Sex determination and differentiation in Plants

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Introduction

- Sex determination is the developmental decision that occurs during the plant life cycle that leads to the differentiation of the two organs or cells that produce the two gametes.

- Sex determination is a process that leads to the physical separation of male and female gamete-producing structures to different individuals of a species.

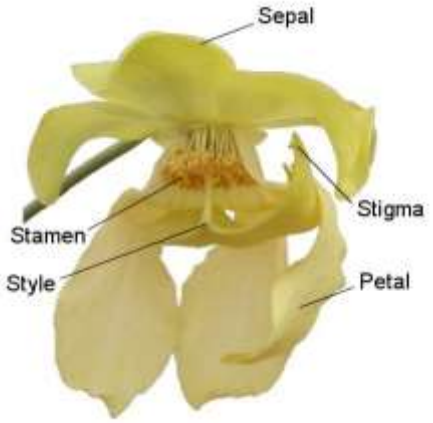
- Even though sexually reproducing species have only three possible options—to relegate the two sexes to separate individuals, to keep them together on the same individual, or to have a combination of both—plants in particular display a great variety of sexual phenotypes.

- In angiosperms, a sex-determining process is manifest in species that are monoecious, in which at least some flowers are unisexual but the individual is not, or dioecious, in which unisexual plants produce flowers of one sex type.

- In plants that produce no flowers and are homosporous, sex determination is manifest in the gametophyte generation with the production of egg- and sperm-forming gametangia on separate individual gametophytes

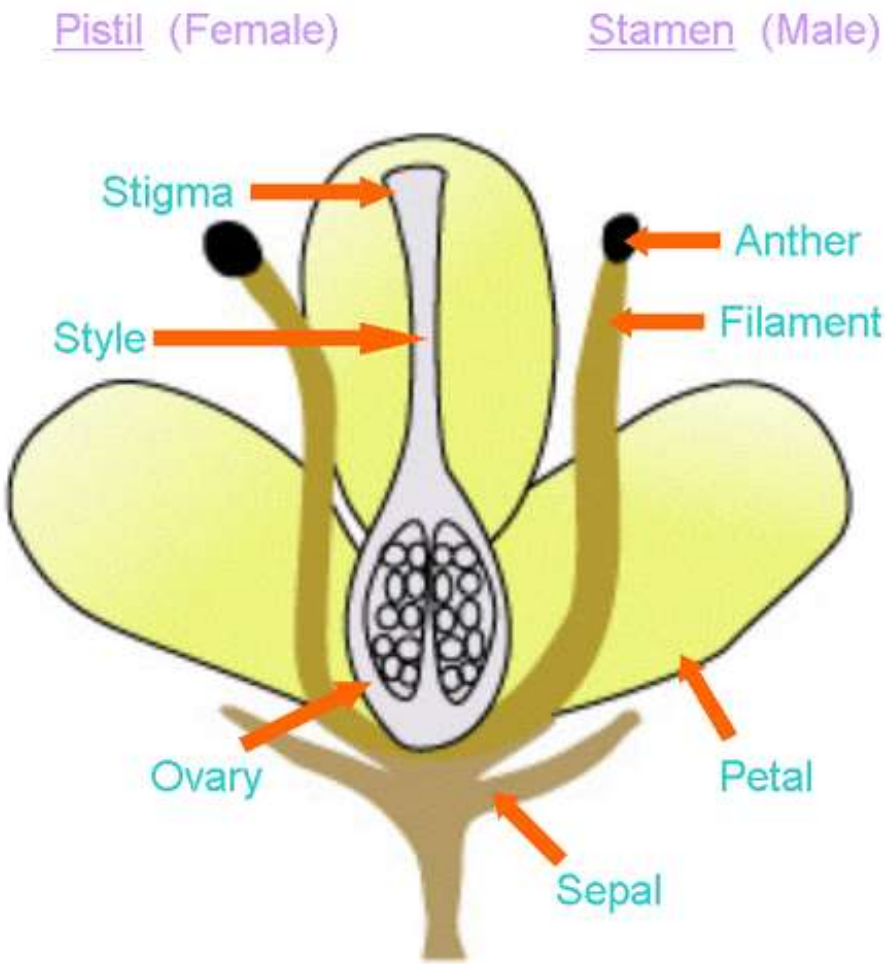
Sex Determination

- Cells of female humans have two X chromosomes
- Cells of males have one X chromosome and one Y chromosome
- Ways in which sex differences arise:
  - Hermaphroditism (that has only bisexual reproductive units)
  - Monoecious (an individual that has both male and female reproductive units)
  - Dioecious (refers to a plant population having separate male and female plants.)



