Chromosomal Basis of Inheritance

Ch. 3

THE CHROMOSOME THEORY OF INHERITANCE AND SEX CHROMOSOMES

- The chromosome theory of inheritance describes how the transmission of chromosomes account for the Mendelian patterns of inheritance

- This theory was independently proposed in 1902-03 by
  - Theodore Boveri, a German
  - Walter Sutton, an American

- The chromosome theory of inheritance is based on a few fundamental principles
  - 1. Chromosomes contain the genetic material
  - 2. Chromosomes are replicated and passed along from parent to offspring
  - 3. The nuclei of most eukaryotic cells contain chromosomes that are found in homologous pairs
    - During meiosis, each homologue segregates into one of the two daughter nuclei
  - 4. During the formation of gametes, different types of (nonhomologous) chromosomes segregate independently
  - 5. Each parent contributes one set of chromosomes to its offspring
    - The sets are functionally equivalent
      - Each carries a full complement of genes

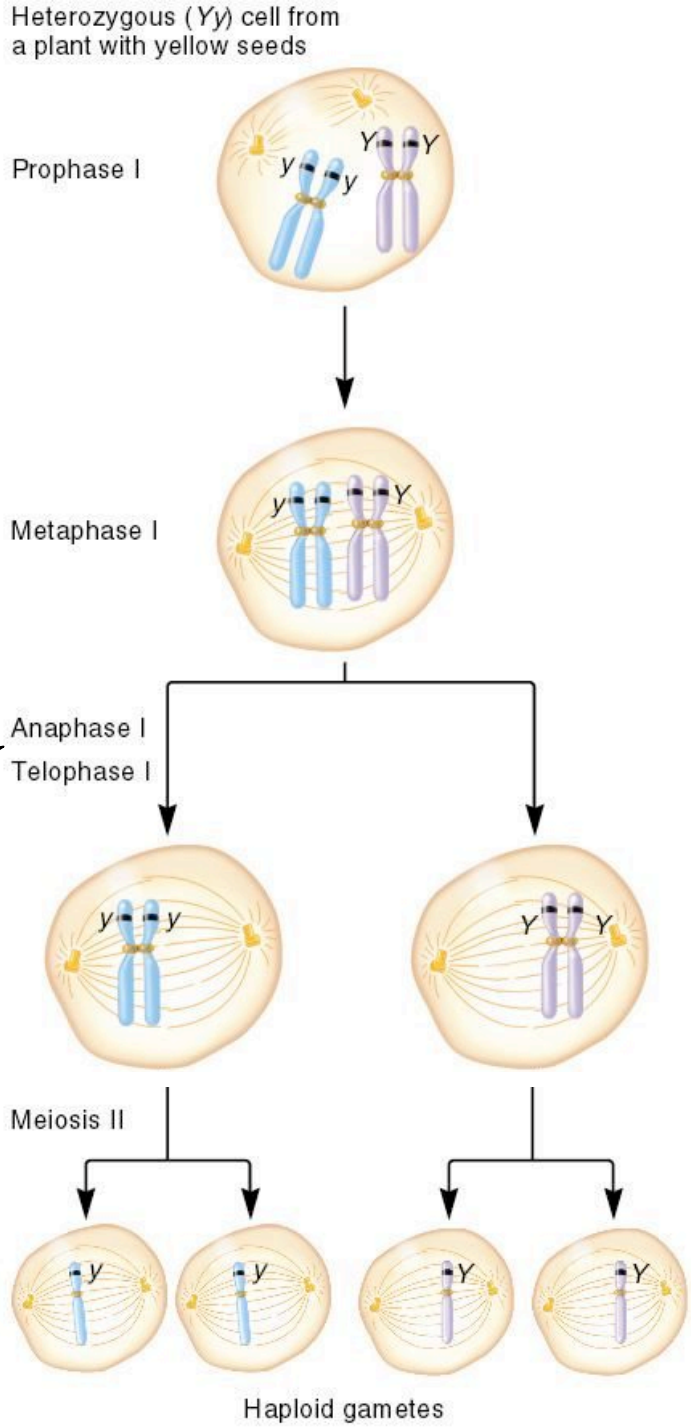
- The chromosome theory of inheritance allows us to see the relationship between Mendel's laws and chromosome transmission

