Growth

Growth is the irreversible increase in mass, weight or volume of an organism, organ or cell as expressed in terms or units of length, volume, weight or area is (quantitative). On the other hand, **Development** is the irreversible change in state such as embryogenesis, juvenile, adult vegetative and adult reproductive**.**

Differentiation is a term given to describe any case in which the meristematic cell are transformed into two or more types of cells, organs or tissues different from each other in shape , structure or function, (qualitative).

Development a term given to describe the overall quantitative and qualitative changes of an organism during its life cycle.

<u>Development = Growth (quantitative) + differentiation (qualitative) changes.</u>

Places of growth:-

I. **In single cell organisms:** Increase of protoplasm ⟶ cell enlargement ⟶ division.

II. **In multicellular organism** such as higher plants; growth takes place in meristematic regions only.

The components of growth at the cell level are;

1. Cell **Division**
2. Cell **Enlargement**
3. Cell **Differentiation**

1. Cell division occurs in Meristematic Cells (Stem Cells).

- **Primary** (at the end, or tip, of each growing stem and root)
    - Shoot Apical Meristem (SAM).
    - Root Apical Meristem (RAM).

- **Secondary**
  - Axillary Buds.
  - Vascular Cambium (produces vascular tissue, increases the thickness of stems over time; is between xylem & phloem).
  - Cork Cambium (produces the outer covering of stems).
  - Pericycle (root).

Types of meristems:

1. Apical meristem: growth in length is restricted to the tip (e.g. stem and root)
2. Lateral meristem: result in secondary growth (or radial growth). Two type of cambium are involved: vascular cambium and cork cambium.
3. Intercalary meristem: meristems are embedded between differentiated tissues (leaf axil and bases of internodes).

2. Cell Enlargement occurs in cells adjacent to meristems

- Internode growth - Shoot.
- Zone of Elongation – Root.
- Turgor Pressure.
  - **H_2O Uptake.**
  - **Cell Wall Loosening.**
  - **new cell walls.**

3. Cell Differentiation:-

- Cessation of Cell Enlargement
- Secondary cell walls
- **Xylem - Vascular tissue**
- **Fibers**
- Epidermal cells
- **root hairs**
- **leaf hairs**
- **guard cells**
- Leaves, Flowers
- Fruit, Tubers, Bulbs, etc.

Patterns of Growth

1. **Annuals;** plants grow from seed to maturity; flower; produce seeds; and die all in the period of one growing season such as marigolds, corn, and peas.

2. **Biennials;** plants that usually live for 2 years. During the first growing season, they grow roots, stems & leaves and in the second season, they produce flowers, and thus seeds such as sugar beets, carrots and turnips.

3. **Perennials**; plants that live for more than two year. Trees and shrubs are examples, because they live for indefinite periods of time .Trees and shrubs whose stems contain woody tissue are called **woody plants** and plants whose stems have little or no woody tissue are called **herbaceous.** In cold climates, herbaceous die back to their roots every year, chrysanthemums and tulips are examples.

Xylem Growth:
The new ring of xylem tissue formed during every growing season, plus the older xylem, become the **wood** of trees. Xylem is called **sapwood** as long as it conducts water. After some period of time, the xylem becomes “clogged up” with tars, resins, etc. and is no longer able to conduct water, however, it still gives strength and support to the tree, and is at this time called **<u>heartwood.</u>**

<u>Annual rings</u> are formed because **large** xylem cells form during the spring, and smaller xylem cells form during late summer and fall, the large cells of spring wood look “lighter” than the smaller cells of summer wood.

- The phloem layer, however, never becomes as thick as the xylem. Why? because the cambium makes only 1 phloem cell for every 6-8 xylem cells and phloem has thin walls; crushed as the stem grows thicker.

- Monocots are also not very tall, an exception is the palm tree. The few monocots trees that do exist will not grow taller the first few seasons, but wider; then they will grow taller, but not wider.

1 . **Indeterminate growth:** is the ability to divide and grow for a long time as in stem and root. Some times no physiological reason is found to explain the longitudinal growth. In such cases growth is arrested due to infection by insects.

2 . **Determinate growth**: Division stops at maturity as in leaf, flower and fruit.