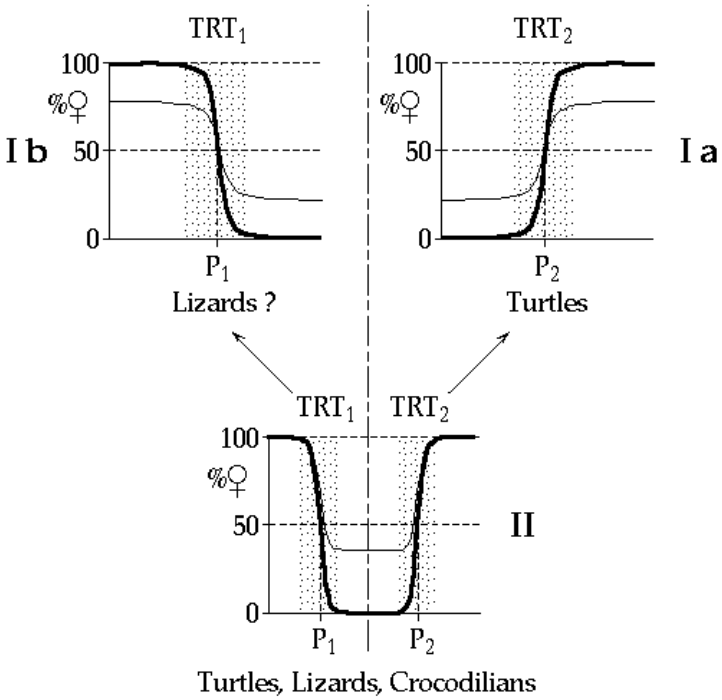
Plants

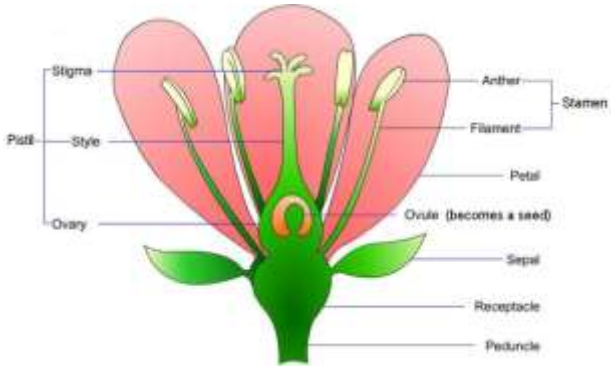
- Hermaphrodite flowers
- Hermaphrodite and male flowers on the same plant
- Male and Female flowers on the same plant
- Male and Female flowers on different plants



More Mechanisms

- Some species have environmentally determined sex. Among reptiles, the temperature at which the eggs develop determines the sex. For example, in the turtles, eggs incubated at 30°C become female, while those incubated at lower temperatures become male.
- Some species have both sexes on the same individual: this is very common among the angiosperms (flowering plants), where 90% of the species have hermaphroditic flowers, and many of the rest have separate male and female flowers on the same plant. A few plants (e.g. date palm and holly) have separate male and female plants.





Now we will go through different types of sex determination

In three types of plants

- Dioecious angiosperm-*Silene latifolia*
- Monoecious angiosperm - *Zea maize*
- Homosporous fern - *Ceratopteris richardii*

Sex determination in *Silene latifolia*

- *Silene latifolia* is a dioecious species (with separate male and female individuals) which harbours XY sex chromosomes and constitutes an important model for sex determination in plants.

- Chromosome deletion experiments have shown that the Y chromosome of *Silene latifolia* carries two loci involved in sex determination: the first involved in the suppression of female organ development and the second involved in the activation of male organ development.

- Four whorls of floral organs are observed in both male and female floral meristems, as it is the case for any hermaphrodite species: sepals, petals, stamens (male reproductive organs) and carpels (female reproductive organs).

- At an early stage, the flower meristem is similar in male and female plants (Undifferentiated). As soon as all floral organ primordia are initiated, the female territory in the centre of the flower meristem is significantly smaller in male compared to female flower buds.

- Later, a filament develops in male flower, in place of female organs. In female flower buds, stamens are initiated but rapidly degenerate, whereas five fused carpels (female organs) develop in the centre.

Sex determination in Monoecious angiosperms

Z***ea maize***

- Maize is a Monoecious plant that develops unisexual female and male flowers within separate inflorescences of the same individual.

