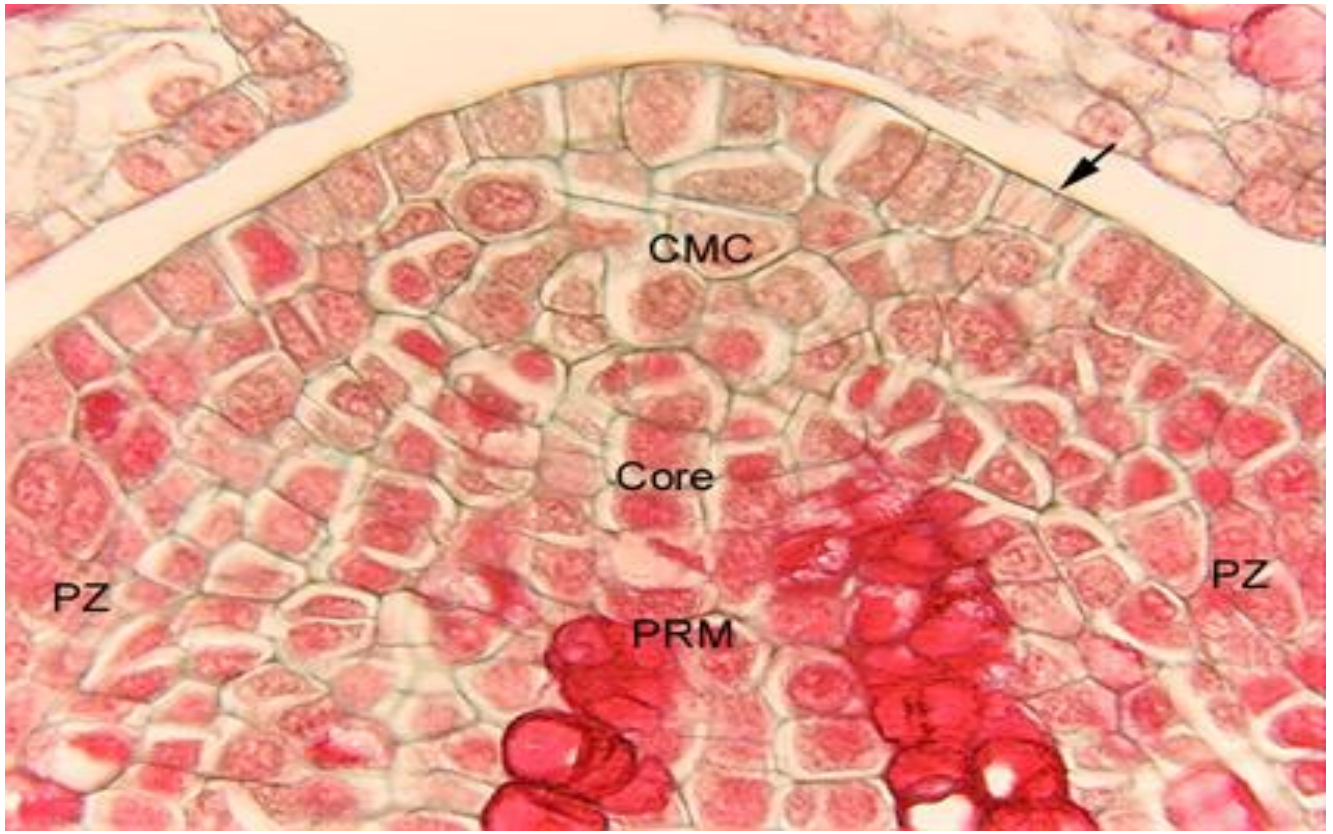
Shoot Apex Organization



- Apical meristems are the completely undifferentiated meristems in a plant. Usually shoot apex and root apex employed as synonyms for apical meristems-both root and shoot.
- The shoot apical meristems are minute but complex structures that are covered within new developing leaves or bracts.
- The shoot tip can then be defined as that portion of the shoot comprising all tissues and organs distal to the still-differentiating leaves
- The functions of the shoot apical meristem (SAM) are the formation of the shoot axis and the initiation of lateral organs, such as leaves, bracts, etc.
- The apical meristem becomes broder before the initiation of each leaf and after giving off the leaves,it again narrows down.
- As a result of this rythemic phenomenon shoot apex look like a cone.
- These broad and narrow areas are called as maximal & minimal areas by Schmidt(1924).
- The spatial pattern of the arrangement of leaves is called phyllotaxy whereas the time between successive leaf initiation events is called the plastochron and the rate of emergence from the apical bud is the phyllochron.
