Lecture 12 & 13. Sex determination: Autosomes and sex chromosomes - chromosomal theory of sex determination - different types – sex determination in human, fowl, butterfly, grasshopper, honey bee, fumea; Genic balance theory of Bridges, quantitative theory, hormonal theory, barr bodies, metabolic differentiation theory; Gynandromorphs – sex reversal in chicken

Dr. DD

Sex Determination Mechanisms

- **Hermaphroditism**: both sexes in the same organism
  - **Monoecious**: both male and female reproductive structures in the same organism
  - **Dioecious**: either male or female reproductive structures in one organism

SEX DETERMINATION ?

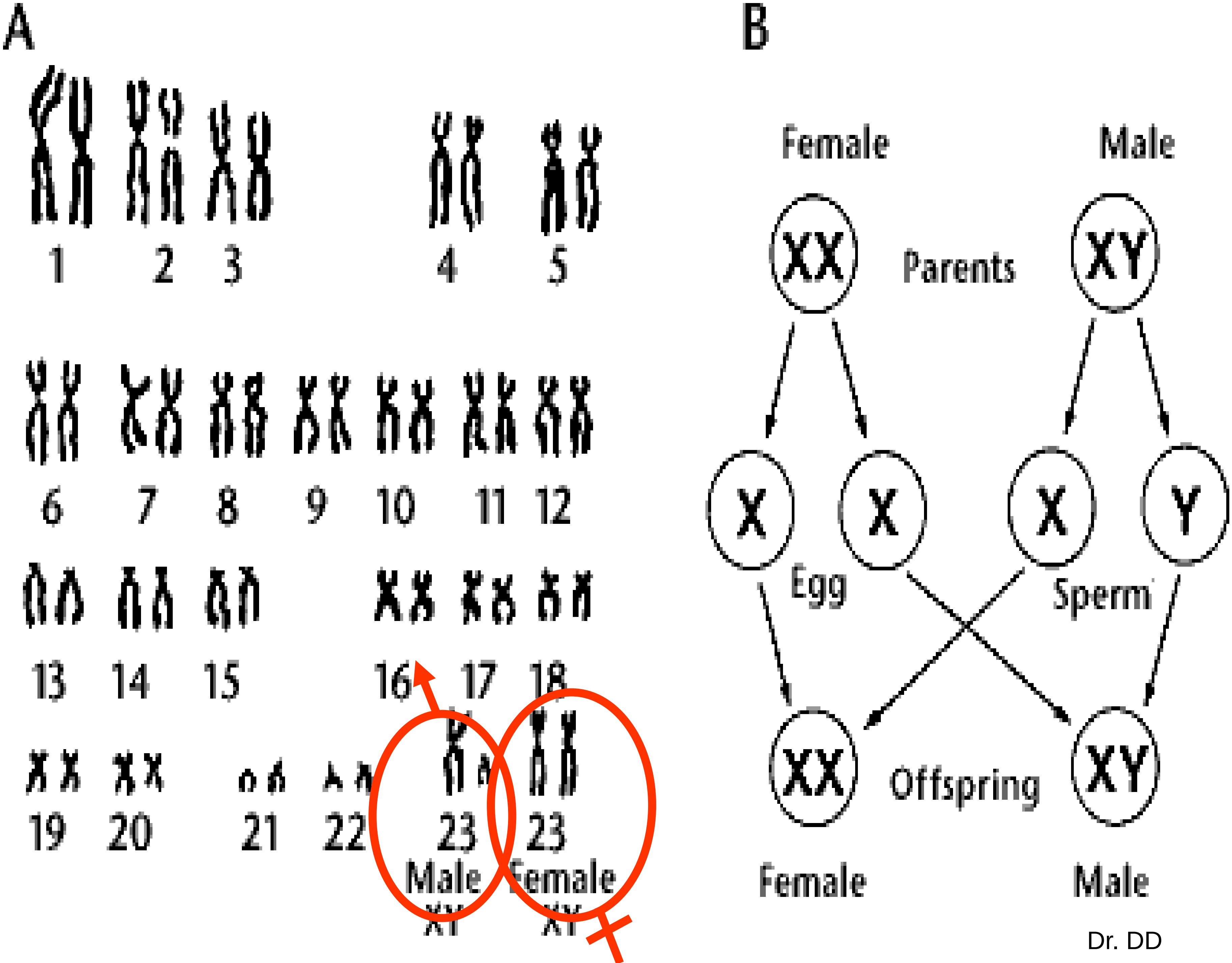
The process of sex differentiation, which utilises various genetical concepts to decide whether a particular individual will develop into male or female sex

