Sex Determination

Sex Determination

- Members of almost all species are often divided into two sections according to the kind of gamete or sex cell produced by them, *i.e.,* male sex and female sex.
- However, some of the lowest forms of plant and animal life are found to have several sexes.
- For example, in **one** variety of the ciliated protozoan *Paramecium bursaria*
- There are **eight sexes** or "**mating types**" all morphologically identical.
- Each mating type is physiologically incapable of conjugating with its own type,
- But may exchange genetic material with any of the seven other types within the same variety.
- Further, in organisms in which the number of sex reduced to just two, sexes may reside in **different** individuals or within the **same** individual.

Sex Determination

- An animal possessing both male and female reproductive organs is usually referred to as a **hermaphrodite or monoecious**.
- The organisms in which both male and female gametes are produced by different individuals are called **dioecious**.
- The sex cells and reproductive organs form the **primary sexual characters** of male and female sexes.
- Besides these primary sexual characters, the male and female sexes differ from each other in many **somatic characters** known as **secondary sexual characters**.
- The phenomenon of molecular, morphological, physiological or behavioral differentiation between male and female sexes is called **sexual dimorphism**

Phenomenon of sexual dimorphism

- Some important and common mechanisms of sex determination are following:

A. **GENETICALLY CONTROLLED SEX DETERMINING MECHANISMS**

1. **Sex chromosome mechanism or Hetero-gamesis**
2. **Genic balance mechanism**
3. **Male haploidy or haplo-diploidy mechanism**
4. **Single gene effects**

B. **ENVIRONMENTALLY CONTROLLED SEX DETERMINING MECHANISM**

Sex Chromosomal Mechanisms (Heterogamesis)

1. Discovery of sex chromosomes

- In sexually dimorphic dioecious organisms besides morphological and behavioural differences between both sexes,
- The **sexual diversity also** occurs at the level of chromosomes.
- The chromosomal differences between the sexes of several dioecious species were found earlier in the course of cytological investigations
- Finally X and Y chromosomes are identified after extensive research

Sex Chromosomal Mechanisms (Heterogamesis)

2. Types of sex chromosomes.

- In dioecious organisms, thus, two types of chromosomes were recognised which are as follows:

a. **Autosomes**

- The chromosomes which have no relation with the sex and **contain the genes** which determine the somatic characters of the individuals are known as **autosomes** (**A**).

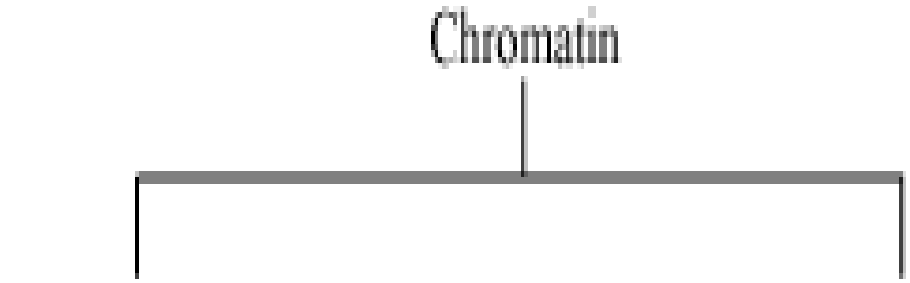
b. **Sex chromosomes**

- The chromosomes which are responsible for the **determination of sex** are known as **sex chromosomes**, *e.g.,* X and Y chromosomes.

Sex Chromosomal Mechanisms (Heterogamesis)

3. Structure of sex chromosomes

- The X and Y sex chromosomes exhibit **structural differences**.
- The **cytological studies** have shown that the X chromosomes of most organisms are **straight**, **rod-like** and **comparatively larger** than Y chromosomes.
- The **Y** chromosome is smaller in size with one end slightly curved or bent to one side in *Drosophila*;
- in man no such curvature of Y chromosome occurs



Euchromatin

- Loosely packed regions of chromatin which stains light
- Transcriptionally active chromatin

Heterochromatin

- Densely packed regions of chromatin which stains dark
- Transcriptionally inactive

Sex Chromosomal Mechanisms (Heterogamesis)

- The X chromosomes have **large** amount of euchromatin and small amount of heterochromatin.
- The euchromatin has large amount of DNA material, hence, **much** genetic information.

