Principles of Breeding (Biol.3064)

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Introduction

Assignment ONE

Plant breeding methods that are applicable to inbreeding crop species.

1. Pure line (single plant) selection
2. Mass selection
3. Pedigree methods
4. Bulk methods
5. Single seed descent method
6. Backcross methods

Submission date: May.22,2015

Assignment TWO

Plant breeding methods that are applicable to out-breeding crop species

1. Selection from genetic variation existing in crops (mass selection, recurrent selection, progeny selection etc).
2. Hybrid variety production
3. Utilization of male sterility in hybrid variety production
4. Synthetic variety production

Submission date: May.30,2015

Prerequisites for the evolution of agriculture

- Intelligent hominids have been eating plant products for millions of years, but agriculture only dates back about 12 millennia.
- What were the factors that apparently precluded the evolution of agriculture for over 99% of human evolution, but then facilitated its appearance throughout the world during the Holocene era?
- Agriculture was not possible without:

1. The right sorts of plants and people to set up the process;
2. The right environmental and cultural conditions to sustain the process; and
3. The right stimuli to push people away from tried and tested hunter–gathering lifestyles towards this new, and untested, means of subsistence.

Box 3.2 Prerequisites for the evolution of agriculture

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(i) The right plants and people

Domestication-ready plant species: Agriculture could not have developed without the ready availability of starch-rich edible plants of moderately high yield with appropriate genomic architecture, such as the cereals, legumes, and tubers. Such plant species existed alongside hominids for several million years and were often exploited as seasonal foods. During this period, domestication-friendly mutations would have occurred regularly, but in the absence of human selection such variants would have been rapidly eliminated from wild populations. Hence, plant material potentially suitable for farming was available long before the arrival of *Homo sapiens*, but could only persist with the assistance of a human coevolutionary partner. Such plants were also very limited in their geographical distribution and ease of identification and selection by humans.

Human cognitive capacity: We have seen that cognitively modern humans have possibly been around since before *100,000 BP* (Box 1.3). By *30,000 BP*, people were producing very sophisticated artwork and probably had the capacity for the kinds of insights and forward planning required for farming. Furthermore, much of the technology used by early farmers, including sickles and grinders, had already been in use for other purposes many millennia before crops were grown.

(ii) The right environmental and cultural conditions

Climatic conditions: The right climatic conditions for farming are twofold; first you need an adverse period to diminish returns from hunter—gathering, and second a prolonged favourable period to enable the fragile seedling of agriculture to take root. Such conditions were provided in some regions by the Younger Dryas episode at the Pleistocene/Holocene transition followed by an unprecedentedly long period of *relative* stability that persists to this day.

Cultural conditions: Farming is a unique method of food generation, representing a paradigm shift from nomadism. A shift to farming might have entailed a high degree of cultural flexibility to circumvent prohibitions on land ownership by individuals or small groups. In some prefarming cultures such as the Natufians, this cultural shift may have begun earlier as they became semisedentary. Such cultural flexibility became increasingly adaptive as the returns from farming at the societal level far exceeded those of hunter—gathering. Farming societies then rapidly evolved new cultural forms and ideologies, such as religion, inequality, and kingship, as urbanized cultures became more powerful than smaller dispersed units.

(iii) The right stimuli

The conjunction of these prerequisites for agriculture did not occur in the Pleistocene, mainly because of climatic instability and the rarity of the right sorts of food plant. The Younger Dryas supplied the appropriate carrot and stick, where the stick was the steady decline in availability of the majority of traditional food resources, and the carrot was the presence of high-yielding protodomesticants that could be stored for months or even years. The result was a gradual switch to farming by several societies in Asia and Africa soon after *11,000 BP*.

The Scientific approach to plant breeding

Mendelian:

Incorporate information from genes into selection decisions championed by plant breeders.

Biometric:

Incorporate information from relatives into selection decisions championed by animal breeders.

Prospects: we now have the technology to combine the two.

Basic concept of varietal development

- produce or identify genetically variable germplasm;
- carry out selection procedures on genotypes from within this germplasm to identify superior genotypes with specified characteristics;
- stabilize and multiply these superior genotypes and release cultivars for commercial production.

Plant breeder will require knowledge in many (if not all) of the following subjects

Evolution

Botany

Genetics

Biology

Pathology

Weed science

Food science

Biometry

Agronomy

Molecular biology

Production

IT etc

Domestication Syndrome

Table 2.1 Characteristics of domestication syndrome traits.

General effect	Specific traits altered
Increased seedling vigor (more plants germinating)	Loss of seed or tuber dormancy Large seeds
Modified reproductive system	Increased selfing Vegetatively reproducing plants Altered photoperiod sensitivity
Increased number of seeds harvested	Non-shattering Reduced number of branches (more fruits per branch)
Increased appeal to consumers	Attractive fruit/seed colors and patterns Enhanced flavor, texture, and taste of seeds/fruits/tubers (food parts) Reduced toxic principles (safer food) Larger fruits Reduced spikiness
Altered plant architecture and growth habit	Compact growth habit (determinacy, reduced plant size, dwarfism) Reduced branching

Domestication related traits in Plants

Table 4.1 Some of the key domestication-related traits in crop plants

Trait	Wild plant	Domesticated crop
Height	Tall	Short or dwarf
Growth habit	Branched and bushy	Unbranched and compact
Ripening	Asynchronous	Synchronous
Seed dormancy	Present	Absent
Seed shattering	Shattering heads	Non-shattering heads
Seed size	Small	Large
Ease of dispersal	Highly dispersible	Loss of dispersal
Threshing	Hard	Easy
Reproduction	Outbreeding	Self-fertilizing
Germination	Asynchronous	Synchronous
Hairs and/or spines	Present	Absent or reduced
Toxins	Present	Absent or reduced

Domestication and Center of Origin

- **Cereal crops**, with world production of maize (*Zea Mays), rice (Oryza sativa) and wheat (Triticum spp.);* each being just under 600 million metric tones annually
- Major **root crops** include potato (*Solanum tuberosum), cassava (Manihot esculenta), and sweet* potato (*Ipimiea batatas).*
- ***Oilseed crops** are soybean oil* (*Elaeis guineensis), coconut palms (Cocos nucifera), and* rapeseed (*Brassica napus).*
- **Fruits and vegetables** are similar where tomato (*Lycopersico esculentum),* cabbage (*Brassica oleracea) and onion (Alliums* spp.) are leading vegetable crops, whilst orange (*Citrus sinesis), apple (Malus spp.), grape (Vitaceae spp.) and* banana (*Musa aceminata and M. balbisiana) predominate* amongst the fruits.

Centers of origin

Table 1.1. Probable geographic origins for crops.

Region	Crops
Near East (Fertile Crescent)	Wheat and barley, flax, lentils, chickpea, figs, dates, grapes, olives, lettuce, onions, cabbage, carrots, cucumbers, melons; fruits and nuts
Africa	Pearl millet, Guinea millet, African rice, sorghum, cowpea, groundnut, yam, oil palm, watermelon, okra
China	Japanese millet, rice, buckwheat, soybean
South-east Asia	Wet- and dryland rice, pigeon pea, mung bean, citrus fruits, coconut, taro, yams, banana, breadfruit, coconut, sugarcane
Mesoamerica and North America	Maize, squash, common bean, lima bean, peppers, amaranth, sweet potato, sunflower
South America	Lowlands: cassava; Mid-altitudes and uplands (Peru): potato, groundnut, cotton, maize

Centers of origins of Major crops/Vavilovian Centers

Time of Domestication and Centers of origin

Crop	Time of domestication (years)	Possible region of origin
Cereals		
Maize, *Zea Mays*	7000	Mexico, Central America
Rice, *Oryza sativa*	4500	Thailand, Southern China
Wheat, *Triticum* spp.	8500	Syria, Jordan, Israel, Iraq
Barley, *Hordeum vulgare*	9000	Syria, Jordan, Israel, Iraq
Sorghum, *Sorgum bicolour*	8000	Equatorial Africa
Oilseeds		
Soybean, *Glycine max*	2000	Northern China
Oil palm, *Elaeis guineensis*	9000	Central Africa
Coconut palm, *Cocos nucifera*	100	Southern Asia
Rapeseed, *Brassica napus*	500	Mediterranean Europe
Sunflower, *Helianthus*	3000	Western United States
Pulses		
Beans, *Phaseolus* spp.	7000	Central America, Mexico
Lentil, *Lens culinaris*	7000	Syria, Jordan, Israel, Iraq
Peas, *Pisum sativum*	9000	Syria, Jordan, Israel, Iraq
Root crops		
Potato, *Solanum tuberosum*	7000	Peru
Cassava, *Manihot esculenta*	5000	Brazil, Mexico
Sweet potato, *Ipimiea batatas*	6000	South Central America
Sugar beet, *Beta vulgaris*	300	Mediterranean Europe
Vegetables		
Tomato, *Lycopersico esculentum*	3000	Western South America
Cabbage, *Brassica oleracea*	3000	Mediterranean Europe
Onion, *Allium*	4500	Iran, Afghanistan, Pakistan
Fruit		
Orange, *Citrus sinesis*	9000	South-eastern Asia
Apple, *Malus* spp.	3000	Asia Minor, Central Asia
Grape, *Vitaceae* spp.	7000	Eastern Asia
Banana, *Musa aceminata, M. balbisiana*	4500	South-east Asia
Others		
Cotton, *Gossypium*	4500	Central America, Brazil
Coffee, *Coffea* spp.	500	West Ethiopia
Rubber, *Hevea brasiliensis*	200	Brazil, Bolivia, Paraguay
Alfalfa, *Medicago sativa*	4000	Iran, Northern Pakistan

Where Crops were Domesticated

- Five areas where crops were domesticated independently are:
- Southwest Asia (Middle East):
  - – wheat, pea, olive

Where Crops were Domesticated

- China: Rice, Millet

Where Crops were Domesticated

- Mesoamerica: corn, beans, squash

Where Crops were Domesticated

- Andes: potato

Where Crops were Domesticated

- America: sunflower

Major Food Crops in the World

Table 1.1 The 25 major food crops of the world, ranked according to total tonnage produced annually.