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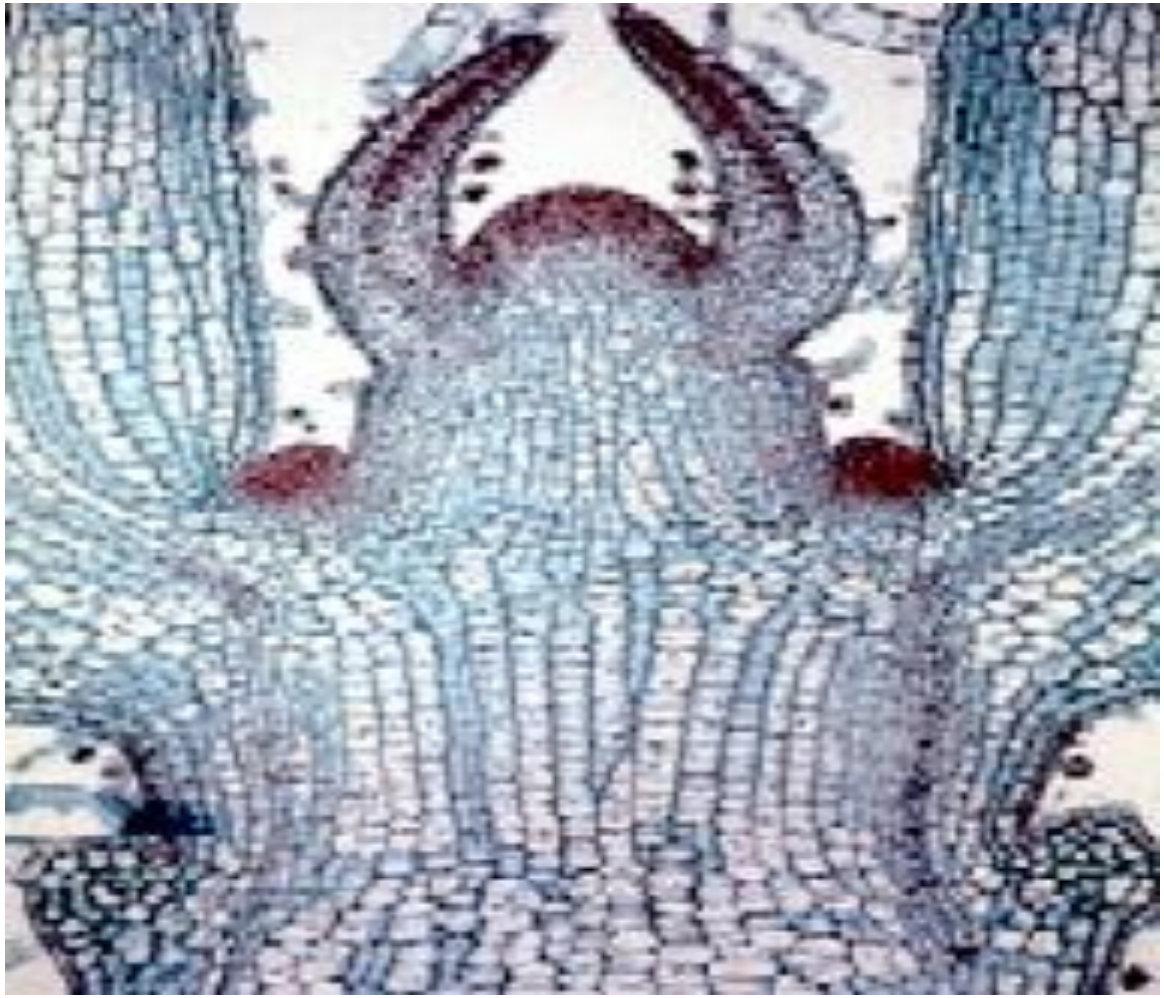


Shape & Size

- The shoot apex is radially symmetrical.
- There occur great variations in shape and size of the shoot apices among the spermatophytes.
- Usually the shoot apex in most of the plants is more or less convex. In Anacharis, and some grasses it is a narrow cone with a rounded tip.
- in some cases,e.g. in Hibiscus syriacus, Drimys, etc, it is slightly concave

Size: The size of shoot apex varies in different plants or in different branches of the same plant.

- The measurement of the diameter is taken as the width of the apex immediately above the newly formed primordium.
- It may be 90 µm in some grasses, 130-200 µm in dicots, 280 µm in banana and 500-800 µm in palmae.
- Clowes (1961) reported the size of Cycas revoluta shoot apex at the level of youngest leaf primordium to be 3300 µm in width.

Theories regarding histological organisation of shoot apical meristem .

