I. The physiological function and economic utilization of the stem

(I) Concept: it is an axial structure connecting the root and leaves to transport the water, inorganic salt and organic nutrients, and mostly an over-ground vegetative organ with the apex extending upward indefinitely.

(II) Function

1. Conduction effect: xylem and phloem
2. Supporting effect: mechanical tissue: tracheid and vessel
3. Other effects: storage (subterraneous stem), propagation (adventitious root and adventitous sprout)

(III) Economic utilization

Food, medicine, industrial materials, woods and bamboo, etc.

II. The morphology of the stem

(I) Morphological features

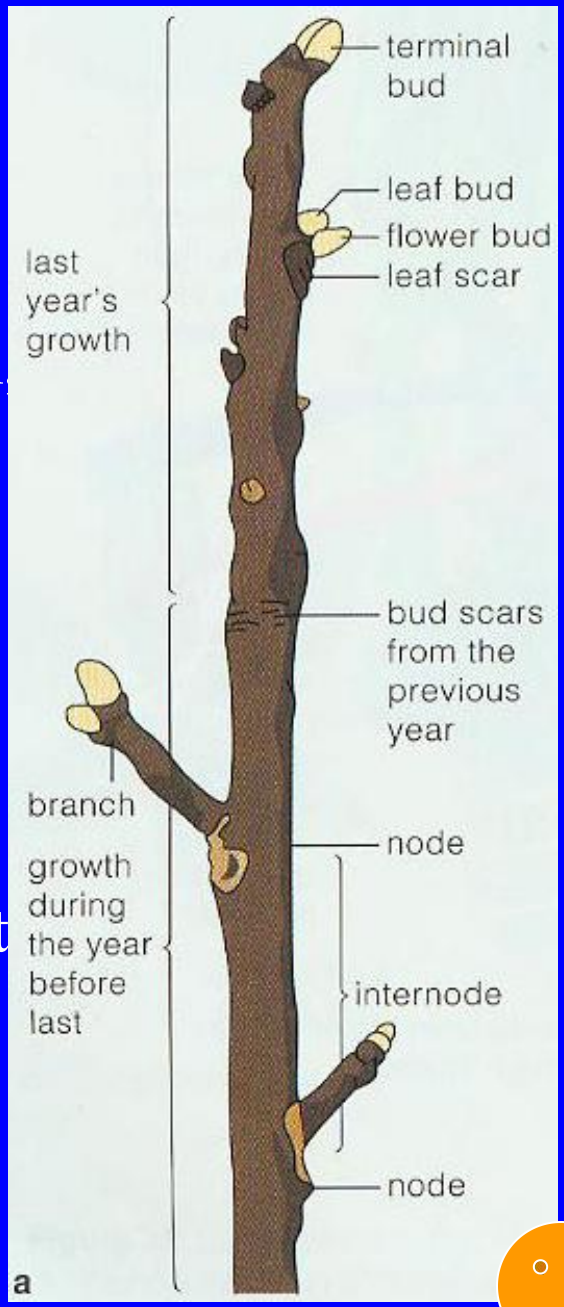
1. Appearance: mostly are cylinder shaped, and some are riangular prism, square cylinder and flat cylinder.

2. Nodes and internodes

① Node: the site where leaves and buds are originated from.

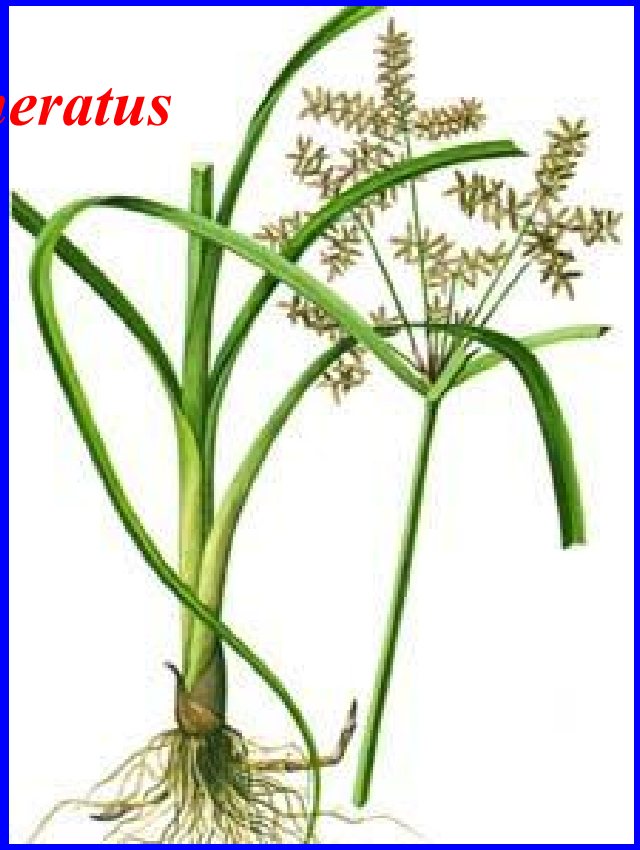
② Internodes: the distance between adjacent 2 nodes.