1	Wheat	11	Sorghum	21	Apple
2	Rice	12	Sugarcane	22	Yam
3	Corn	13	Millet	23	Peanut
4	Potato	14	Banana	24	Watermelon
5	Barley	15	Tomato	25	Cabbage
6	Sweet potato	16	Sugar beet		
7	Cassava	17	Rye		
8	Grape	18	Orange		
9	Soybean	19	Coconut		
10	Oat	20	Cottonseed oil		

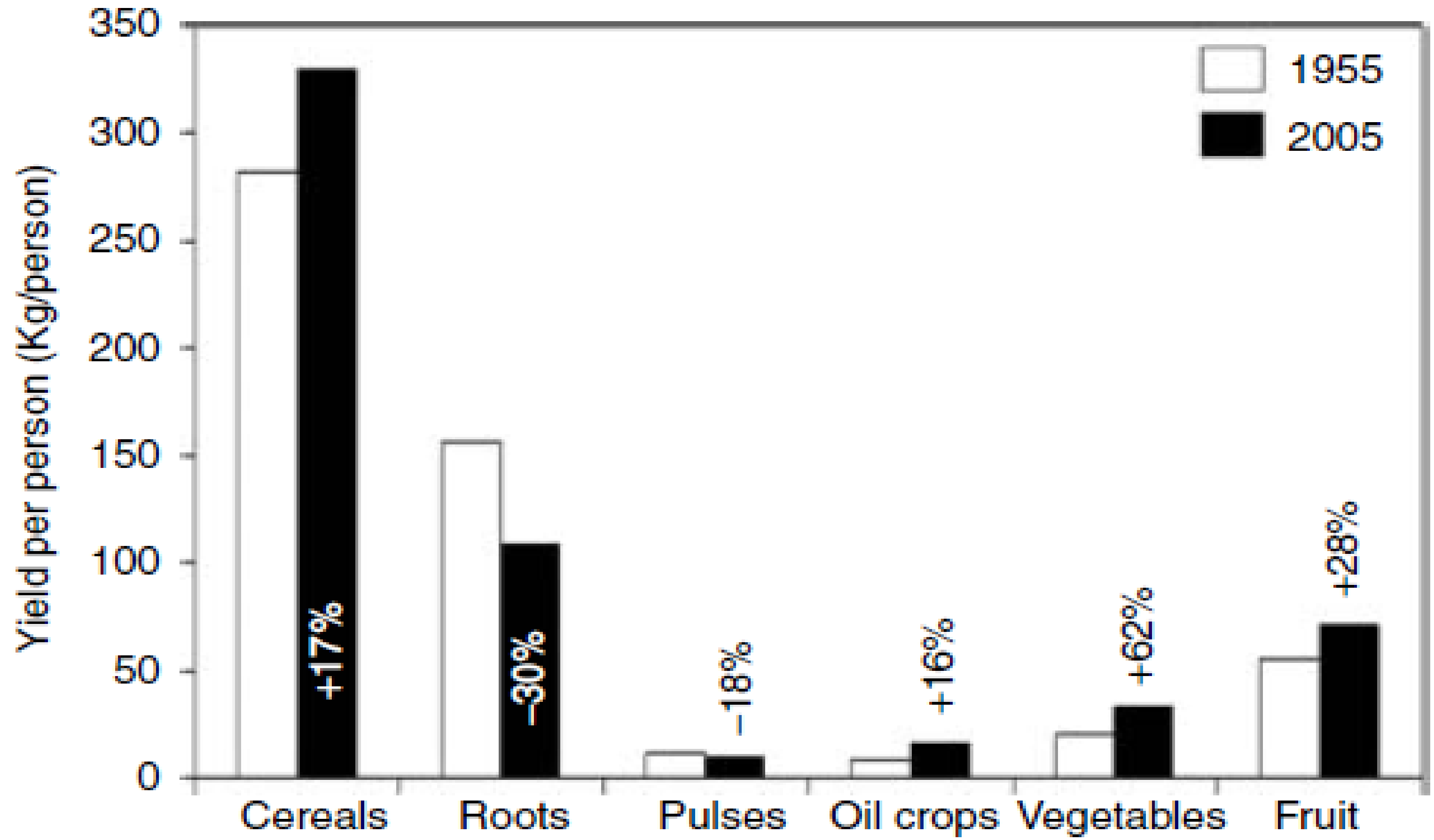


Figure 1.4 Total world crop production per capita 1955 and 2005.

Technologies of Plant Breeding

Table 2.2 An operational classification of technologies of plant breeding.

Technology/tool	Common use of the technology/tool
Classic/traditional tools	
Emasculation	Making a complete flower female; preparation for crossing
Hybridization	Crossing unidentical plants to transfer genes or achieve recombination
Wide crossing	Crossing of distantly related plants
Selection	Primary tool for discriminating among variability
Chromosome counting	Determination of ploidy characteristics
Chromosome doubling	For manipulating ploidy for fertility
Male sterility	To eliminate need for emasculation in hybridization
Triploidy	To achieve seedlessness
Linkage analysis	For determining association between genes
Statistical tools	For evaluation of germplasm
Relatively advanced tools	
Mutagenesis	To induce mutations to create new variability
Tissue culture	For manipulating plants at the cellular or tissue level
Haploidy	Used for creating extremely homozygous diploid
Isozyme markers	To facilitate the selection process
In situ hybridization	To detect successful interspecific crossing
More sophisticated tools	
DNA markers	
RFLP	More effective than protein markers (isozymes)
RAPD	PCR-based molecular marker
Advanced technology	
Molecular markers	SSR, SNPs, etc.
Marker-assisted selection	To facilitate the selection process
DNA sequencing	Ultimate physical map of an organism
Plant genomic analysis	Studying the totality of the genes of an organism
Bioinformatics	Computer-based technology for prediction of biological function from DNA sequence data
Microarray analysis	To understand gene expression and for sequence identification
Primer design	For molecular analysis of plant genome
Plant transformation	For recombinant DNA work

Breeding Objectives

Breeding Objectives

- The first exercise which must precede any of the breeding operations is preparing a breeding plan or setting **breeding objectives.**
- **Objectives should be both economically and biologically feasible**.
- Many new cultivars fail when they reach the agricultural practice.
- Associated with the wrong economic objectives.
- Many excellent new genotypes fail to become successful cultivars

1. Unforeseen defect which was not considered important
2. Overlooked in the breeding scheme.

Breeding objectives

- Yield
- Resistance to lodging (bending or breaking over of plants before harvest) and shattering (fall out of seeds before harvest)
- Winter hardiness (to survive winter stress)
- Heat and drough resistance
- Soil stress
- Resistance to plant pathogens
- Resistance to insect pests
- Product quality

The breeder will have to decide on such considerations as:

- What political and economic factors are likely to be of greatest importance in future years?
- What criteria will be used to determine the yielding ability required of a new cultivar?
- What end-use quality characters are likely to be of greatest importance when the new releases are at a commercial stage?
- What diseases or pests are likely to be of greatest importance in future years?
- What type of agricultural system will the cultivar be developed for?

It is only after answering these questions that breeders will be able to ask:

- What type of cultivar should be developed?
- How many parents to include in the crossing scheme, which parents to include, how many crosses to examine, to examine two-way or three-way parent cross combinations and why?
- How should progeny progress through the breeding scheme (pedigree system, bulk system, etc.)?
- What characters are to be selected for or against in the breeding scheme and at what stage should selection for these characters take place?
- How to release the variety and promote its use in agriculture?

PEOPLE, POLITICAL AND ECONOMIC CRITERIA

- In 1863, 58% of the US population were actual farmers.
- Indeed only a few decades ago, the majority of people in the western world were directly involved in agricultural and food production.
- In 2006, less than 2% of the United States population were directly involved with agriculture.
- This past century therefore has resulted in a dramatic shift away from working on the land to living and working in cities.
- Agricultural output has, and continues, to increase almost annually despite fewer and fewer people working directly in agriculture than ever before.