Several theories have been put forward from time to time to explain the zonation of the shoot apices-

Shoot apex was first recognised by Wolff (1759) as an undeveloped region, from which growth of plant proceeded. He termed this region as 'punctum vegetationis'. Since then, the concept has undergone profound changes and different theories dealing with the histological organisation of shoot apical meristem have been put forward.

1.Apical cell theory (Nageli 1858).

Apical cell theory was postulated by Nageli in 1878, while examining the shoot apical meristems of most **cryptograms.**

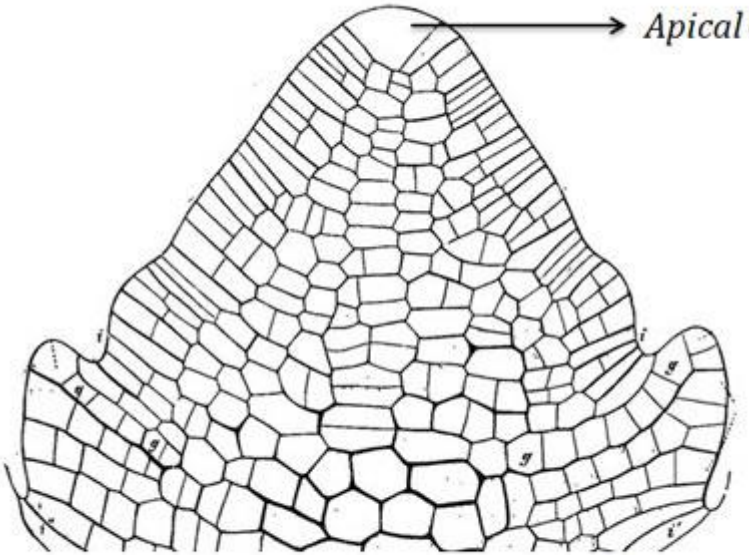
According to this theory, a single apical cell is the structural and functional unit of apical meristem, and it governs the whole process of growth.

Single apical cells occurs in many vascular cryptograms like *ferns, horse tails* and many species of *Selaginella.*

Most single apical cells are pyramidal (tetrahedral) in shape, e.g. In *Equisetum.*

Single apical cells may also be three sided, e.g. water ferns, *Salvinia and Azolla*.

Recent studies on shoot apex using colchicine have confirmed that shoot apex of spermatophytes consists of a group of cells which constitute the meristem.



Apical Meristem Organization in Shoot

Apical Cell Theory

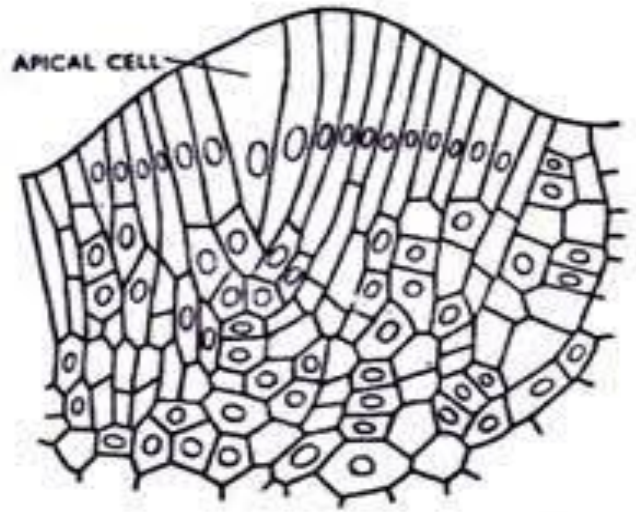


FIG. 530. Meristem. Apical cell in the apex of rhizome of *Pteridium* (longitudinal).

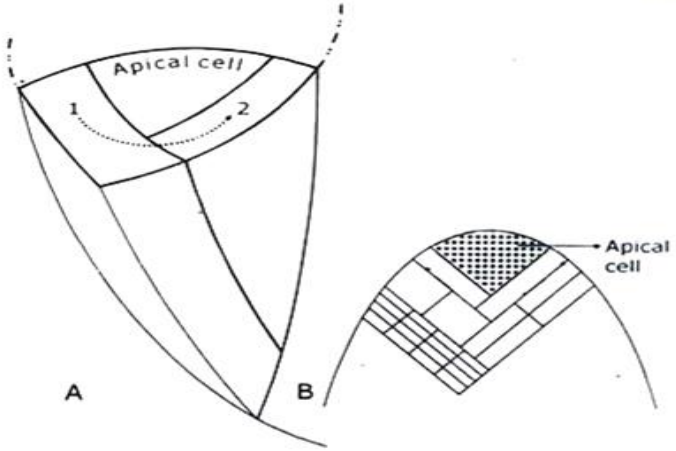


Figure 7.7

A. Diagram showing an apical cell of leptosporangiate fern and its derivatives that are formed in helical succession. The new cells are numbered as 1 & 2. B. Diagram showing a packet of cells formed by an apical cell by division and subdivision.

