Flower parts

Flower parts are arranged in 4 whorls

1. The gynoecium (female)
1. The gynoecium (female)

- stigma
- style
- carpel
- ovary

Flower parts are arranged in 4 whorls

2. The androecium (male)

- anther
- filament

Flower parts are arranged in 4 whorls
Flower parts are arranged in 4 whorls

1. The gynoecium (female)
2. The androecium (male)
3. The corolla (petals)
4. The calyx (sepals)
Flower parts are arranged in 4 whorls:
1. The gynoecium (female)
2. The androecium (male)
3. The corolla (petals)
4. The calyx (sepals)

All four whorls are attached to the receptacle.
FLOWERS, FRUITS and SEEDS

Angiosperms: vessel-seeded
vessel: gynoecium

flower parts:
- stamen (androecium)
  - anther
  - filament
- pistil (gynoecium)
  - stigma
  - style
  - ovary (carpels)
    - ovule
- petals (corolla)
- receptacle
- sepals (calyx)
- corolla
- perianth

Flowers

FLOWERS, FRUITS and SEEDS
Ovules attached to **placenta** of ovary

- **Placentation**: pattern of ovule attachment
  - free central
  - parietal
  - axile

**CARPEL**
- Carpel derived evolutionarily from leaves
- **Gynoecium types**:
  - Simple
  - Complex
OVULE
- ovule functions as:
  - megasporangium
  - **megagametophyte**
  - embryo sac

MEGASPOROGENESIS
- ovule / megasporangium
  - nucellus
  - megaspore mother cell (2N)
    - [meiosis] → 4 megaspores (1N)

MEGAGAMETOGENESIS
- functional megaspore
  - 3 mitotic divisions
    → eight nuclei
    - 2 polar nuclei
    - 3 antipodal cells
    - 2 synergids
    - 1 egg
DOUBLE FERTILIZATION

- pollen tube penetrates micropyle
- one sperm fuses with egg cell → 2n zygote
- one sperm fuses with polar nuclei → triploid (3n) endosperm

Biology 101
Fall, 2008
Fruit and Seed

SEED

- mature (fertilized) ovule
- mitotic divisions of zygote → embryo
- endosperm + other nutritive tissues + embryo + seed coat
The endosperm and parental tissues from the carpel, together with the embryo, form the seed. However, the maternal tissues are often retained after fertilization and become part of what we commonly call a fruit.

Thus, botanically, a fruit is any ovary and its accessory parts that has developed and matured.

The ovary wall (pericarp) often gives rise to three regions as it matures:

- **exocarp**: the skin of the fruit; originally the outer layer of the mature ovary wall (pericarp)
- **mesocarp**: the fleshy part of the fruit
- **endocarp**: surrounding the seeds

Fertilization is usually a prerequisite for fruit development, but treatment with hormones can induce seedless fruit formation.

POMES
Types of fruits include:

**Simple fleshy fruits** - develop from a flower with a single pistil.
- **Drupe** - simple, single seed enclosed by a stony endocarp, e.g. peach, plum, cherry
- **Berry** - from a compound ovary, commonly have >1 seed, e.g. tomato, grape
- **Pome** - simple, fleshy fruit largely composed of an enlarged floral tube, e.g. apple

**Aggregate fruits** - derive from a single flower with several to many pistils, e.g. blackberry

**Multiple fruits** - derive from many individual flowers in a single inflorescence, e.g. mulberry, fig

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**DRUPES**
- Peaches
- Almonds
- Olives

**BERRIES**
- Grapes
- Tomatoes
AGGREGATE FRUIT - Blackberry

COMPOUND FRUIT
Osage orange
Ovaries of many flowers become united

Types of Seeds and Fruits Dispersed by Wind
- dandelion
- maple
- tumbleweed
- poppy
- orchid
- cottonwood
SEED GERMINATION

- primary growth from apical meristems of root (radicle) and shoot
- energy for growth from:
  - endosperm
  - cotyledons (storage proteins)
Bean seed structure, germination and seedling

EMBRYO AND SEEDLING
- cotyledonary node
- epicotyl
- hypocotyl
- radicle

Corn seed structure, germination and seedling
GROWTH

Growth is an irreversible increase in the size of an organism or its parts through the use of metabolic energy.