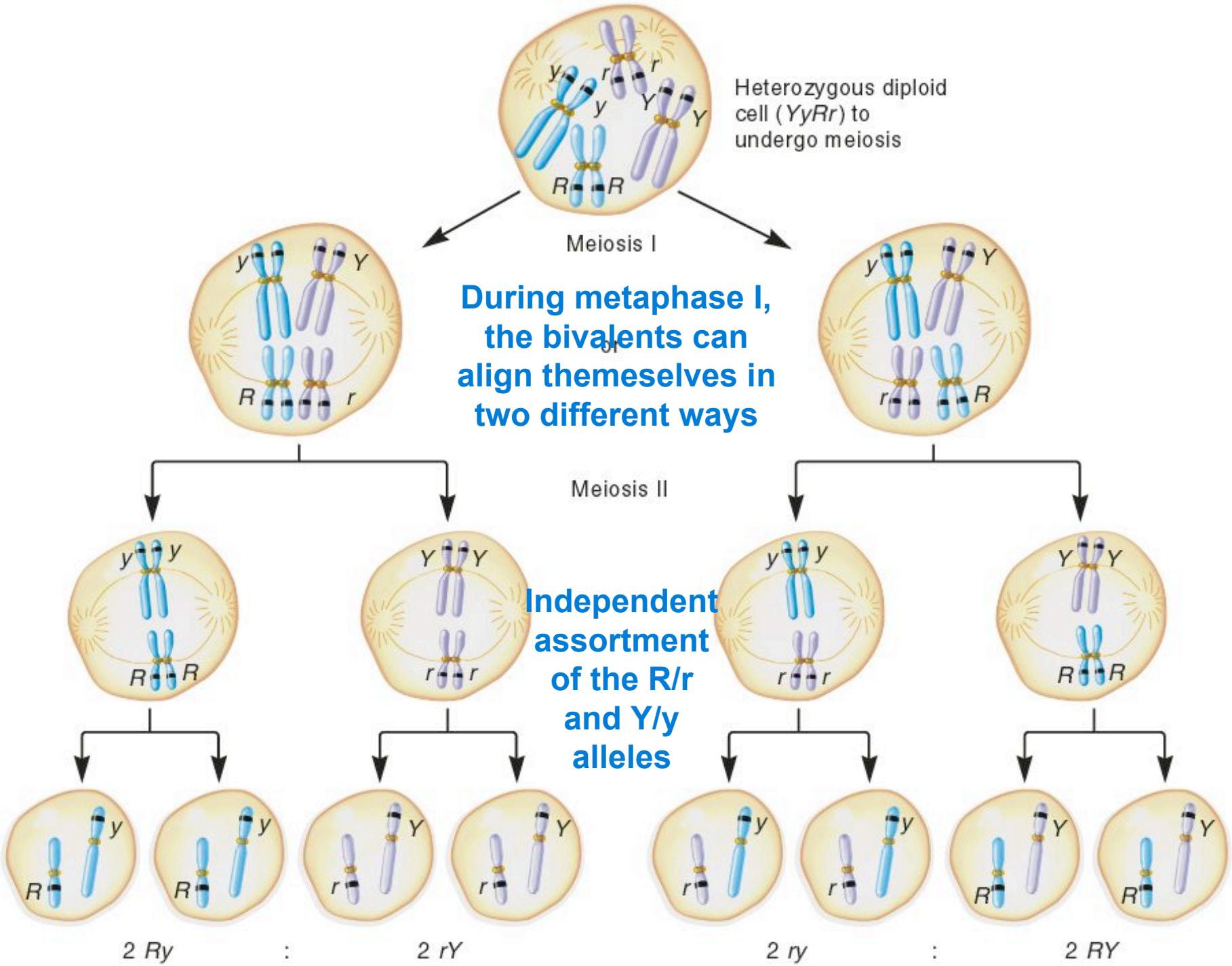
  – Mendel's law of segregation can be explained by the homologous pairing and segregation of chromosomes during meiosis

