General Biology: Reproduction And Domestication Of Flowering Plants

AI-Generated Study Guide

(Based on [lectures delivered by Dr. Ty C.M. Hoffman])

I. Overview of Flowering Plants (Angiosperms)
Angiosperms are the most successful group of plants, characterized by the development of flowers, fruit, and double fertilization (the three "F"s). Flowers are specialized reproductive structures that act primarily as advertisements to attract agents of reproduction.

II. Flower Structure and Development
A complete flower consists of four major parts, or whorls, arranged concentrically:

Whorl Type	Examples	Function / Characteristics
Sterile Whorls (Do not produce gametes)	Sepals and Petals	Sepals are the outermost layer, covering the bud before it opens. Petals are usually brightly colored to attract pollinators.
Fertile Whorls (Produce gametes/sex cells)	Stamens and Carpels	Stamens are the male parts; carpels are the female parts.

• Stamen (Male Part): Typically consists of a filament (stalk) and an anther (bag-like end). Pollen grains, which contain the male gametes, are produced within the anther.
• Carpel (Female Part): Typically bowling-pin shaped, consisting of a stigma (sticky receptive surface where pollen lands), a slender style, and a bulbous ovary at the base. The ovary contains ovules (potential seeds) where eggs are made.
• Flower Completeness: A flower is termed complete if it possesses all four whorls. An incomplete flower is missing one or more whorls.
ABC Hypothesis of Whorl Development
The development of the four whorls is governed by the expression of three genes (A, B, and C):
1. A gene only: Develops into Sepals (outermost).
2. A gene + B gene: Develops into Petals.
3. B gene + C gene: Develops into Stamens.

4. C gene only: Develops into Carpels (innermost).
Mutations in these genes can lead to changes in flower structure, sometimes resulting in sterile flowers incapable of reproduction.

III. Angiosperm Life Cycle and Alternation of Generations

Angiosperms demonstrate alternation of generations, meaning both the diploid (sporophyte, 2N) and haploid (gametophyte, N) stages are multicellular. The plant you typically see is the diploid sporophyte. The haploid stage is small and contained within the flower structures.

Female Gametophyte Development

1. Megasporangium tissue (2N) in the ovule undergoes meiosis, resulting in four cells. Three disintegrate, and one survives as the large haploid megaspore (N).
2. The megaspore undergoes three rounds of mitosis without full cytokinesis, resulting in a mature female gametophyte (embryo sac) composed of seven cells and eight nuclei.
3. Key cells of the female gametophyte:
- **Egg Cell (N): The target for fertilization.**
- **Synergids (N): Produce chemicals to attract the pollen tube.**
- **Central Cell: The largest cell, containing two haploid nuclei (N + N), making it functionally diploid.**

Male Gametophyte Development

1. Microsporangium tissue (2N) in the anther undergoes meiosis, producing four equally viable haploid microspores (N).
2. A microspore undergoes mitosis and unique cytokinesis to form a pollen grain (the male gametophyte) consisting of one large tube cell surrounding one generative cell.
3. The generative cell then divides again to produce two sperm cells, which reside within the tube cell. The mature pollen grain is three cells big.

IV. Pollination and Fertilization

Pollination Modes

Pollination is the transfer of pollen (containing the male gametophyte) to the sticky stigma (female receptive part).
- **Abiotic Pollination: Does not involve organisms. Primarily carried out by wind or, in some cases, water. This method is generally less reliable.**
- **Biotic Pollination: Involves organisms, primarily insects, but also birds and bats. This is more reliable as animals learn to repeatedly visit the same flower species for a reward (e.g., nectar). Flowers often have visual cues (like bullseyes visible under UV light) to guide pollinators.**

Double Fertilization

Pollen landing on the stigma triggers the tube cell to bore a tunnel (pollen tube) through the style down into the ovule, guided by chemicals from the synergids.
1. First Fertilization: One sperm fertilizes the haploid egg (N + N), forming the diploid zygote (2N). This zygote develops into the sporophyte embryo.
2. Second Fertilization: The second sperm fertilizes the central cell (N + 2N), forming a triploid (3N) cell. This cell develops into the endosperm.