INCREASING GROWER/Farmers PROFITABILITY

Plant breeders can increase grower's profitability by:

- Increasing the yield per planted area, assuming input costs remain constant
- Increasing the region of crop production
- Reducing input costs: **herbicides, insecticides and fungicides)**
- Increasing the inherent **quality component** of the end products
- Higher unit price when the harvestable product is sold, or such that the **product is more nutritious**.

Increasing harvestable yield

Have two main components:

1. *Biomass, the ability to produce* and maintain an adequate quantity of vegetative material
2. *Partition, the capacity to divert biomass* to the desired product (seeds, fruits, or tubers etc.)

- Eenhancement of yield of desired parts of the plant product at the expense of unwanted plant parts.

The Three Main Forms

1. Increased reproductive growth.

- ✓ Short stature, or indeed are dwarf mutants.
- ✓ Wheat, barley, oat, sunflower, several legumes, along with fruit trees like apple, orange, peach and cherry.

2. Increased a vegetative product.

- Vegetative growth (e.g. potato, sugarcane, sugarbeet and various vegetables).

3. Vegetative production to different vegetative parts can be used to increase yield of root and vegetable crops like potato, rudabaga (swede) and carrot.

- Vegetative yield (e.g. tubers in the case of potato) while maintaining the minimum biomass of unused plant parts.

Selection for yield increase

- Multiple modifications to the plants' ***morphology, physiology and biochemistry*.**
- Quantitatively inherited
- Highly modifiable by a wide range of environmental factors.
- Genotypic response to ***differing environments and genotype–environment interactions are the major limiting factors to maximizing selection response in plant breeding.***
- Despite advances in ***molecular marker selection*** (mainly ***quantitative trait loci***), increased yield is achieved by evaluating the phenotype of breeding lines under a wide range of rather atypical environments

INCREASING END-USE QUALITY

- End-use quality of the saleable product.
- Y***ear-round fruits and vegetables*** has resulted in food products being shipped greater and greater distances to arrive fresh almost on a daily basis.
- **Storage of perishable agricultural products** to make them available at times of shortage of local supplies.

Organoleptic

- Taste, size, texture and color.
- Taste panels as to general preference towards certain levels of expression of these attributes, thus ‘liking’ some genotypes over others.
- Ability to be stored for long periods without loss of quality.
- Hence many vegetable or fruit crops have a certain ‘*harvest window’ where the majority of the crop is harvested.*

Chemical

- In oil crops, where the quality of the oil can be determined with great accuracy by determination of the oil **fatty acid profile**.
- Pharmaceutical *industry* where the quality of drugs are chemically determined.
- Fibre plants like cotton, and indeed fodder crops where protein content and digestibility.

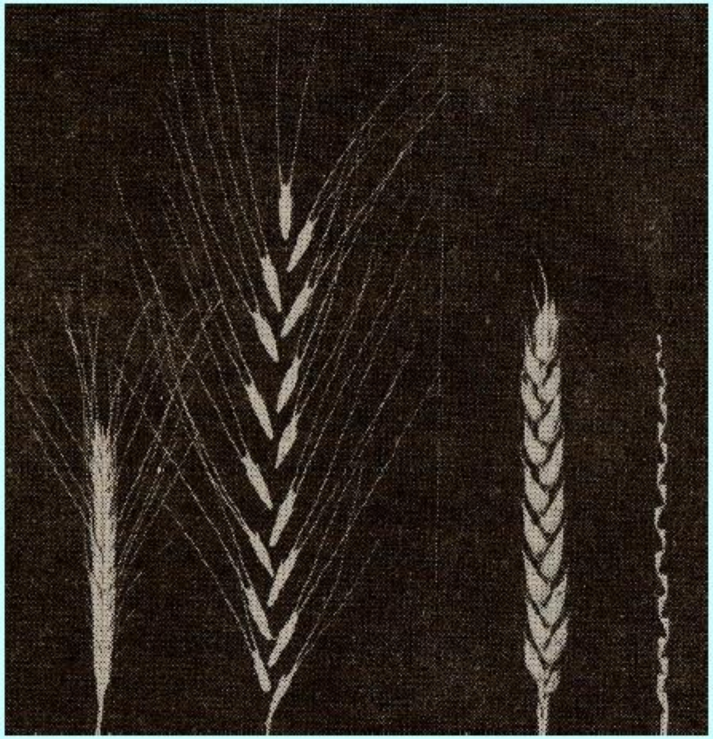
Testing for end-use quality

- If new cultivars are released which have special quality characters there may be justification, and **economic merit, in introducing this as a '*specialty' product even* if overall yielding ability is not high.**
- **Economic returns were sufficiently high to overcome the deficiencies in total yield.**

INCREASING PEST AND DISEASE RESISTANCE

- Infection or infestation by plant pests and diseases.
- The genetic variability of the pest or disease as well as the variability in resistance (or tolerance) that exists within the crop species.
- Disease and pests include fungi (air- and soil-borne), bacteria, viruses, eelworms and insects.

Wild plant *versus* cultivated plant



T. monococcum *T. aestivum*

Difference in:
- yield
- content
- germination synchronity
- maturaion
- resistance

Mating Systems in Plant

Purpose and expected outcomes

After studying this chapter, the student should be able to:

- Discuss the types of plant life cycles and their implication in breeding.
- Describe the basic types of floral morphology.
- Discuss the mechanisms of pollination and fertilization.
- Discuss the breeding implications of self- and cross-pollination.
- Describe the constraints to pollination and their implication in breeding.
- Discuss the genetics and applications of male sterility in breeding.

Importance of mode of reproduction to plant breeding

1. *The genetic structure of plants depends on their mode of reproduction.*
2. *In flowering species*

- *Artificial hybridization is needed*
- *To conduct genetic studies to understand the inheritance of traits of interest,*
- *For transfer of genes of interest from one parent to another.*

3. *Artificial hybridization requires*

- *Effective control of pollination so that only the desired pollen is allowed to be involved in the cross.*

4. *The mode of reproduction also determines the procedures for multiplication and maintenance of cultivars developed by plant breeders.*

Overview of reproductive options in plants

1. Hermaphrodity vs. unisexuality
2. Self-pollination vs. cross-pollination.
3. Self-fertilization vs. cross-fertilization.
4. Sexuality vs. asexuality.

Genetic Consequences of Modes of Reproduction

- Hermaphrodity promoting a reduction in genetic variability.
- Unisexuality, promotes genetic variability.
- **A*utogamous* (pollen comes from the same flower – selfing),**
- ***Allogamous* (pollen** comes from a different flower).
- Differences between the time of pollen shed and stigma receptivity.
- S***elf-incompatibility*** causes some species to reject pollen from their own flowers, thereby promoting outcrossing.

Sexual reproduction

Alternation of Generations

1. Sporophytic Generation

Key activities:

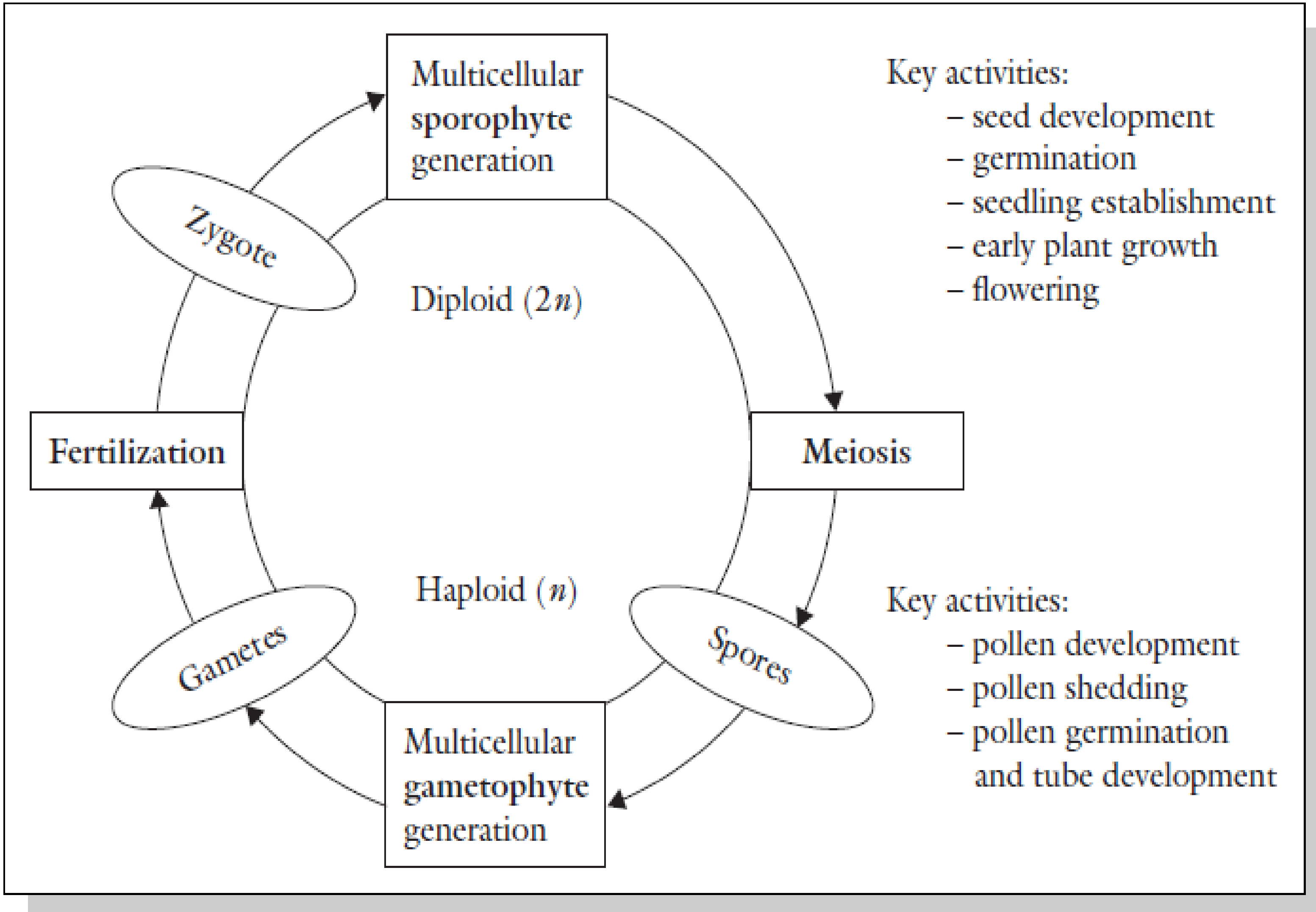
- seed development
- germination
- seedling establishment
- early plant growth
- flowering

