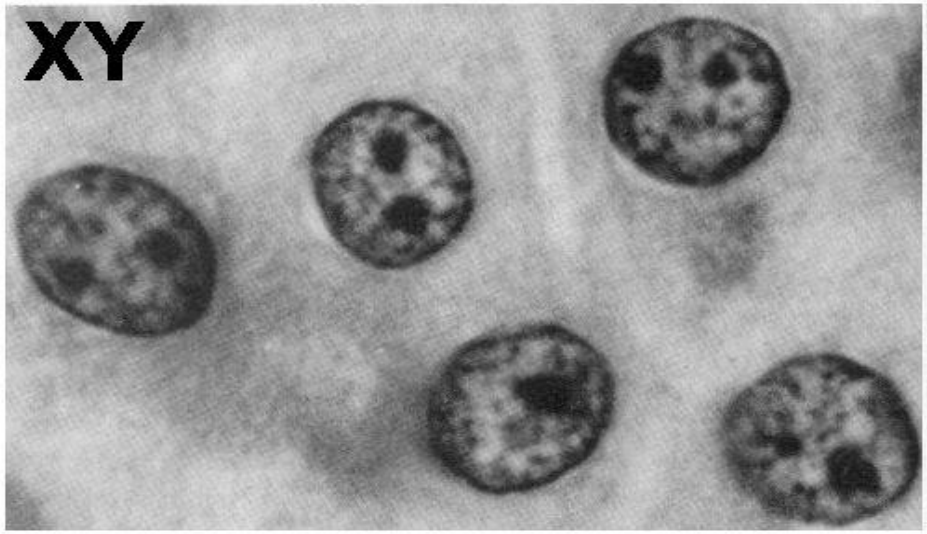

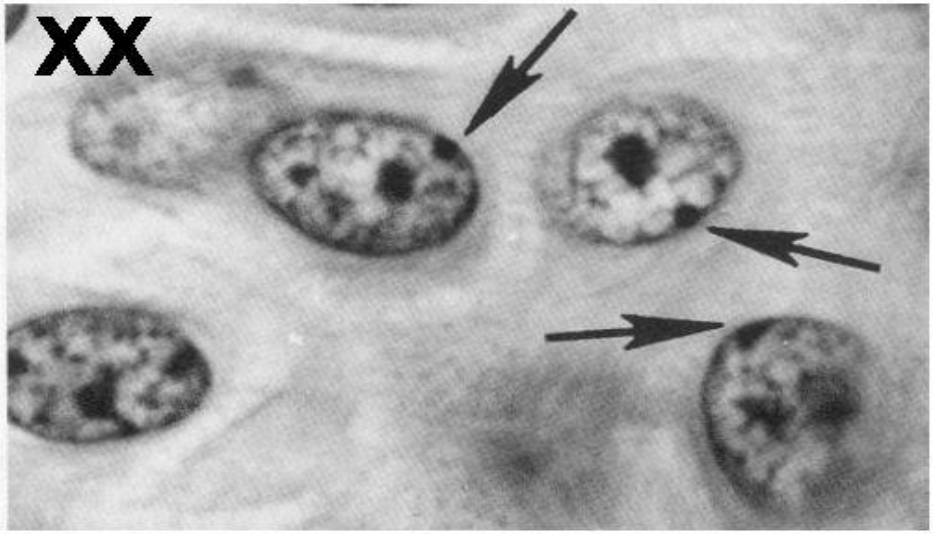

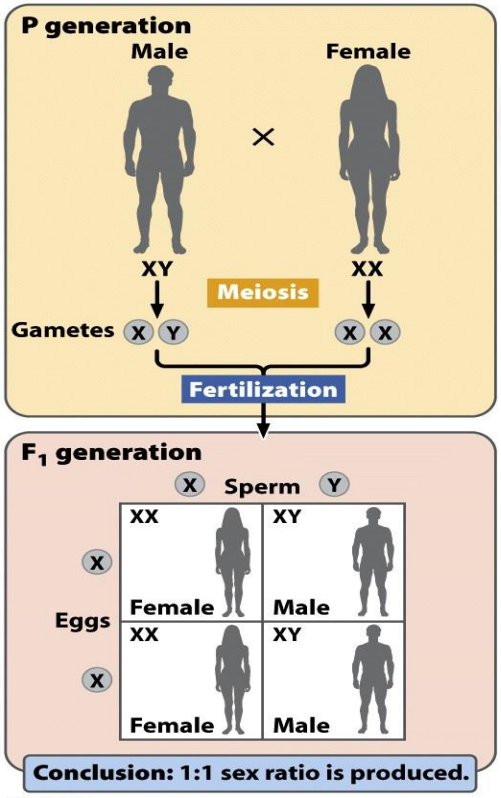

Figure 4-4
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Unit- 5
Sex Determination

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Sex Determination

Mechanism of development of sexual characters in an organism

The act of determining or knowing the organism or embryo to develop into a male or female is called sex determination or differentiation of sex

Majority of animals exhibit sexual dimorphism through distinct external characters

1. Plumage difference between cock and hen, peacock and peahen
2. The hair pattern difference between lion and lioness
3. A man and women are the best examples of sexual dimorphism

History

Aristotle (ca. 335 B.C.):
Sex is determined by "the heat of the male partner during intercourse"

Vesalius (~ 1543) held the same view

During the 1600s and 1700s:
Females were seen as producing eggs that could transmit parental traits, and the physiology of sex organs began to be studied

Until 20th century:
The environment – temperature and nutrients, in particular – was believed to be important

In 1900:

Rediscovery of Mendel's work

In 1902:

Rediscovery of the sex chromosomes (McClung)

In 1905:

Establishment of the correlation (in insects) of the female sex with XX sex chromosomes and the male sex with XY or XO chromosomes (Stevens; Wilson)

- **A specific nuclear component is responsible for directing the development of the sexual phenotype**
- **Evidence accumulated that sex determination occurs by nuclear inheritance rather than by environmental influence**

Today:

Both environmental and internal mechanisms of sex determination can operate in different species

1. **Genotypic sex determination**

2. **Environmental sex determination**

Genotypic sex determination

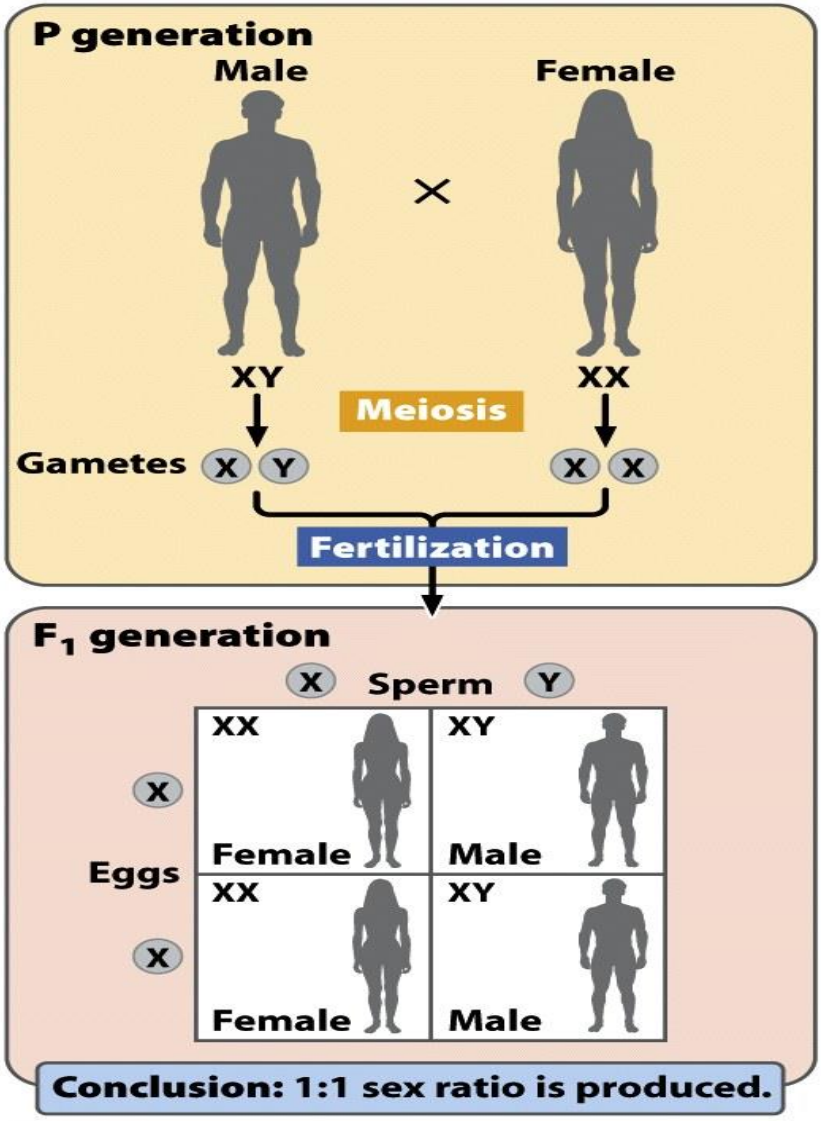
Sex determination is associated with sex chromosomes that are different between male and female individuals