  – Mendel's law of independent assortment can be explained by the relative behavior of different (nonhomologous chromosomes) during meiosis

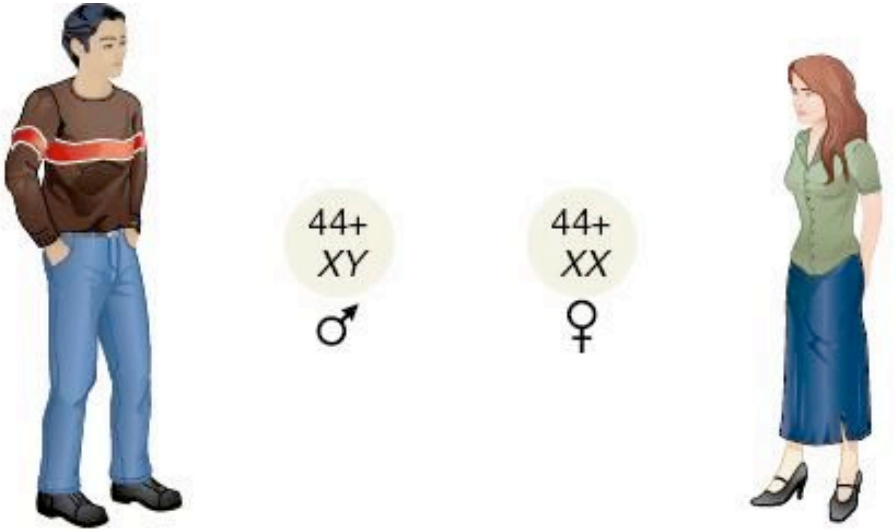
Homologous chromosomes segregate from each other

This leads to the segregation of the alleles into separate gametes



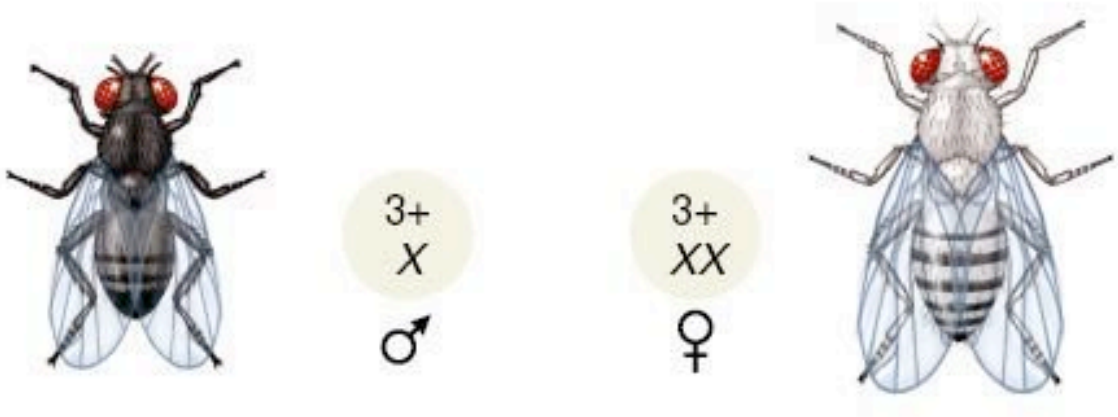

Heterozygous diploid cell (YyRr) to undergo meiosis
Meiosis I
During metaphase I, the bivalents can align themeselves in two different ways
or
Meiosis II
Independent assortment of the R/r and Y/y alleles
2 Ry : 2 rY
2 ry : 2 RY

- Humans have 46 chromosomes
  - 44 autosomes
  - 2 sex chromosomes
- Males contain one X and one Y chromosome
  - They are termed heterogametic
- Females have two X chromosomes
  - They are termed homogametic
- The Y chromosome determines maleness