2. Gametophytic Generation

Key activities:

- – pollen development
- – pollen shedding
- – pollen germination
- and tube development

Alternation of Generation in Flowering Plants



Dura ration of plant growth cycle

Annuals

- complete their life cycle in one growing season.

Biennials

- completes its life cycle in two growing seasons.

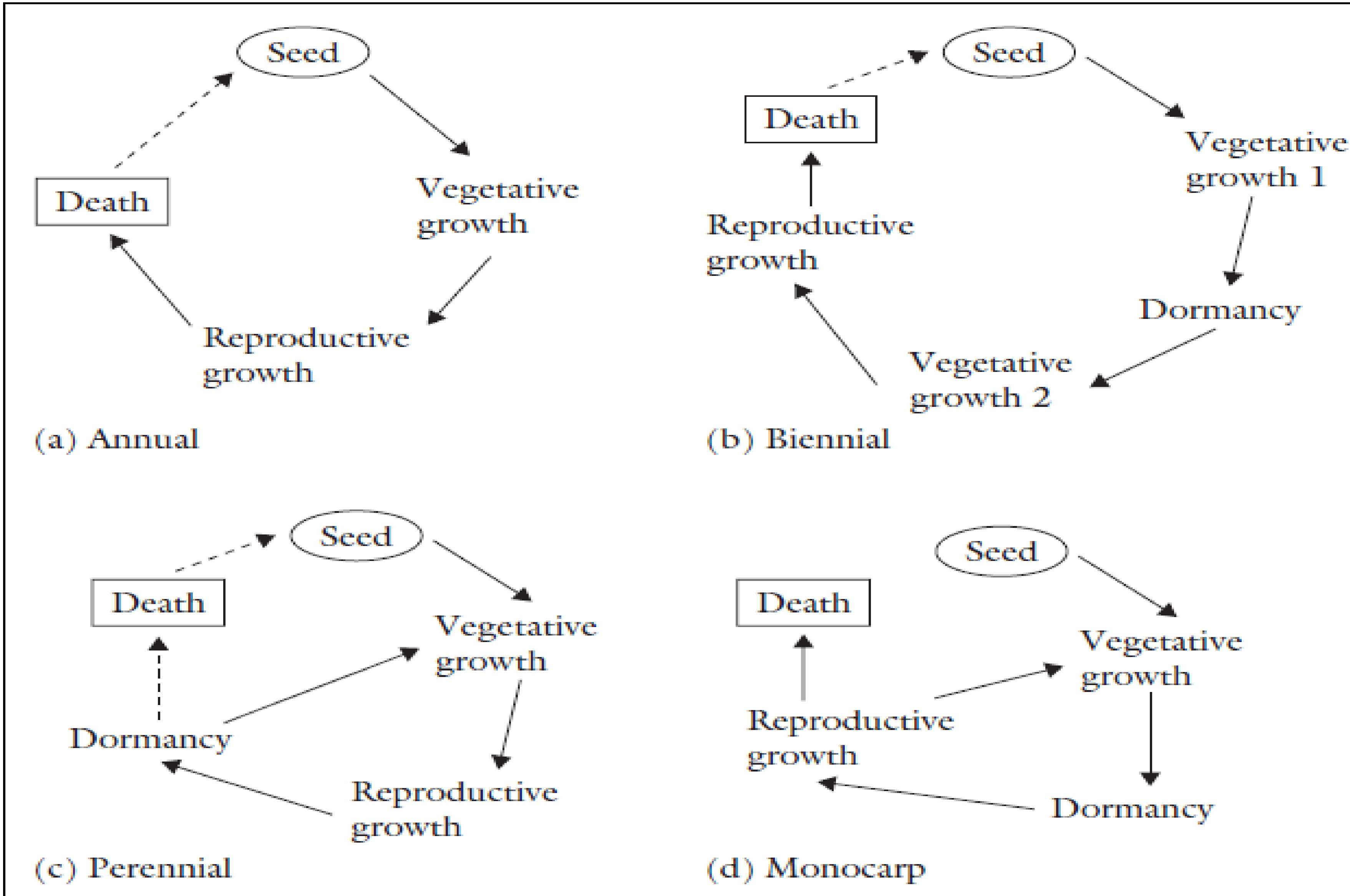
Perennials

- Repeat their life cycles indefinitely by circumventing the death stage.

Monocarps

- Repeated, long vegetative cycles that may go on for many years without entering the reproductive phase.