- The maize inflorescence has the male and female florets initially perfect and become unisexual by a process of selective arrest.

- Abortion of pistils in staminate florets of the tassel, and of stamens in pistillate florets of the ear takes place.

- Gibberellins promote pistil development and suppress stamen development in the ear florets.

- Another two types of sex determining mutations, ***Silkless (sk1)*** and ***Tassel seed (Ts)*** have been identified.

- In *sk1* plants, the pistils and stamens of both ear florets are aborted although secondary sexual traits remain female, indicating that *Sk1 is necessary for the formation of* a functional pistil in the upper ear floret. In *ts* plants, functional pistillate florets form in the tassel.

- Non allelic ***ts*** mutations :
  - *ts1* and *ts2* affect the primary sex characteristics
  - *ts4* and *ts6* affect secondary sex characteristics

The *ts2* gene produces hydroxysteroid dehydrogenases which is involved in the pistil abortion in tassels.

Normally *ts2* is epiststic over *sk1* in ear, where as *sk1* particularly suppresses *ts2* in tassel .

Sex determination in Homosporous fern

C***eratopteris richardii***

- It has the potential to develop either male or hermaphroditic gametophytes.

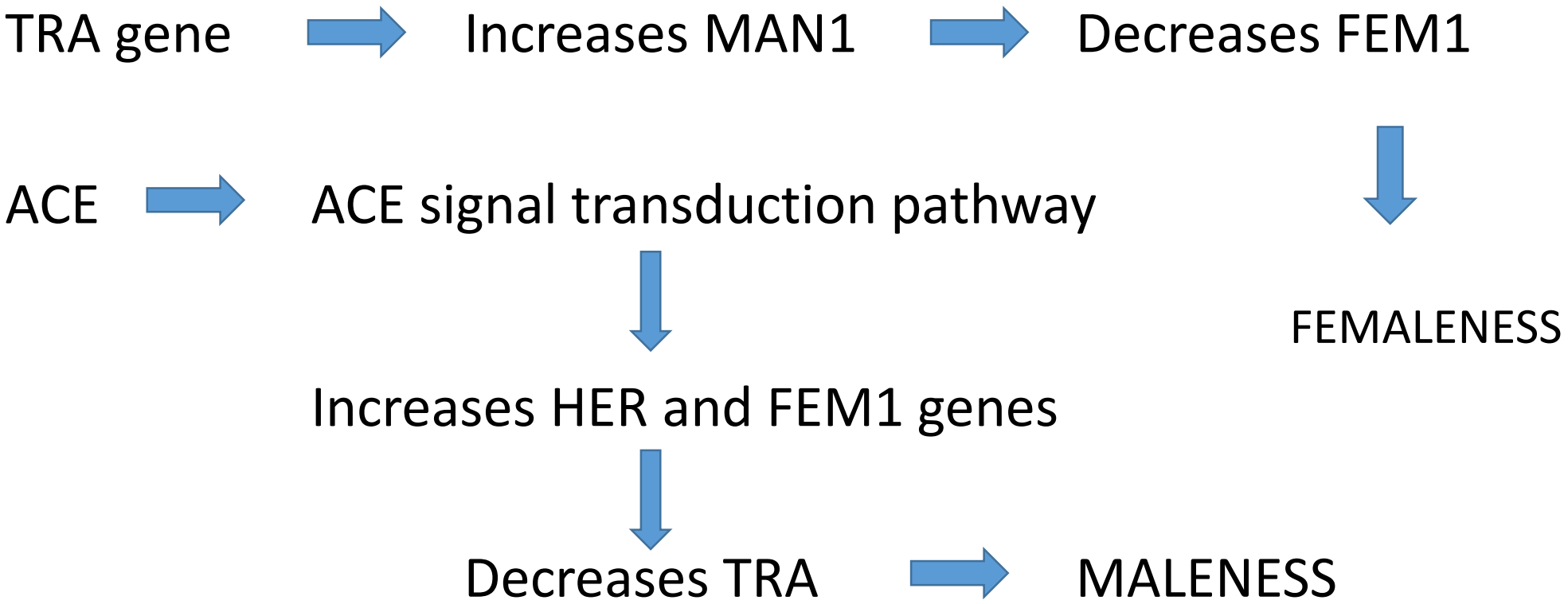
- A Hormone, referred to as ACE- *Antheridiogen Ceratopteris* produces male gametophytes

- The epistatic interactions among these genes have been examined and a genetic regulatory pathway controlling sex determination in C*eratopteris was* defined.