(a) *X-Y* system in mammals

- In some insects,
  - Males are XO and females are XX
- In other insects (fruit fly, for example)
  - Males are XY and females are XX
- The Y chromosome does not determines maleness
- Rather, it is the ratio between the X chromosomes and the number of sets of autosomes (X/A)
  - If X/A = 0.5, the fly becomes a male
  - If X/A = 1.0, the fly becomes a female



(b) The *X*-O system in certain insects

Transmission of Genes Located on Human Sex Chromosomes

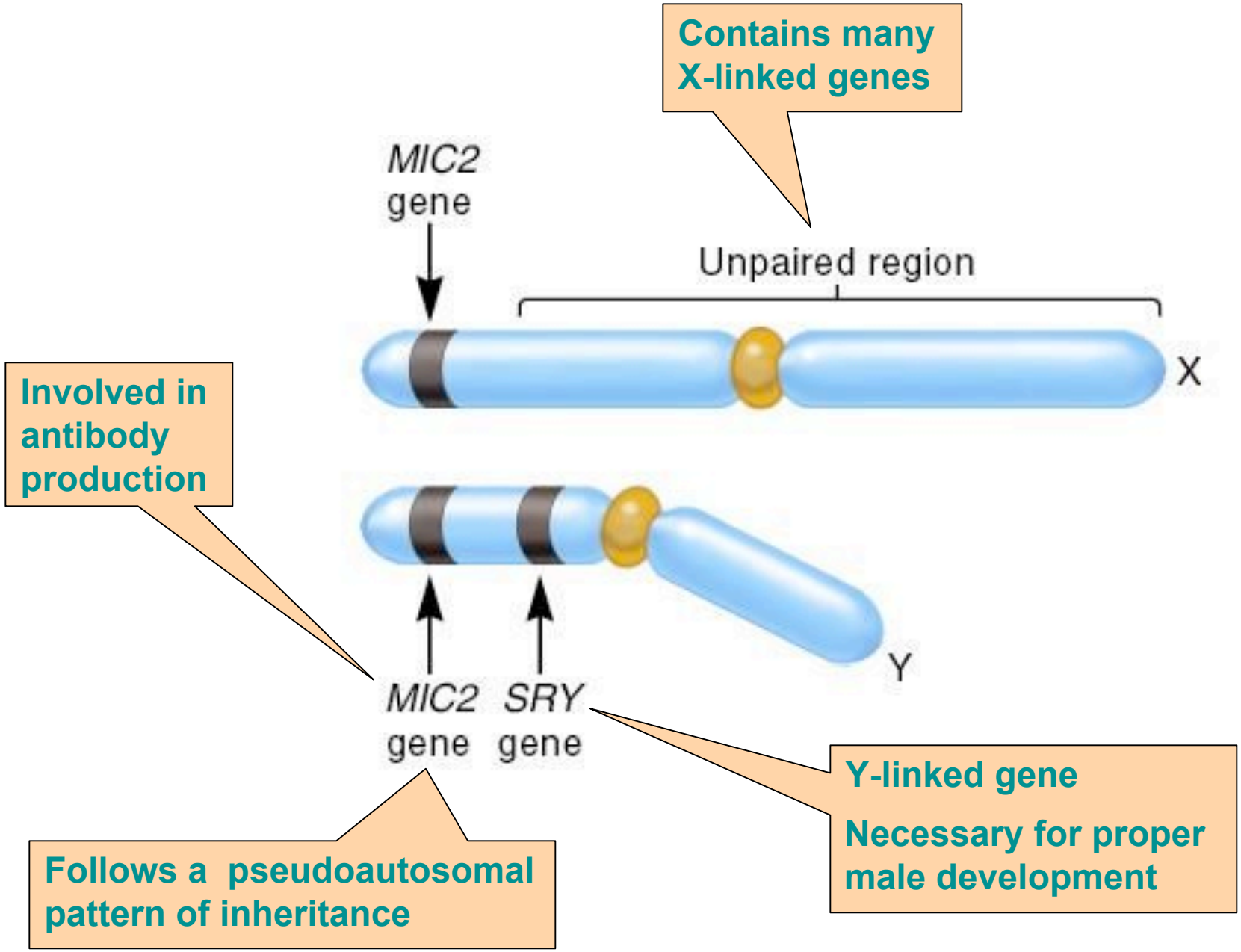
- Genes that are found on one of the two types of sex chromosomes but not on both are termed sex-linked
  - Indeed, sex-linked and X-linked tend to be used synonymously