SEX DETERMINATION

Sex chromosomes were first discovered by

Mc Lung in 1902, in grass hoppers and later by

Wilson and Stevens in 1905 in Protenor



A
1
2
3
4
5
6
7
8
9
10
11
12
13
14
15
16
17
18
19
20
21
22
23
23
Male
Female
B
Female
Male
XX
Parents
XY
X
X
X
Y
Egg
Sperm
XX
Offspring
XY
Female
Male

Dr. DD

Sexual Differentiation

1. Autosomes
2. Sex chromosomes
3. Heterogametic sex (2 types of gametes)
4. Homogametic sex (1 type of gamete)
5. Males are not always heterogametic sex - females are heterogametic in birds, moths, fish and chickens

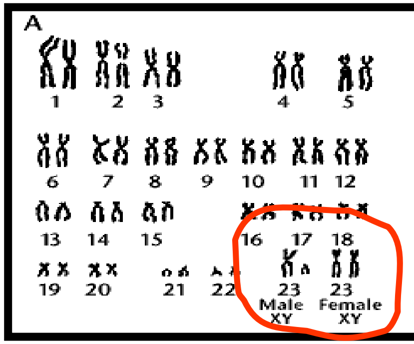
XX/XY – male heterogametic sex

ZZ/ZW – female heterogametic

Sexual Differentiation

A. Primary Sexual Differentiation – gonads
B. Secondary Sexual Differentiation – overall appearance of the organism
C. Unisexual, Dioecious, Gonochoric – containing only male or female reproductive organs
D. Bisexual, Monoecious, Hermaphorditic – both male and female reproductive organs

Difference between autosomes and allosomes



Autosomes:	Allosomes: or sex chromosomes
Other than sex chrom.	These are sex chromosomes
Morphology similar to male and female sex	Morphology is different in male and female sex
Number is same in both sexes	Number sometime differ in male and female sex
Generally control traits other than sex	Usually determine sex of an individual
Number of autosomes differ from sp. to sp.	Each diploid organism has two allosomes
Do not exhibit sex linkage	Exhibit sex linkage

Mechanism of sex determination

Environmnmtal

Equisetum plants- under optimum condition- female; adverse condition- male

Melons , cucumber , *Cannabis* etc., the sex of flower is affected by env. factors such as temperature, day-length, GA_3 , Some ions – Ca^{++}, Mg^{++} etc.,

Chromosomal

Some species of plants show clear cut sex chromosomes :

XX female, XY male

XY female, XX male

XX female, $XY_1 Y_2$ male

XX female, XO male

Genic

Papaya single gene with 3 alleles

Chromosomal Sex-Determination Systems: Sex chromosomes and non-sex chromosomes (autosomes)