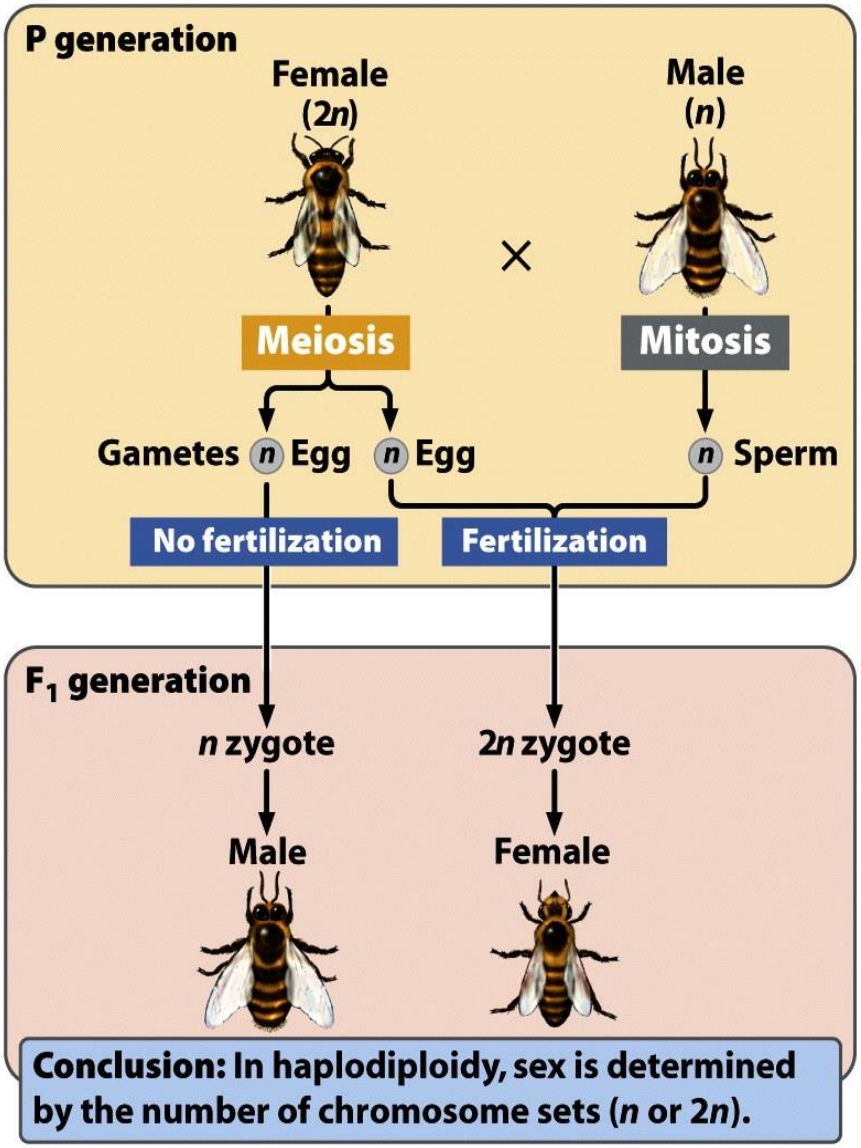
1. Sex chromosomes play a decisive role in the inheritance and determination of sex.

2. Two methods:

    1. Y chromosome mechanism (e.g., humans and other mammals)

    2. X chromosome-autosome balance system (e.g., *Drosophila*, *Caenorhabditis elegans* nematode)


P generation
Male
Female
×
XY
XX
Meiosis
Gametes
X
Y
X
X
Fertilization
F1 generation
X
Sperm
Y
XX
Female
XY
Male
X
Eggs
XX
Female
XY
Male
X
Conclusion: 1:1 sex ratio is produced.


P generation
Female
(2n)
Male
(n)
×
Meiosis
Mitosis
Gametes
n
Egg
n
Egg
n
Sperm
No fertilization
Fertilization
F1 generation
n zygote
2n zygote
Male
Female
Conclusion: In haplodiploidy, sex is determined by the number of chromosome sets (n or 2n).

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

***Drosophila* uses X chromosome autobalance to determine sex.**

Designated X and Y in species in which the male is heterogametic (XY).

W and Z in species in which the female is heterogametic (WZ).