Life Cycle of Flowering Plants



General reproductive morphology

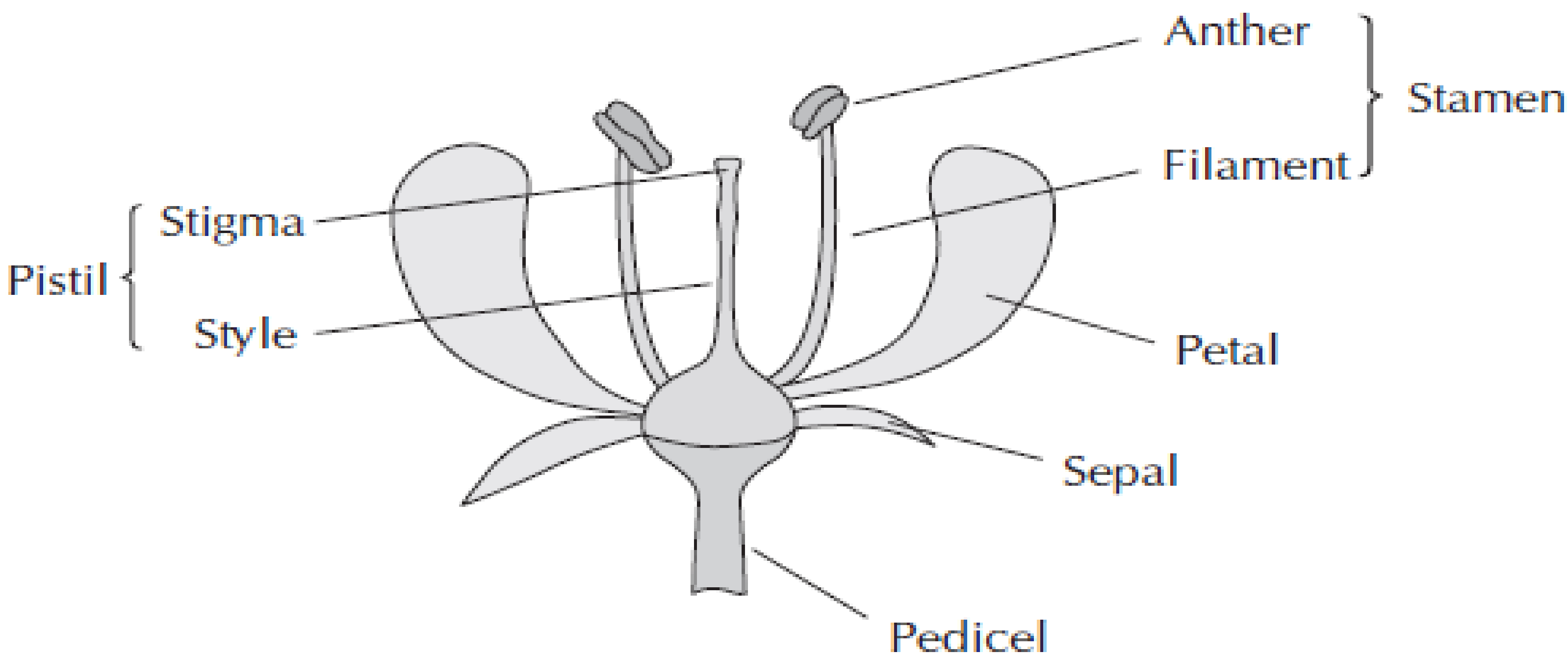
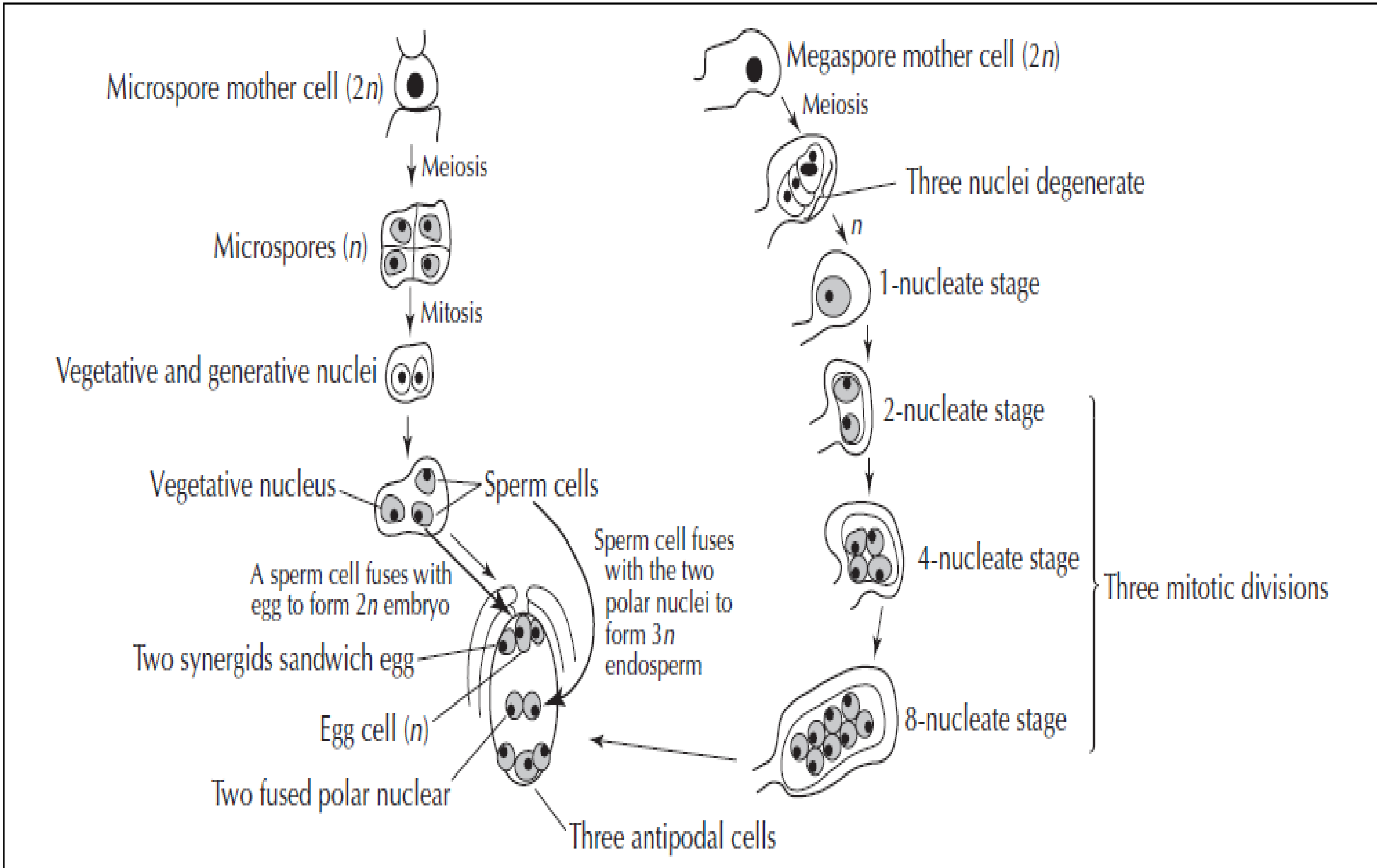


Figure 4.3 The typical flower has four basic parts – the petals, sepals, pistil, and stamen. The shape, size, color, and other aspects of these floral parts differ widely among species.

Pollination and Fertilization



Self-pollination

Mechanisms that promote self-pollination

- **Cleistogamy** is the condition in which the flower fails to open.
- C**hasmogamy** a condition in which the flower opens only after it has been pollinated.
- Some floral structures such as those found in legumes, favor self pollination.
- The stigma of the flower is closely surrounded by anthers, making it prone to selfing.
- Very few species are completely self-pollinated.

Self pollination Continued ….

- Nature and amount of insect pollination, air current, and temperature.
- Pollen may become sterilized when the temperature dips below freezing.
- Flower that opens prior to self-pollination is susceptible to some cross-pollination.

Genetic and breeding implications of self-pollination

- Highest degree of inbreeding a plant can achieve.
- It promotes homozygosity of all gene loci and traits.
- To be classified as self-pollinated, cross-pollination should not exceed 4%.
- The genotypes of gametes of a single plant are all the same.
- Progeny of a single plant is homogeneous.
- A population of self-pollinated species, in effect, comprises a mixture of homozygous lines.

Genetic and breeding implications continued…

- Restricts the creation of new gene combinations.
- New genes may arise through mutation,
- Mutations (which are usually recessive) are readily exposed through homozygosity.

Genetic and breeding implications…..

- Repeated selfing has no genetic consequence in self pollinated species (no **inbreeding depression** or loss of vigor following selfing).
- Self-incompatibility does not occur.
- Specific breeding methods: pure-line selection, pedigree breeding, bulk populations, and backcross breeding.

Cross-pollinating species

Mechanisms that favor cross-pollination

- **Dioeciou**s: A plant is either female or male (e.g., hemp, date, palm).
- Monoecious species can receive pollen from their own male flowers.
- **Dichogamy** occurs in hermaphroditic flowers, whereby cross-pollination may be enforced.
- **Protandry: s**tamens mature before the pistil is mature and receptive.
- **Protogyny**: pistil mature before stamen.

Cross-pollinating species continued...

- S**elf-incompatibility**.
- **Male sterility**: the pollen of the male is sterile, compels the plant to receive pollen from different flowers.
- H**eterostyly:** difference in the lengths of the stamen and pistil makes it less likely for self-pollination.

Genetic and breeding implications of cross-pollination

- Sporophytic generation is heterozygous while the gametes of a single plant are all different.
- The genetic structure is characterized by heterozygosity.
- Self-incompatibility occurs in such species.
- Share a wide gene pool from which new combinations are created to form the next generation.
- When selfed, they suffer inbreeding depression.

Genetic and breeding implications continued…

- Deleterious recessive alleles that were suppressed.
- Depression is reversed upon cross-pollination.
- **Hybrid vigor** is exploited in hybrid seed production.
- **Mass selection, recurrent selection, synthetic cultivars) are common methods of breeding cross-pollinated species.**

Asexual reproduction

- **Vegetative propagation and apomixis.**
- **Clonal propagation:** products are genetically identical to the propagules

Vegetative propagation

- Reproduction by bulbs, corms, rhizomes, stems, and buds.
- Widely used in the **horticultural industry**.
- C**uttings** are parts of the plant (e.g., root, stem, leaf) for that used for planting (e.g., Potato, cassava and sugarcane)
- Grafting and budding are used for propagating tree crops.
- **Micropropagation:** Numerous plantlets may be generated from a small piece of vegetative material.
- T**issue culture** technique is used to rapidly multiply planting material under aseptic conditions.

Apomixis

- **Apomixis**: the natural ability to develop seed without fertilization.
- Seeds are clones of the mother plant.
- Asexual production of seed.
- No new recombination to occur to produce diversity in the offspring.

Occurrence in nature

- 1% of the estimated 40,000 species they comprise exhibit apomixis.
- **Many species of citrus, berries, mango, perennial forage grasses, and guayule reproduce apomictically**.
- **Facultative apomicts:** both sexual and apomictic seeds and are called (e.g., bluegrass,*Poa pratensis*).
- **Obligate apomicts**: reproduce exclusively or nearly so by apomixis (e.g. *Paspalum notatum*).

Indicators of Apomixis

- **Progeny from a cross in a cross-pollinated species fails to segregate**.
- **When plants expected to exhibit high sterility** (e.g., aneuploids, triploids) instead show significantly high fertility.
- **Obligate apomicts may display multiple floral features** (e.g., multiple stigmas and ovules per floret, double or fused ovaries, or multiple seedlings per seed.
- **Facultative apomixis may be suspected if the progeny of a cross shows an unusually high number of identical homozygous.**

Apomixis Benefits to the plant breeder

- Develop hybrids that can retain their original genetic properties indefinitely with repeated use.
- Hybrid seed can be produced from hybrid seed.
- No need to make crosses each year to produce the hybrid.
- Accelerates breeding programs and reduces development costs of hybrid cultivars.
- Greatly beneficial when uniformity of product is desired.
- Help to quickly fix superior gene combinations.
- Vigor can be duplicated, generation after generation without decline.
- Cultivars could be developed for smaller and more specific production environments.