③ Difference between the stem and root the former has nodes and internodes, and the leaves are originated from the nodes and buds from axil and apex.



Mint *(Mentha haplocalyx)*

Cyperus glomeratus



Broad bean *(Vicia faba)*

3. Twig/branch: the stem with leaves and buds.

Long twig: the twig with significantly extended internodes.

Short twig : the twig with internodes closely connected, even undistinguishable from each other.

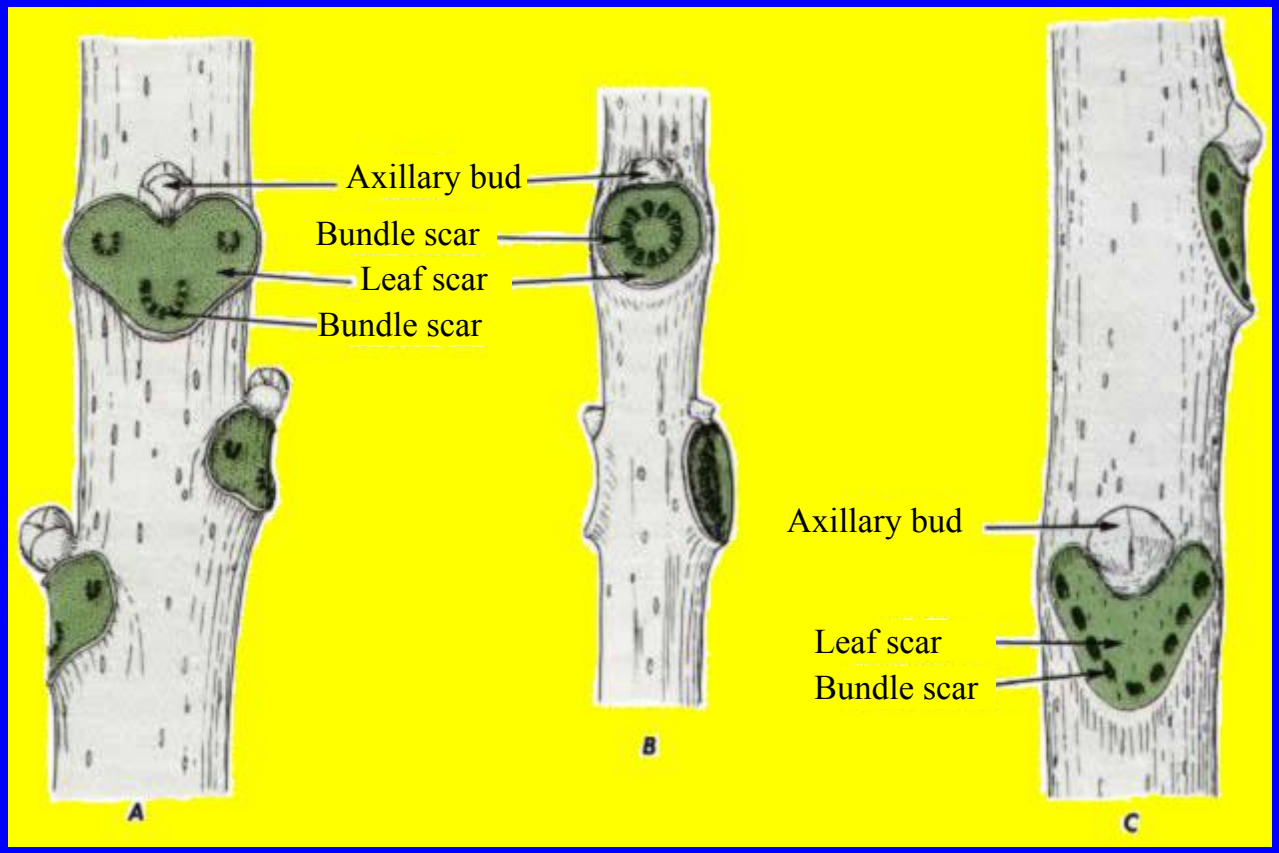
4. Leaf scar and vascular bundle scar, etc.

- Leaf scar: the scar left on the stem from the disconnection of petiole after the leaf falls off.
- Vascular bundle scar: raised spots/line within the leaf scar, and also the mark left after the disconnection between the petiole and vascular bundle in the stem.
- Bud scale scar: the mark left after the fall-off of peripheral bud scale in the course of spreading of terminal bud/bulbil.
- Lenticel: the channel for inside-outside gas exchange on the woody stem.

Gingkgo gingko

Masson pine *(Pinus massoniana)*

Chapter IV Vegetative Organs of Seed Plants – The Stem



(II) Bud concept and type

1. Bud concept: the non-extended twig, flower or inflorescence in juvenile form, that is, the miniature twig, flower or inflorescence before development.