Methods of measuring growth:

1. Length: for organs growing in one direction such as shoot and root.
2. Dry weight: good but not suitable for etiolated plants
3. Fresh weight: used in some cases, but it is variable with time.
4. Area: useful for organs that grow in two directions.

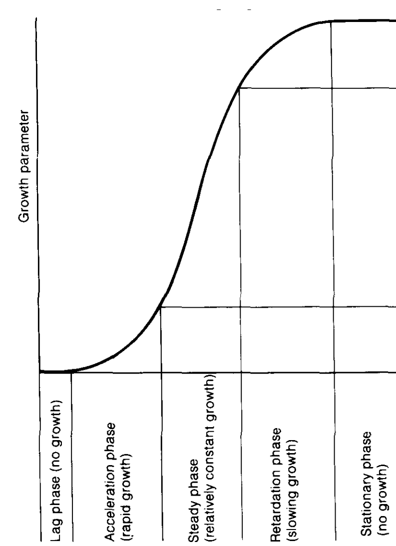
Factors affecting growth and development:

1. Internal factors: such as genetical factor, hormones, age, nutritional status etc.
2. Ecological (external factors): such as temperature, photo period and intensity, water availability…etc.

Growth Kinetics:

Rate of growth is not constant during the life cycle of an organism. Several factors (internal and external) may affect growth rate. However, under normal condition, growth of an organism follows a special pattern. Theoretically, in single cell organisms , such as bacteria , yeasts and mosses , grown under fixed ecological and nutritional condition, the rate of cell division is expected to be constant (i.e. the no. of cell is expected to increase exponentially). However, this is not the case. In reality, several factors limit the growth such as nutrient deficiency or production of toxic substances during growth. Therefore, the growth follows a **sigmoid curve**, which also applies for multicellular organisms.

1. **Sigmoid Curve:** with respect **to time**, the curve can be divided into:
lag phase , **acceleration phase** , **steady phase**, **retardation** phase and **stationary phase.**



The sigmoid growth curve

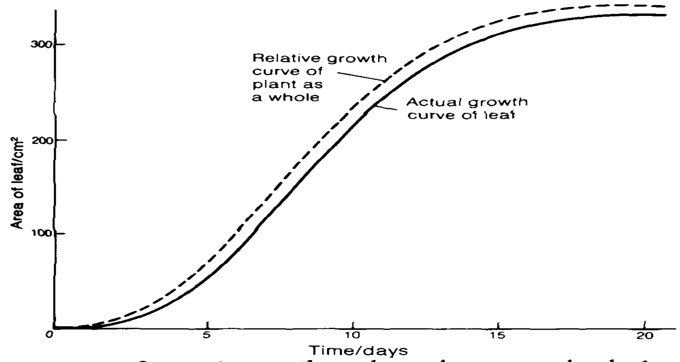
2. **Sigmoid Curve** with respect **to growth rate**, the curve can be divided into:

a- Initial period of increasing growth:- slow growth at first, because there are so few cells that even when dividing rapidly the actual increase in size is small.

b- Central period of rapid growth:- as the number of cells becomes larger, the size increases more quickly because more cells carry out division.

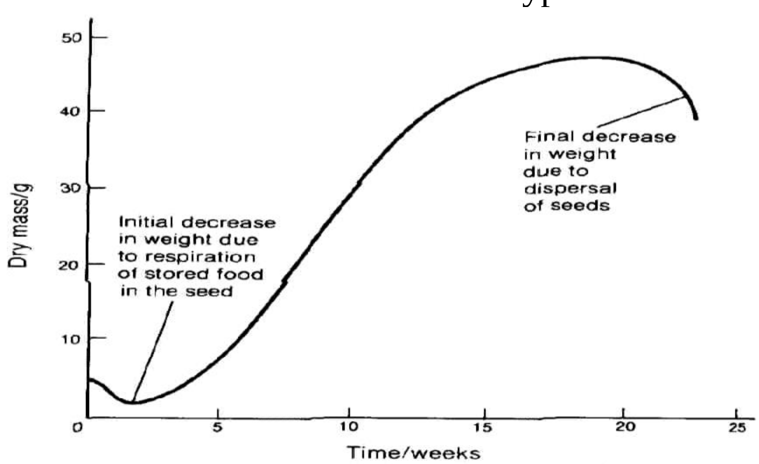
c-Final period of growth:- a limit to rapid growth due to genotype, external factors like food. Growth rate decreases and stops when no. of cell dividing= no. of cells dying.