Demerits

It may hold for algal groups,bryophyts and pteridophytes.

It is not applicable for seed plants.

In higher plants the apical cell theory was replaced by the concept that the different parts of a plant body have independent origin.

So the apical cell theory was later superseded by histogen theory.

HISTOGEN THEORY

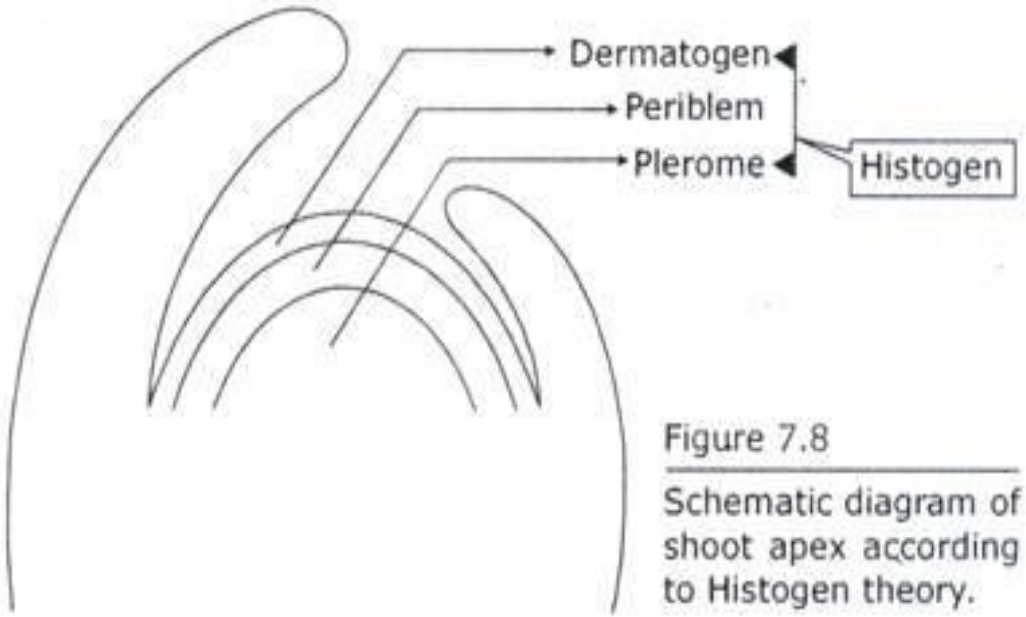
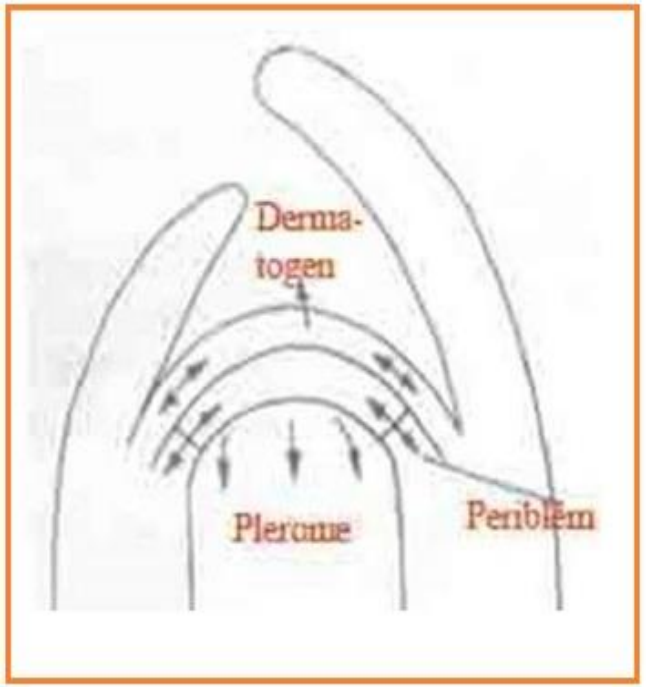


Figure 7.8

Schematic diagram of shoot apex according to Histogen theory.