- **XX-XO system**:
  - XX – female
  - XO – male
  - grasshoppers

- **XX-XY system**:
  - XX – female
  - XY – male
  - mammals

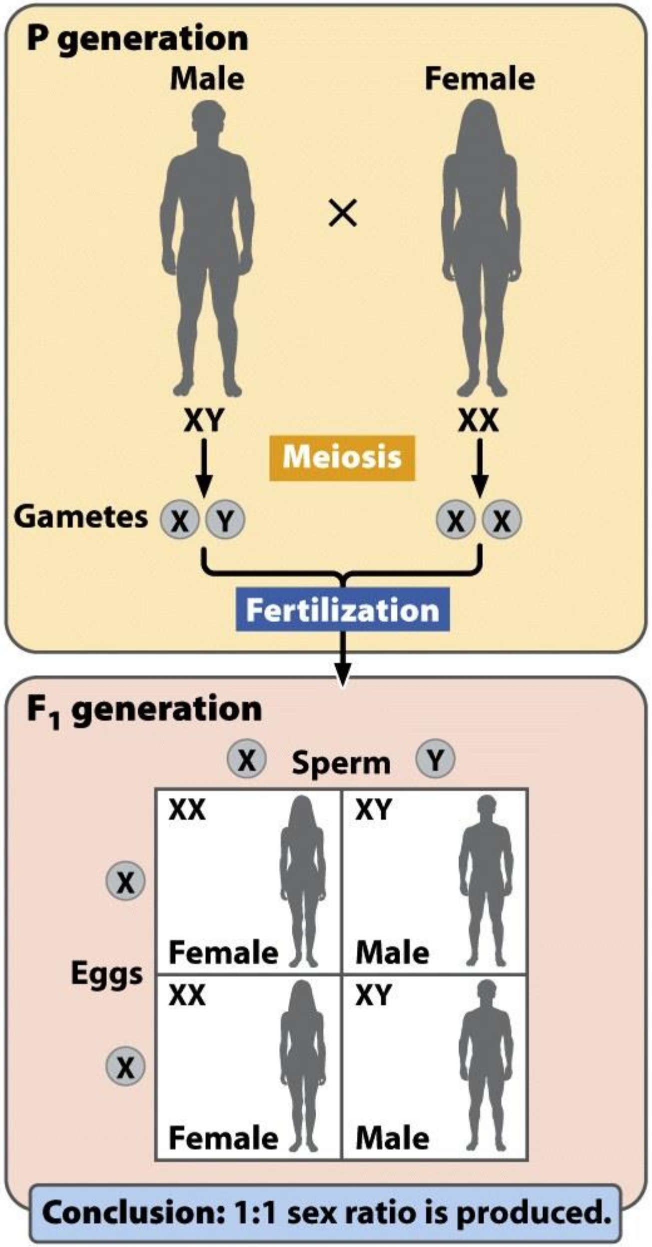


Figure 4-4
Genetics: A Conceptual Approach, Third Edition

Dr. DD

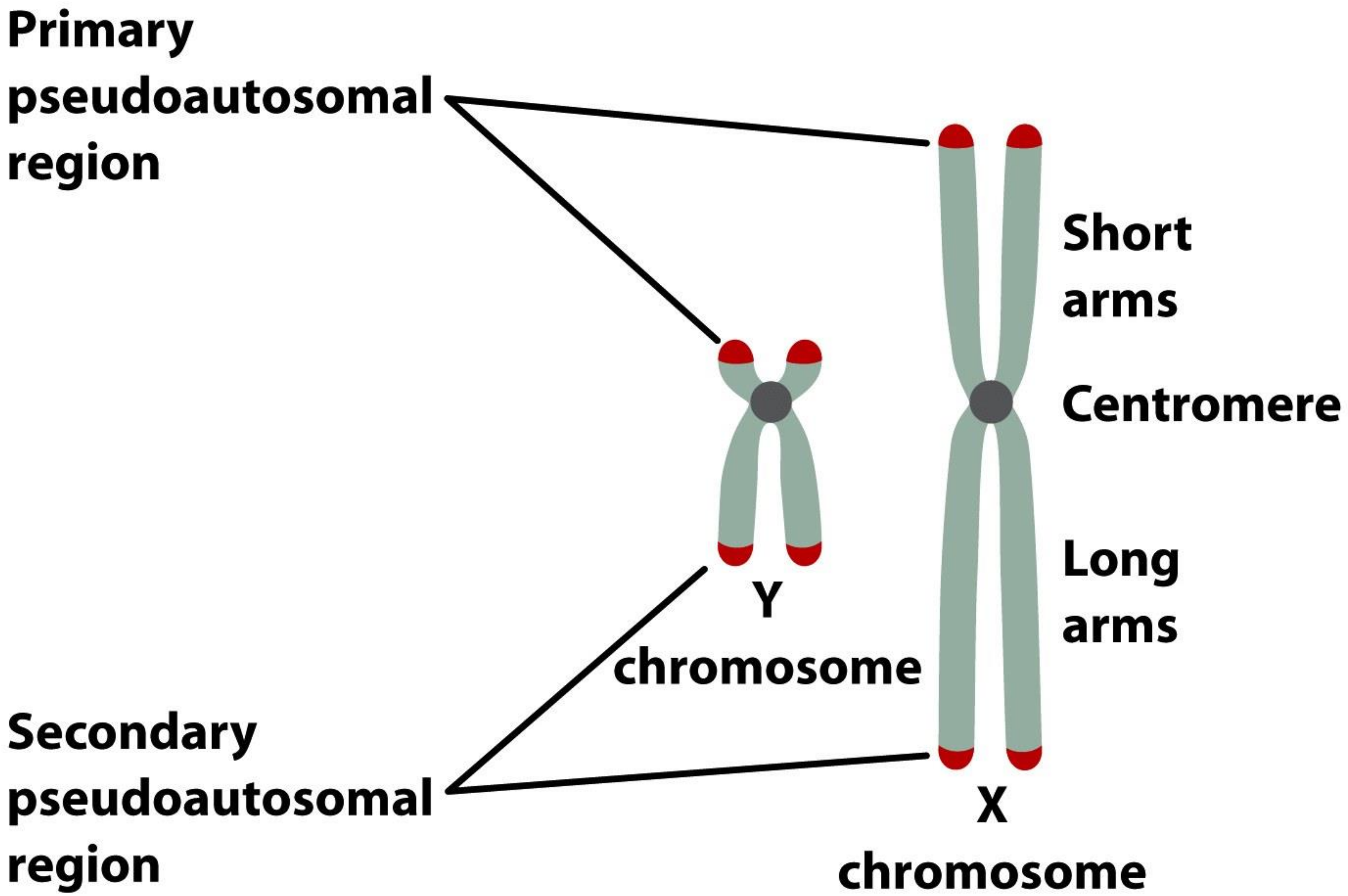
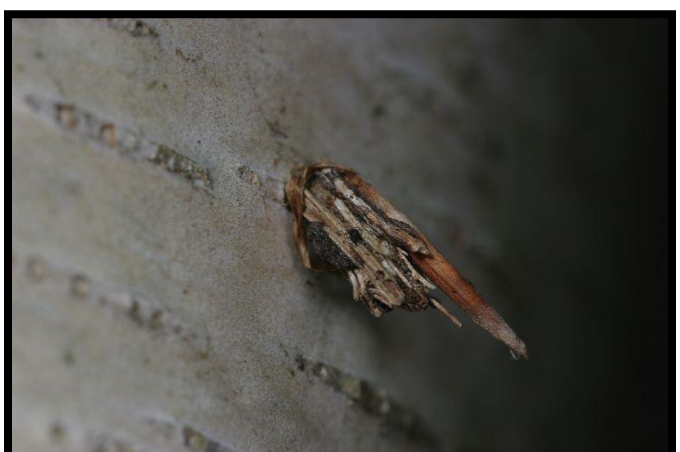


Figure 4-5
Genetics: A Conceptual Approach, Third Edition

XO female and XX male: Female heterogametic and male homogametic

Eg: insects like Fumea



Chromosomal Sex-Determination Systems

- **ZZ-ZW system**:
  - ZZ – male
  - ZW – female
  - Birds, snakes, butterflies, some amphibians, and fishes
- **Haplodiploidy system**:
  - Haploid set – male
  - Diploid set – female
  - Bees, wasps, and ants