1- Isometric growth; e.g. leaves of most plant grow at the rate as the organism as a whole.



Isometric growth as shown by a cucumber leaf

2. Limited Growth Curve: initial **negative growth** during germination due to respiration of food reserves in the seed; then, **positive growth** started because green leaves have grown above ground and photosynthesis is faster than that of respiration. At 20th week, a sudden decrease in dry mass due to the dispersal of fruits and seeds a typical S-shaped (**sigmoid**) curve.



Annual plant growth curve, e.g. Pea

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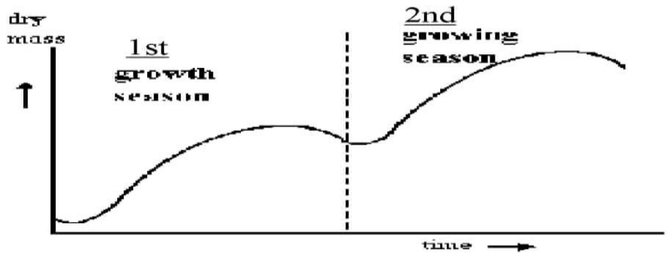
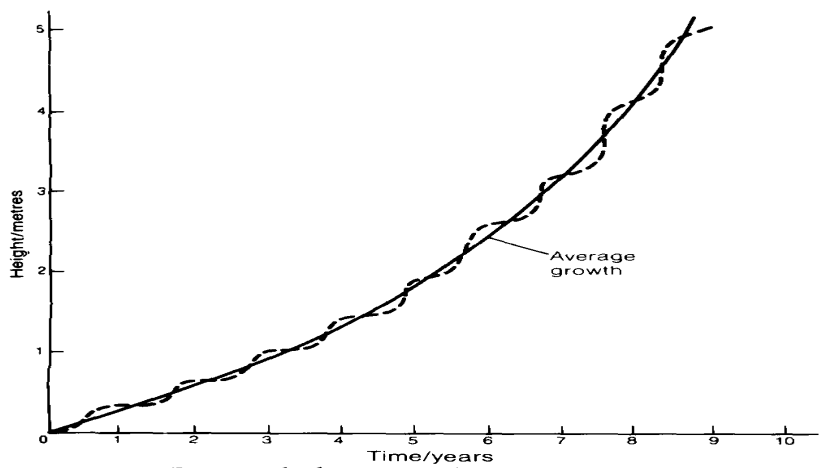
3. Biennial plants: 1st season: produces green leaves, photosynthesis occur, food stored underground and at the 2nd season, stored food is used to produced flowers & seeds. Growth curve: 2 sigmoid curves joined together, example: carrot.



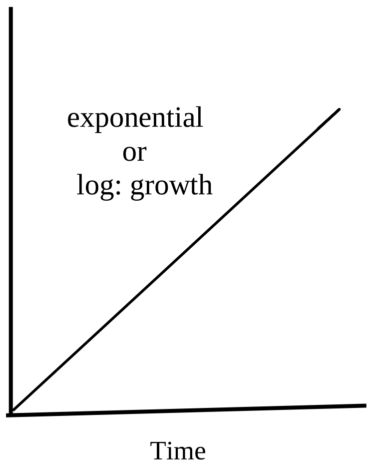
Growth Curve of A Biennial Plant

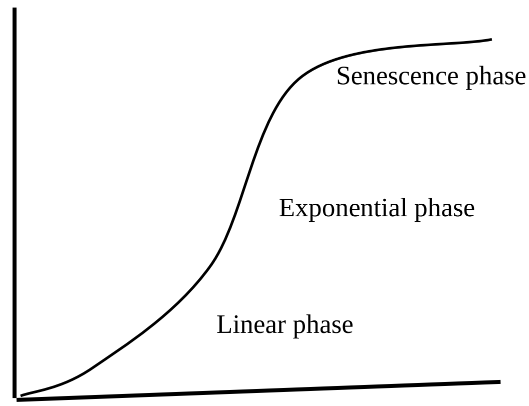
4. Perennial Plant Growth Curve: may live for many years, two types: herbaceous and woody. For **herbaceous perennials**, the aerial shoots die away in autumn but develop underground storage organs (**perennating organs**) to survive the winter, e.g. tubers. For **woody perennials**, they persists above ground throughout the year; grow continues from year to year, e.g. trees. Growth curve: a cumulative series of sigmoid curves, each of which represents one year's growth .Variations occur from year to year according to environmental conditions: cold dry year has less growth than a mild wet year.