Sex determination in Humans

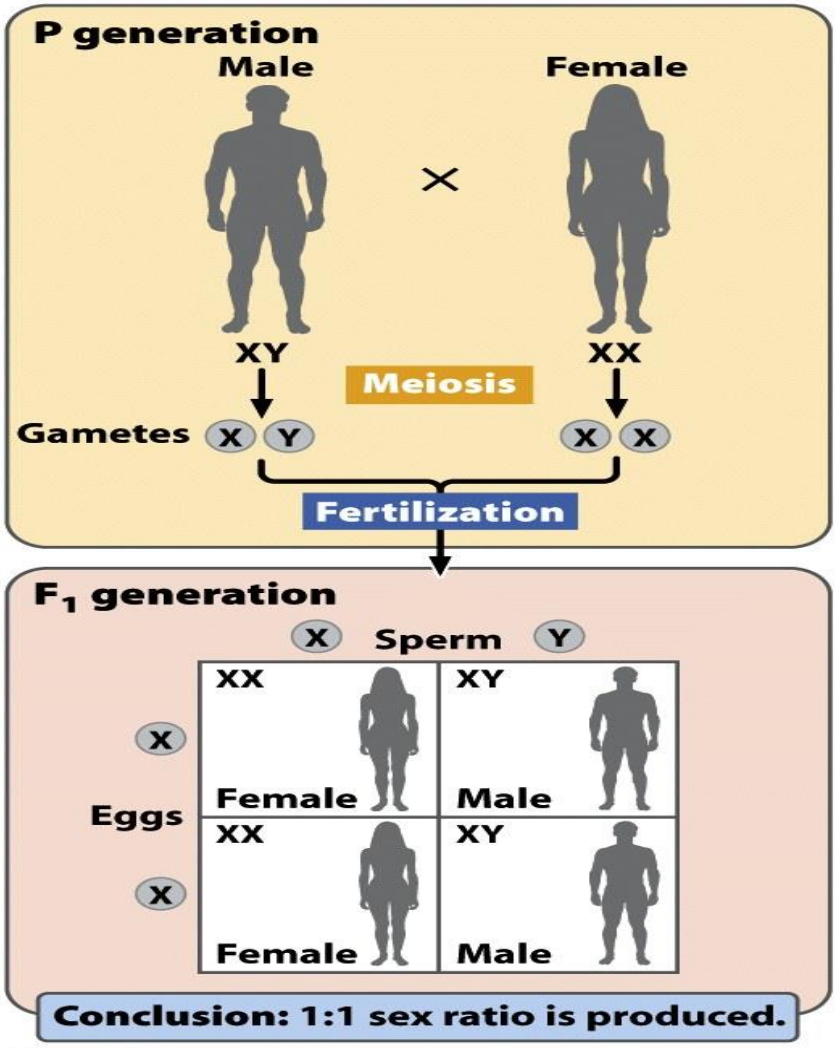


Figure 4-4
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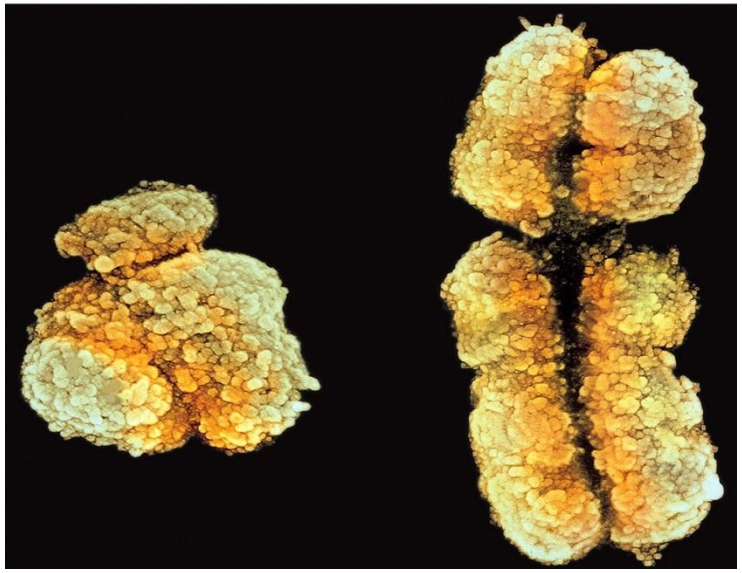

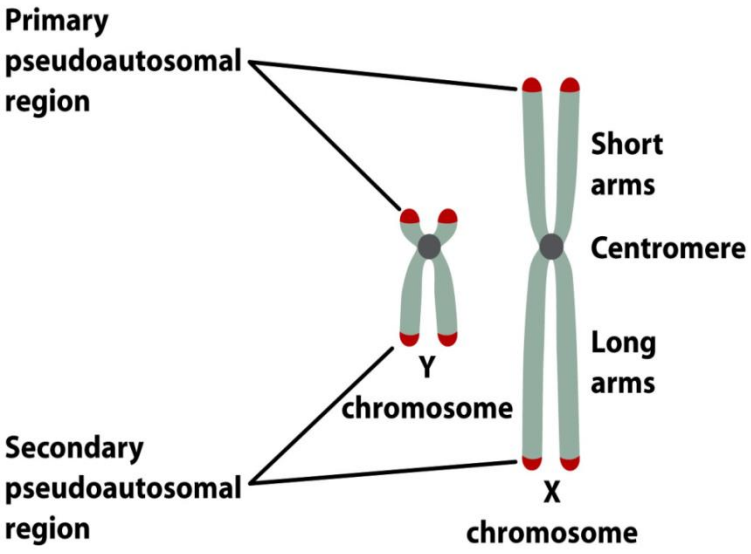

Figure 4-5
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1. Fertilization and determination of genetic sex
2. Formation of organs common to both the sexes
    A. the Gonadal ridges (4-5 weeks)
    B. the Internal ducts (6-7 weeks)
    C. the External genitalia (6-7 weeks)
3. Gonadal differentiation
4. Differentiation of the internal ducts and external genitalia

SRY gene on the Y chromosome determines maleness

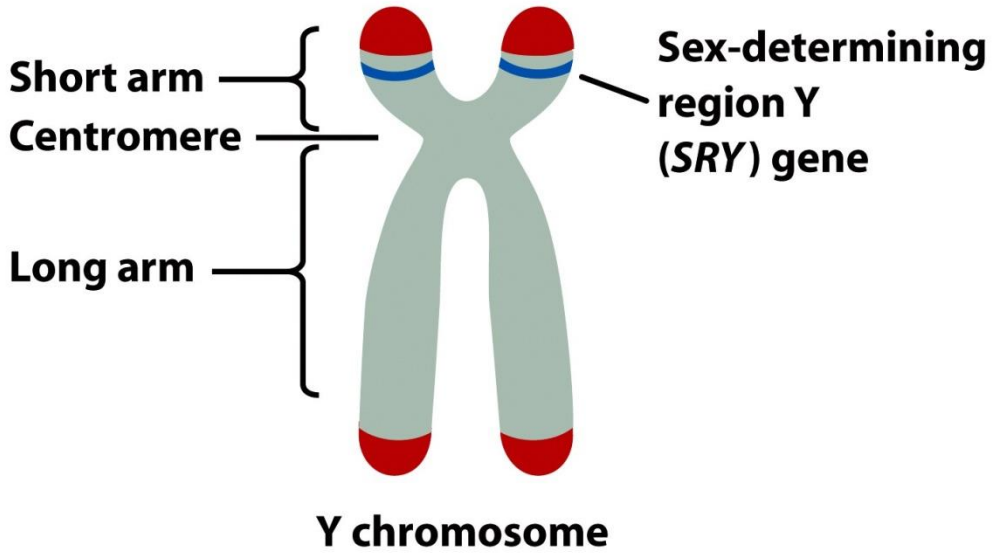

Figure 4-10
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During early embryonic development, there is a **sexually indifferent stage** in which the embryo has the potential to develop either a male or a female structures at about sixth week of gestation.