2. Bud structure

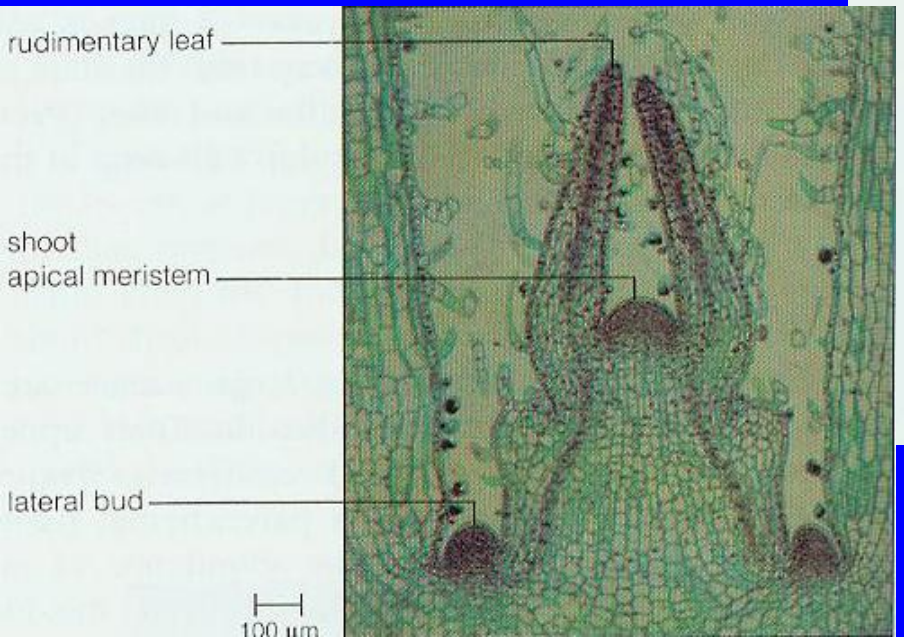
Apical meristem: the part at the top of shoot bud.

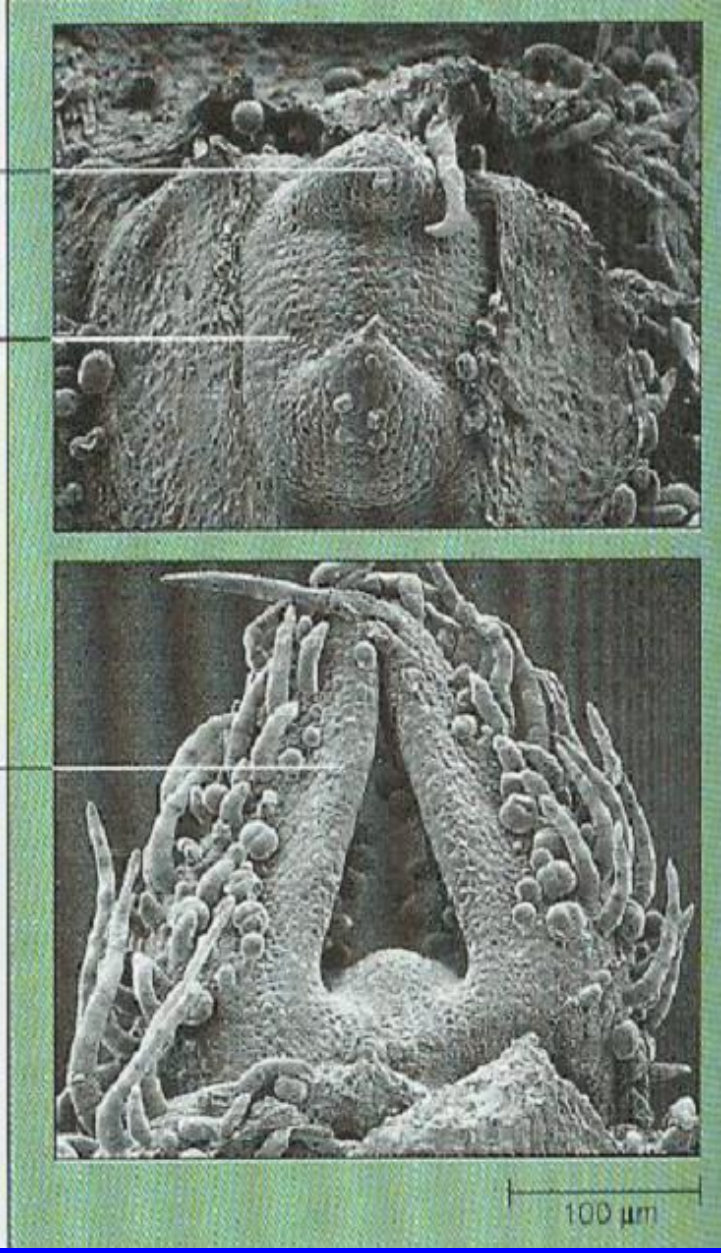
Leaf primordium: the raised part below apical meristem, or the leaf miniature, or the leaf in early stage of development.

