Chapter 38

Angiosperm Reproduction and Biotechnology

Many angiosperms lure insects with nectar; both plant and pollinator benefit

Mutualistic symbioses are common between plants and other species

Angiosperms can reproduce sexually and asexually

Angiosperms are the most important group of plants in terrestrial ecosystems and in agriculture

Flowers, double fertilization, and fruits are unique features of the angiosperm life cycle

Plant lifecycles are characterized by the alternation between a multicellular haploid (*n*) generation and a multicellular diploid (2*n*) generation

Diploid sporophytes (2*n*) produce spores (*n*) by meiosis; these grow into haploid gametophytes (*n*)

Gametophytes produce haploid gametes (*n*) by mitosis; **fertilization** of gametes produces a sporophyte

In angiosperms, the sporophyte is the dominant generation, the large plant that we see

The gametophytes are reduced in size and depend on the sporophyte for nutrients

The angiosperm life cycle is characterized by “three Fs”: *f*lowers, double *f*ertilization, and *f*ruits

Flower Structure and Function

Flowers are the reproductive shoots of the angiosperm sporophyte; they attach to a part of the stem called the **receptacle**

Flowers consist of four floral organs: **sepals**, **petals**, **stamens**, and **carpels**

Stamens and carpels are reproductive organs; sepals and petals are sterile

A stamen consists of a filament topped by an **anther** with pollen sacs that produce pollen

A carpel has a long **style** with a **stigma** on which pollen may land

At the base of the style is an **ovary** containing one or more **ovules**

A single carpel or group of fused carpels is called a **pistil**

Complete flowers contain all four floral organs

Incomplete flowers lack one or more floral organs,

for example stamens or carpels

Clusters of flowers are called **inflorescences**

Development of Male Gametophytes in Pollen Grains

- Pollen develops from **microspores** within the microsporangia, or pollen sacs, of anthers
- Each microspore undergoes mitosis to produce two cells: the generative cell and the tube cell
- A pollen grain consists of the two-celled male gametophyte and the spore wall

If pollination succeeds, a **pollen grain** produces a **pollen tube** that grows down into the ovary and discharges two sperm cells near the embryo sac

Development of Female Gametophytes (Embryo Sacs)

The **embryo sac**, or female gametophyte, develops within the ovule

Within an ovule, two integuments surround a megasporangium

One cell in the megasporangium undergoes meiosis, producing four **megaspores**, only one of which survives

The megaspore divides, producing a large cell with eight nuclei

This cell is partitioned into a multicellular female gametophyte, the embryo sac

Pollination

In angiosperms, **pollination** is the transfer of pollen from an anther to a stigma

Pollination can be by wind, water, or animals

Wind-pollinated species (e.g., grasses and many trees) release large amounts of pollen

Coevolution of Flower and Pollinator

Coevolution is the evolution of interacting species in response to changes in each other

Many flowering plants have coevolved with specific pollinators

The shapes and sizes of flowers often correspond to the pollen transporting parts of their animal pollinators

- For example, Darwin correctly predicted a moth with a 28 cm long tongue based on the morphology of a particular flower

Double Fertilization

After landing on a receptive stigma, a pollen grain produces a pollen tube that extends between the cells of the style toward the ovary

Double fertilization results from the discharge of two sperm from the pollen tube into the embryo sac

One sperm fertilizes the egg, and the other combines with the polar nuclei, giving rise to the triploid food-storing **endosperm** ($3n$)

Seed Development, Form, and Function

After double fertilization, each ovule develops into a

seed

The ovary develops into a fruit enclosing the seed(s)

Endosperm Development

Endosperm development usually precedes embryo development

In most monocots and some eudicots, endosperm stores nutrients that can be used by the seedling

In other eudicots, the food reserves of the endosperm are exported to the cotyledons

Embryo Development

The first mitotic division of the zygote splits the fertilized egg into a basal cell and a terminal cell

The basal cell produces a multicellular suspensor, which anchors the embryo to the parent plant