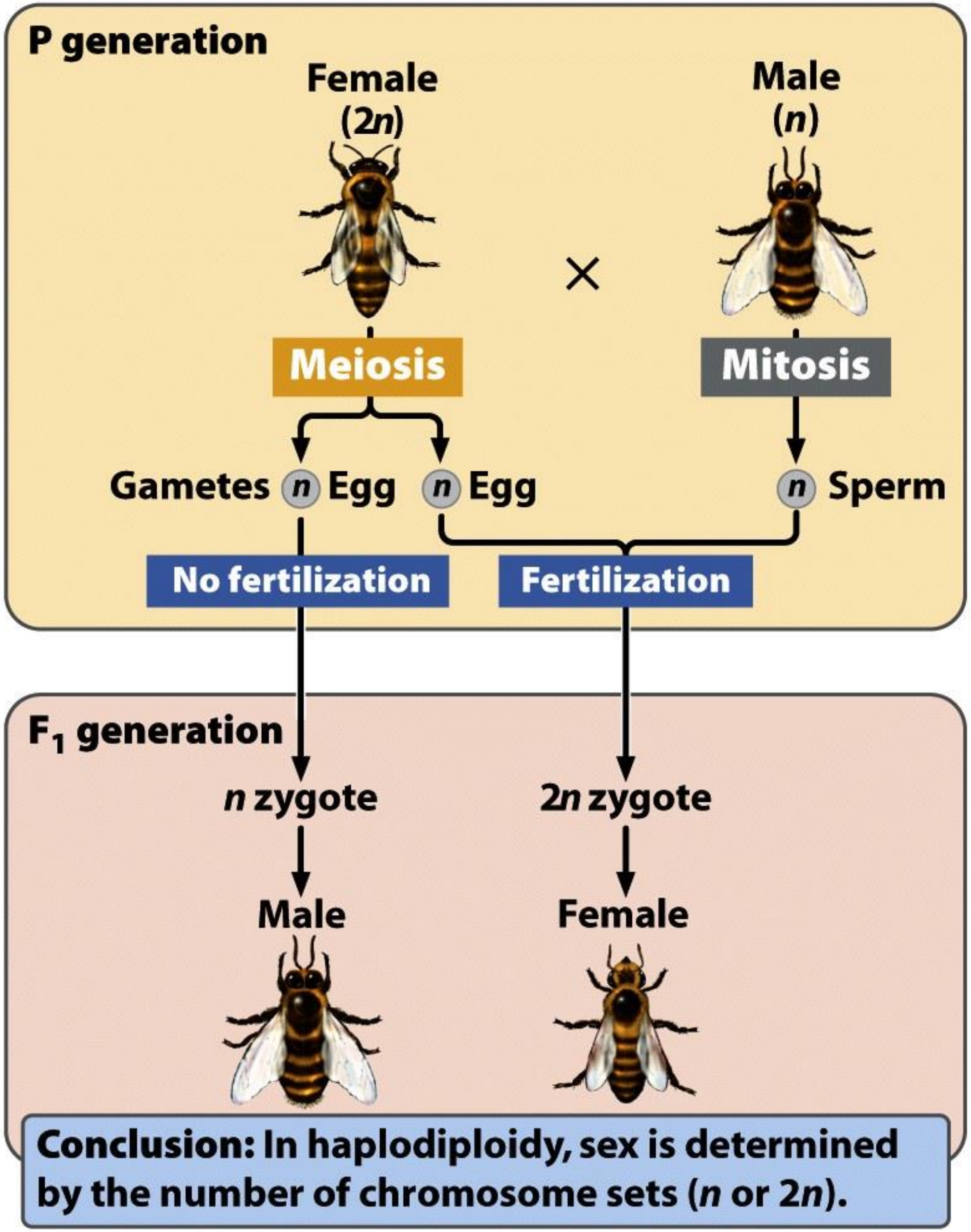


Figure 4-6

Genetics: A Conceptual Approach, Third Edition

Dr. DD

Genic Sex-Determining System

- No sex chromosomes, only the sex-determining genes

Genetic Balance system –Bridges Genic Balance theory

Proposed by Bridges in 1922 in Drosophila

Genetic balance theory states that sex determining genes are present in X chromosomes as well as autosomes; male sex determining genes in autosomes and female in X chromosomes. The sex expression is determined by the balance of genes on autosomes and X chromosomes.