Young leaf:

Axillary bud primordium: the raised part in the axil of young leaf to develop into axillary bud in the future and eventually lateral branch.

Light micrograph of a shoot tip and SEMs of new leaves forming at the same type of shoot tip.





3. Bud type

(1) Classified by the position on the twig

Normal bud
- Apical bud: the bud growing on the apex of main stem or lateral branch.
- Axillary bud: the bud growing in the lateral leaf axil of branch.

Adventitious bud: the bud growing on the position other than the apex of branch or leaf axil.

Infrappetiole bud : some axilliary buds grow at a lower position – covered by the base of petiole, and will not appear until the leaf falls off, and it is called infrappetiole bud.

Plane tree *(Platanus acerifolia)*

Locust tree *(Robinia pseudoacacia)*

(2) Classified by presence of bud scale

Naked bud: no bud scale outside of the bud, and the bud is only covered by young leaves.

Covered bud: presence of bud scale, and the bud scale is metamorphosed leaf with thick cuticle, sometimes it is covered by trichoma or resin mucus secreted to reduce evaporation and prevent drought, freeze injury and protect young leaves.

(3) Classified by the physiological activity of the bud

Active bud: it is the active bud in growing season, which is able to grow into new twig, flower or inflorescence in the same growing season.

Dormant bud: it does not grow or develop in the growing season and remain in dormant state.

(4) Classified by the nature of the organ to be formed from the bud

Shoot bud: it includes the apical meristem and peripheral appendages, i.e., leaf primordium, axillary bud primordium and young leaf. It is relatively tiny.

Flower bud: it is the miniature to generate flower of inflorescence, consisted of some flower primordia or a cluster of flower primordia, but not leaf primordium, or axillary bud primordium. After the completion of flower or inflorescence formation, the apex stops growing. It is relatively full.

Mixed bud: it is a constituent part of both shoot bud and flower bud, which is able to develop into both twig and flower. It is relatively full.

Flower bud of Berberis approximata

Flower bud of elm (*Ulmus pumila L.*)

Mixed bud of apple tree (*Malus pumila*)

(III) Growth habit of the stem

Erect stem: the stem grows up-right away from the ground.

Twining stem: the stem is relatively flexible at juvenile stage, and unable to grow up-right, so it twines around other brace to rise.

Climbing stem: the stem is relatively flexible at juvenile stage, and unable to grow up-right, so it rises by climbing on other objects with its special structure (towel gourd: tendril, *Trachelospermum jasminoide*: aerial root, *Tropaeolum majus*: petiole, bedstraw (*Galium aparine L.*): hooked spine, Boston ivy (*Parthenocissus tricuspidata*): sucker)

Stolon: the stem is long, thin and delicate, and creeps along the ground to extend. Generally, it has long internodes, with adventitious root growing on the node, and the bud will grow into a new plant.

Cypress vine
(Quamoclit pennata)

Birthwort
（Aristolochia debilis）

Morning glory
(Pharbitis purpurea)

Scandent hop
(Humulus scandens)

Polygonum multiflorum

Sponge gourd
(Luffa cylindrica)

Pumpkin *(Cucurbita moschata)*

Pea *(Pisum sativum)*

Trachelospermum jasminoides

Ivy *(Hedera nepalensis)*

Nasturtium *(Tropaeolum majus)*

Bedstraw *(Galium aparine)*

Boston ivy ***(Parthenocissus tricuspidata)***

Sweet potato
(Ipomoea batatas)

Strawberry *(Fragaia ananassa)*

(IV) Branching pattern

1. Monopodial branching: the main stem is the principal axis, formed by continuous extending of apical bud upward, and the main stem is very obvious.
2. Sympodial branching: the apical bud on the main stem grows slow or dies in the growing season, or the apical bud is a flower bud, so the axillary bud right under the apical bud takes the place to extend, so as to maintain continuous growth of the main stem. Such main stem is a combo of many lateral branches developed from axillary buds, which is a advanced branching pattern.
3. False dichotomous branching: for the plant with opposite leaves, after the apical bud stops growing or the apical bud is a flower bud, both lateral axillary buds under the apical bud develop into dichotomous branches, and it is a variation of sympodial branching.

