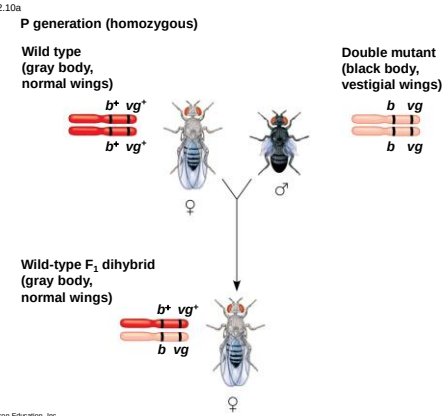


Figure 12.10b

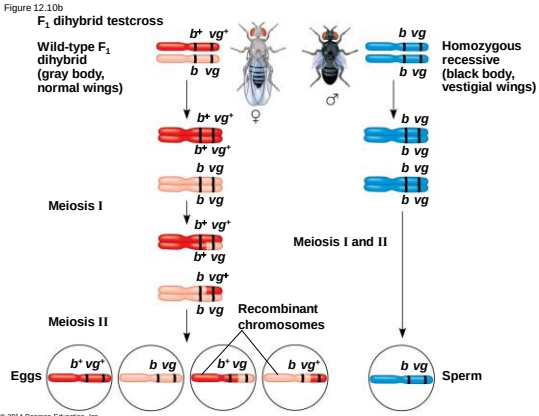
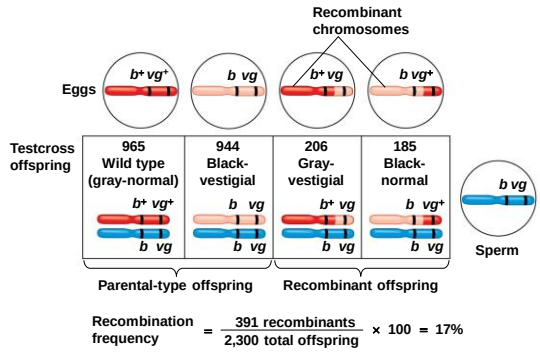


Figure 12.10c

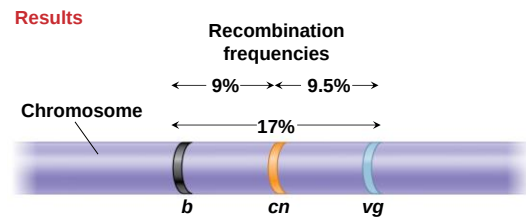


Mapping the Distance Between Genes Using Recombination Data: *Scientific Inquiry*

- Alfred Sturtevant, one of Morgan's students, constructed a **genetic map**, an ordered list of the genetic loci along a particular chromosome
  - Sturtevant predicted that *the farther apart two genes are, the higher the probability that a crossover will occur between them and therefore the higher the recombination frequency*

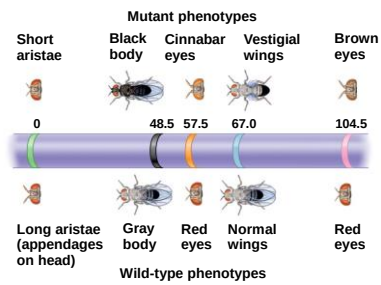
Figure 12.11

- A **linkage map** is a genetic map of a chromosome based on recombination frequencies
- Distances between genes can be expressed as **map units**; one map unit represents a 1% recombination frequency



- Genes that are far apart on the same chromosome can have a recombination frequency near 50%
  - These genes are physically linked, but genetically unlinked, and behave as if found on different chromosomes
- Sturtevant used recombination frequencies to make linkage maps of fruit fly genes
- **Cytogenetic maps** indicate the positions of genes with respect to chromosomal features

Figure 12.12



Five traits		Recombination frequencies		Genetic map
y	Yellow body color	*y* and *w*	0.010	.58 *r*
w	White eye color	*v* and *m*	0.030	
v	Vermilion eye color	*v* and *r*	0.269	.34 *m*
m	Miniature wing	*v* and *w*	0.300	.31 *v*
r	Rudimentary wing	*v* and *y*	0.322	
		w and *m*	0.327	
		y and *m*	0.355	.01 *w*
		w and *r*	0.450	0 *y*

Sturtevant's map

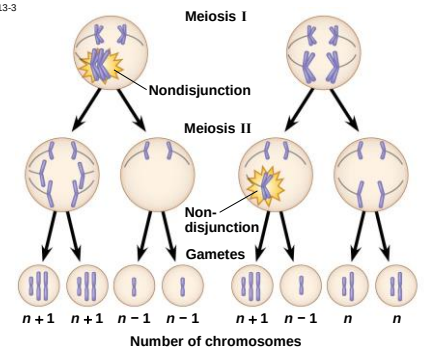
Concept 12.4: Alterations of chromosome number or structure cause some genetic disorders

- Large-scale chromosomal alterations in humans and other mammals often lead to spontaneous abortions (miscarriages) or cause a variety of developmental disorders
- Plants tolerate such genetic changes better than animals do