The endosperm provides nutrients for the growing embryo. Double fertilization is hypothesized to be an energy-saving mechanism, ensuring that investment in nutrient-rich endosperm and fruit development only proceeds if successful egg fertilization has occurred.

V. Seed and Fruit Development
• Seed: A former ovule that has undergone successful fertilization. It contains the embryo (2N) and the endosperm (3N).
• Cotyledons (Seed Leaves): Part of the embryo responsible for transferring nutrients from the endosperm to the developing embryo.
 ◦ Eudicots typically have two cotyledons (e.g., bean).
 ◦ Monocots typically have one cotyledon (e.g., maize).
Germination
The seed must receive an environmental cue (e.g., water or fire) to stop dormancy and germinate.
• Eudicot Germination: A hook-shaped structure (the early taproot) emerges and drags the cotyledons out of the soil. Energy stored in the cotyledons is spent establishing the root system before conventional leaves develop for photosynthesis.
• Monocot Germination: Both a radicle (root system) and a protective cylinder called the coleoptile grow upward, safeguarding the tender structures until they reach the light.
Fruit Classification
A fruit is the structure that develops from a successfully fertilized flower; its purpose is to bear and protect the seeds.
1. Simple Fruit: Develops from one carpel containing one ovary (e.g., pea pod).
2. Aggregate Fruit: Develops from a single flower that has multiple carpels, resulting in many small fruitlets grouped together (e.g., raspberry).
3. Multiple Fruit: Develops from an inflorescence (a tight cluster of multiple flowers). The fruits from each flower grow together to form one larger structure (e.g., pineapple).
4. Accessory Fruit: The edible, fleshy part of the fruit develops not from the ovary, but from surrounding floral structures like the receptacle (e.g., the flesh of an apple).
Seed Dispersal
Seed dispersal from the parent plant is crucial for successful survival.
• Abiotic Dispersal: Wind (e.g., dandelion fruit/seed structure) and water (for buoyant seeds).
• Biotic Dispersal: Animals carry seeds. Edible fruits incentivize consumption, allowing tough seeds to pass through the digestive tract and be deposited with fertilizer.
Non-edible fruits use mechanisms like barbs or stickiness to cling to animal hides (e.g., puncture vine).

VI. Plant Breeding and Biotechnology
Asexual Reproduction and Outbreeding Strategies
• Asexual Reproduction (Cloning): Produces genetically identical duplicates, favorable in stable environments. Aspen trees often form massive clones.

• Sexual Reproduction: Favored in changing environments due to increased genetic variability.
• Minimizing Inbreeding: Plants evolve strategies to prevent self-fertilization, as inbreeding increases the chances of harmful recessive traits appearing.
◦ Dioecious Species: Produce male (staminate) and female (carpellate) flowers on separate plants.
◦ Heterostyly: Complete flowers (e.g., pin and thrum flowers) are structured so that a pollinator entering one flower deposits pollen onto the stigma of the other type, maximizing cross-pollination.

Cloning and Genetic Modification

Plants are easier to clone than animals because they retain totipotent stem cells in their meristems throughout their lives. Artificial cloning involves cultivating a cell from a meristem into a multicellular callus, which eventually develops into a new, viable adult plant.

Biotechnology involves using organisms for human benefit. Agriculture is the old-fashioned form of genetic modification, relying on artificial selection over generations (e.g., turning ancestral grass into modern corn).

Genetically Modified Organisms (GMOs) involve direct human intervention to modify genes.

• Transgenesis: Transferring genes between highly unrelated species (e.g., a glowing gene from a jellyfish into a mouse).
• Cisgenesis: Transferring genes between closely related organisms (e.g., within the same kind of plant).

GMOs are used to improve food quality (e.g., modifying cassava to increase vitamin content or reduce natural toxins) or to make plants resistant to pests, potentially reducing the need for chemical pesticides.