Sympodial branching

False dichotomous branching

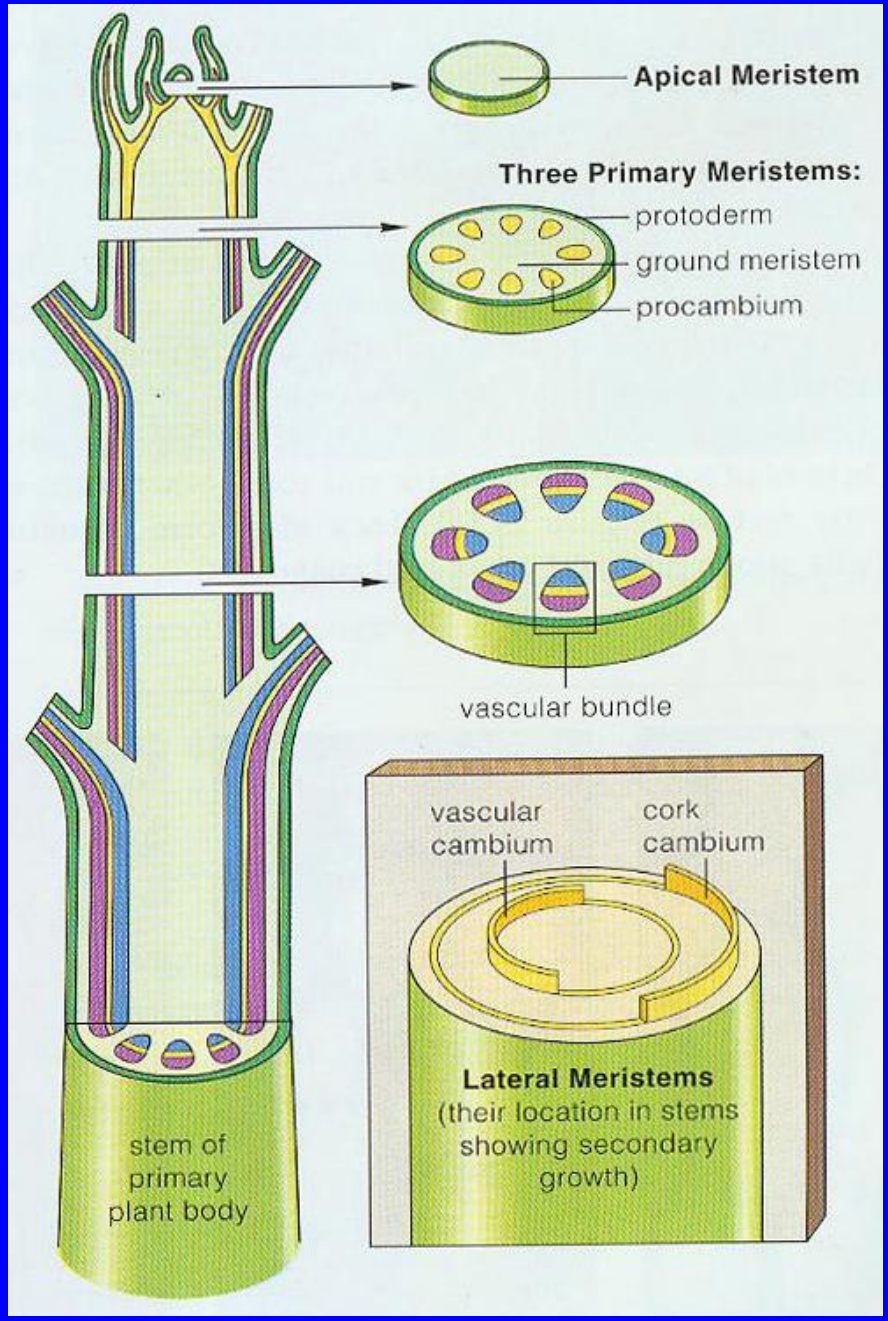
Monopodial branching

III. Stem Development

(I) Apical meristem

- Promeristem
- Primary meristem
  - Procuticle → Cuticle (Differentiation)
  - Fundamental meristem → Cortex
  - Procambia → Vascular cylinder

Approximate locations of primary meristems and lateral meristems in a plant showing both primary and secondary growth.

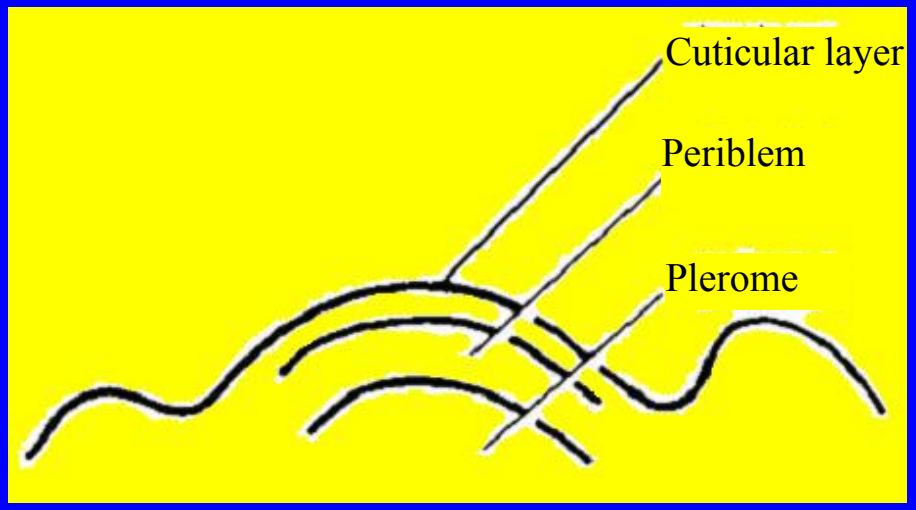


(II) Theory of composition of apical meristem

1. Histogen theory

It was proposed by Hanstein in 1868. According to this theory, the stem apex is composed of the predecessor of 3 tissue regions (cuticle, cortex and vascular cylinder), that is, the histogen, and each histogen is generated from one cell or a group of initial cells, and they are called dermatogen periblem and plerome.