Or

the expression of sex depends on the ratio of X chromosomes to that of autosomes;
represented by **X/A** ratio

Sex determination in Drosophila in relation to

Ratio of chromosomes and autosomes (X:A)	Sex index (X/A)	Expression of sex
2X : 2A	1.00	FEMALE
1X : 2A	0.50	MALE
2X : 3A	0.67	INTER SEX
1X : 3A	0.33	SUPER MALE
3X : 2A	1.50	SUPER FEMALE

Quantitative theory of sex determination

- **Goldschmidt** formulated theory based on expt in genetics of Gipsy moth
- When different geographical races like Japanese and European were crossed --- produced intersexes
- Maleness and femaleness are detemined by enzyme produced. GYNASE and ANDREASE responsible for femaleness and maleness respectively.
- The balance between these two enzymes produces different sexes and intersexes in varying degree.

Genic Sex Determination

Papaya (*Carica papaya)*
Spinach (*Spinacea oleracea)*
Graybark grape (*Vitis cinerea)*
Asparagus sex is postulated to be governed by single gene

In Papaya single gene with three alleles m,M_1, M_2 is controlling sex differentiation

Genotype	Survival	Sex-expression
mm	Vital	Female
M_1m	Vital	Male
M_2m	Vital	Hermaphrodite
M_1M_1,M_2M_2 and M_1M_2	Lethal (all die)	

drosophila- transformer gene *(tra)*

tra gene present in autosomes plays a role in sex expression

tra/tra transform the normal diplod females into sterile male

Hetrozygous condition – no effect on male or female

Environmental sex determination (ESD),

in which sex is determined by

1. **temperature (as with turtles),**
2. **local sex ratio (as with some tropical fish), or**
3. **population density (as with mermithid nematodes).**

Little is known about the molecular mechanisms

Environmental sex determination

Bonelia

Larvae attach to proboscis of females

Develop into male

Free living larvae

Develop into female

Fishes - Labroides

Social order of an individual in the colony determines the sex

Male – largest body size

Environmental sex determination

- In most **turtle** species only females are produced at high temperature (30-35°C) and only males are produced at low temperature (23-28°C).
- The sex ratio changes abruptly from all male to all female over just 2°C change in temperature.

Environmental sex determination

- The reverse is true in many **crocodilians** (crocodiles and alligators) and some **lizards** (in other species of lizards and probably in all snakes, sex is genetically controlled), where males are produced at high temperature and females are produced at low temperature

Sex reversal in chicken

Partial sex reversal found in chickens

Crew's chicken

Female – egg layers

Develop male comb , male plumage, begin to crow

Severe disease – destroys the ovary removal of ovary by surgery

Barr bodies

- A **Barr body** is the **inactive** X chromosome in a female somatic cell, rendered inactive in a process called lyonization, in those species in which sex is determined by the presence of the Y (including humans) or W chromosome rather than the diploidy of the X or Z.
- Barr body discovered by Murray Barr)
-

Lyon hypothesis

The Lyon hypothesis states that in cells with multiple X chromosomes, all but one are inactivated during mammalian embryogenesis. This happens early in embryonic development at random in mammals

Barr bodies

- In men and women with more than one X chromosome, the number of Barr bodies visible at interphase is always one less than the total number of X chromosomes.
- For example, men with a 47, XXY karyotype have a single Barr body, whereas women with a 47, XXX karyotype have two Barr bodies. Barr bodies can be seen on the nucleus of neutrophils.

gynandromorph

- A **gynandromorph** is an organism that contains both male and female characteristics. The term *gynandromorph*, from Greek "gyne" female and "andro" male
- These characteristics can be seen in butterflies, where both male and female characteristics can be seen physically because of sexual dimorphism

Gynandromorph in butterfly

Normal female
of *Papilio androgeus*

Mosaic
gynandromorph of
Papilio androgeus

Normal male
of *Papilio*
androgeus

Lecture 26
Sex determination in plants – Melandrium, papaya, maize.