- Different types of genes participate in this pathway for the determination of sexes.

Transformer gene (TRA) – Femaleness

Feminization gene (FEM1) – Maleness



Sex-Determining Mechanisms

- The bryophytes are a group of plants that includes the modern liverworts, hornworts, and mosses.

- The haploid gametophyte is the dominant phase of the life cycle (Figure).

- Diploid spore-producing sporophytes are very small, short-lived, and parasitic upon the independent gamete-producing gametophyte generation.

- All bryophytes are homosporous, producing only one type of spore, yet all three groups of extant bryophytes are represented by species that are homothallic, with one individual gametophyte producing both male and female sex organs (gametangia)

- Species that are heterothallic, with one individual producing only male or female gametangia (Smith, 1955).

- Studies of bryophyte sex determination of heterothallic liverwort *Marchantia polymorpha*. The male and female thalli (vegetative gametophytes) look alike, although males and females can be distinguished easily by differences in the morphology of the sexual structure each produces.

- A gametophyte bears gametangia on stalked branches called antheridiophores (if male) or archegoniophores (if female) that arise from the upper surface of the thallus (Figure 1). Antheridiophores produce sperm-forming antheridia, and archegoniophores produce egg-forming archegonia.

- Haploid gametophytes develop gametangia in antheridiophores and archegoniophores that produce the sperm and egg, respectively. Upon fertilization, which is facilitated by raindrops, the diploid sporophyte remains attached to the archegoniophore and produces yellow sporangia, in which haploid spores are formed after meiosis. The spores are liberated and germinate to form a new gametophyte thallus. The sex of the thallus depends on which sex chromosome it inherits.

- *7.1 Life Cycles Depend on Sexual Differentiation*

- In multicellular organisms, it is important to distinguish between:
  - **primary sexual differentiation**
    - involves only the gonads where gametes are produced
  - **secondary sexual differentiation**
    - involves the overall appearance of the organism

Section 7.1

- Some organisms (*e.g. Chlamydomonas*) spend most of their life cycle in the haploid phase, asexually producing daughter cells by mitotic division.

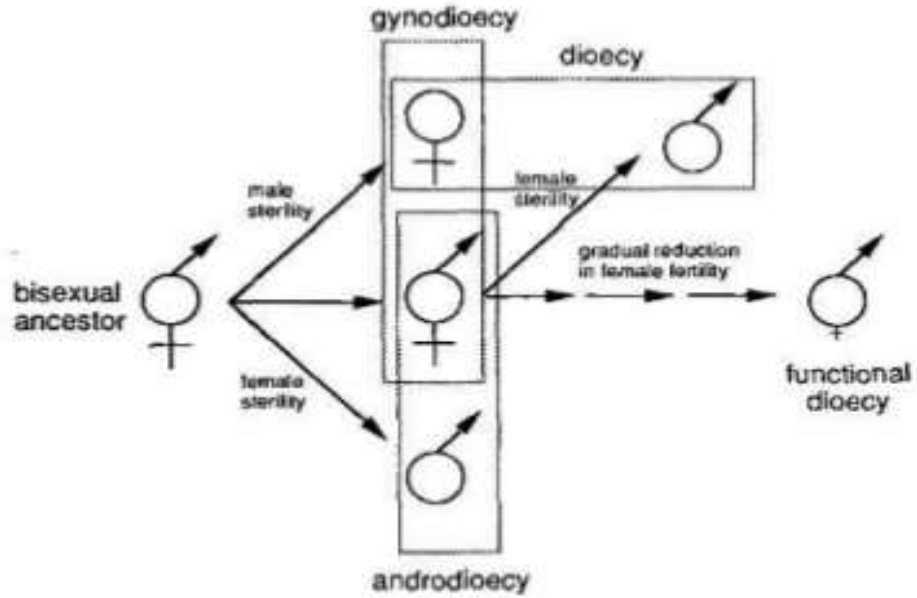
Figure 7.1

Figure 7.2

- In maize (*Zea mays*), the diploid sporophyte stage predominates and both male and female structures are present on the adult plant.

- This indicates that sex determination must occur differently in different tissues of the same plant

Figure 7.3.2



Major Pathways in the Evolution of Dioecy.

The first step is the establishment of females in the population by a male sterility mutation, forming a gynodioecious population The path way to androdioecy is rare in plants. A second process involving the loss of female fertility of the hermaphrodite leads to dioecy.