Cell enlargement and cell division are regulated separately. Enlargement requires both loosening of the cell wall and positive turgor pressure.

Orientation of growth is determined by microfibrils, whose orientation is determined by microtubules. Colchicine disrupts microtubules but not microfibrils, resulting in spherical cell growth.

DEVELOPMENT

Since roots, stems and leaves of many species of plants have basically the same organization, it is logical to believe that similar processes are used in their development.

Differentiation reflects the orderly processes by which genetically identical cells become different, forming specialized tissues and organs.
**Dedifferentiation** is the reversal of cell specialization. It is important in the repair of injury, where cells near damaged sites become **totipotent** and reprogram their development.

**Tissue culture** is the application of plant growth regulators to mimic the above processes.

**Polarity** (directionality expressed as differences between different sides or ends of a cell, organ or whole plant) is controlled by the environment in combination with the genome. It is changed only with difficulty in angiosperms.
Asymmetry is often associated with development, e.g. in the formation of pollen and of stomata from epidermal cells.
Electric currents enter pollen tubes and roots at their tips and exit laterally behind tips. Abolition of the current abolishes polar growth.
Biophysical factors: Physical pressure or restraint can affect growth patterns -- e.g. microfibrils.

Genetic factors: It is now known that certain genes are responsible for growth patterns -- e.g. *Knotted-1*.

Timing: Different developmental responses may result from timing, e.g. effect of hormones may differ if applied late or early in development.

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Modular growth

Plants are modular organisms having generally standardized parts, e.g. roots, shoots and leaves.

This may help in grafting but may hinder recognition of parasites (e.g. mistletoe).

Modules may exist within standard parts, e.g. the radicle, hypocotyl and cotyledon of an embryo.

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Chemical signals

**Nutrients** - provide the elements and energy for organic molecules.

**Vitamins** - activate enzymes, many produced by plants and used by animals.

**Hormones** - plant growth regulators - produced in actively growing regions of plants. Produced and active in much smaller amounts than are vitamins and enzymes.
Milestones

1881 Charles & Francis Darwin discovered phototropism and gravitropism.
1901 Dimitry Neljubow identified ethylene as defoliation agent.
1926 Frits W. Went isolated auxin.
1939 Eiichi Kurosawa discovered gibberellin.
1950's Carlos O. Miller & Folke Skoog discovered cytokinins.
1960's F.T. Addicott initiated the misnomer abscisic acid, which is involved in dormancy but not abscission.

Hormones

- **Auxins**
- **Cytokinins**
- **Abscisic acid**
- **Gibberellins**
- **Ethylene**

In addition to the five known major classes of plant growth regulators, **oligosaccharins** and other compounds (**batasins**, **brassosteroids**) are known to affect plant development. Specific types of compounds, amounts, and cellular sensitivity affect the observed response to a given regulator.

Auxins

- Synthesized in apical meristems and young plant parts.

  - *Stimulate* cellular elongation, differentiation of vascular tissue, formation of roots, production of ethylene, and fruit development but

  - *Delay* fruit and leaf abscission.

  Monocots are less sensitive than dicots and shoots are less sensitive than are roots (applied in herbicides)
Auxins

The most active naturally occurring auxin is indoleacetic acid (IAA), which is transported polarly (downwards at ~1cm/h) in roots and stems.

Other natural auxins are phenylacetic acid (PAA), 4-chloroindoleacetic acid (4-chloroIAA) and indolebutyric acid (IBA).

Auxins

Synthetic auxins:
naphthalene acetic acid, NAA;
2,4-dichlorophenoxyacetic acid, 2,4-D;
2-methyl-4-chlorophenoxyacetic acid, MCPA
are used extensively in modern agriculture (seedless fruit).