The annual growth follows a normal sigmoid curve. Variations occur from one year to the next according to environmental conditions. In a cold dry year for example there will be less growth than in a mild, wet one.



Perennial plant growth curve





Sigmoid growth curve

Absolute Growth Rate=Amount of growth per unit time.
Relative growth rate = Amount of growth per unit time per unit area.

For normal growth of plant, several factors should be available:

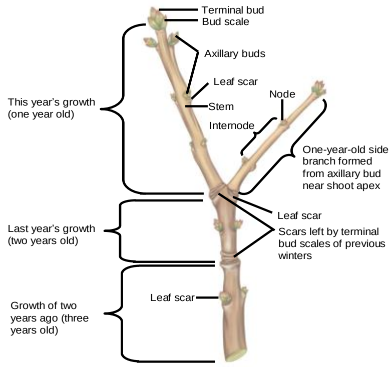
1. Raw materials: includes essential elements, water, CO_2, O_2 etc.
2. Building blocks: includes carbohydrates, proteins, amino acids, fatty acids.
3. Energy sources: such as inorganic phosphates, turgor pressure... etc.
4. Catalysts: such as enzyme and co-factors.
   In addition to those factors, there is another group that dose not fit in those factors, which regulates and coordinates the growth and development of plant called plant growth regulators.

*The plant is provided by the first group only (i.e. raw material) from the outside. The remaining groups are provided by the plant itself.

Growth

- In woody plants primary and secondary growth occur simultaneously but in different locations

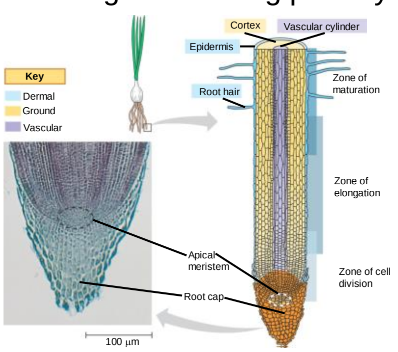
Each year apical meristems produce young extensions of roots and shoots, while lateral meristems produce secondary growth that thickens and strengthens older plant areas.



Primary Growth of Roots

- The root tip is covered by a root cap, which protects the delicate apical meristem as the root pushes through soil during primary growth

- The primary growth of roots: Produces the epidermis, ground tissue, and vascular tissue

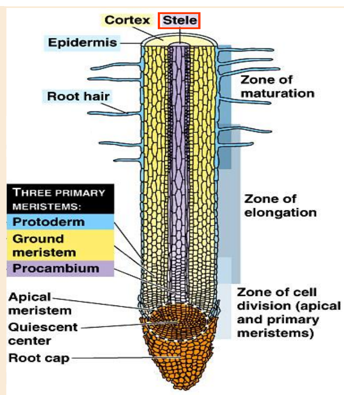


Primary growth in roots

Pericycle

Outermost layer of stele

These cells retain meristematic capabilities, and can produce lateral roots



See Fig. 35.12

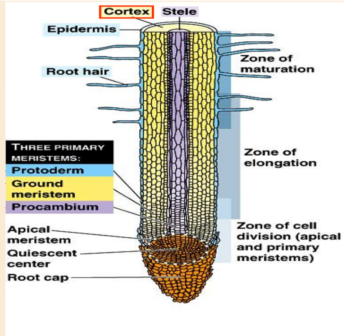
Primary growth in roots

Endodermis

Innermost layer of cortex

These cells regulate the flow of substances into the vascular tissues of the stele