- The Y chromosome contains small amount of euchromatin and large amount of heterochromatin.
- The Y chromosome has **little genetic information**, therefore, sometimes it is referred to as genetically **inert** or **inactive**.

TYPES OF SEX CHROMOSOMAL MECHANISM OF SEX DETERMINATION

- In dioecious diploidic organisms following two systems of sex chromosomal determination of sex have been recognized:
- **(a) Heterogametic males;**
- **(b) Heterogametic females.**

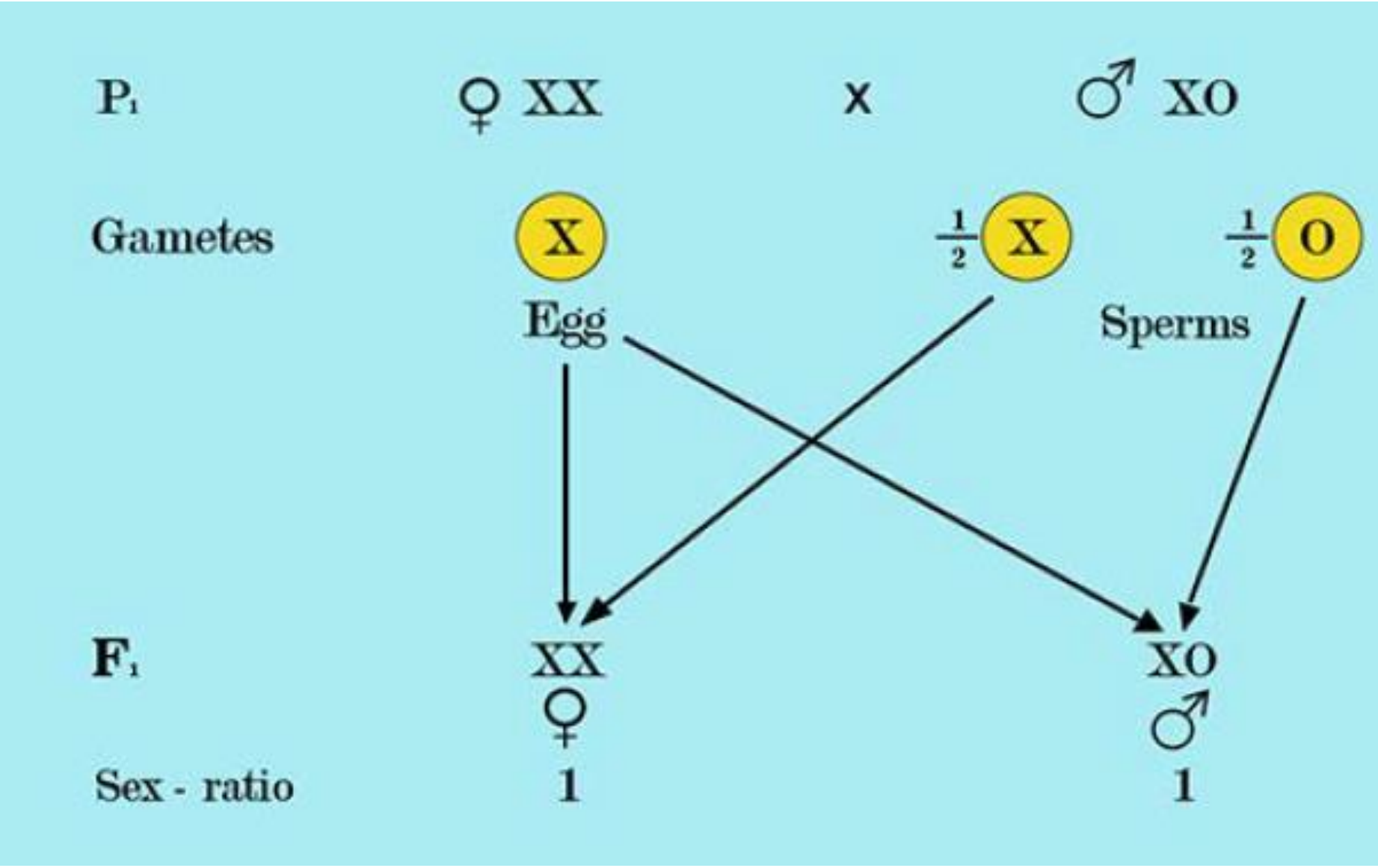
Heterogametic males

- In this type of sex chromosomal determination of sex, the female sex has two X chromosomes,