Most auxins are not toxic to humans but use of 2,4,5-T is banned because it is typically contaminated with small traces of TCDD, which is very toxic.
Cytokinins

Synthesized in root tips and germinating seeds.

*stimulate* cellular division, expansion of cotyledons, and growth of lateral buds

*delay* leaf aging and, in combination with IAA, may influence formation of roots and shoots.

Abscisic acid (ABA)

Synthesized in plastids, from carotenoid pigments.

In some respects, ABA is enigmatic in that it can counteract the stimulatory effects of other hormones, especially auxin.

It can *delay* germination of seeds, but is important in *stimulating* the synthesis of seed storage proteins.

By interfering with K⁺ retention or transport in guard cells, it causes stomata to close.
Gibberellins (GA)

Originally isolated from the fungus *Gibberella fujikuroi*, there are >110 known gibberellins.

GA stimulates extensive growth of intact plants, and influences the transition from juvenile to adult growth, the bolting of biennials, fruit formation, and germination of some cereal grains.

Has many remarkable but mechanistically obscure effects – it can induce flowering, break the dormancy of buds and seedlings, eliminate cold requirement for germination.
**Ethylene ($\text{H}_2\text{C}=$CH$_2$)**

Synthesized from methionine in fruit and other tissues.

Ethylene is a *gaseous hormone* that is very active in minute amounts.

It stimulates fruit ripening (bananas, mangoes, honeydew melon), leaf abscission, sex expression and the radial expansion of cells.

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**Oligosaccharins**

are fragments of cell walls that regulate plant growth and development.

Unlike other plant hormones, oligosaccharins have specific effects.

**Brassinosteroids**

Found in legumes and some other plants have a GA-like effect on stem elongation.
Hormones

**Interactions**

Combinations of growth regulators influence growth. For instance:

- **High auxin : cytokinin ratio** dictates root formation, but
- **high cytokinin : auxin ratio** dictates shoot formation, and
- **similar concentrations of auxin and cytokinin** (i.e. ca. 1:1 ratio) inhibit differentiation.
III - Tropisms

TROPISMS
Tropisms result from differential growth of specific regions of a plant.

Positive tropisms are towards the stimulus and negative tropisms are away from the stimulus.

Phototropism
is the response to unidirectional light, particularly blue light with $\lambda < 500$ nm.
IAA moves towards the shaded side of the stem, causing cell extension of that side.
Zeaxanthin is probably the photoreceptor.
**Gravitropism**

The Darwins noted that decapitated roots did not respond to gravity.

Much evidence implicates starch-laden **amyloplasts** in the center of the root cap.

However, the **protoplast** may also be involved. Shoots are *negatively* geotropic.

Perception probably involves local Ca$^{2+}$ concentration which triggers IAA accumulation.

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**Thigmotropism**

is the response of plants to touch.

**Convolvulus tendrils** can encircle an object in 5-10 min.

The stimulus is often **long-lasting** - a 5 min stroking of a garden pea tendril can induce curling response for days.

**Memory** is also demonstrated and light may be required for ATP synthesis for action to occur.
Hydrotropism is the growth of roots towards soil moisture. Roots with caps removed are not responsive to soil moisture. The textbook (Stern) is skeptical that this is a true tropism.

Heliotropism is the solar tracking of plant organs, such as sunflowers. Movement can be 60°/hr. Orientation towards the position of sunrise can start several hours before dawn. Stern (p. 202) denies this effect occurs – what do you think?
Growth Movements

induced by internal stimuli

Nutation - Also known as spiraling movements - initially demonstrated in an experiment by Charles Darwin.

Twining - Although many twining movements are touch-induced (thigmotropism), they can also occur as a result of internal stimuli. Some tendrils are stimulated by auxin, others by ethylene.

Nodding - A slow oscillating movement - seen in beans as the seedling pushes up through the soil.

Contraction - Several monocots and dicots have contractile roots that pull them deeper into the ground.