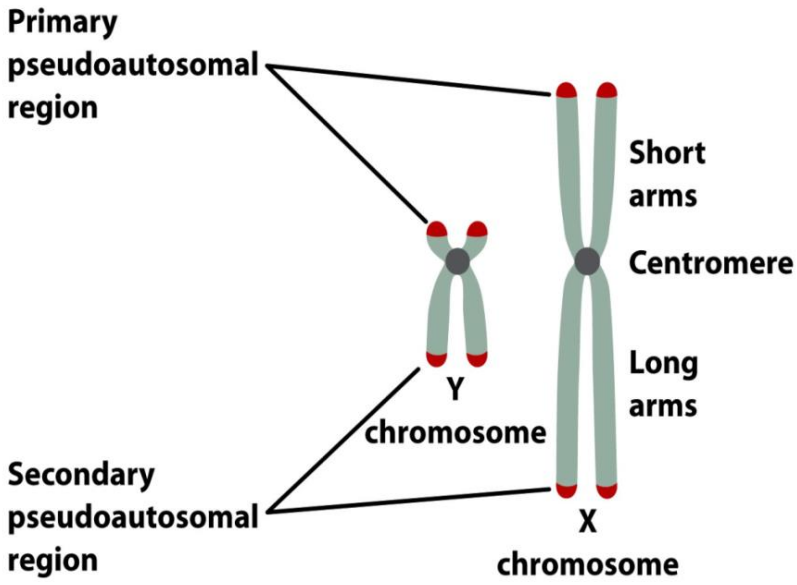

Figure 4-5
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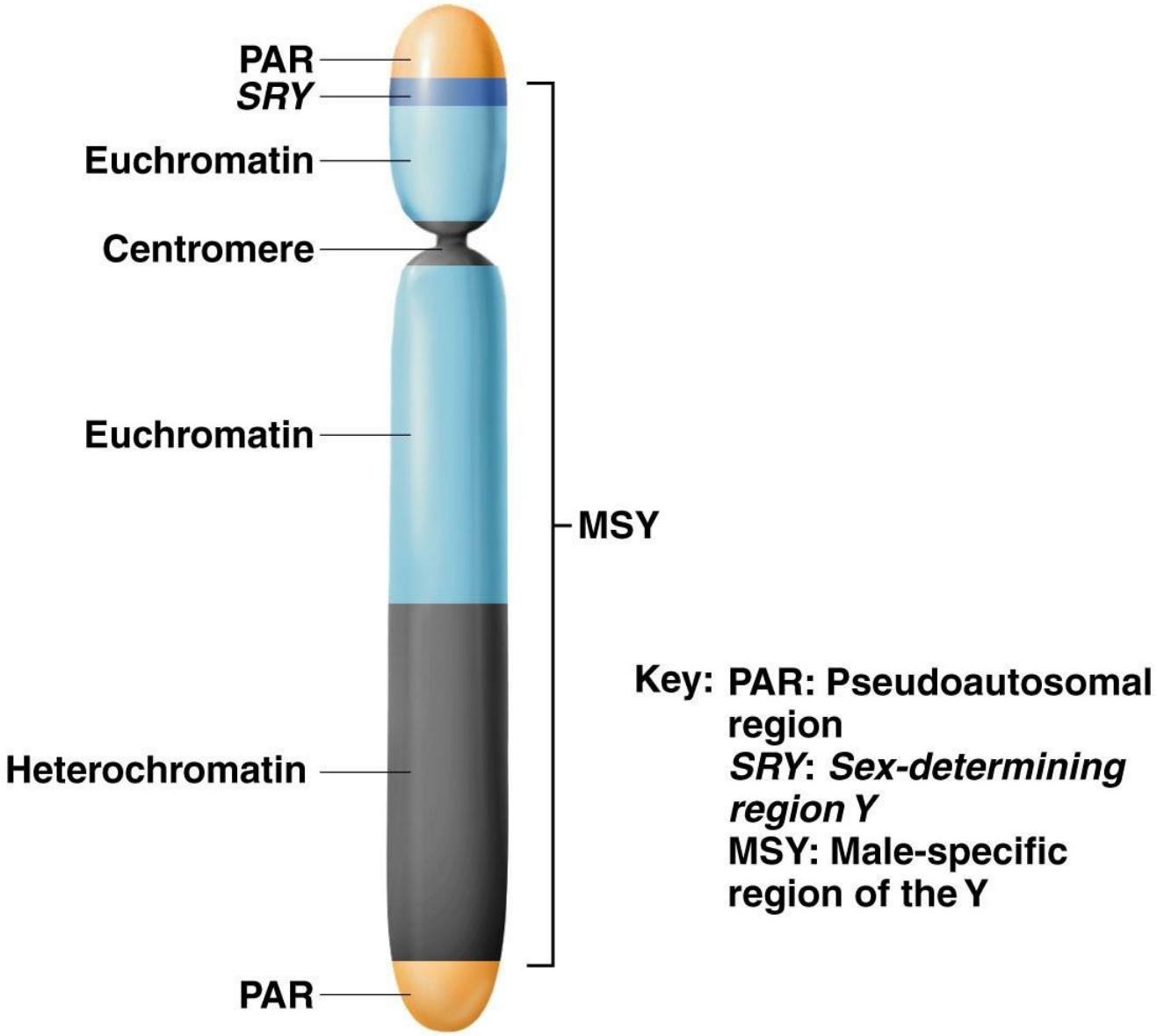
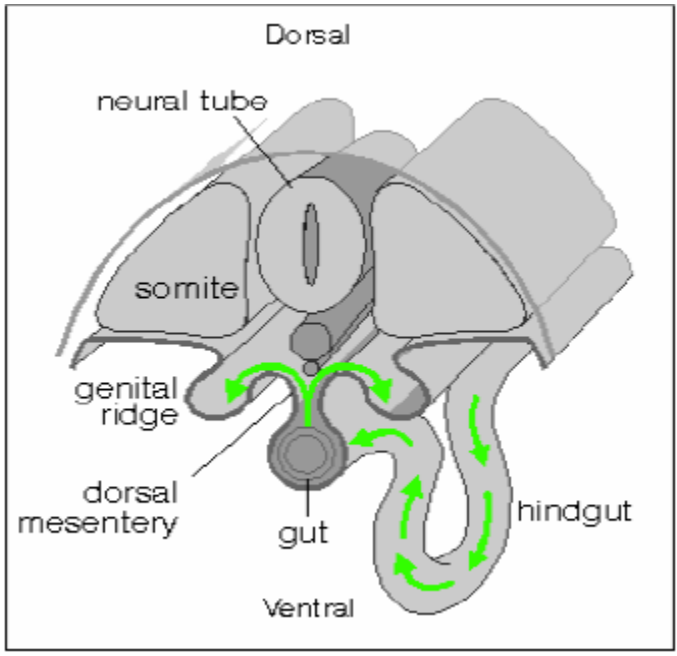


Genes determining development of the bi-potential Gonad

The initial formation of the bi-potential gonad (from uncommitted urogenital ridge) requires the function of Wilm's tumor (WT1) and Steroidogenic factor (SF-1).



Both are transcription factors and important for both gonadal and kidney development

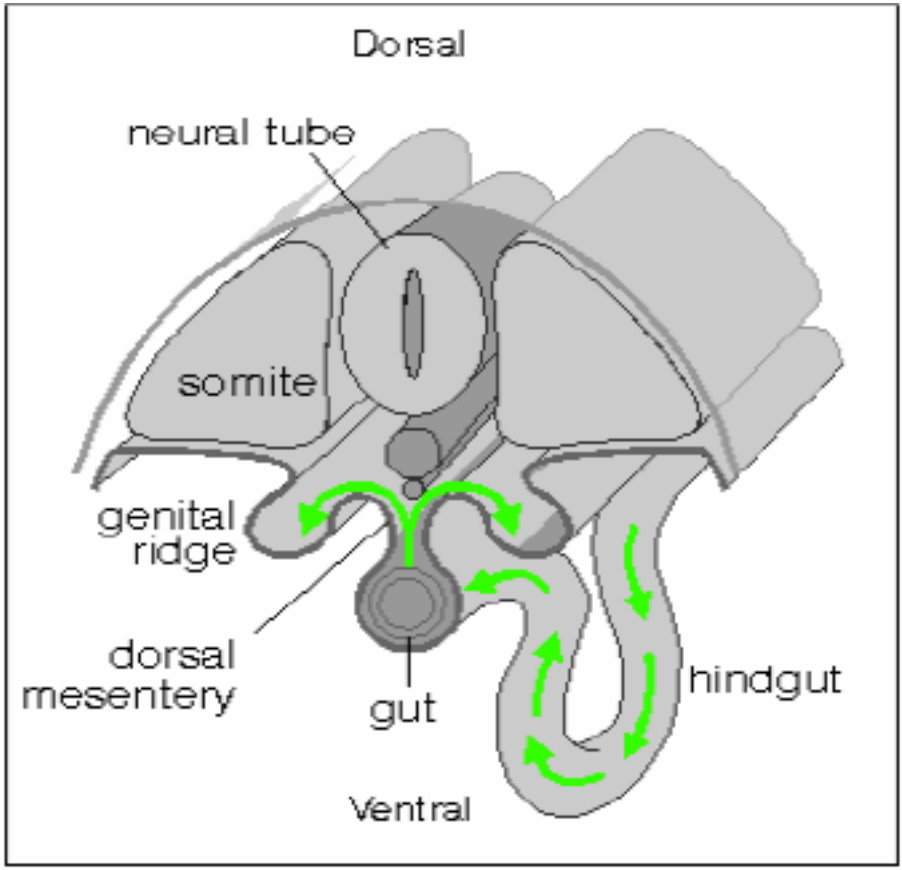
If the embryo is XY (genetic male), the presence of the ***SRY* gene** (sex determining region of the Y chromosome) will direct the gonads to develop as testes.

In the absence of a Y chromosome and SRY gene, the gonads develop as ovaries.

SF-1: Steroidogenic factor-1. A transcription factor essential in gonadal ridge determination.

WT-1: Wilm's Tumor 1, a transcription factor essential in **urogenital ridge determination**

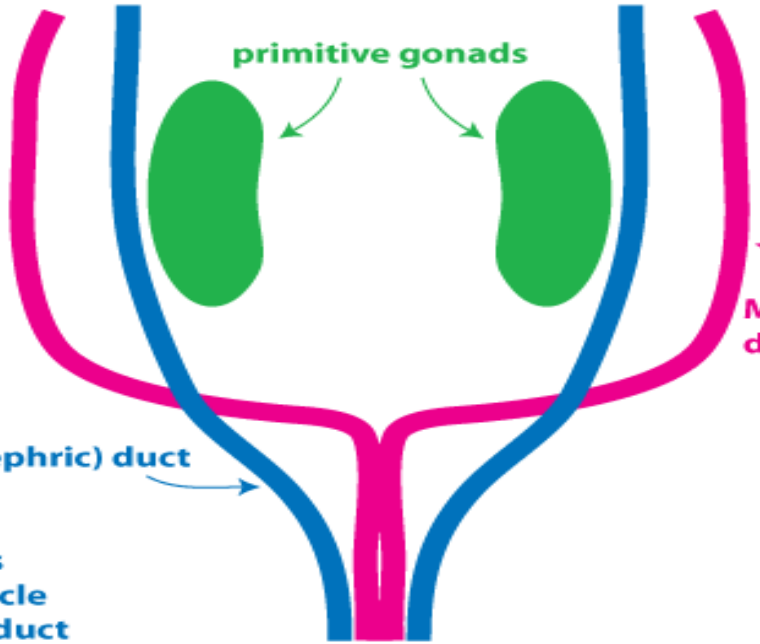
Internally, adjacent to developing gonad, there are two primitive ducts that can give rise to either the male or the female reproductive tracts.