- while the male sex has only one X chromosome.
- Because, male lacks a X chromosome, therefore,
- during gametogenesis produces two types of gametes, 50 per cent gametes carry the X chromosomes, while the rest 50 per cent gametes lack in X chromosomes.
- Such a sex which produces two different type of gametes in terms of sex chromosomes, is called **heterogametic sex**.
- The female sex, because, produces similar type of gametes, is called, **homogametic sex**.

Heterogametic males

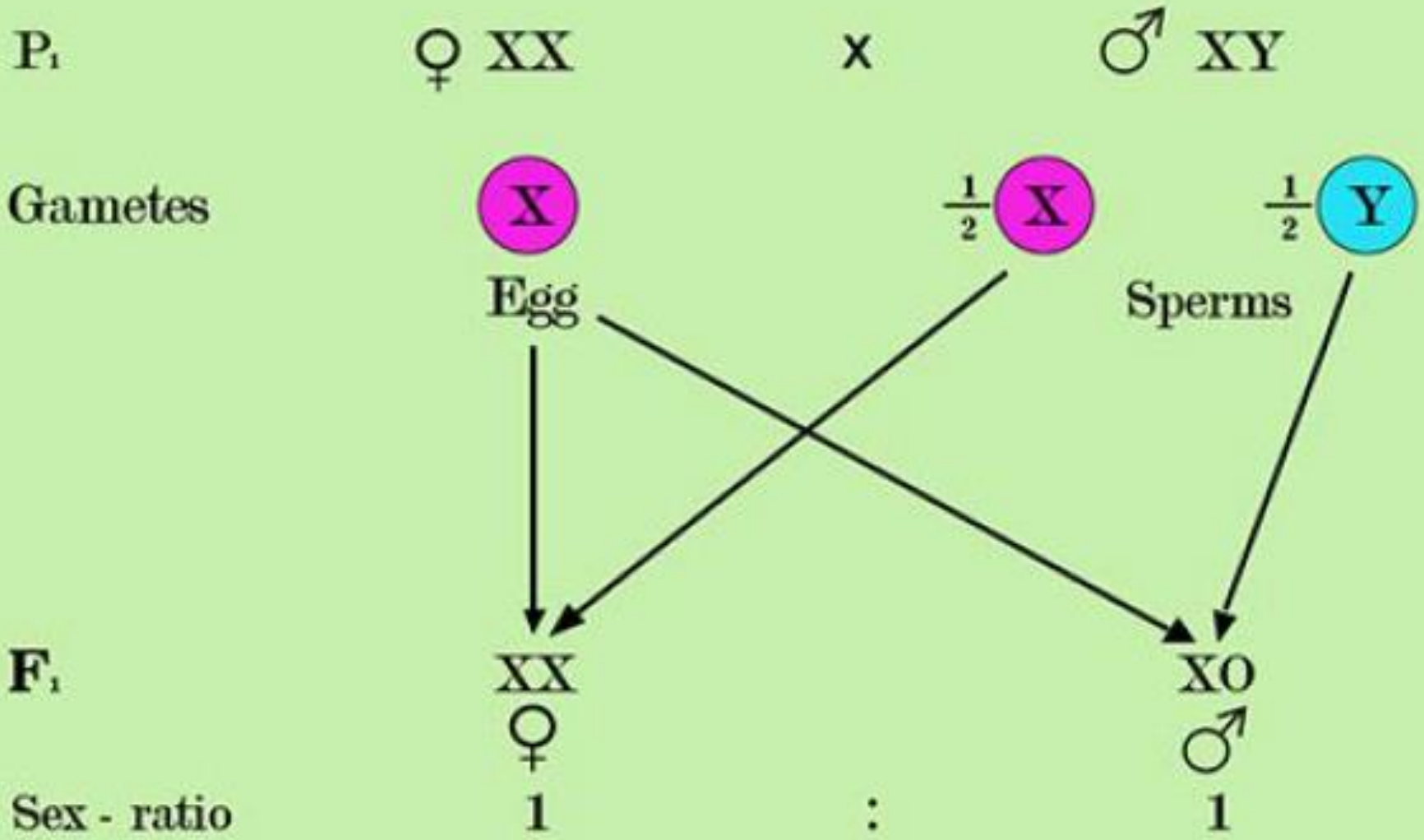
The heterogametic males may be of following two types:

- **(i) XX-XO type.**
- In certain insects specially those of the orders Hemiptera (true bugs) and Orthoptera (grasshoppers), the female having two X chromosomes (hence, referred to as XX) and are, thus, homogametic,
- While the male having only one X chromosome (hence, referred to as XO).
- The presence of an unpaired X chromosome determines the sex.
- The male lacking in one X chromosome produces two types of sperms:
- half with X chromosome and half without X chromosome.
- The **sex of the offspring** depends upon the sperm that fertilizes the egg (each of which carries a single X chromosome)


P1
♀ XX
x
♂ XO
Gametes
X
1/2 X
1/2 O
Egg
Sperms
F1
XX
♀
XO
♂
Sex - ratio
1
1

Heterogametic males

- **(ii) XX-XY type.**
- In man, other mammals, certain insects including *Drosophila,* the female possesses two homomorphic X chromosomes in their body cells (hence, referred to as XX) and
- They being homogametic, produce one kind of eggs, each with one X chromosome.
- The males of these organisms possess one X chromosome and one Y chromosome (hence, referred to as XY).
- The males having two heteromorphic sex chromosomes produce two kinds of sperms : half with X chromosome and half with Y chromosome.
- The sex of embryo depends on the kind of sperm.
- An egg fertilized by a X-bearing sperm, produces a female, but,
- if fertilized by a Y-bearing sperm, a male is produced.


P1
♀ XX
x
♂ XY
Gametes
X
1/2 X
1/2 Y
Egg
Sperms
F1
XX
♀
XO
♂
Sex - ratio
1
:
1

Heterogametic Females

- In this type of sex chromosomal determination of sex, the male sex possesses two homomorphic X chromosomes, therefore, is homogametic and
- produces single type of gametes, each carries a single X chromosome.
- The female sex **either** consists of single X chromosome or one X chromosome and one Y chromosome.
- The female sex is, thus, heterogametic and produces two types of eggs, half with a X chromosome and half without a X chromosome (with or without a Y chromosome).
- To **avoid confusion** with that of XX-XO and XXXY types of sex determining mechanisms,
- **instead** of the X and Y alphabets, Z and W alphabets are generally used respectively.