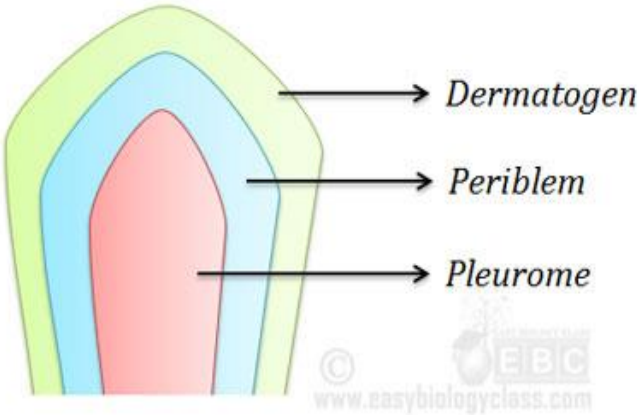


Hanstein in 1868 put forward histogen theory (histogen means tissue builder.

It maintains that the shoot apex in angiosperms consists of a central core of irregularly arranged cells covered by a variable number of mantlelike layers.

It proposes that each layer, and the core, is derived from a distinct initial cell or small group of cells (the histogens or tissue formers). Thus the origin of different parts of the apex cannot be traced to a single cell.

These Layers are -**1.Dermatogen 2.Periblem 3.Plerome**



Apical Meristem Organization in Shoot
Histogen Theory

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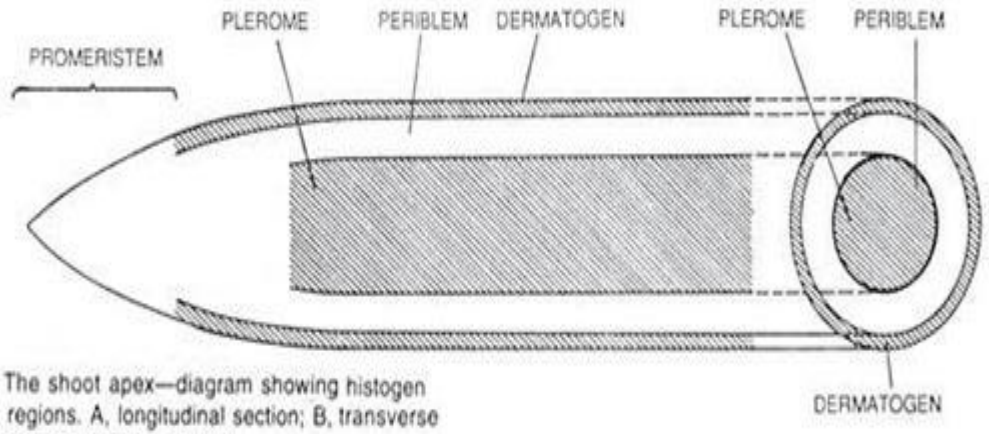
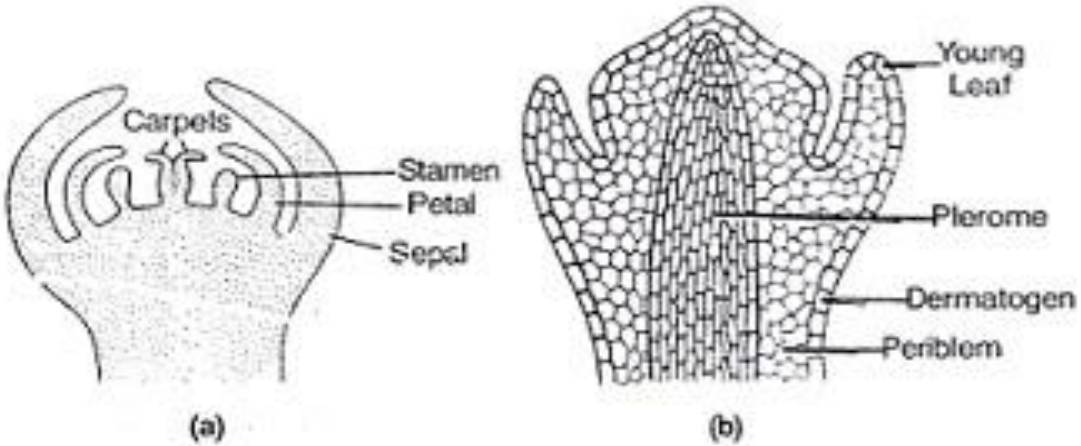


The shoot apex—diagram showing histogen regions. A, longitudinal section; B, transverse section. (After E. & M.).



(a) Reproductive apex (Diagrammatic)

(b) Vegetative shoot apex showing histogens

“Dermatogen,(In Greek meaning skin) a meristematic external layer .Hanstein believed, that it produced only the epidermal system.