Limitation: the 3 histogens are at stem apex and undistinguishable, but conform to the tissues of root tip.



2. Tunica-corpus theory

It is proposed by Schmidt in 1924.

（1）The original area includes 2 parts – tunica and corpus.

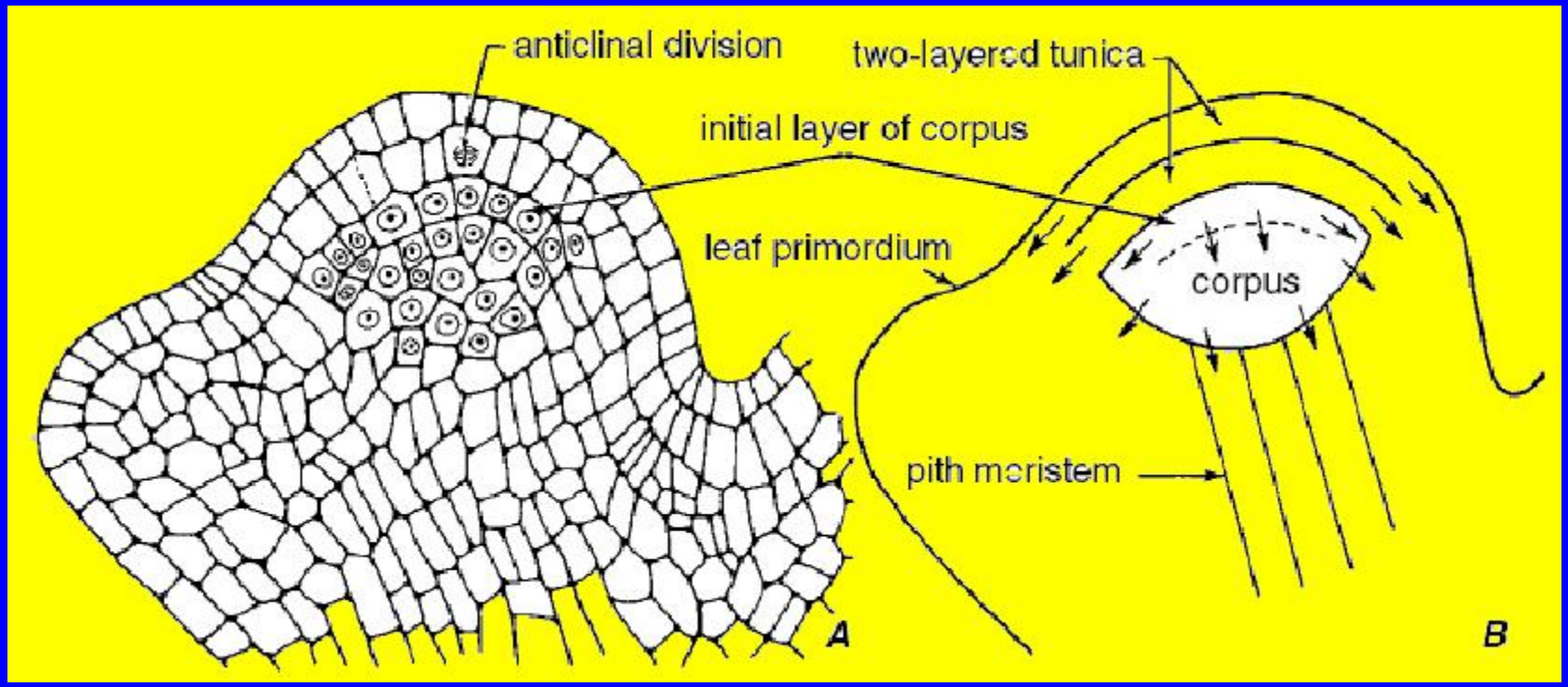
（2）The tunica cells only divide themselves vertically to maintain the continuity of surface growth.

（3）The corpus cells divide themselves tangentially and at all other directions to increase the volume and enlarge the stem apex.

（4）The tunica and corpus both have respective initial cells, and the tunica is at the center of axis and the corpus is situated under the initial tunica cells.

（5）The tunica and corpus are unable to expand or enlarge indefinitely. More than half of tunicae of dicotyledon are 2 layers, or 4-5 layers; those of monocotyledon are only 1-2 layers.