Heterogametic Females

The heterogametic females may be of following two types :

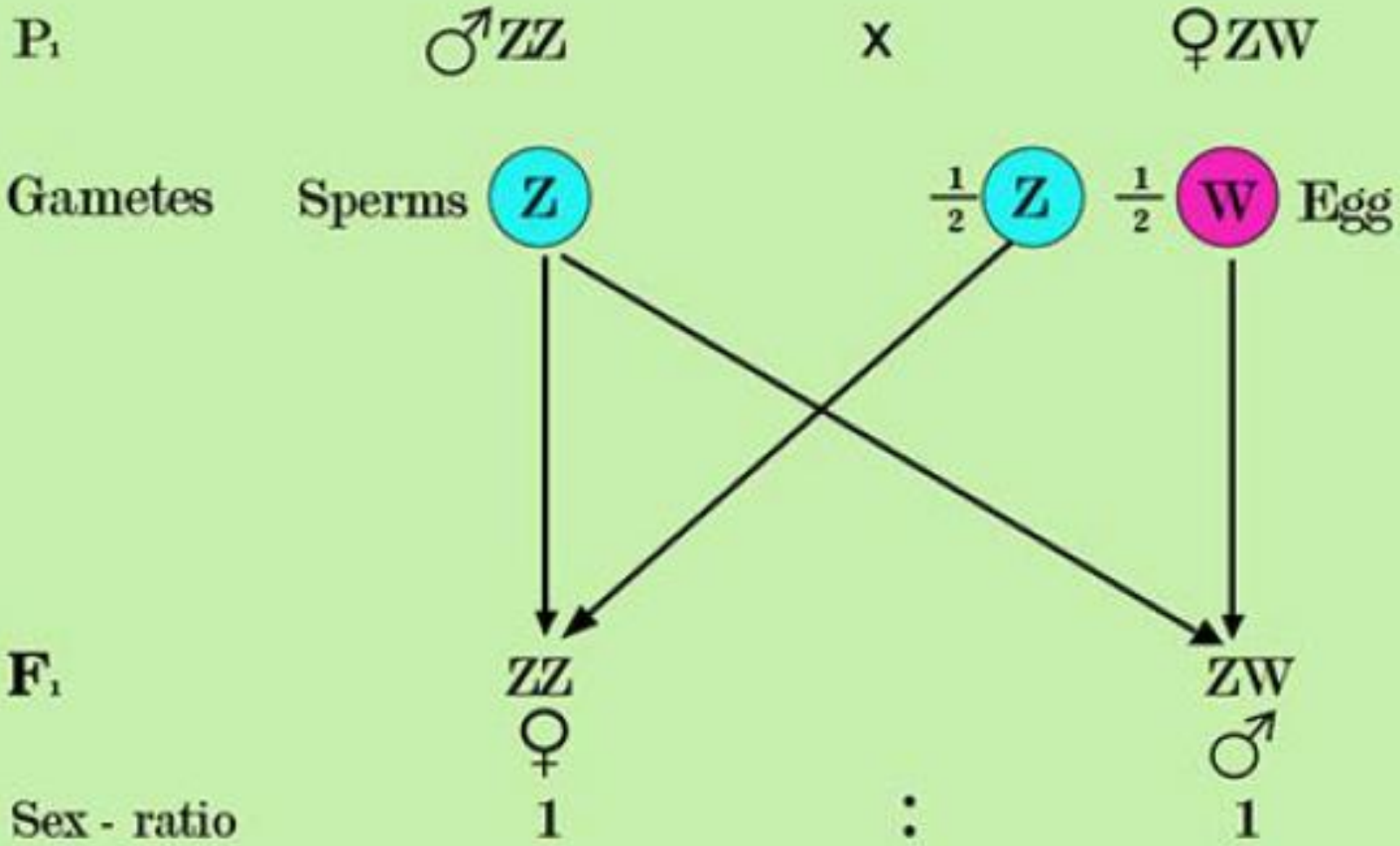
(i) **ZO-ZZ system.**

- This system of sex determination is found in certain moths and butterflies.
- In this case, the female possesses single Z chromosome in its body cells (hence, is referred to as ZO)
- and is heterogametic,
- producing two kinds of eggs, half with a Z chromosome and half without any Z chromosome.
- The male possesses two Z chromosomes (hence, referred to as ZZ) and is homogametic,
- producing single type of sperms, each of which carries a single Z chromosome.
- The sex of the offspring depends on the kind of egg

Heterogametic Females

(ii) ZW-ZZ system.

