CHAPTER 28 REPRODUCTION IN PLANTS

Chapter Outline

28.1 Reproductive Strategies

A. Life Cycles
   1. In contrast to animals with one type of adult generation, flowering plants exhibit an **alternation of generations life cycle** that includes a diploid and a haploid generation.
   2. The **sporophyte** is a diploid generation in an alternation of generations life cycle.
      a. A sporophyte produces haploid spores by meiotic division.
      b. Spores develop into a haploid **gametophyte**.
   3. A **gametophyte** is a haploid generation in an alternation of generations life cycle.
      a. A gametophyte produces haploid gametes by mitotic division; gametes fuse to form diploid zygote.
      b. The zygote undergoes mitotic cell division to develop into the sporophyte.
   4. A flower produces two types of spores, microspores and megaspores.
      a. A **microspore** is a plant spore that develops into a microgametophyte.
         1) The **male gametophyte** is a pollen grain; wind or animals carry it to megagametophyte.
         2) When mature, its nonflagellated sperm cells travel down pollen tube to megagametophyte.
      b. A **megaspore** is a plant spore that develops into a **female gametophyte**, the embryo sac which remains within a sporophyte plant.
   5. In flowering plants, the diploid sporophyte is **dominant** (longer lasting); it is what we commonly recognize.
   6. The sporophyte is the generation that contains vascular tissue and has other adaptations suitable to living on land, including production of flowers.
   7. Flowers are unique to angiosperms; aside from producing the spores and protecting gametophytes, flowers attract pollinators and produce fruits to enclose the seeds.

B. Flowers
   1. A **flower** is the reproductive organ of a flowering plant; it develops in response to environmental signals.
   2. The shoot apical meristem stops forming leaves to form flowers; axillary buds can become flowers directly.
   3. Monocot flower parts are in threes or multiples; eudicot flower parts are in fours or fives or multiples.
   4. **Sepals** are leaflike, usually green; this outermost whorl protects the bud as a flower develops within.
   5. **Petals** are interior to sepals; coloration accounts for attractiveness of many flowers.
      a. The size, shape, and color of a flower are attractive to a specific pollinator.
      b. Wind-pollinated flowers often have no petals at all.
   6. Grouped about a pistil are **stamens,** stalked structures that have two parts.
      a. The **anther** is a saclike container within which pollen grains develop.
      b. A **filament** is a slender stalk that supports the anther.
   7. The **carpel** is the vaselike structure located at the center of a flower; carpels usually has three parts.
      a. The **stigma** is an enlarged sticky knob on end of a style; stigma serves to receive pollen grains.
      b. The **style** is a slender stalk that connects stigma with the **ovary**.
      c. The **ovary** is an enlarged base of a carpel that contains a number of **ovules**.
   8. Not all flowers have sepals, petals, stamens, and a pistil.
      a. **Complete flowers** have sepals, petals, stamens, and a pistil; **incomplete flowers** do not.
      b. **Bisexual flowers** have both stamens and a pistil.
      c. **Staminate flowers** have only stamens.
      d. **Carpellate flowers** have only carpels.
   9. If staminate and carpellate flowers are on same plant, the plant is **monoecious.**
   10. If staminate and carpellate flowers are on different plants, the plant is **dioecious**.

C. From Spores to Gametes
   1. In plants, the sporophyte produces haploid spores by meiosis; in animals, meiosis produces gametes.