Sex determination in Papaya

m, M_1 & M_2 (3 alleles)

♀ mm

♂ M_1m

M_1M_2
M_1M_1
M_2M_2 } **inviable**

⚥ M_2m

M_1 & M_2 alleles are lethals

Sex determination in maize

Maize being a monoecious plant bears both female (silk) and male (tassel) inflorescences on the same plant.

A recessive gene *ba (barren cob) in* homozygous condition (*baba) makes the cobs barren or non-functional.*

Similarly, a recessive gene *ts in homozygous condition (tsts) converts the male flowers of* tassel into female flowers.

Sex determination in maize

Thus, homozygous state of gene *ba (baba) converts* the monoecious plant into male.

Similarly, gene *ts in homozygous condition (tsts)* converts the monoecious plant into female.

The plants with both dominant genes (*Ba_Ts_) are monoecious, with babaTs_ normal male, with Ba_tsts female, and* with *baba tsts rudimentary females*

Maize –Sex determination

Monoecious

Two recessive genes *ba ts*

BaBa TsTs – monoecious (normal)

baba TsTs – ♂ (♀rudimentary)

BaBa tsts – ♀ (male develop into female)

baba tsts – **(♀rudimentary ♂ flower develop into ♀)**
Female

Sex determination in *Melandrium album (Silene latifolia*)

White Campion- dioecious plant

Sex determination in *Melandrium album (Silene latifolia*)

Table 17.8. **Expression of sex in *Melandrium* with different numbers of X-chromosomes and autosome sets.**

Chromosome constitution	X/A Ratio	Sex	
2A + XX	1.00	Female	
2A + XY	0.50	Male	
2A + XXY	1.00	Male	
3A + XXY	0.67	Male	(occasional ○)
4A + XXY	0.50	Male	
4A + XY	0.25	Male	
4A + XXXY	0.75	Male (occasional ○)	
4A + XXXXY	1.00	Hermaphrodite (occasional ○)	

Comparing to *Drosophila* with *Melandrium, it was* found that male determining genes are present on autosomes in *Drosophila,* but on Y-chromosome in *Melandrium* plants.