- This system of sex determination occurs in certain insects (gypsy moth) and vertebrates such as fishes, reptiles and birds.
- Here the female sex has one Z chromosome and one W chromosome.
- It is heterogametic
- And produces two types of ova, 50 per cent ova carry the Z chromosomes,
- While rest 50 per cent ova carry W chromosomes.
- The male sex has two homomorphic Z chromosomes and is homogametic
- Producing single type of sperms, each carries a Z chromosome.
- The sex of the offspring depends on the kind of egg,
- The Z bearing eggs produces males but
- The W bearing eggs produce females


P1
♂ZZ
x
♀ZW
Gametes
Sperms
Z
1/2 Z
1/2 W
Egg
F1
ZZ
♀
ZW
♂
Sex - ratio
1
:
1

B. GENIC BALANCE MECHANISM

GENIC BALANCE MECHANISM

- By studying sex chromosomal mechanism of sex determination, it **may** appear at first glance that some genes carried by the sex chromosomes (X and Y) were entirely **responsible** for sex.
  - ***But this is not the case.***
- Extensive experimentation of different workers (**Wilson**, 1909 ; **Bridges**,1921 and **Goldschmidt**, 1934) on different organisms have **revealed the fact**
- That **most organisms generally** have inherent potentialities for **both sexes** and **each** individual is found to be more or less **intermediate** between male and female sexes (Hence may be referred to as **intersex**).

GENIC BALANCE MECHANISM

- There seems to exist a delicate **balance** of masculine and feminine tendencies in the hereditary compliment of an individual and mechanisms like the XY, ordinarily serve to trip the balance in one **direction** or another.
- Such **genic balance** mechanism of determination of sex was first of all studied in *Drosophila* by **C.B. Bridges** in 1921.

GENIC BALANCE MECHANISM

Sex determination in Drosophila

- In *Drosophila,* the presence of Y chromosome has been found essential for the fertility of male sex but that has **nothing to do** with the determination of male sex.
- In this fly, the sex is determined polygenically.
- The sex determining genes were so distributed that the net effect results in the **autosomes** determining maleness and the **X** chromosomes femaleness.
- The **sex of an individual** then depends upon the ratio of X chromosomes to autosomes.
- If **each haploid set** of autosomes carries factors with a male-determining value equal to one (1),

Sex determination in Drosophila

- Then **each** X chromosome carries factors with a female determining value of one and half (1½).
- Let A represent a haploid set of autosomes. In a normal male (AAXY) the male and female determinants are in the ratio of 2: 1½ and, therefore, the genic balance is in the **favour** of maleness.
- A normal female (AAXX) has a male and female ratio of 2:3 and, therefore, the balance is in the favour of femaleness
- **Recent studies** indicate that the determination in chickens and probably in birds in general, is similar to that of *Drosophila, i.e.,* it is dependent upon the ratio between the Z chromosomes and the number of autosomal sets of chromosomes.
- The W chromosome is not a strong female sex determining element (see **Stansfield**, 1986).
- Same system of genic balance in which the X/A ratio is critical, has been reported for the flowering plant (angiosperm)

GENIC BALANCE MECHANISM

Sex Determination in Man

- In man like *Drosophila* XX-XY type sex determining mechanism occurs
- **But** here the Y chromosome contains **potent** male sex-determining **genes**
- Which can almost **completely overcome** the **feminizing** action of the **rest of** the genotype.
- The **conclusive** evidences that Y chromosome is a **determiner of** fertility and sex of male individual came from certain abnormal conditions (called syndromes) which contained aneuploidic sex-chromosomal abnormalities

GENIC BALANCE MECHANISM

Sex Determination in Man

- For instance, **Turner's syndromes** (XO) are sterile female individuals having certain abnormalities such as short stature, congenital malformations, shield chest, pronounced webbing of the neck, colour blindness, etc.
- Similarly, **Klinefelter's syndromes** (XXY) are males, despite the presence of two X chromosomes.
- A person with **extra** one X and Y chromosome display true **hermaphroditism** having **both ovarian and testicular tissues** and variable degrees of intersexual development of the genitalia.