The **Wolffian (mesonephric) ducts** are more medial. The **Müllerian (paramesonephric) ducts** are more lateral, but then fuse in the midline more caudally.

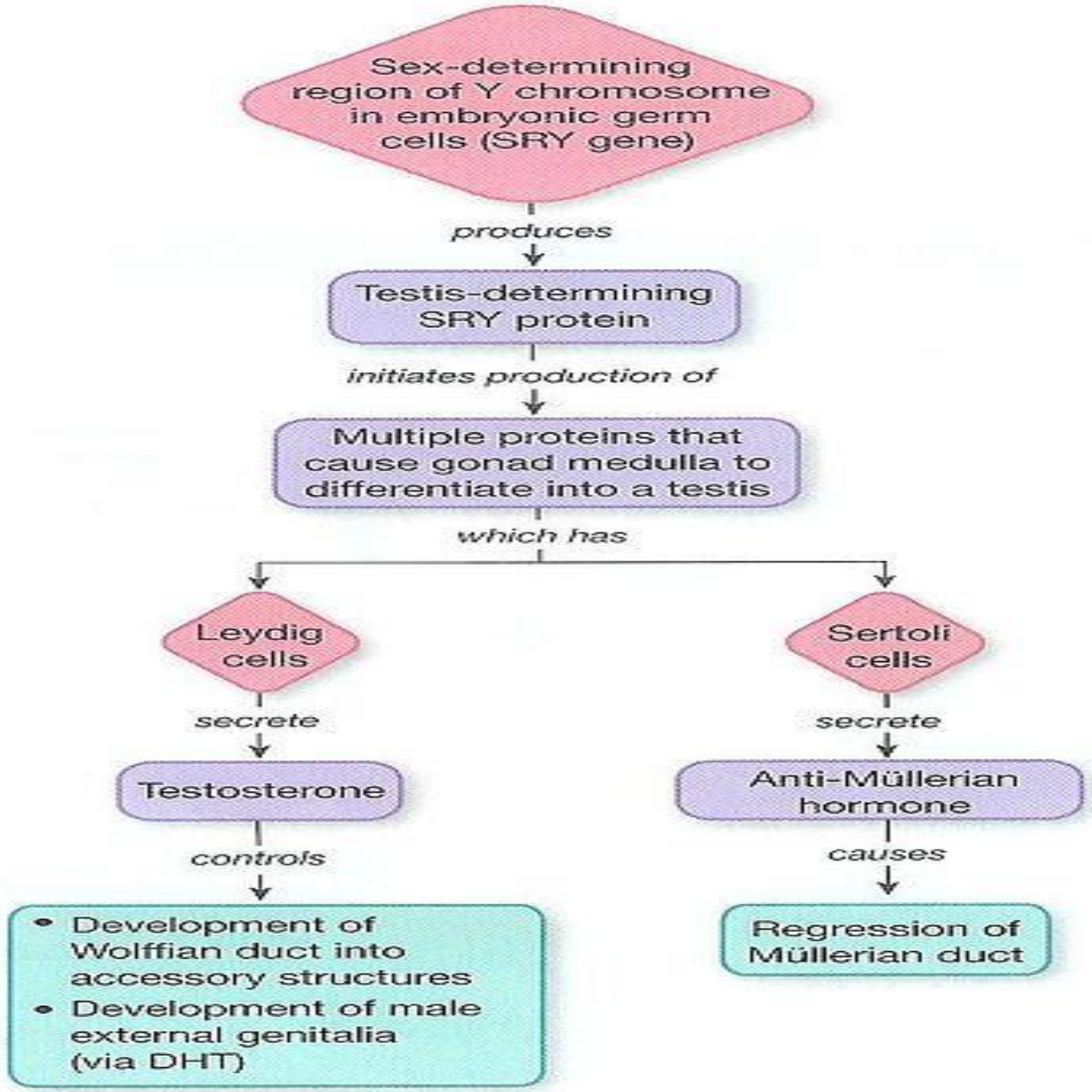
gender determination

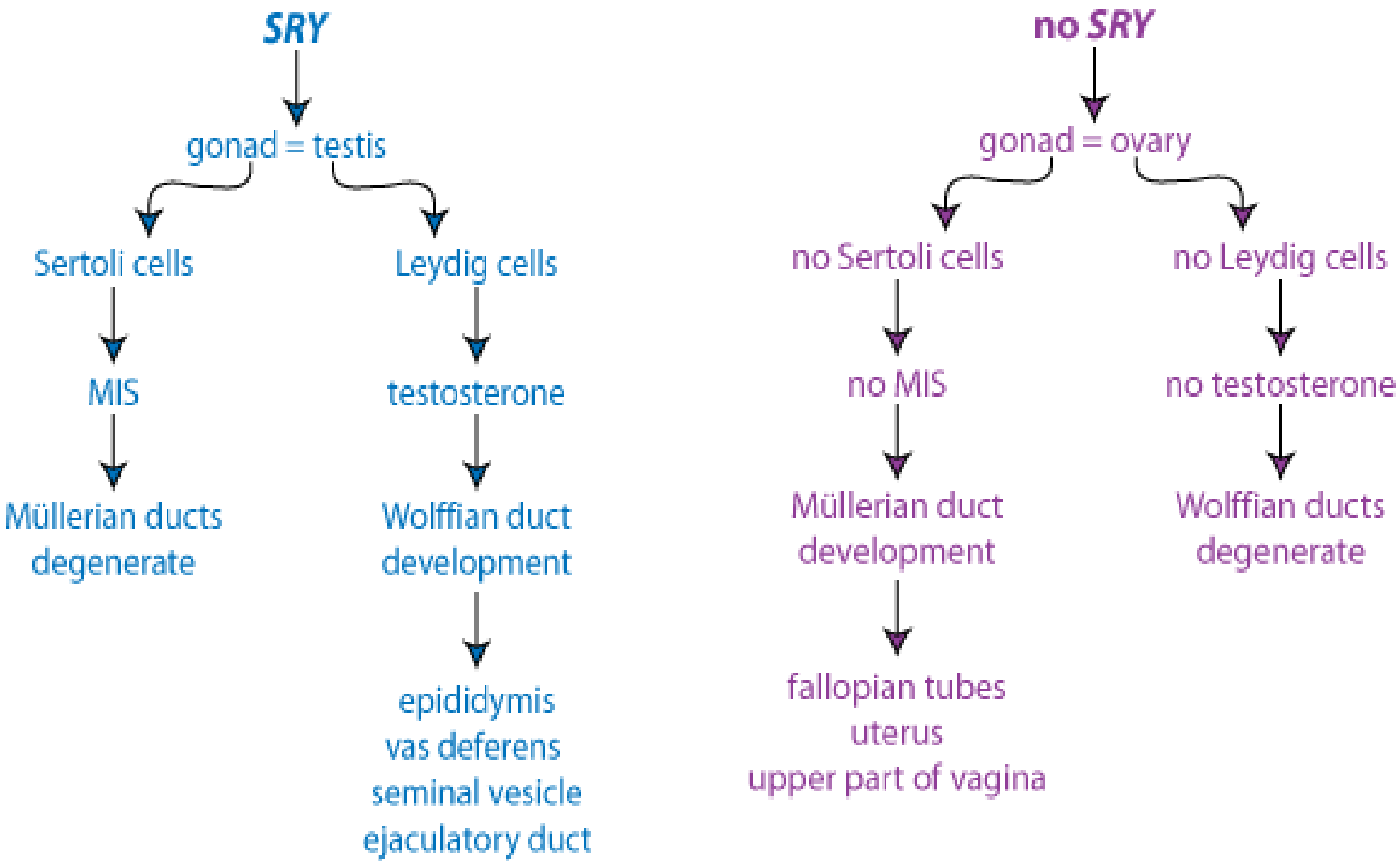
SEXUALLY INDIFFERENT STAGE (6 weeks)