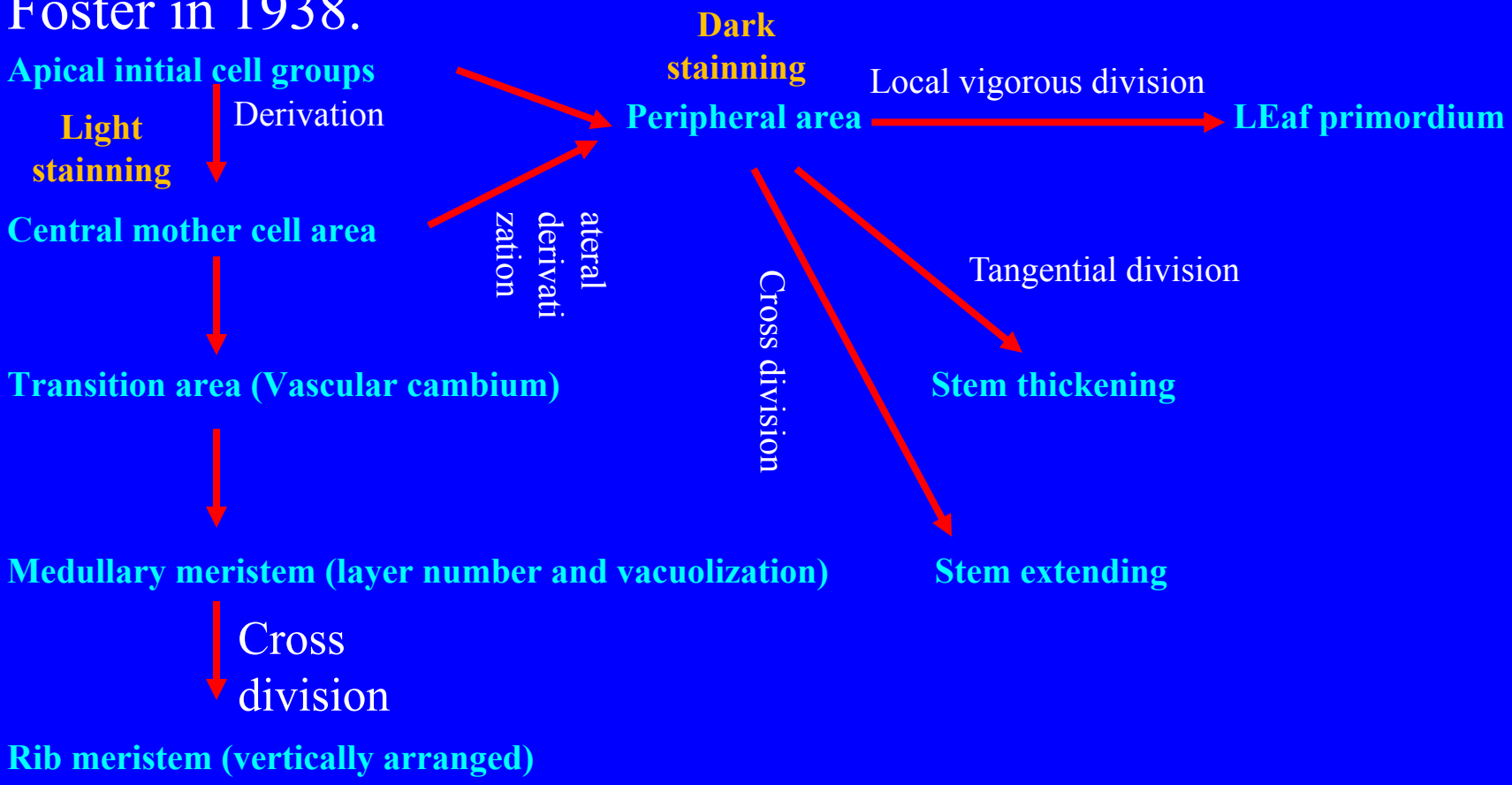
（6）Except that the cuticular layer is differentiated from the surface cell layer of tunica, there is no pre-determinated tissue area for the composition of apical meristem.