Abnormal Chromosome Number

- In **nondisjunction**, pairs of homologous chromosomes do not separate normally during meiosis
- As a result, one gamete receives two of the same type of chromosome, and another gamete receives no copy

Figure 12.13-3



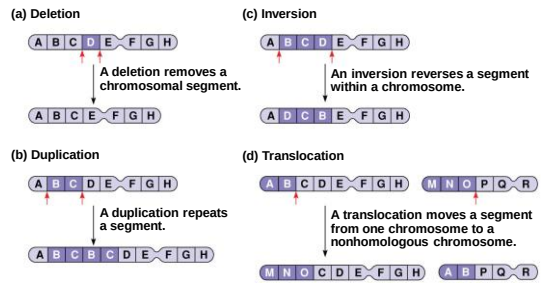
- **Aneuploidy** results from the fertilization of gametes in which nondisjunction occurred
  - Offspring with this condition have an abnormal number of a particular chromosome
  - A **monosomic** zygote has only one copy of a particular chromosome
  - A **trisomic** zygote has three copies of a particular chromosome

- **Polyploidy** is a condition in which an organism has more than two complete sets of chromosomes
  - Triploidy (3*n*) is three sets of chromosomes
  - Tetraploidy (4*n*) is four sets of chromosomes
- Polyploidy is common in plants, but not animals
- Polyploids are more normal in appearance than aneuploids

Alterations of Chromosome Structure

- Breakage of a chromosome can lead to four types of changes in chromosome structure
  - **Deletion** removes a chromosomal segment
  - **Duplication** repeats a segment
  - **Inversion** reverses orientation of a segment within a chromosome
  - **Translocation** moves a segment from one chromosome to another
- Might be able to be identified by chromosomal banding

Figure 12.14



- A diploid embryo that is homozygous for a large deletion is likely missing a number of essential genes; such a condition is generally lethal
- Duplications and translocations also tend to be harmful
- In inversions, the balance of genes is normal but phenotype may be influenced if the expression of genes is altered

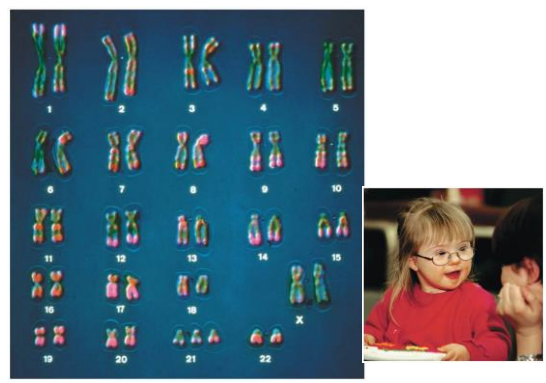
Human Disorders Due to Chromosomal Alterations

- Alterations of chromosome number and structure are associated with some serious disorders
- Some types of aneuploidy upset the genetic balance less than others, resulting in individuals surviving to birth and beyond
- These surviving individuals have a set of symptoms, or syndrome, characteristic of the type of aneuploidy

Down Syndrome (Trisomy 21)

- **Down syndrome** is an aneuploid condition that results from three copies of chromosome 21
- It affects about one out of every 700 children born in the United States
- The frequency of Down syndrome increases with the age of the mother, a correlation that has not been explained

Figure 12.15a

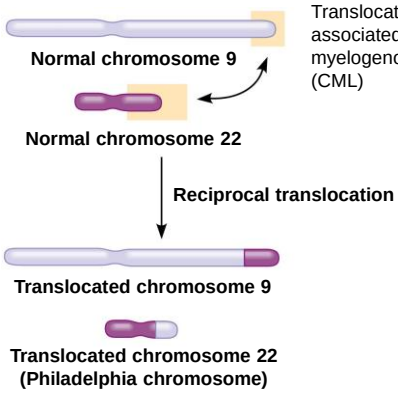


Aneuploidy of Sex Chromosomes

- Nondisjunction of sex chromosomes produces a variety of aneuploid conditions
  - Klinefelter syndrome is the result of an extra chromosome in a male, producing XXY individuals
  - Females with trisomy X (XXX) have no unusual physical features except being slightly taller than average
  - Monosomy X, called Turner syndrome, produces X0 females, who are sterile
    - It is the only known viable monosomy in humans

Disorders Caused by Structurally Altered Chromosomes

- The syndrome *cri du chat* ("cry of the cat") results from a specific deletion in chromosome 5
  - A child born with this syndrome is mentally retarded and has a catlike cry; individuals usually die in infancy or early childhood
- Certain cancers, including *chronic myelogenous leukemia* (CML), are caused by translocations of chromosomes



Translocation associated with chronic myelogenous leukemia (CML)

Figure 12.UN03b

Testcross offspring	Expected (e)	Observed (o)	Deviation ($o - e$)	$(o - e)^2$	$(o - e)^2/e$
Purple stem/ short petals ($A-B-$)		220			
Green stem/ short petals ($aaB-$)		210			
Purple stem/ long petals ($A-bb$)		231			
Green stem/ long petals ($aabb$)		239			
				χ^2 = Sum	