The terminal cell gives rise to most of the embryo

The cotyledons form and the embryo elongates

Structure of the Mature Seed

The embryo and its food supply are enclosed by a hard, protective **seed coat**

The seed enters a state of **dormancy**

A mature seed is only about 5–15% water

In some eudicots, such as the common garden bean, the embryo consists of the embryonic axis attached to two thick cotyledons (seed leaves)

Below the cotyledons the embryonic axis is called the **hypocotyl** and terminates in the **radicle** (embryonic root); above the cotyledons it is called the **epicotyl**

The plumule comprises the epicotyl, young leaves, and shoot apical meristem

A monocot embryo has one cotyledon

Grasses, such as maize and wheat, have a special cotyledon called a scutellum

Two sheathes enclose the embryo of a grass seed: a **coleoptile** covering the young shoot and a **coleorhiza** covering the young root

Seed Dormancy

Seed dormancy increases the chances that germination will occur at a time and place most advantageous to the seedling

The breaking of seed dormancy often requires environmental cues, such as temperature or lighting changes

Seed Germination and Seedling Development

Germination depends on **imbibition**, the uptake of water due to low water potential of the dry seed

The radicle (embryonic root) emerges first

Next, the shoot tip breaks through the soil surface

In many eudicots, a hook forms in the hypocotyl, and growth pushes the hook above ground

Light causes the hook to straighten and pull the cotyledons and shoot tip up

In maize and other grasses, which are monocots,

the coleoptile pushes up through the soil

Fruit Form and Function

A **fruit** develops from the ovary

It protects the enclosed seeds and aids in seed dispersal by wind or animals

A fruit may be classified as dry, if the ovary dries out at maturity, or fleshy, if the ovary becomes thick, soft, and sweet at maturity

Fruits are also classified by their development

Simple, a single or several fused carpels

Aggregate, a single flower with multiple separate carpels

Multiple, a group of flowers called an inflorescence

An **accessory fruit** contains other floral parts in addition to ovaries

Fruit dispersal mechanisms include

- Water
- Wind
- Animals

Flowering plants reproduce sexually, asexually, or both

Many angiosperm species reproduce both asexually and sexually

Sexual reproduction results in offspring that are genetically different from their parents

Asexual reproduction results in a clone of genetically identical organisms

Mechanisms of Asexual Reproduction

Fragmentation, separation of a parent plant into parts that develop into whole plants, is a very common type of asexual reproduction

In some species, a parent plant's root system gives rise to adventitious shoots that become separate shoot systems

Apomixis is the asexual production of seeds from a diploid cell

Advantages and Disadvantages of Asexual Versus Sexual Reproduction

Asexual reproduction is also called **vegetative reproduction**

Asexual reproduction can be beneficial to a successful plant in a stable environment

However, a clone of plants is vulnerable to local extinction if there is an environmental change

Sexual reproduction generates genetic variation that makes evolutionary adaptation possible

However, only a fraction of seedlings survive

Some flowers can self-fertilize to ensure that every ovule will develop into a seed

Many species have evolved mechanisms to prevent selfing

Mechanisms That Prevent Self-Fertilization

Many angiosperms have mechanisms that make it difficult or impossible for a flower to self-fertilize

Dioecious species have staminate and carpellate flowers on separate plants

The most common is **self-incompatibility**, a plant's ability to reject its own pollen

Researchers are unraveling the molecular mechanisms involved in self-incompatibility

Some plants reject pollen that has an *S*-gene matching an allele in the stigma cells

Recognition of self pollen triggers a signal transduction pathway leading to a block in growth of a pollen tube

Vegetative Propagation and Agriculture

Humans have devised methods for asexual propagation of angiosperms

Most methods are based on the ability of plants to form adventitious roots or shoots

Clones from Cuttings

Many kinds of plants are asexually reproduced from plant fragments called cuttings

A **callus** is a mass of dividing undifferentiated cells that forms where a stem is cut and produces adventitious roots

Grafting

A twig or bud can be grafted onto a plant of a closely related species or variety

The **stock** provides the root system

The **scion** is grafted onto the stock

Test-Tube Cloning and Related Techniques

Plant biologists have adopted *in vitro* methods to create and clone novel plant varieties

A callus of undifferentiated cells can sprout shoots and roots in response to plant hormones