2. Flowering plants are heterosporous, producing microspores and megaspores that become sperm-bearing pollen grains and egg-bearing embryo sacs, respectively.
3. Production of the Male Gametophyte
    a. Microspores are produced in the anthers of flowers.
    b. An anther has four pollen sacs; each contains many **microsporocytes** (microspore mother cells).
    c. Microsporocytes undergo meiotic cell division to produce four haploid **microspores**.
    d. The haploid nucleus then divides mitotically forming two cells enclosed in a finely sculptured wall; this is a **pollen grain** containing a tube cell and a generative cell.
    e. The larger tube cell will eventually form the pollen tube.
    f. Eventually each generative cell will divide mitotically to form two sperm.
    g. One both events have occurred, the pollen grain is the mature male gametophyte.
5. Pollination
    a. Walls separating the pollen sacs in the anther break down when the pollen grains are to be released.
    b. The shape and pattern of pollen grains is distinctive and allows close identification.
    c. Pollen grains have strong walls resistant to chemicals and also become readily fossilized.
    d. **Self-pollination** is transfer of pollen from anther to stigma of the same plant.
    e. **Cross pollination** is transfer of pollen from anther of one plant to stigma of another plant; plants often have mechanisms that promote cross pollination such as the carpel only maturing after anthers have released their pollen.
    f. Using a pollinator to carry pollen from flower to flower of only one species increases the efficiency.
    g. Secretion of nectar is one way to attract certain pollinators, and they may be adapted to reach only one type of flower.
3. Production of the Female Gametophyte
    a. The ovary contains one or more ovules.
    b. An ovule is covered by parenchymal cells except for one small opening, the micropyle.
    c. One parenchyma cell enlarges to become a **megasporocyte** that undergoes meiotic cell division to produce four haploid **megaspores**.
    d. Three megaspores are nonfunctional; one megaspore nucleus divides mitotically into eight nuclei in a female gametophyte.
    e. When cell walls form around the nuclei later, there are seven cells, one of which is binucleate.
    f. The female gametophyte (or embryo sac) consists of seven cells:
        1) one egg cell,
        2) two synergid cells,
        3) one central cell with two polar nuclei, and
        4) three antipodal cells.
4. Fertilization
    a. When a pollen grain lands on a stigma, it germinates, forming a pollen tube.
    b. A germinated pollen grain, containing a tube cell and two sperm, is the mature **male gametophyte**.
    c. As a pollen tube grows, it passes between the cells of the stigma and the style to reach the micropyle of an ovule.
    d. **Double fertilization** occurs after the release of both sperm cells into the ovule.
    e. One sperm nucleus unites with the egg nucleus, forming a 2n zygote.
    f. The other sperm nucleus migrates and unites with the polar nuclei of the central cell, forming a 3n endosperm nucleus.
    g. The zygote divides mitotically to become the **embryo**; the endosperm nucleus divides mitotically to become the **endosperm**.
    h. The **embryo**, in most plants, is a young sporophyte.
    i. The **endosperm** is tissue that will nourish the embryo and seedling as they undergo development.

28.2 Seed Development

A. Stages
   1. Development of the seed is the next event.
   2. Plant growth and development involves cell division, cell elongation, and differentiation of cells into tissues and then organs.

B. Development of the Eudicot Embryo
   1. Immediately after double fertilization, the endosperm nucleus divides to produce a mass of endosperm surrounding the embryo.
   2. The single-celled zygote also divides, but asymmetrically, forming two parts: **embryo** and **suspensor**, which anchors the embryo and transfers nutrients to it from the sporophyte plant.
   3. Globular Stage
      a. During this stage, the proembryo is a ball of cells.
      b. The root-shoot axis is established; cells near the suspensor will become a root, those at the opposite end will become a shoot.
      c. The outermost cells become dermal tissue; by dividing with the cell plate perpendicular to the surface, they produce one outer cell layer.
      d. Dermal tissue prevents dessication and also has stomata that regulate gas exchange.
   4. The Heart-shaped and Torpedo-shaped Embryos
      a. The embryo has a heart-shape when the cotyledons appear; it then grows to a torpedo shape.
      b. With elongation, the root and shoot apical meristems are distinguishable.
      c. Ground meristem responsible for most of the interior of the embryo is also present now.
   5. The Mature Embryo
      a. After differentiation into embryo and suspensor, one or two **cotyledons** develop.
      b. The embryo continues to differentiate into three parts.
      c. The **epicotyl** is between the cotyledons and first leaves; it contributes to shoot development.
      d. The **hypocotyl** is below the cotyledon and contributes to stem development.
      e. The **radicle** is below the hypocotyl and contributes to root development.
      f. The cotyledons are quite noticeable in a eudicot embryo, and may fold over.

C. Monocots Versus Eudicots
   1. Monocot Embryo Only Has One Cotyledon
      a. In monocots, the cotyledon rarely stores food.
      b. It absorbs food molecules from the endosperm and passes them to embryo.
   2. The Eudicot Embryo Has Two Cotyledons
      a. During development of a eudicot embryo, cotyledons usually store the nutrients the embryo uses.
      b. The endosperm seemingly disappears as the nutrients are consumed.

28.3 Fruit Types and Seed Dispersal

A. Fruits
   1. A **fruit** is a mature ovary that encloses seeds; sometimes they retain other flower parts.
   2. Fruits serve to protect and disperse offspring.
   3. The fruit protects the peach seed well but makes germination difficult; the peas escape easily but are lightly protected.