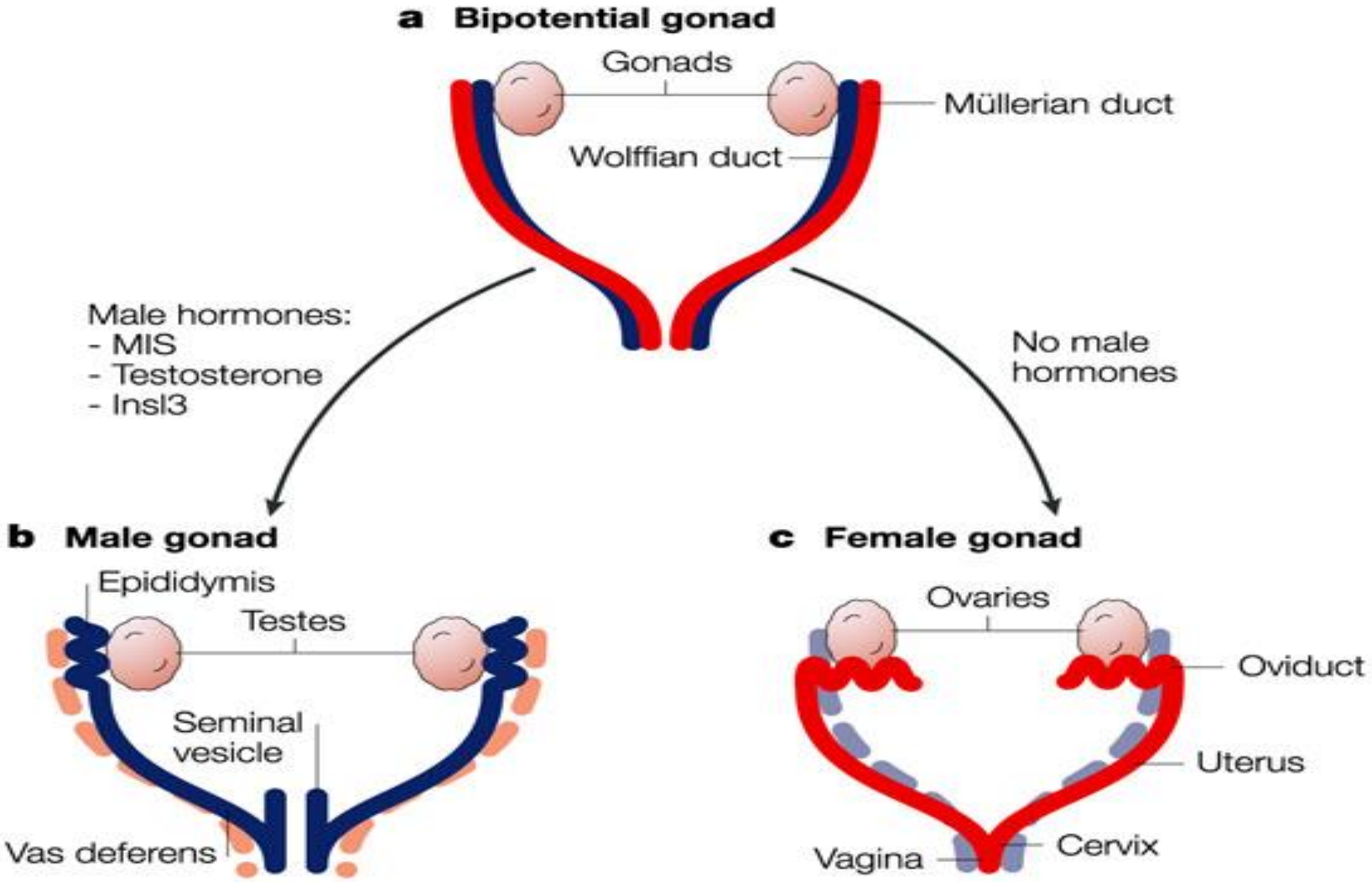


Müllerian (paramesonephric) duct develops into:
- fallopian tubues
- uterus
- upper part of vagina

Wolffian (mesonephric) duct develops into:
- epididymis
- vas deferens
- seminal vesicle
- ejaculatory duct


Sex-determining region of Y chromosome in embryonic germ cells (SRY gene)
produces
Testis-determining SRY protein
initiates production of
Multiple proteins that cause gonad medulla to differentiate into a testis
which has
Leydig cells
Sertoli cells
secrete
secrete
Testosterone
Anti-Müllerian hormone
controls
causes
• Development of Wolffian duct into accessory structures
• Development of male external genitalia (via DHT)
Regression of Müllerian duct


MALE (XY)
SRY
gonad = testis
Sertoli cells
Leydig cells
MIS
testosterone
Müllerian ducts degenerate
Wolffian duct development
epididymis
vas deferens
seminal vesicle
ejaculatory duct
FEMALE (XX)
no SRY
gonad = ovary
no Sertoli cells
no Leydig cells
no MIS
no testosterone
Müllerian duct development
Wolffian ducts degenerate
fallopian tubes
uterus
upper part of vagina



Nature Reviews | Genetics

Human prenatal sexual differentiation

Fetal age (weeks)	Size (mm)	Sex differentiating events
0	Blastocyst	Inactivation of one X chromosome
4	2-3	Development of Wolffian ducts
5	7	Migration of primordial germ cells in the undifferentiated gonad
6	10-15	Development of Müllerian ducts
7	13-20	Differentiation of seminiferous tubules
8	30	Regression of müllerian ducts in male fetus
8	32-35	Appearance of Leydig cells. First synthesis of testosterone
9	43	Total regression of müllerian ducts. Loss of sensitivity of müllerian ducts in the female fetus
9	43	First meiotic prophase in oogonia

10	43-45	Beginning of masculinization of external genitalia
10	50	Beginning of regression of wolffian ducts in the female fetus
12	70	Fetal testis is in the internal inguinal ring
12-14	70-90	Male penile urethra is completed
14	90	Appearance of first spermatogonia
16	100	Appearance of first ovarian follicles
17	120	Numerous Leydig cells. Peak of testosterone secretion
20	150	Regression of Leydig cells. Diminished testosterone secretion
24	200	First multilayered ovarian follicles. Canalisation of the vagina
28	230	Cessation of oogonia multiplication
28	230	Descent of testis

Sex determination in *Drosophila*

The Y chromosome in drosophila – unlike that in humans – play no role in sex determination

Instead, the sex of the fly is determined by the ratio of X chromosomes to autosomes

But, the Y chromosome is very essential to provide the male fertility.

Bridges in 1926

Normal diploid flies have a pair of sex chromosomes either XX or XY, and three pair of Autosomes denoted by AA