- Males have only one copy of the X chromosome
  - They are said to be hemizygous for their X-linked genes

- Genes that are found on the Y chromosome are called holandric genes

- The X and Y chromosomes also contain short regions of homology at one end
  - These promote the necessary pairing of the two chromosomes in meiosis I of spermatogenesis

- The few genes found in this homologous region follow a pseudoautosomal pattern of inheritance
  - Their inheritance pattern is the same as that of a gene found on an autosome



Dosage Compensation

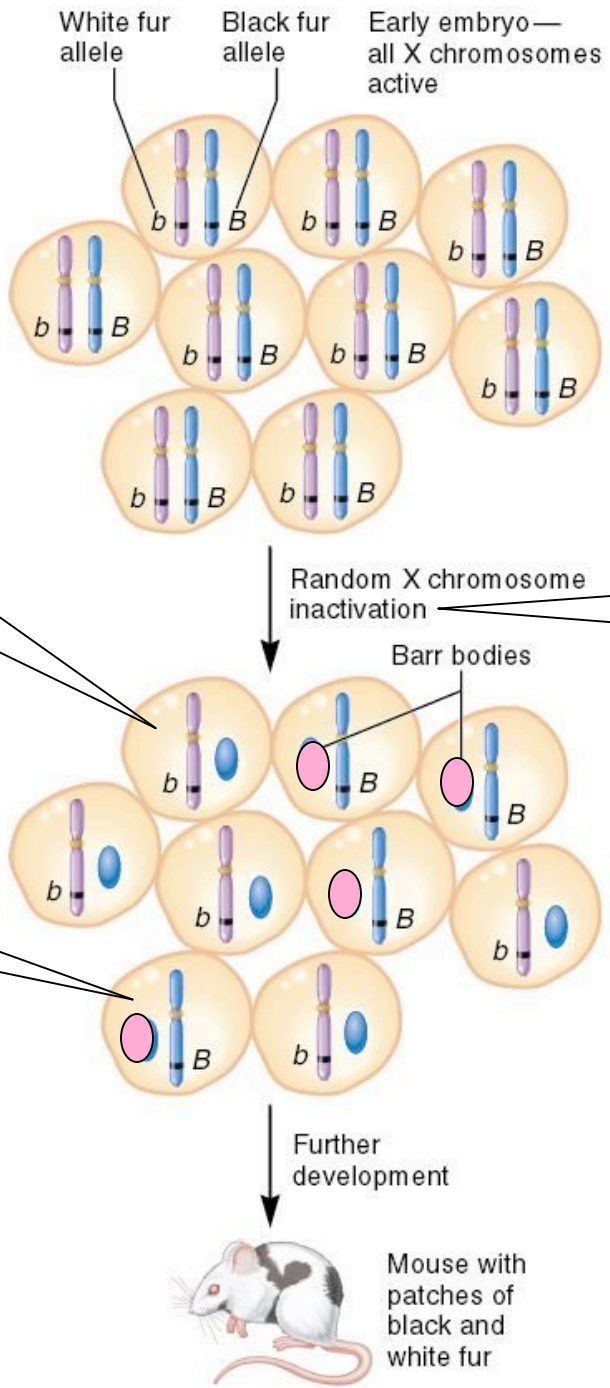
- The purpose of dosage compensation is to offset differences in the number of active sex chromosomes, and their gene products.

- In order for dosage compensation to work, one copy of the X chromosomes in females must be “inactivated” during embryonic development to prevent over expression of gene products.