B. Simple Fruits
   1. **Simple fruit** develops from a single carpel or several united carpels of a compound ovary.
   2. A pea pod breaks open on both sides and releases seeds; legumes are fruits that split to two sides when mature.
   3. Legumes and cereal grains are examples of dry fruits; such fruits are mistaken for seeds because a dry pericarp adheres to the seed within.
   4. For plants to be widely distributed, seeds have to be dispersed away from the parent plant.
      a. Hooks and spines of clover, bur, and cocklebur attach to the fur of animals.
      b. Woolly hairs, plumes, and wings disperse by wind.
   5. A **fleshy fruit** has a fleshy pericarp (e.g., peach, plum, olive, grape, tomato, apple, and pear).
      a. Birds and mammals eat fruits, including seeds, and defecate them at a distance.
      b. Squirrels and other animals gather seeds and fruits and bury them some distance away.
   6. An apple is an example of an accessory fruit; the bulk of the fruit is not from the ovary but from the receptacle; a cross-section shows it came from a compound ovary with several chambers.

C. Compound Fruits
    1. A **compound fruit** develops from several individual ovaries.
    2. An **aggregate fruit** develops from ovaries from a single flower (e.g., blackberry).
    3. An aggregate fruit where each ovary becomes a one-seeded fruit is called an **achene** (e.g., strawberry).
    4. A **multiple fruit** develops from ovaries from separate flowers fused together (e.g., pineapple).

D. Seed Germination
    1. Seed germination occurs when growth and metabolic activity resume.
    2. The embryo forms with both shoot and root apical meristem enclosed in a seed.
        1) Protoderm gives rise to the epidermis.
        2) Ground meristem produces the cells of the cortex and pith.
        3) Procambium produces vascular tissue.
    3. Seeds retain their viability for varying times: maples seeds only last a week while lotus seeds are viable for hundreds of years.
    4. Some seeds do not germinate until they have been dormant for a period of time.
        a. Seed **dormancy** is a time during which no growth occurs even though conditions are favorable.
        b. In temperate zones, seeds may have to be exposed to cold weather before dormancy is broken.
        c. In deserts, germination requires rain; this ensures that seeds do not germinate until a favorable growing season has arrived.
    5. **Germination** has environmental requirements.
        a. Oxygen must be available for increased metabolism.
        b. Adequate temperature allow enzymes to act.
        c. Adequate moisture hydrates cells.
        d. Light may also be required.
    6. Respiration and metabolism continue throughout dormancy but at a reduced level.
    7. Some seeds have a surface coating that attracts water; imbibing plant cells can swell dramatically.
    8. Seeds that must be planted near the surface probably require light (e.g., lettuce).
    9. When a seedling grows in the dark, it becomes long and spindly (etiolated); phytochrome induces normal growth in light.
    10. Germination in Eudicots and Monocots
        a. Prior to germination, a eudicot embryo consists of the following:
            1) two cotyledons that supply nutrients to the embryo and seedling, but soon shrivel and disappear;
            2) a **plumule—**a rudimentary plant consists of an epicotyl bearing young leaves;
            3) the hypocotyl, which becomes the stem; and
            4) the radicle, which develops into roots.
        b. As dicot seedling emerges, the shoot is hook-shaped to protect the delicate plumule.
        c. In monocots, the endosperm is the food-storage tissue and the cotyledon does not have a storage role.
        d. A monocot "seed" such as a corn kernel is actually the fruit and the outer covering is the pericarp.
        e. The plumule and radicle are enclosed in protective sheaths, the **coleoptile** and the **coleorhiza**, respectively.
        f. The plumule and radicle burst through these coverings when germination occurs.

28.4 Asexual Reproduction in Plants

A. Means of Asexual Propagation
    1. Plants contain nondifferentiated meristem tissue and often reproduce asexually by vegetative propagation.
    2. In **asexual reproduction**, offspring arise from a single parent and inherit genes of that parent only.
    3. **Vegetative propagation** utilizes the meristematic tissue of a parent plant.
        a. Violet plants grow from nodes of rhizomes.
        b. The nodes of stolons will produce strawberry plants.
        c. Each eye of a potato plant tuber is a bud that produces a new plant.
        d. Sweet potatoes can be propagated from their modified roots.
        e. Many trees can be started from small "suckers."
    4. Stem cuttings have long been used to propagate a wide array of plants (e.g., sugarcane, pineapple).
    5. The discovery that auxin will cause roots to develop has expanded our ability to use stem cuttings.