Apomixis to the producer/Farmers

- The ability to save seed from their field harvest of hybrid cultivars for planting the next season.
- The farmer does not need to purchase fresh hybrid seed each season.
- This especially benefits the producer in poor economies, who often cannot price of hybrid seed.

Mechanisms of apomixis

- Seed formation without sexual union is called **agamospermy**.
- G**ametophytic apomixis** and **adventitious apomixis**.

1. **Apospory:**

- Agamospermy that involves the nucellar.
- The somatic cells of the ovule divide mitotically to form unreduced (2*n*) embryonic sacs.
- The megaspore or young embryo sac aborts.

2. **Diplospory**.

- An unreduced megaspore mother cell produces embryo sacs following mitosis instead of meiosis.

Mechanisms of apomixis Continued....

3 Adventitious embryo.

- No embryo sac is formed in adventitious embryony.
- Source of the embryo could be somatic cells of the ovule, integuments, or ovary wall.
- This mechanism occurs commonly in citrus but rarely in other higher plants.

4 Parthenogenesis.

- This mechanism is essentially equivalent to haploidy.
- The reduced (*n*) egg nucleus in a sexual embryo sac develops into a haploid embryo without fertilization by the sperm nucleus.

- ***Mechanisms of apomixis Continued....***
- **Androgenesis: A** seed embryo from the sperm nucleus upon entering the embryo sac.
- **Semigamy:** sperm nucleus and egg nucleus develop independently without uniting, leading to a haploid embryo.
- The resulting haploid plants contain sectors of material from both maternal and paternal origin.

Constraints of sexual biology in plant breeding

- Some constraints of sexual biology are exploited as tools for breeding plants.
- **Dioecy, monoecy, self-incompatibility, and male sterility.**
- **In hybrid seed production, success depends on the presence of an efficient, reliable, practical, and economic pollination control system for large-scale pollination.**

Pollination control Methods

1. Mechanical control

- **Emasculation:** removing anthers from bisexual flowers to prevent pollination.
- Removing one sexual part (e.g., detasseling in corn), or excluding unwanted pollen by covering the female art.
- Time-consuming, expensive, and tedious, limiting the number of plants that can be crossed.
- In crops such as corn, mechanical detasseling is widely used in the industry to produce hybrid seed.

Pollination control continued ….

2. Chemical control

- Chemical hybridizing agents or other names (e.g., male gametocides, male sterilants, pollenocides, androcides) are used to temporally induce male sterility in some species.
- Examples of such chemicals include Dalapon®, Estrone®, Ethephon®, Hybrex®,and Generis®.
- **These agents induces male sterility in plants, thereby enforcing cross-pollination.**

3. Genetic control.

- Certain **genes** are known to impose constraints on sexual biology.
- Incapacitating the sexual organ (**as in male sterility**).
- Inhibiting the union of normal gametes (**as in self-incompatibility**).

Dioecy and monoecy

- **Monoecy**: separate male and female flowers occur on the same plant.
- **Dioecy:** the sexes occur on different plants (i.e., there are female plants and male plants).
- Seed from **dioecious** species are hybrid in composition.
- Where the economic product is the seed or fruit, it is imperative to have female and male plants in the field in an appropriate ratio.
- In orchards, 3–4 males per 100 females may be adequate.
- In terms of seed production, **dioecy** and **monoec**y are inefficient because not all flowers produce seed.

Self-incompatibility/SI (or lack of self-fruitfulness)

- Pollen from a flower is not receptive on the stigma of the same flower and hence is incapable of setting seed.
- It is caused by a genetically controlled physiological hindrance to self-fertilization.
- Incompatibility reaction is genetically conditioned by a locus designated *S*.
- Multiple alleles that can number over 100 in some species such as *Trifolium pretense*.

Self-incompatibility systems

- Two basic types of SI: **heteromorphic and homomorphic.**
- **Heteromorphic SI. d**ifferences in the lengths of stamens and style (i.e. **Heterostyly).**
- **Pin, the styles are long while the anthers are** short.
- T**hrum, the reverse is** true (e.g., in *Primula)*.
- **Pin** trait has genotype ***ss***.
- *Thrum has the* genotype ***Ss***.
- ***Pin (ss) X** pin **(ss)** as well as* **thrum (*Ss*) *X thrum (Ss)*** *are incompatible.*
- Pin **(*ss*) *X*** *thrum* ***(Ss)*** *or vice versa, is compatible.*

Heteromorphic incompatibility

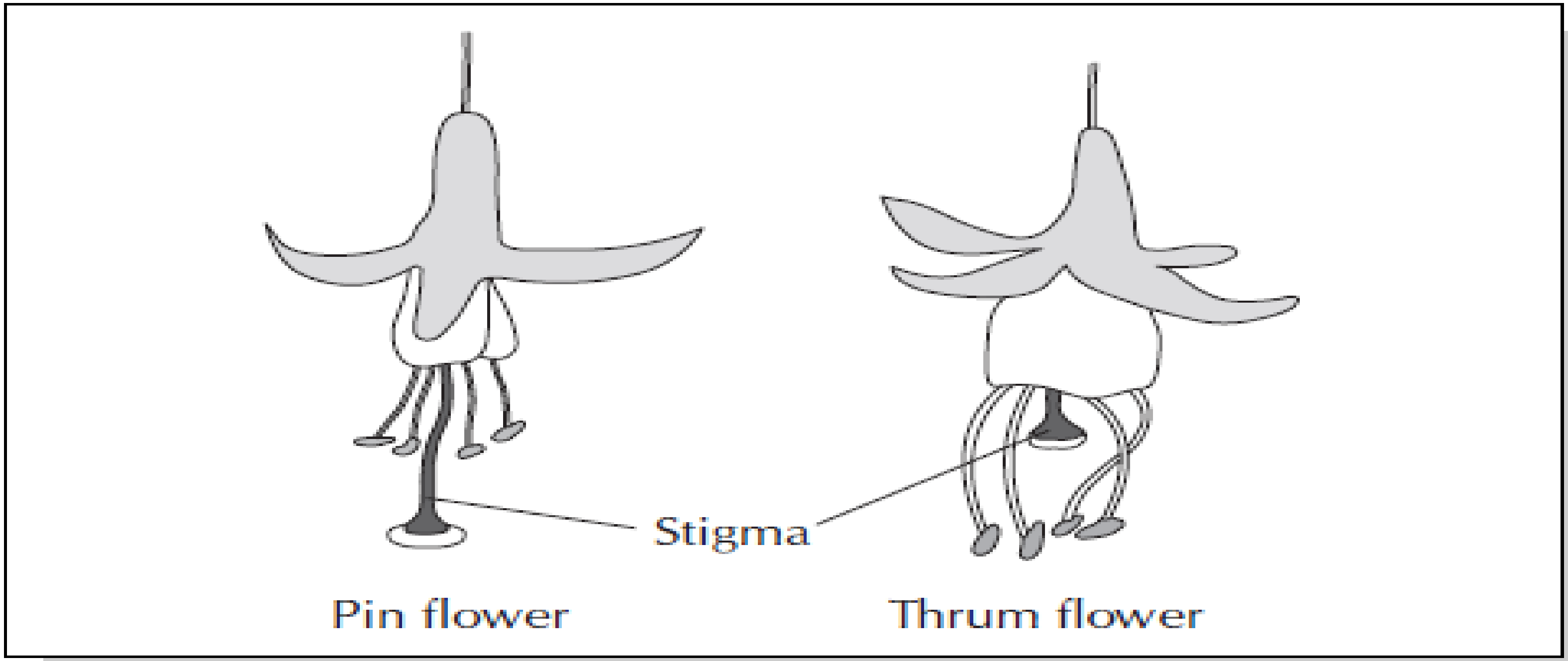


Figure 4.5 Heteromorphic incompatibility showing floral modifications in which anthers and pistils are of different lengths in different plants (heterostyly). This type of incompatibility is believed to be always of the sporophytic type. Pin and thrum flowers occurs in flowers such as *Primula*, *Forsythia*, *Oxalis*, and *Silia*.

Homomorphic incompatibility.