Species	XX	XY	X0	XXY
DROSOPHILA	♀	♂	♂	♀
Humans	♀	♂	♀	♂

Fig 22.23 Comparison of sex determination in man and *Dorsophilia*

C. MALE HAPLOIDY OR HAPLODIPLOIDY

MECHANISM

MALE HAPLOIDY OR HAPLODIPLOIDY MECHANISM

- Male haploidy or haplodiploidy parthenogenesis is particularly common in the hymenopterous insects such as ants, bees and wasps.
- In these insects, since, **fertilized eggs** develop into diploid females and **unfertilized** ones into haploid males;
- so haploidy is **both** a **form** of reproduction and a **means** of sex determination.
- Meiosis is normal in females, but crossing over and reduction in chromosome number fail to occur during spermatogenesis in males due to their haploidy
- For example, a **honeybee queen** (whose diploid number is 32) can lay **two** types of eggs.

MALE HAPLOIDY OR HAPLODIPLOIDY MECHANISM

- By controlling the sphincter of her sperm receptacle (which holds sperms previously obtained in matings with males during nuptial flight),
- She produces a **fertilized egg** (a **diploid** zygote having **32** chromosomes and developing into a **female**) or an **unfertilized egg** (a **haploid** zygote having **16** chromosomes and developing into a **male**).
- The **diploid** female zygotes can differentiate into either workers (sterile) or queens (fertile) depending on the diet they consume during their development.

D. SINGLE GENE CONTROL OF SEX

SINGLE GENE CONTROL OF SEX

- In **certain** organisms, for example *Chlamydomonas, Neurospora,* *Y*east, *Asparagus,* maize, *Drosophila,* etc.,
- **Individual single genes** are found to be responsible for the **determination** or **expression of sex**, following cases exemplified the single gene control of sex:

a. Monogenic sex determination in Drosophila

- In *Drosophila,* a **transformer gene** (**tra**) has been recognized which when present in homozygous condition (tra/tra) transforms a **female fly** into a **sterile male**,
- But, it does **not act** upon **normal male** individuals.
- Thus, a XX female **with tra/tra genotype will be a sterile male,** but, a XY male with tra/tra genotype will **still** be a normal male fly.