The underlying layer or layers, which he called the "periblem, (In Greek meaning clothing) a central core "produced the cortex and endodermis.

The central core, or "plerome,(In Greek meaning that fills), “the region between the two, produced the procambial and pith tissue of the axis. .

Hanstein originally applied his terms to zones of meristematic tissue in the early stages of development from initials, but in later literature the same terms were sometimes applied to the initials themselves.

DEMERITS

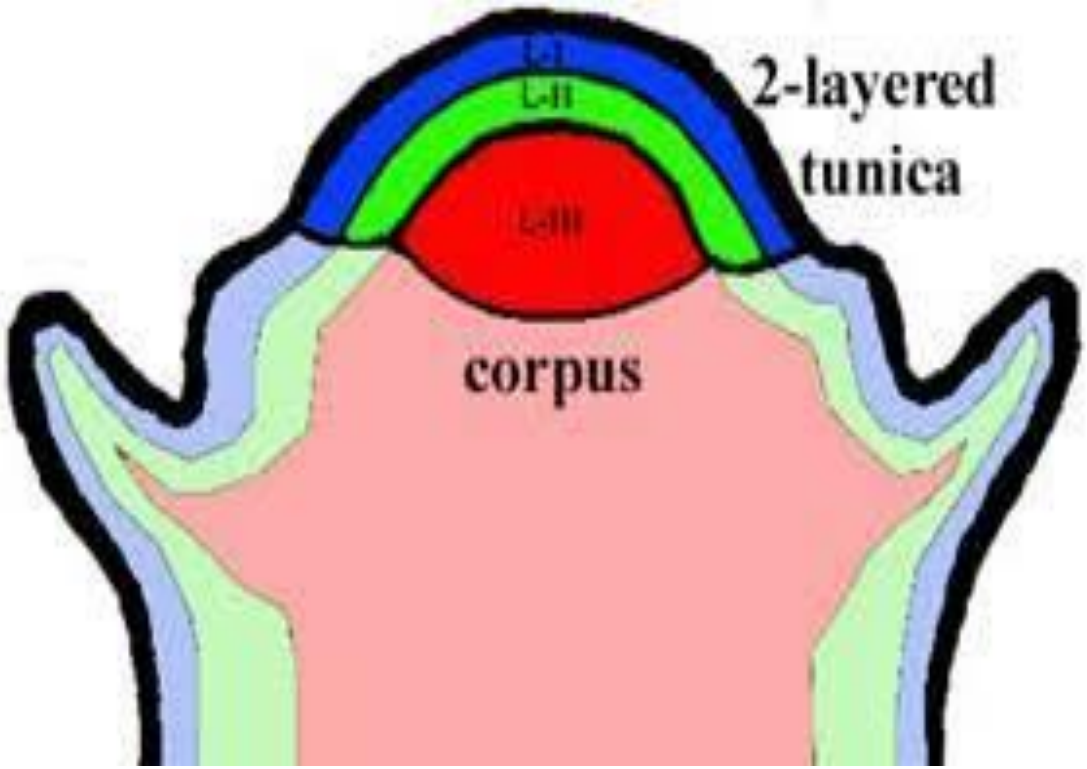
Hanstein's theory drew a great amount of criticism which was reviewed and discussed by Schmidt (1924).

(i) In gymnosperm and angiosperm there exists no clear distinction between periblem and plerome.

(ii) The respective roles of the three histogens cannot be demonstrated.

TUNICA CORPUS THEORY

Schmidt in 1924 proposed this theory for the organization of shoot apex.



According to this theory, there are **two** zones of tissues in the apical meristems **the tunica** (Tunic = cover) consisting of one or more layers of peripheral layers of cells, and the **corpus** (corpus = body) a mass of cells enclosed by the tunica.