- Similar flower structure
- **Two kinds: gametophytic** and **sporophytic .**

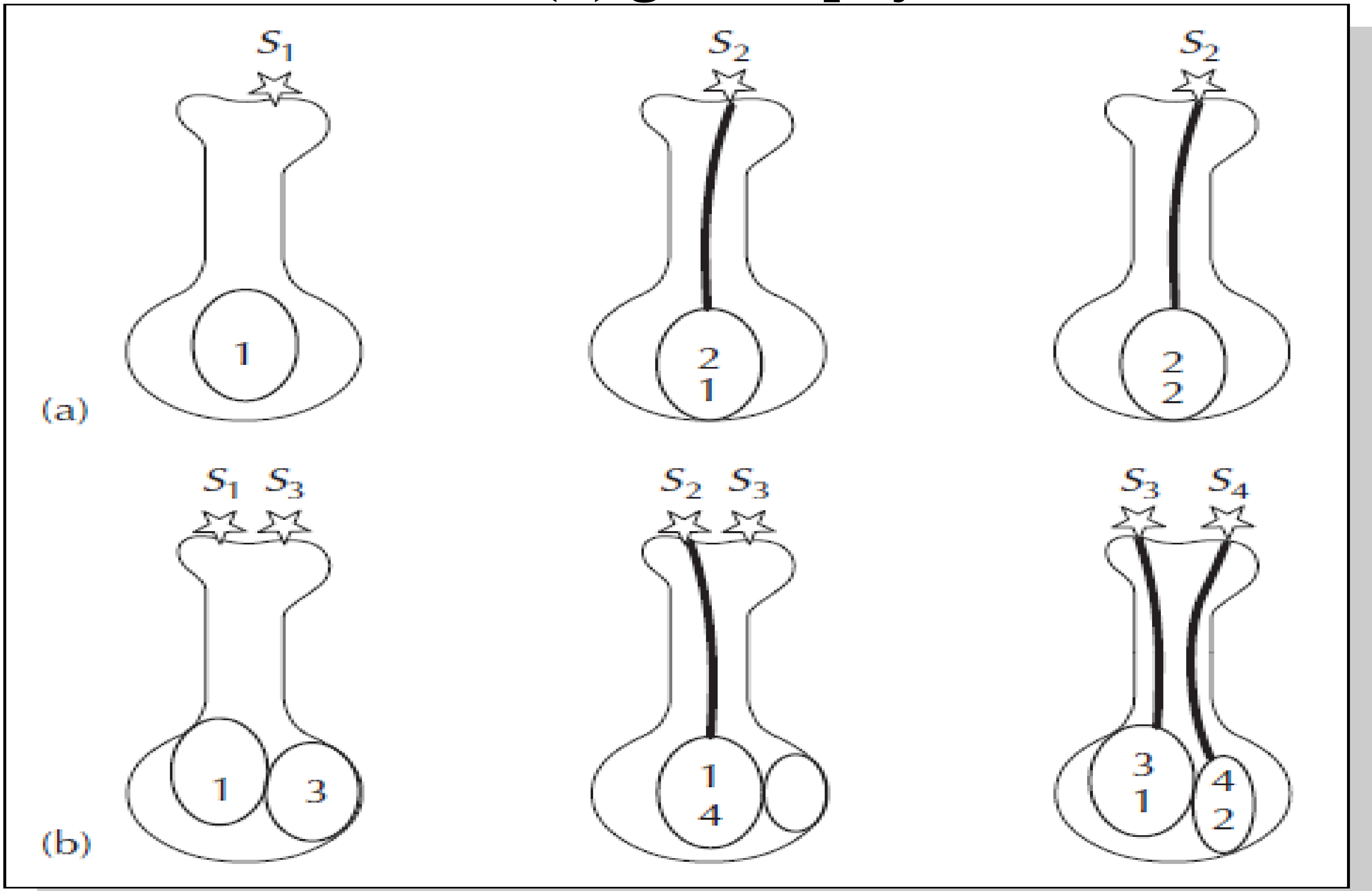
1. Gametophytic incompatibility.

- The pollen to function is determined by its own genotype.
- Gametophytic SI is more widespread than sporophytic SI.
- **The alleles of the SI gene(s) act individually in the style.**
- They exhibit no dominance.
- The incompatible pollen is inhibited in the style.
- **Reactions occur if identical alleles in both pollen and style are encountered.**
- Only heterozygotes for *S* alleles are produced in this system.

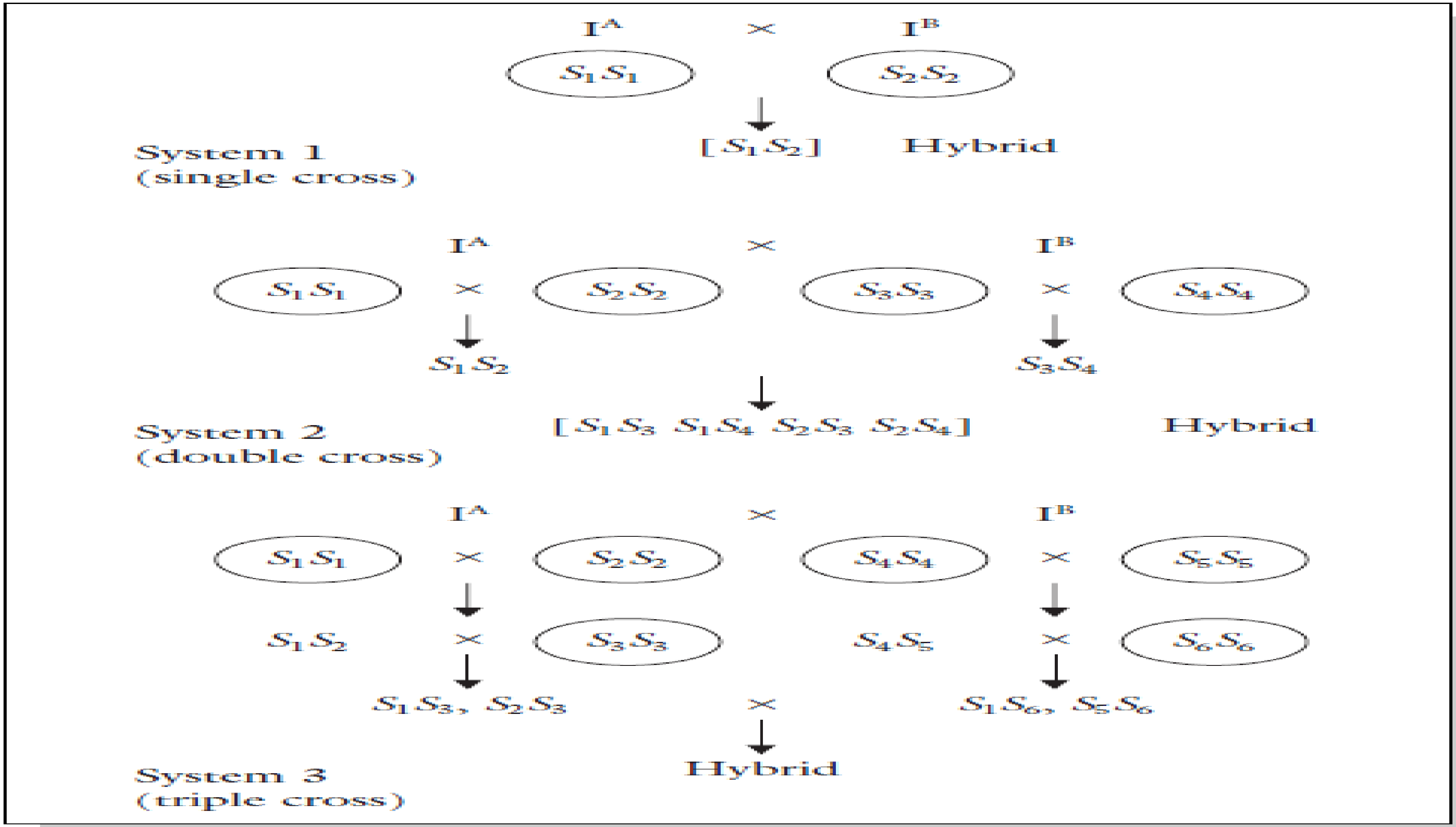
2. Sporophytic incompatibility.

- Incompatibility characteristics of the pollen are determined by the plant (sporophyte) that produces it.
- The *S* allele exhibits dominance.
- Have individual action in both pollen and the style, making this incompatibility system complex.
- The dominance is determined by the pollen parent.
- Incompatible pollen may be inhibited on the stigma surface.

Types of self-incompatibility: (a) sporophytic and (b) gametophytic



Application of Self-Incompatability in Hybride seed production



Male sterility

- **Male sterility is a condition in plants whereby the** anthers or pollen are non-functional.
- Absence, or extreme scarcity, of pollen, severe malformation or absence of flowers or stamens, or failure of pollen to dehisce.
- Male sterility enforces cross pollination.
- Can be exploited as a tool to eliminate the need for emasculation for producing hybrid seed.

- **Types of male starility**

1 True male sterility.

- Unisexual flowers that lack male sex organs (dioecy and monoecy) or to bisexual flowers with abnormal or non-functional microspores (leading to pollen abortion).

2 Functional male sterility.

- Anthers fail to release their contents even though the pollen is fertile.

3 Induced male sterility.

Plant breeders may use chemicals to induce sterility.