SINGLE GENE CONTROL OF SEX

2. Sex reversal gene (Sxr) in mammals.

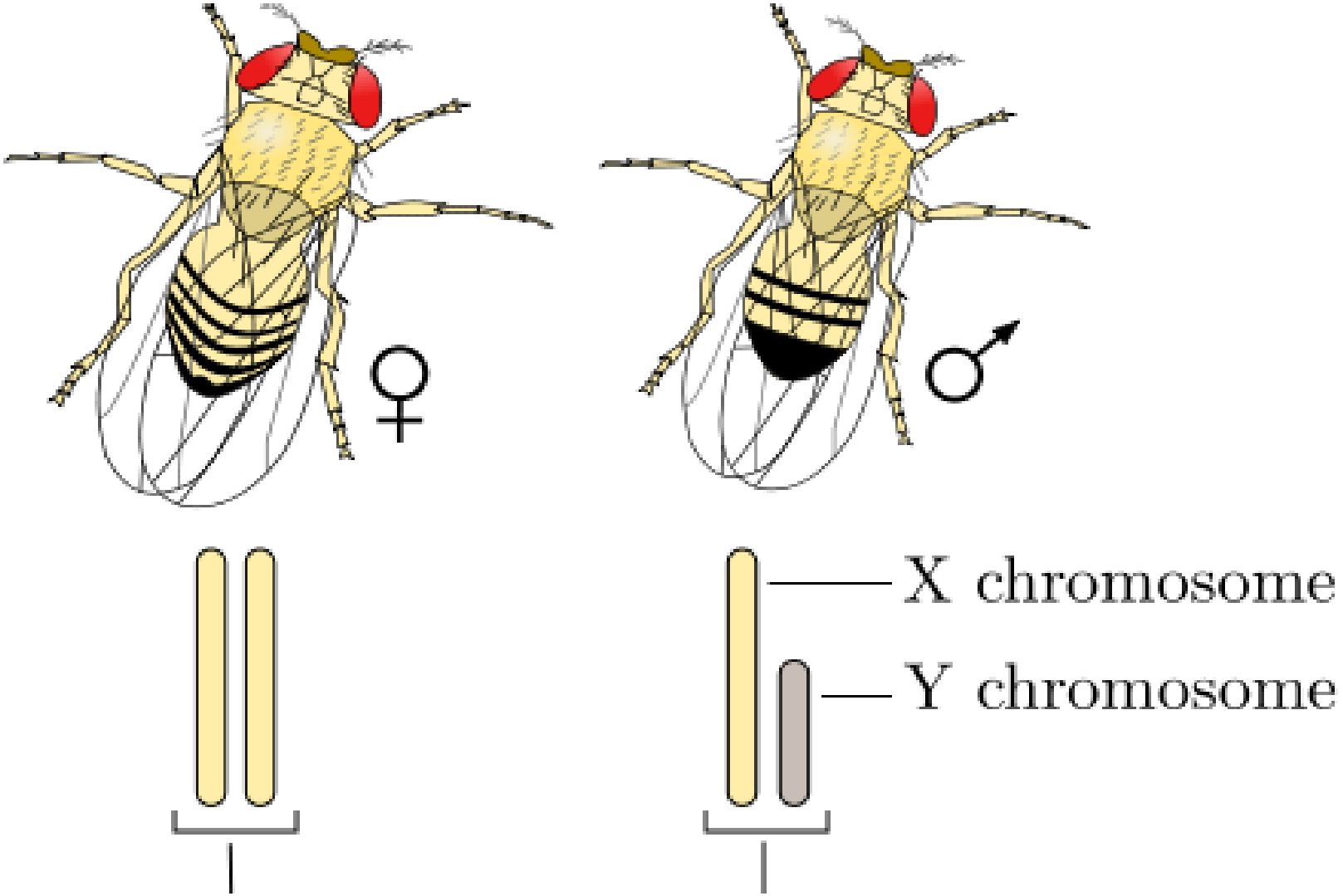
- Recently a **sex reversal gene** (**Sxr**) has been discovered in human beings, so that in the presence of this gene XX female individuals may become male.
- Such cases of sex reversal are also reported in goat and mice.
- Mice also contain **two other genes** Tdy and Tda-1 which interact to cause sex reversal in **XY male** individuals to transform them into **females**.

D. ENVIRONMENTALLY CONTROLLED SEX DETERMINING MECHANISM

- In some organisms, the environment determines the sexual **phenotype** of the individuals.
- Thus, some environmental factors as size of parent body or of egg, age of parent and temperature are found to determine the sex in following cases:

1. In the marine annelids sex appears to depend solely on size of the egg produced by a female. Small eggs produce males, where as larger sized eggs always develop into females.
2. The sex of some reptiles may depend upon the temperature at which the individual develops.

- For example, in most turtles, only **females** are produced at high temperature (30–35°C) and **only males** are produced at low temperatures (23–28°C).
- The **reverse is true** in crocodiles, alligators and some lizards, where **males** are produced at high temperature and **females** are produced at low temperature.


♀
♂
X chromosome
Y chromosome