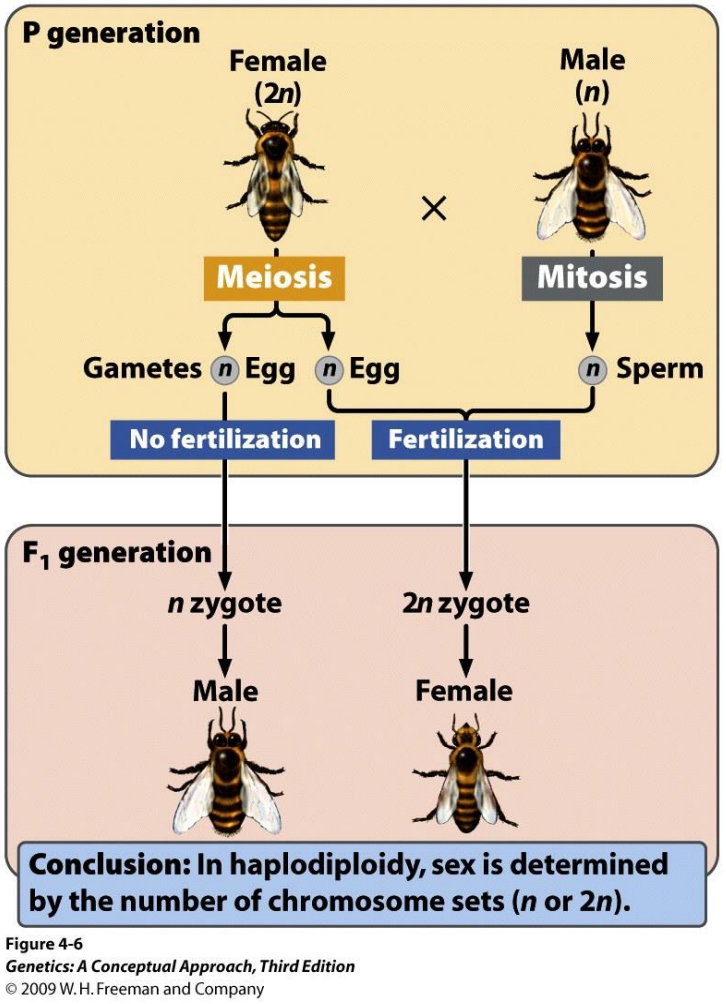


Figure 4-6
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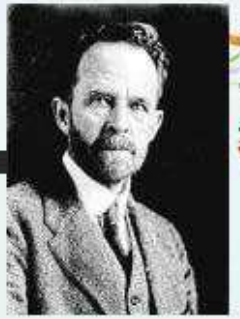
Sex determination in Drosophila melanogaster:

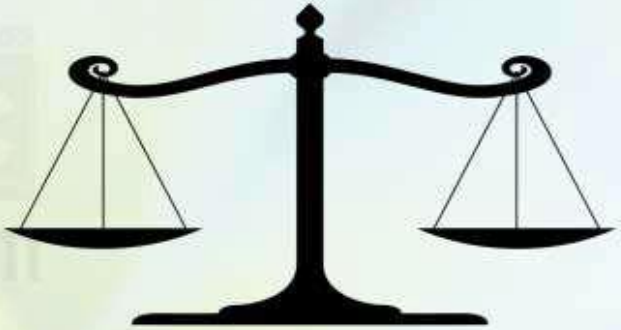
- Sex determination in *Drosophila* is quite different from humans
- *Drosophila* has eight chromosomes (n = 4)
- Three pairs of autosomes and one pair of sex chromosomes
- *Drosophila* possesses XX and XY sex chromosome similar to human
- Unlike human beings, Y chromosome does not have any role in determining the sex of individuals
- ***Sex in Drosophila is determined by the ratio of number of X chromosomes to that of the number of sets of autosomes***

GENIC BALANCE THEORY



Sex determination in Drosophila melanogaster:

- In simpler terms, sex determination in *Drosophila* is achieved by a **balance of female determinants on the X chromosome (X) and male determinants on the autosomes (A).**



- This type of sex determination is called **Genic Balance System**
- Genic balance system was proposed by Calvin Bridges in 1926
- Genic balance system of sex determination also explains the reasons for the occurrence of sexual variants in the fruit fly population such as inter-sex, metamales and metafemales apart the normal male and female individuals

GENIC BALANCE THEORY

Sex determination in Drosophila melanogaster:

- There are many suggestions regarding the exact molecular mechanism genic balance system of sex determination in *Drosophila*
- The exact mechanism is still unknown
- Studies shown that the X chromosome contains female determining factors
- Autosomes contains male determining factors
- Y chromosome in *Drosophila* does not have any role in sex determination.

GENIC BALANCE THEORY

Sex determination in Drosophila melanogaster:

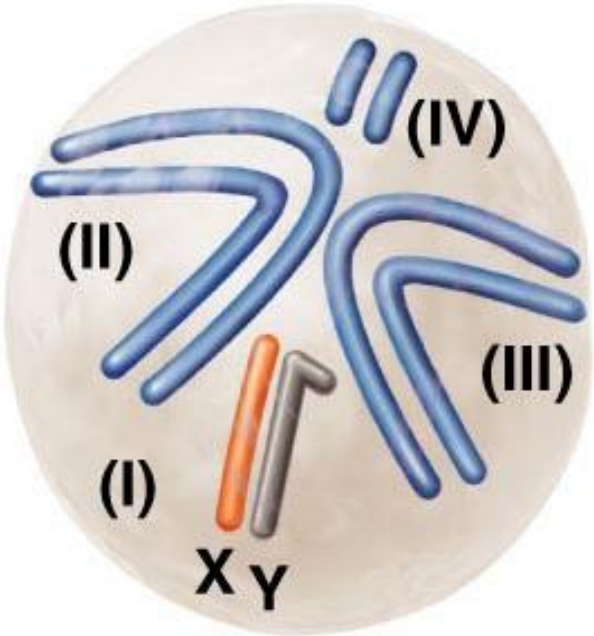
- The table shows the formation of sexual variants in *Drosophila* according to the X/A ratio

Sl. No.	Number of X chromosomes	Number of Sets of Autosomes	X / A ratio	Sex of the individuals
1	3	2	3 / 2 = 1.50	Metafemale
2	4	3	4 / 3 = 1.33	Metafemale
3	4	4	4 / 4 = 1.00	Normal Female
4	3	3	3 / 3 = 1.00	Normal Female
5	2	2	2 / 2 = 1.00	Normal Female
6	2	3	2 / 3 = 0.66	Intersex
7	1	2	1 / 2 = 0.50	Normal male
8	1	3	1 / 3 = 0.33	Metamale

Sex expression in Drosophila in relation to X/A ratio Sex Index

Ploidy	Number of X chromosomes (=X)	No. of Autosomal sets (=A)	Sex Index (X/A)	Expression of sex
2n	3	2	3/2=1.5	Super-female
3n	4	3	4/3=1.33	Super-female
4n	4	4	4/4=1.0	Female
3n	3	3	3/3=1.0	Female
2n	2	2	2/2=1.0	Female
4n	3	4	3/4=0.75	Intersex
3n	2	3	2/3=0.67	Intersex
2n	1	2	1/2=0.5	Male
4n	2	4	2/4=0.5	Male
3n	1	3	1/3=0.33	Super-male

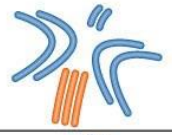
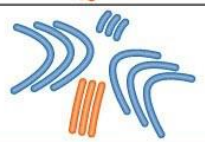
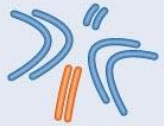
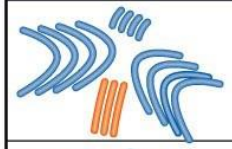
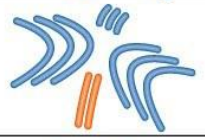
Normal diploid male



2 sets of autosomes

+

X Y

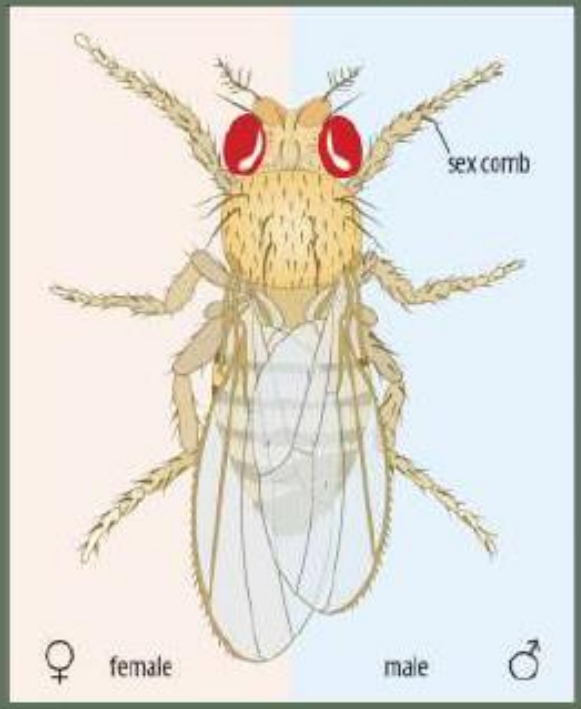
Chromosome composition	Chromosome formulation	Ratio of X chromosomes to autosome sets	Sexual morphology
	$3X/2A$	1.5	Metafemale
	$3X/3A$	1.0	Female
	$2X/2A$	1.0	Female
	$3X/4A$	0.75	Intersex
	$2X/3A$	0.67	Intersex
	$X/2A$	0.50	Male
	$XY/2A$	0.50	Male
	$XY/3A$	0.33	Metamale

Sex Mosaic in Drosophila

Sex mosaic - Combination of male and female features in the body of an individual.