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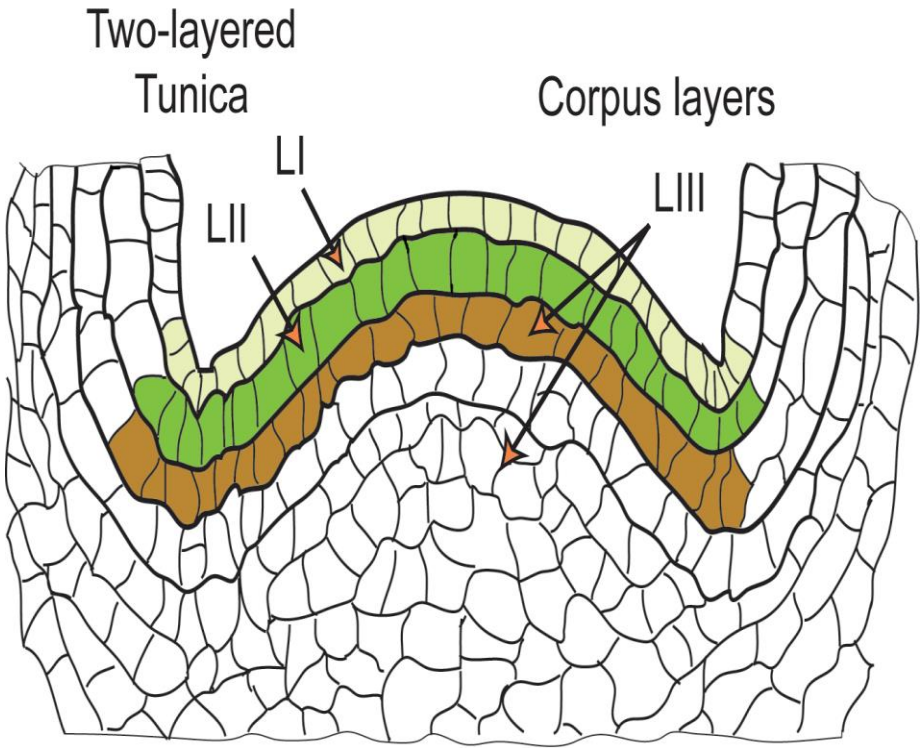
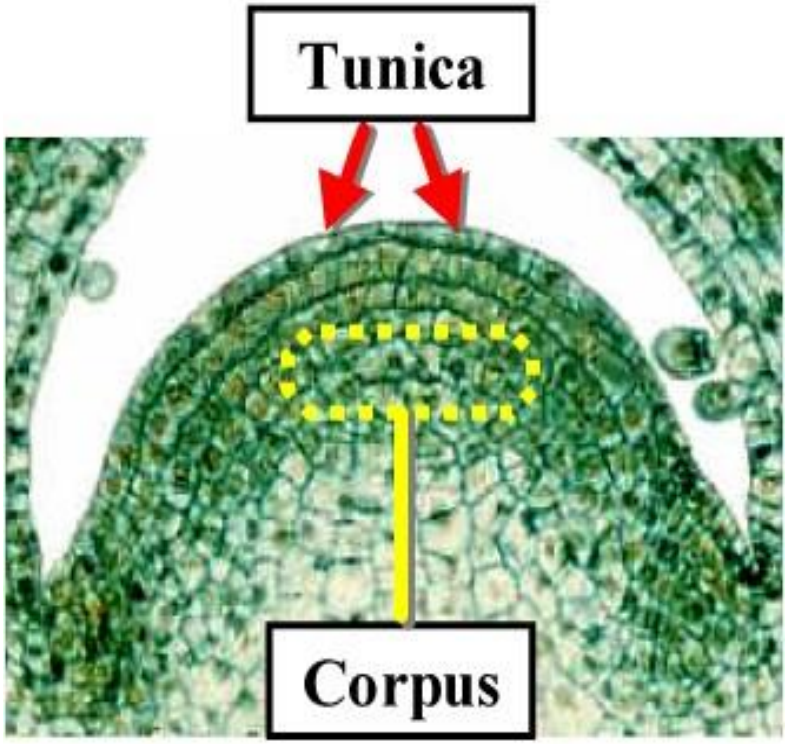
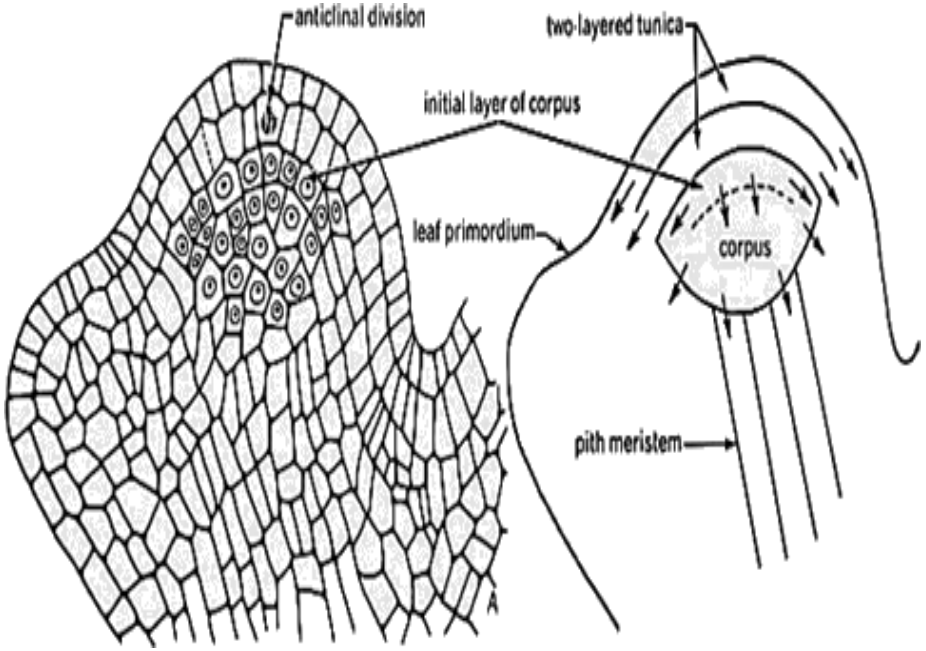
Tunica- It consists of one or more peripheral layers of small cells.
The layers of the tunica show the predominantly anticlinal divisions.
Final result is increase in surface areas.
Each layer of tunica arises from a group of seperate initials.
It gives rise **to epidermis and cortex.**