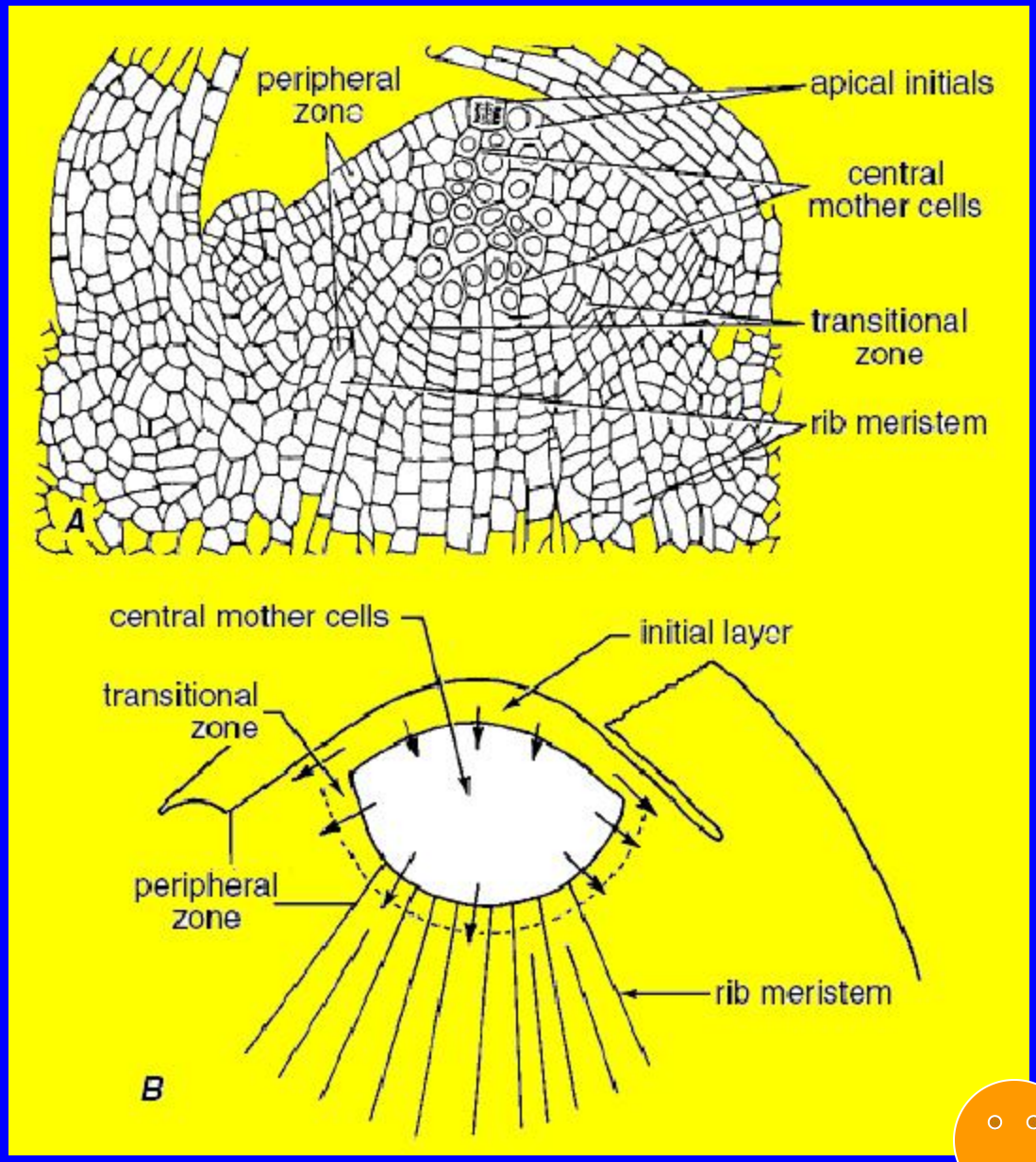
Shoot apex of *Pisum* (pea). Cellular details in A, interpretative diagram in B. The pith meristem does not show typical rib-meristem form of growth. (From Esau, 1977)

3. Concept of cellular partition

The gymnosperm has no tunica structure. It is proposed by Foster in 1938.



Shoot tip of *Pinus strobus* in longitudinal view. Cellular details in A, interpretative diagram in B. Apical initials contribute cells to the surface layer by anticlinal divisions and to the central mother-cell zone by periclinal divisions. The mother-cell zone (cells with nuclei) contributes cells to the transitional zone composed of actively dividing cells arranged in a series radiating from the mother-cell zone. Products of these divisions form the rib meristem and the subsurface layers of the peripheral zone. (A, ×139. A, as drawn from a slide by A. R. Spurr; B, from Esau, 1977)



(III) Origin of leaf and bud

1. Leaf origin

It is developed from leaf primordium

（1）Dicotyledon: the division begins tangentially from the surface of apical meristem.

（2）Gymnosperm and dicotyledon: the second or third layer of the surface of apical meristem begins to divide tangentially firstly, and then vertically, and later by both division methods.

（3）When the tunica is relatively thick, the leaf primordium can be generated from the cells derived from tunica; otherwise, it can be generated from both tunica and corpus.

2. Bud origin

（1）Apical bud: it is generated from the apical meristem of stem apex (main stem or lateral stem).

（2）Axillary bud: it is originated from axillary bud primordium at the axillary area of leaf primordium, and like leaf origin, it first divides tangentially and vertically to form a raised area, but it is originated later than the leaf is, and not many leaf primordia are formed from a distance from stem apex.

3. External origin

The leaf and bud on the stem are originated from the first or second, third layer of cells of apical meristem, and this method of origin is called external origin.

Assignments

- What is stem and what is its difference from the root?