See Fig. 35.12



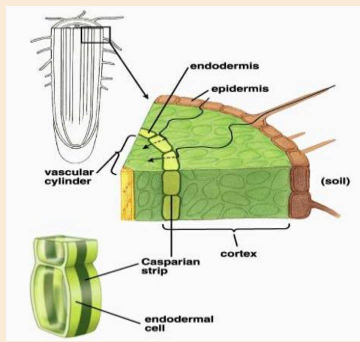
Primary growth in roots

Endodermis

Innermost layer of cortex

These cells regulate the flow of substances into the vascular tissues of the stele

Casparian strip disallows flow of substances except through the endodermal cells themselves



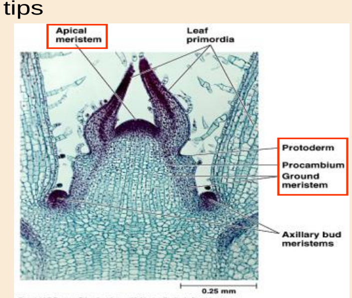
Primary growth in shoots

Primary growth in shoots lengthens shoots from the tips

The **apical meristem** produces the same three primary meristems as in the roots:

Protoderm
Ground meristem
Procambium

See Fig. 35.15

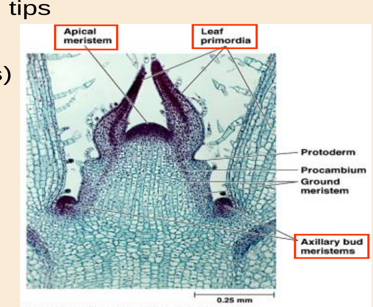


Primary growth in shoots

Primary growth in shoots lengthens shoots from the tips

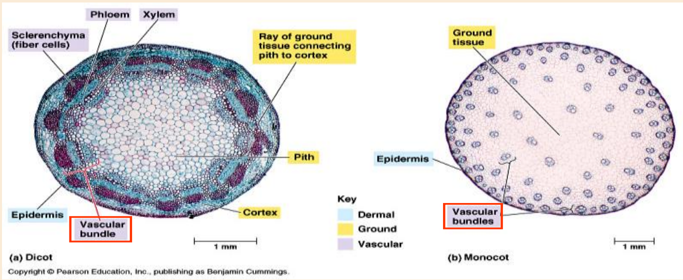
Axillary buds (that could produce **lateral branches**) develop from islands of **meristematic cells** left at the bases of **leaf primordia**

See Fig. 35.15



Primary growth in shoots

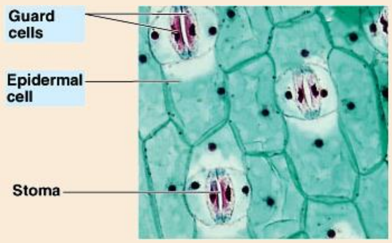
Procambium cells develop into **vascular bundles**



See Fig. 35.16

Primary growth in shoots

Protoderm cells develop into **epidermis**



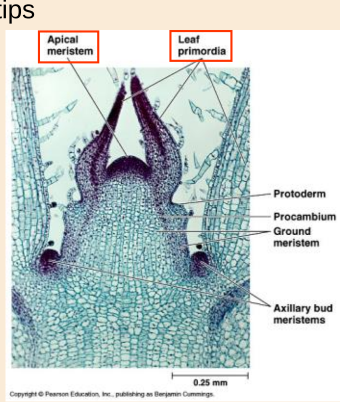
Some epidermal cells are **guard cells** surrounding **stomata**