- In 1949, Murray Barr and Ewart Bertram identified a highly condensed structure in the interphase nuclei of somatic cells in female cats but not in male cats
  - This structure became known as the Barr body.
- In 1960, Susumu Ohno correctly proposed that the Barr body is a highly condensed X chromosome
- In 1961, Mary Lyon proposed that dosage compensation in mammals occurs by the inactivation of a single X chromosome in females
  - Note: Liane Russell also proposed the same theory at about the same time

The epithelial cells derived from this embryonic cell will produce a patch of **white** fur

While those from this will produce a patch of **black** fur



At an early stage of embryonic development

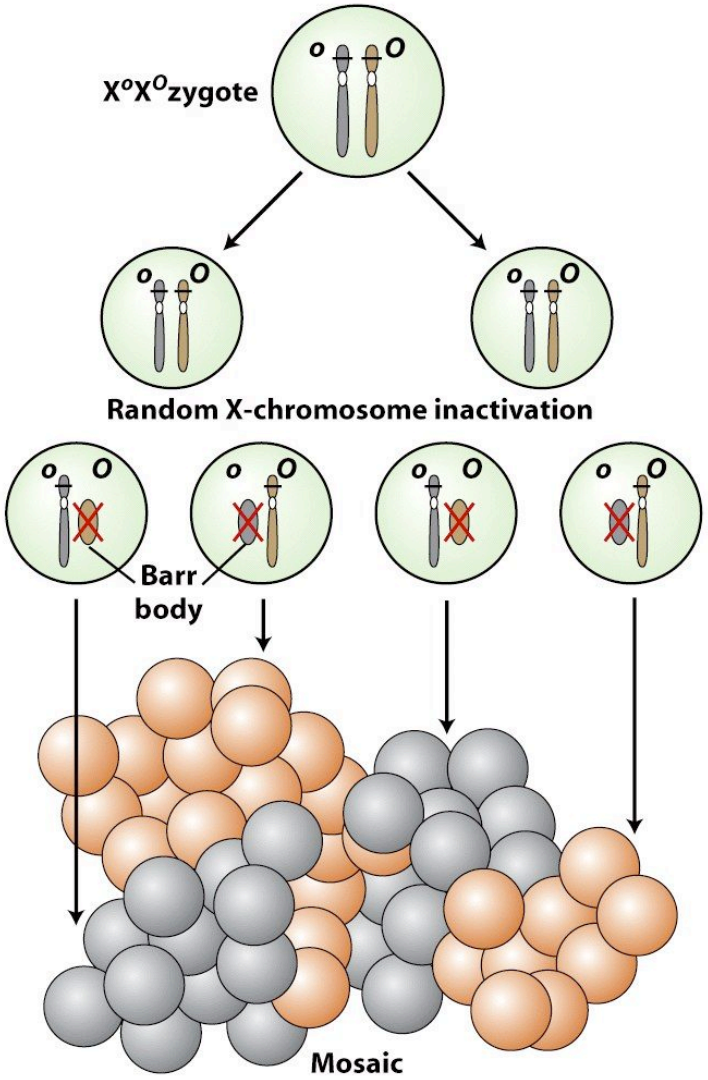
Calico cats are almost always female.

X linked coat color gene:

O - orange
o - black

Are there any male calico cats? → They are very rare and sterile. (XXY Klinefelter male cat)

X Inactivation Example



- During X chromosome inactivation, the DNA becomes highly compacted
  - Most genes on the inactivated X cannot be expressed
- When the inactivated X is replicated during cell division
  - Both copies remain highly compacted and inactive
- In a similar fashion, X inactivation is passed along to all future somatic cells

X Inactivation

- X inactivation involves three steps:
  - Chromosome counting (determining number of Xs in the cell).
  - Selection of an X for inactivation.
  - Inactivation itself.

Facts on X inactivation

- Involves tight condensation of extra X chromosomes into Barr bodies
- Occurs randomly within cells (no preference between maternal or paternal derived X chromosome).

Homework Problems

- Chapter 3
- # 5, 12, 18,