NASTIC MOVEMENTS

• These are independent of the direction of the stimulus.
Thigmonasty

Touching a leaf mimosa (**Mimosa pudica**) leaf generates a signal that moves along the petiole and is translated into a **chemical signal** that causes pulvinus cell membranes to be more permeable to K⁺ ions.

Exit of these ions decreases water potential of neighboring cells and shrinkage of the motor cells.

Thigmorphogenesis

is mediated by **touch-induced (tch) genes** that are expressed as proteins that inhibit elongation and promote the growth of shorter, stockier plants with more supportive tissue (i.e. collenchyma and sclerenchyma fibers).

It is stimulated in nature by **wind and rain** as well as by physical contact.

Like thigmonasty, this is similar to thigmotropism but is independent of direction of stimulus.
Seismonasty results from mechanical disturbances such as shaking.

Electrical responses are often involved.

Venus flytrap (*Dionaea muscipula*) has two lobes on its leaves with three trigger hairs that snap the trap shut in 0.1 to 0.5 sec (at high ATP expense).

Opening takes 8-12 hr.

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Circadian rhythms are daily rhythms, usually of approximately but not exactly 24 hr duration. They are widespread among eukaryotes and have recently been discovered in bacteria.

Unlike most biological processes, they are essentially unaffected by temperature.

Entrainment is the synchronization of the plant's biological clock by the environment.

Temporally uniform metabolic functions by a group of plants are important in various functions, such as pollen dispersal.
Circadian rhythms
Stern includes among these:

**Nyctinasty.**
A sleep response triggered by daily rhythms of light and dark.
Frequent in legumes, e.g., *Phaseolus vulgaris,* whose nyctinastic plumular leaf movements occur at regular times each day.

He incorrectly includes

**Thermonasty**
A response to temperature, e.g., opening and closing of tulip petals and curling of *Rhododendron* leaves.

FLOWERING

- Seasonal differences in flowering have long been recognized.
Some plants exhibit **obligate** photoperiodism: soybean (*Glycine max*) will not flower without exposure to long days – some varieties will not flower with a 14 hr day but will with a 14.5 hr day.

**Long day** plants require light periods longer than a critical length, usually 9-16 hr, prior to flower initiation.

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Phytochrome

is the pigment that senses light quality, which is often intrinsically related to photoperiod. It occurs in two forms. It is synthesized as the inactive \( (P_r) \) form.

Red (660 nm) light in sunlight converts \( P_r \) phytochrome to the active far red (730 nm) \( (P_f) \) form that promotes flowering of long-day plants and inhibits flowering of long-night plants. Conversion of \( P_f \) back to \( P_r \) in the dark takes 3-4 hr.

Etiolation occurs in the dark, resulting in non-green (chlorophyll-deficient), spindly plants. Light produces the active \( P_f \) form of phytochrome which rapidly stimulates chlorophyll synthesis.

Phytochrome Interconversions

Dormancy

is a period of decreased metabolism.

Acclimation to cold, in which changes in plant membranes and proteins occur, is one facet.

Abscisic acid (ABA) is involved in seed dormancy; as ABA breaks down with time, the seed prepares to germinate.

Many stone fruits (cherries, peaches, plums) need several weeks at temperatures below 7°C before buds will develop into flowers.

Some plants become sensitive to photoperiod only after a period of chilling, either as seeds or shortly after germination (after-ripening; stratification).

Sometimes plants require a series of stimulations to break dormancy. Seeds may need mechanical abrasion of the seed coat, or exposure to the digestive tract of an animal or bird.
Autumnal leaf colors are an example that results from changes in light quality and photoperiod that trigger chlorophyll destruction, unmasking the other pigments in the leaf.

Senescence is the collective term for aging processes that lead to the death of a plant or plant part. Autumnal leaf colors are an example that results from changes in light quality and photoperiod that trigger chlorophyll destruction, unmasking the other pigments in the leaf.

Quiescence is a state in which a seed cannot germinate unless environmental conditions suitable for growth are present.

Structure of Indole-3-acetic Acid (IAA)