See Fig. 35.17

Primary growth in shoots

Primary growth in shoots lengthens shoots from the tips

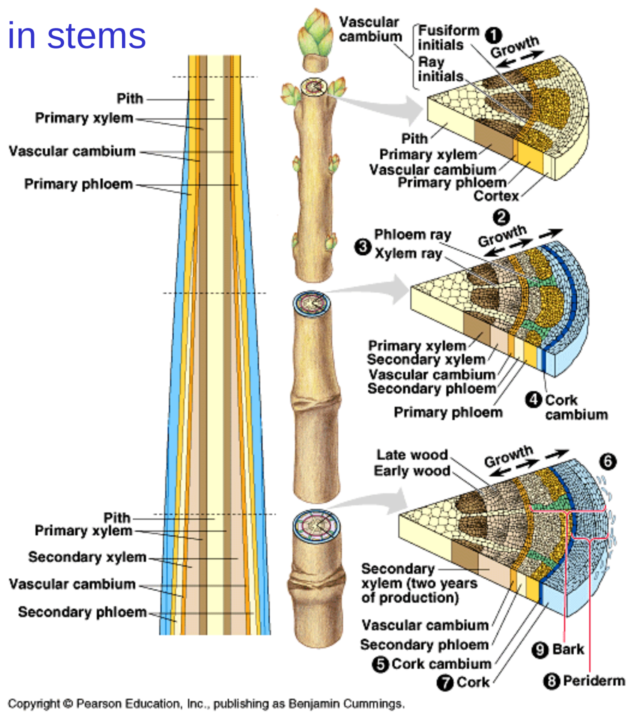
Leaves arise from **leaf primordia** on the flanks of the **apical meristem**



See Fig. 35.15

Secondary growth in stems

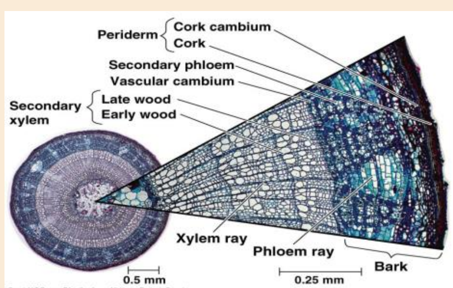
As the stem continues to expand its girth, the **cork cambium** reforms in deeper layers of cortex tissue, and then in **secondary phloem** when the primary cortex is gone



See Fig. 35.18

Secondary growth in stems

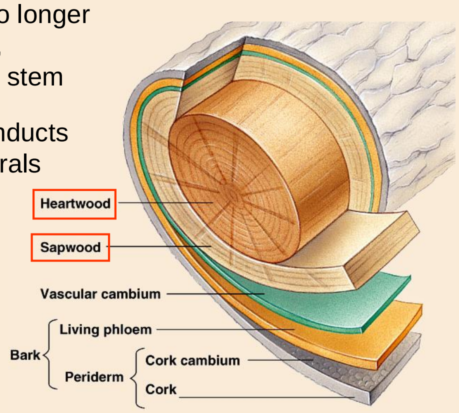
Periderm: **Cork cambium** and **cork**
Bark: All tissue outside **vascular cambium**



See Fig. 35.18

Heartwood: No longer conducts water, but strengthens stem

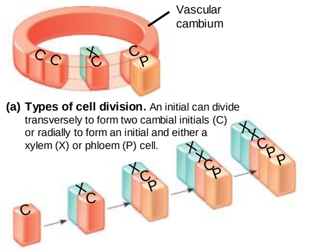
Sapwood: Conducts water and minerals



See Fig. 35.20

growth

- Viewed in cross section, the **vascular cambium**
  - Appears as a ring, with interspersed regions of dividing cells called fusiform initials and ray initials

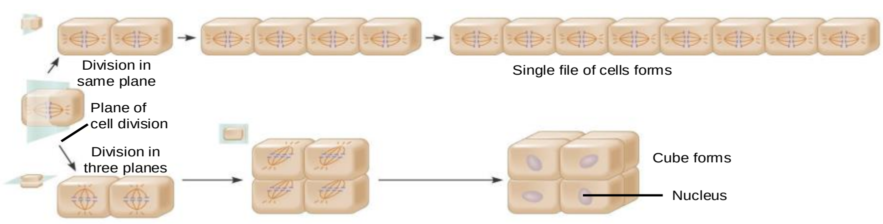


(a) **Types of cell division.** An initial can divide transversely to form two cambial initials (C) or radially to form an initial and either a xylem (X) or phloem (P) cell.

(b) **Accumulation of secondary growth.** Although shown here as alternately adding xylem and phloem, a cambial initial usually produces much more xylem.

The Plane and Symmetry of Cell Division

- The plane (direction) and symmetry of cell division are important in determining plant form
- If the planes of division of cells are parallel to the plane of the first division a single file of cells will be produced



(a) Cell divisions in the same plane produce a single file of cells, whereas cell divisions in three planes give rise to a cube.