B. Tissue Culture of Plants
    1. In 1902, German botanist Gottleib Haberlandt suggested producing entire plants from tissues.
    2. **Tissue culture** is process of growing tissue artificially in a liquid or solid **culture** medium.
    3. Haberlandt stated plant cells were **totipotent**; each cell has full genetic potential of the organism.
    4. In 1958, Cornell botanist F. C. Steward grew a complete carrot plant from a tiny piece of phloem.
    5. When cultured cells were provided with sugars, minerals, vitamins, and cytokinin from coconut milk, the undifferentiated cells divide and initially formed a **callus**, an aggregation of undifferentiated cells.
    6. The callus then differentiated into shoot and roots and developed into a complete plant.
    7. **Micropropagation** is a commercial method of producing thousands to millions of identical seedlings, by tissue culture in limited space.
    8. **Meristem culture** micropropagates many new shoots from a single shoot apex culture in a medium with correct proportions of auxin and cytokinin.
        a. Since the shoots are genetically identical, the adult plants that develop are clonal plants.
        b. **Clonal plants** have the same genome and display the same traits.
        c. Meristem culture generates meristem that is virus-free; the plants produced are also virus-free.
    9. Entire plants can be grown from single plant cells.
        a. Enzymes can digest cell walls and produce naked plant cells called **protoplasts**.
        b. Protoplasts regenerate a cell wall and begin cell division.
        c. Clumps of cells can be manipulated to form **somatic embryos**.
        d. **Somatic embryos** encapsulated in a hydrated gel ("artificial seeds") can be shipped anywhere.
        e. Somatic embryos are cultured by the millions in large tanks (bioreactors).
        f. Plants generated from somatic embryos vary because of mutations; these **somaclonal** variations may produce new traits.
    10. **Anther culture** cultures mature anthers in a medium of vitamins and growth regulators.
        a. The haploid tube cells within a pollen grain divide, producing **proembryos** made of 20 to 40 cells.
        b. Finally the pollen grains rupture, releasing haploid embryos.
            1) The researcher can then generate a haploid plant.
            2) Chemical agents are added to encourage chromosomal doubling; the resulting plants are diploid and homozygous for all alleles.
            3) This produces plants that express recessive alleles.
    11. **Cell suspension culture** uses rapidly growing calluses cut into small pieces and shaken in a liquid nutrient medium.
        a. Single cells or small clumps form a suspension of cells; all produce the same chemicals as the entire plant.
        b. This technique is a more efficient way of producing chemicals used in drugs, cosmetics, and agricultural applications than farming plants simply to acquire chemicals they produce.

C. Genetic Engineering of Plants
    1. Traditionally **hybridization** (crossing different varieties or species) was used to produce new plants.
    2. **Transgenic plants** carry foreign genes directly introduced into their cells.
    3. Tissue Culture and Genetic Engineering
        a. **Genetic engineering** alters genes of organisms so they have new and different traits.
        b. Protoplasts in particular lend themselves to direct genetic engineering in tissue culture.
        c. High voltage electric pulses create pores in plasma membrane so new DNA can be introduced.
        d. When genes for production of firefly enzyme luciferinase were inserted into tobacco protoplasts, adult plants glowed when sprayed with the substrate luciferin.
        e. Regeneration of cereal grains from protoplasts has been difficult; corn and wheat protoplasts produce infertile plants.
        f. Foreign DNA can be inserted into a plasmid of *Agrobacterium*; this bacterium infects plant cells and can be used to deliver the recombinant DNA to target cells.
        f. John C. Sanford and Theodore M. Klein of Cornell University developed a **gene gun** to bombard a callus with DNA coated metal particles; later, adult plants are generated.
        g. Crops have been engineered to resist frost, fungal and viral infections, insect predation, and herbicides.
        h. Future crops could have higher protein content and require less water and fertilizer.
        i. Sequencing the genomes of a dicot *Arabidopsis thaliana* and rice will give a blueprint to the genes of other monocots and dicots.

4. Agricultural Plants with Improved Traits
    a. Corn, potato, soybean, and cotton plants have been engineered to be resistant to insect predation or herbicides.
    b. If the crops are resistant to herbicide and the weeds are not, then less tillage is needed.
    c. Salt-tolerant *Arabidopsis* has been developed by cloning a gene for sequestering sodium ions n a vacuole.
    d. Such techniques would allow development of crops that could grow where irrigation causes salinization.
    e. Genes from *Vernonia* and castor bean seeds have been inserted into soybeans to produce vernolic acid and ricinoleic acid used as hardeners in paints and plastics.
    f. Other genetic engineering goals could be the increase in productivity by altering water and carbon dioxide intake.
    g. Genetic engineering is attempting to improve efficiency of RuBP carboxylase and introduce C_4 photosynthesis to rice.
5. Commercial Products
    a. Corn has made antibodies to deliver radioisotopes to tumor cells.
    b. Soybeans make an antibody to treat genital herpes.
    c. Researchers can introduce a human gene into tobacco plants using tobacco mosaic virus.
    d. Tobacco plants produced antigens to treat non-Hodgkin's lymphoma.