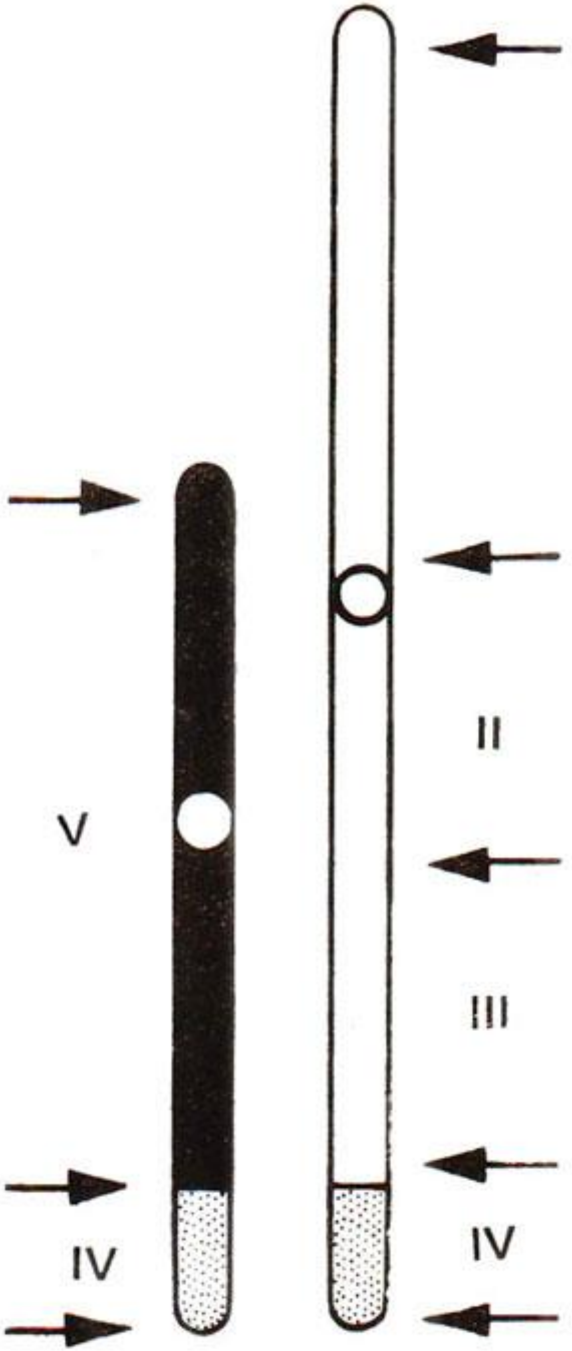
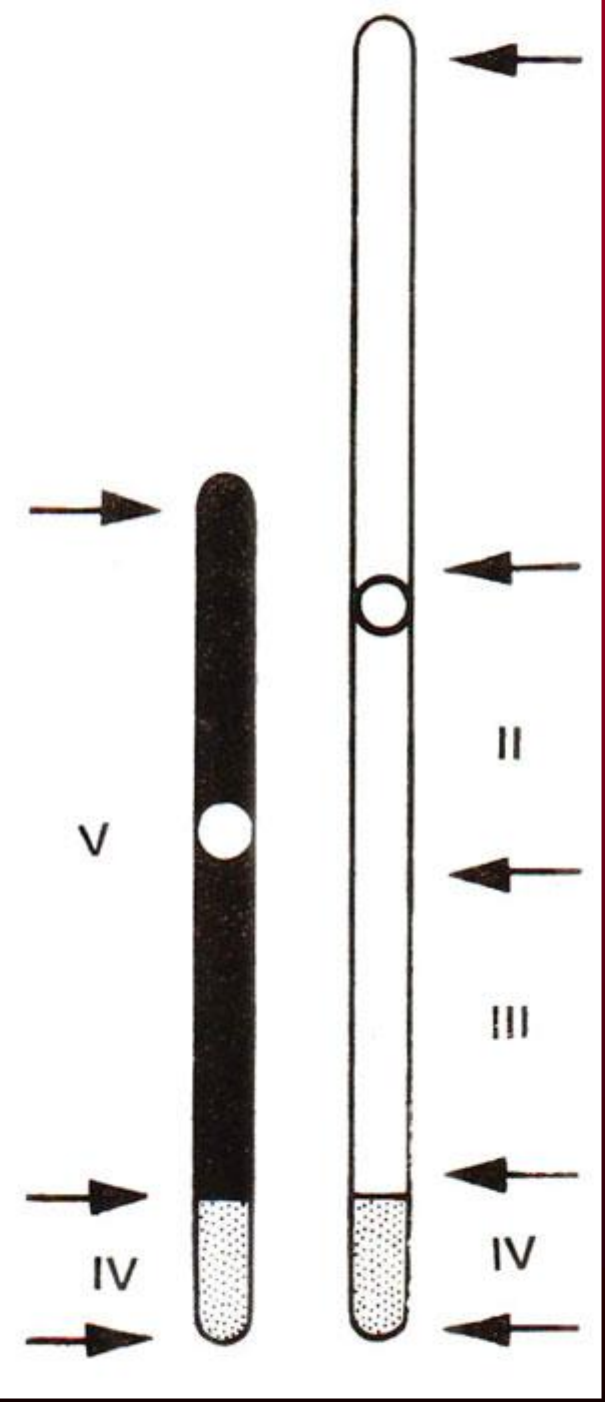


Fig. X and Y chromosomes in *Melandrium album* showing different segments (I, II, III, IV, V) controlling different stages of sex determination and sex differentiation

In *Melandrium,* Y chromosome is longer than X-chromosome, and they form a heteromorphic bivalent at meiosis

Y and X-chromosomes divided into five different segments.

These segments are known to control different stages of development of sex organs



The X and the Y chromosomes have a common segment IV, which helps in pairing and regular disjunction of X and Y chromosomes during meiosis. The remainder of Y chromosome has three segments,

I, suppressing femaleness;

II, initiating anther development

III, controlling late stage of anther development.

The X-chromosome also has a differential segment V, which should promote femaleness in the absence of female suppressing segment I on Y chromosome.