Genetic male sterility Genetic (nuclear, genic)

- Found in species including barley, cotton, soybean, tomato, potato, and lima bean.
- May be manifested as pollen abortion (pistillody) or abnormal anther development.
- Genetic male sterility is often conditioned by a single recessive nuclear gene, *ms,* the dominant allele, *Ms, conditioning normal anther* and pollen development

Application of Genetic Male sterility in Plant Breeding

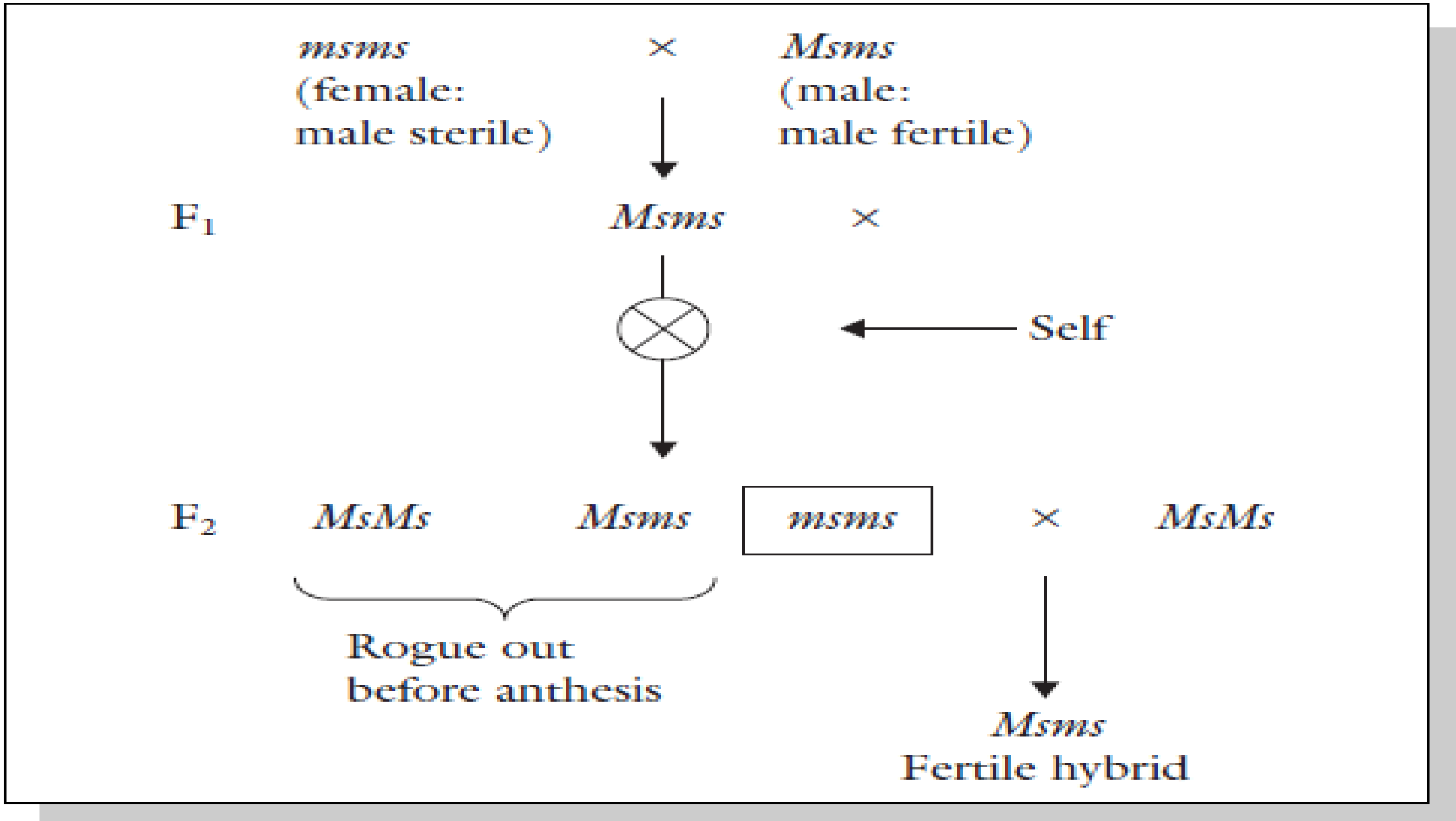


Figure 4.8 Genetic male sterility as used in practical breeding.

- ***Cytoplasmic male sterility***
- Controlled by mitochondrial gene but may be influenced by nuclear genes.
- A cytoplasm without sterility genes is described as normal (N) cytoplasm,
- Cytoplasm that causes male sterility is called a sterile (s)
- **Cytoplasmic male sterility (CMS).**
- **CMS is transmitted through the** egg only (maternal factor).
- Corn, sorghum, sugar beet, carrot, andflax.

Cytoplasmic male sterility as applied in plant breeding.

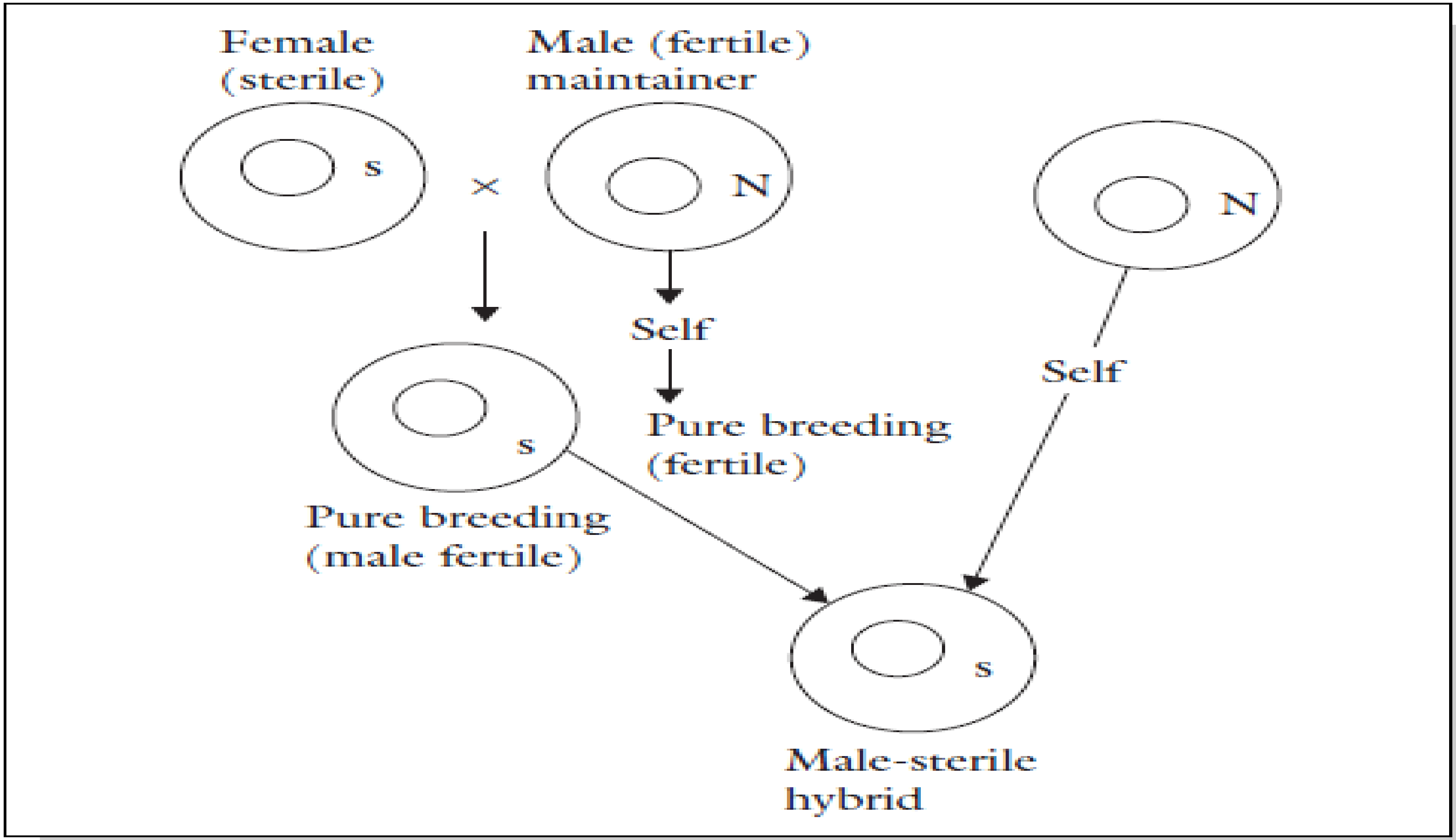


Figure 4.9 Cytoplasmic male sterility as applied in plant breeding. N, normal cytoplasm; s, sterile cytoplasm.

Exploiting male sterility in breeding

- Used as a tool in plant breeding to eliminate emasculation in hybridization.
- Hybrid breeding of self-pollinated species is tedious and time consuming.
- Plant breeders use male-sterile cultivars as female parents in a cross without emasculation.
- Using genetic male sterility in plant breeding is problematic
- Not possible to produce a pure population of male-sterile plants using conventional methods.
- CMS is used routinely in hybrid seed production in corn, sorghum, sunflower, and sugar beet.