

## Chromosomal Theory of Inheritance

1. Around 1900, cytologists and geneticists began to notice connections between the behavior of chromosomes and the behavior of genes.
  - a. Chromosomes and genes are both present in pairs in diploid cells.
  - b. Homologous chromosomes separate and alleles segregate during meiosis.
  - c. These observations led to the development of the **chromosome theory of inheritance**.
    - i. Genes occupy specific loci on chromosomes.
    - ii. Chromosomes undergo segregation during meiosis.
    - iii. Chromosomes undergo independent assortment during meiosis.
  - d. The behavior of homologous chromosomes during meiosis can account for the segregation of the alleles at each genetic locus to different gametes.
  - e. The behavior of nonhomologous chromosomes can account for the independent assortment of alleles for two or more genes located on different chromosomes.
  - f. Fertilization restores chromosomes and genes to pairs.
  
2. Thomas Morgan was the first to show that genes are located on chromosomes.
  - a. Morgan worked with *Drosophila melanogaster*, a fruit fly that eats fungi on fruit.
  - b. Morgan spent a year looking for variant individuals among the flies he was breeding. He discovered a single male fly with white eyes instead of the usual red.
    - i. The normal character phenotype is the **wild type**.
    - ii. Alternative traits are called *mutant phenotypes* because they are due to alleles that originate as mutations in the wild-type allele.
      - (1) He developed a different notation for genetic symbols. For example, the allele for the white eye mutation is symbolized by  $w$ , while the normal allele is symbolized by  $w^+$ .
      - (2) If the mutation is recessive, a lower case letter is used. Upper case is used for dominant mutant alleles. For example, curly wings is caused by a dominant allele and is symbolized by  $Cy$ , while normal wings is  $Cy^+$ .
  - c. When Morgan crossed his white-eyed male with a red-eyed female, all the  $F_1$  offspring had red eyes, suggesting that the red allele was dominant to the white allele.
  - d. Crosses between the  $F_1$  offspring produced the 3:1 phenotypic ratio in the  $F_2$  offspring.
    - i. On closer inspection, however, he noticed that only males had white eyes and, among males, he noticed only half of them had white eyes.
    - ii. Morgan concluded that a fly's eye color was linked to its sex and that the gene with the white-eyed mutation is on the X chromosome, with no corresponding allele present on the Y chromosome.
      - (1) Females (XX) may have two red-eyed alleles and have red eyes or may be heterozygous and have red eyes.
      - (2) Males (XY) have only a single allele. They will be red-eyed if they have a red-eyed allele or white-eyed if they have a white-eyed allele.
  
3. In female mammals, only one X chromosome is active.
  - a. Therefore, males and females have the same number of copies of the genes on the X chromosome.
  - b. During early embryonic development, one X chromosome per cell condenses into a compact object near the nuclear membrane called a **Barr body**.
    - i. Most of the genes on the Barr-body chromosome are not expressed.
    - ii. The selection of which X chromosome will form the Barr body occurs randomly and independently in embryonic cells at the time of X inactivation.

- iii. As a result, females consist of a mosaic of two types of cells, some with an active paternal X chromosome, others with an active maternal X chromosome.
  - (1) After an X chromosome is inactivated in a particular cell, all the cells that result from that cell by mitosis will have the same inactive X.
  - (2) If a female is heterozygous for a sex-linked trait, approximately half her cells will express one allele, and the other half will express the other allele.
  
- 4. The number of genes in a cell is far greater than the number of chromosomes so it stands to reason that each chromosome must carry many genes. These genes would tend to be inherited together and are called **linked genes**.
  - a. Results of crosses with linked genes are different from those expected according to independent assortment because the genes travel together.
  - b. In one cross, Morgan considered body color and wing size.
    - i. The wild-type body color is gray ( $b^+$ ), and the mutant is black ( $b$ ).
    - ii. The wild-type wing size is normal ( $vg^+$ ), and the mutant has vestigial wings ( $vg$ ).
    - iii. The mutant alleles are recessive to the wild-type alleles.
    - iv. Morgan crossed  $F_1$  heterozygous females ( $b^+bvg^+vg$ ) with homozygous recessive males ( $bbvgvg$ ).
  - c. According to independent assortment, this should produce 4 phenotypes in a 1:1:1:1 ratio.
  - d. He found that most offspring had the same phenotypes as the parents, but other phenotypes were also observed.
  - e. He reasoned that body color and wing shape are usually inherited together because the genes for these characters are on the same chromosome.
  - f. We would not expect linked genes to recombine into assortments of alleles not found in the parents because they travel on the same chromosome.
    - i. If the genes are completely linked, we should expect to see a 1:1:0:0 ratio with only parental phenotypes among offspring because no other combinations are possible.
  - g. Although most of the offspring did have the parental phenotype, some of the flies were **genetic recombinants**, having phenotypes different from the parents.
    - i. Morgan figured something must have broken the linkage and allowed the genes to be inherited separately.
  - h. This process is called **crossing over**.
    - i. Crossing over should occur more often between two genes as the distance between those two genes increased.
    - ii. The percentage of recombinant offspring, the **recombination frequency**, is related to the distance between linked genes.
    - iii. The farther apart two genes are, the higher the probability that a crossover will occur between them, and therefore, the higher the recombination frequency.