Drosophila flies (1 in 2000) have male tissues in one part of the body and female tissues in other.

Individuals with such sex mosaic are known as gynandromorphs or gynanders.



Three patterns of sex mosaic may be found in Drosophila:

1. Bilateral sex mosaic - one side of the fly is male and the other side is female. This is the most common type of sex mosaic.

2. Antero-posterior sex mosaic - the front half of the fly is one sex and the rear half of the other sex.

3. Sex mosaic in Patches - Sometimes, only a quarter of the body is male, and rest is female or just a small patch of tissues may be male and rest of the body is female.

Bilateral Sex Mosaic in Drosophila

Male

Female

Sexual Dimorphism in Butterfles

ENVIRONMENTAL SEX DETERMINATION

- Sex Determination : Enviroment
- Sex Determination : social
- Sex Determination : chance
- Sex Determination : number of offspring

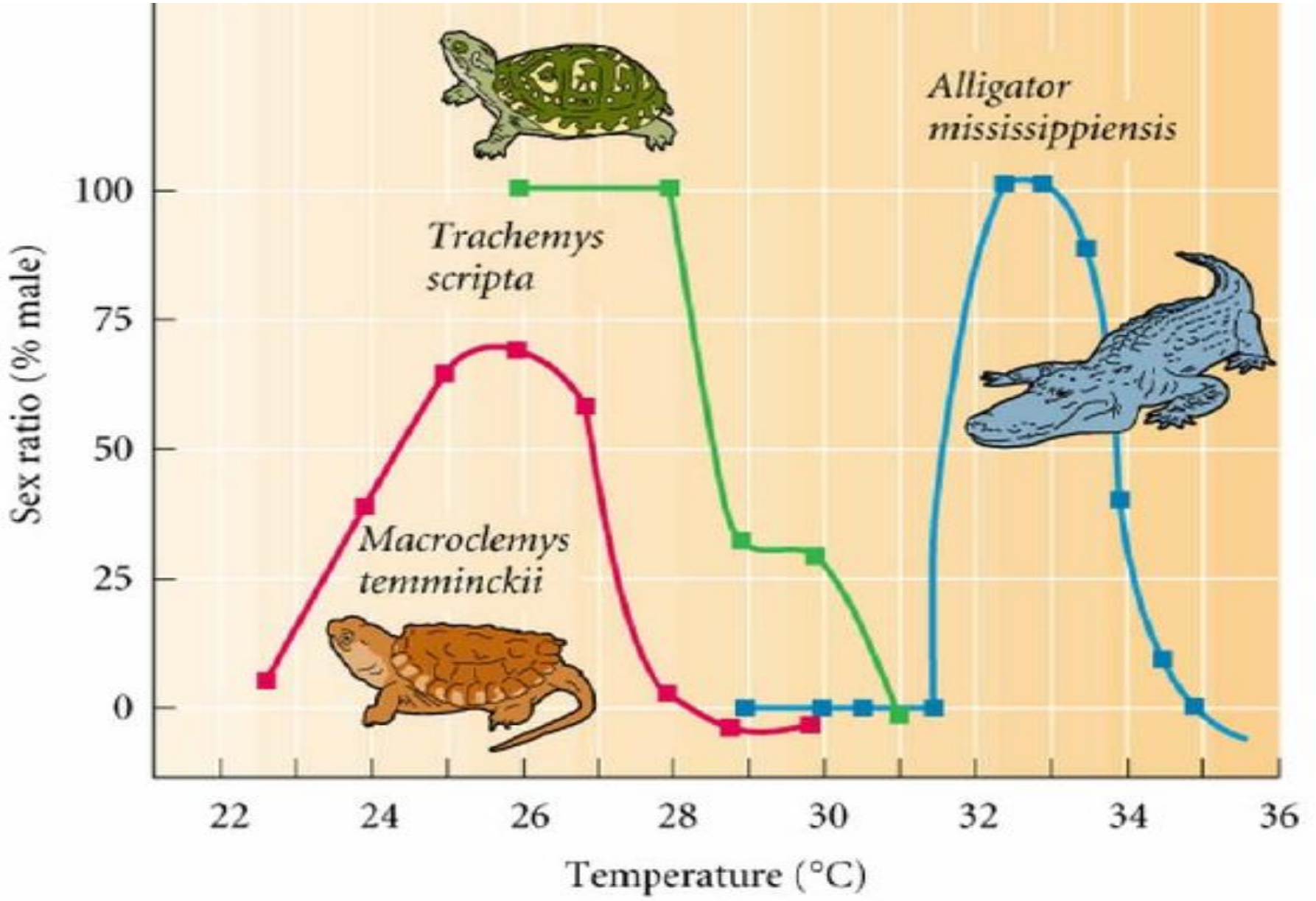
Temperature-dependent sex determination (reptiles)

Sex of most snakes and most lizards

Sex of most turtles and all species of crocodilians
environment (temperature)

Turtles use temperature

> 32°C produces females
< 28°C produces males
28-32°C 50% male, 50% female


Alligator mississippiensis
Trachemys scripta
Macroclemys temminckii
Sex ratio (% male)
100
75
50
25
0
22
24
26
28
30
32
34
36
Temperature (°C)

Body size:

Some fish are first male then female

Location:

Limpet's position in the stack

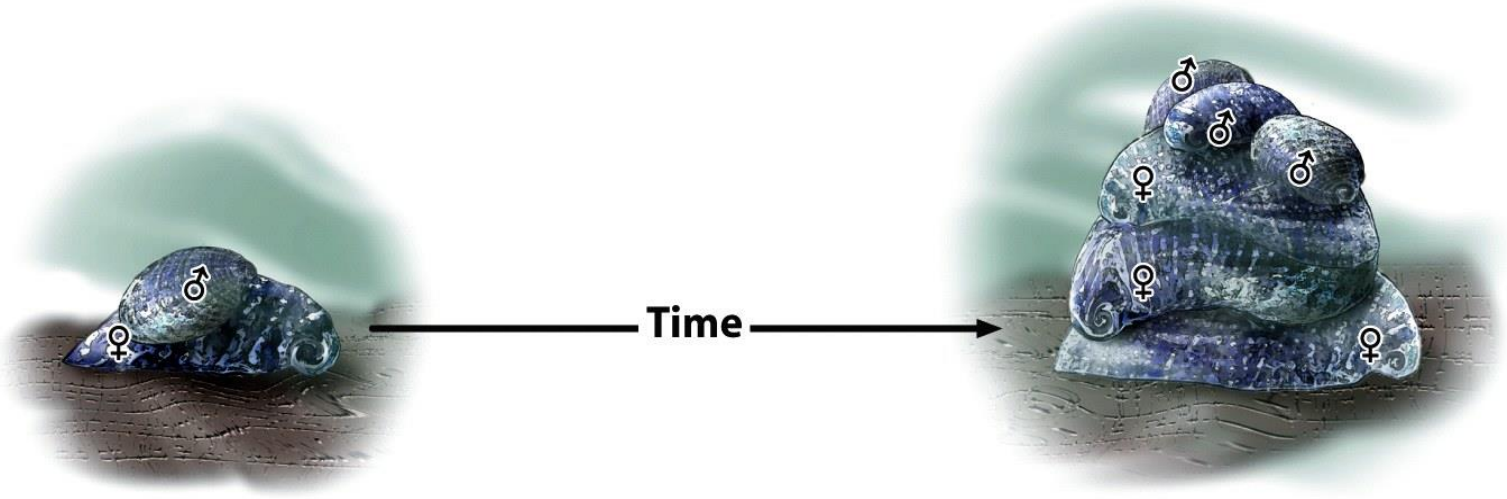


Figure 4-7
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