Corpus- A mass of cells enclosed by tunica.
Divide by is periclinal division.
Divisions are in various planes.
As a result whole mass grows in volume.
It arises from single tier of initials.
. It gives rise to **endodermis,pericycle, pith and vascular tissues.**


Two-layered
Tunica
Corpus layers
LI
LII
LIII


Tunica
Corpus



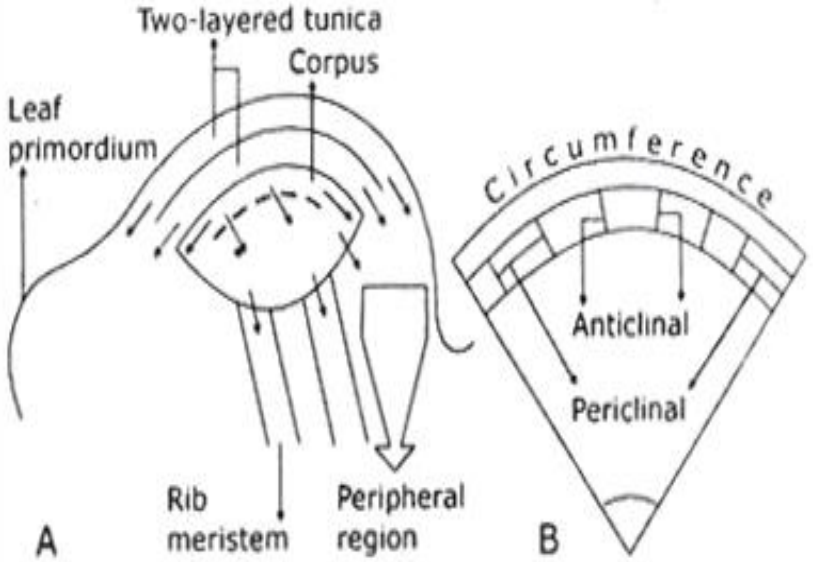


Figure 7.9

A. Diagram illustrating the tunica-corpus organization in dicotyledonous shoot apex. Arrows indicate the direction of cell formation in apical meristem.

B. Schematic representation of anticlinal (= division wall perpendicular to surface) and periclinal (= division wall parallel to circumference) division.

- The corpus and each layer of tunica are visualize as having their own initial.

- In the tunica, initial cells divide anticlinally to form daughter cells: one remain at the apex as initial, other as derivatives, by subsequent division contribute cells to the peripheral part of the shoot.

- Initial corpus by periclinal division give derivatives to the corpus below, the cells of which divide in various planes. Cells produced added to the center of the axis: the pith meristem also commonly to the peripheral region .

- The derivatives of tunica & corpus involve in the formation of the axillary bud meristem. If the axillary buds develops into a shoot its apical meristems copy the pattern found in its parent shoot apex to form leaves.

- Some unknown mechanism,which adjusts the balance between surface and volume growth,controls the development of leaf and bud primordia.

DEMERIT

The tunica-corpus theory was formulated with reference to angiospermous apices.

It found to be largely **inapplicable to the characterization of apical meristems of gymnosperms.**

The tunica layers are variable in number in various taxon.

During seasonal fluctuations of growth the no. of periclinal layers vary even in the same species.

The tunica corpus organization absent in some cases- *Saccharum.*

Modification of tunica corpus concept

The shoot apices of gymnosperms are adequately described by neither the apical cell theory nor the histogen theory.

Organization of Gymnosperm Shoot Apices
Cytohistological Zonation

The usefulness of the tunica-corpus theory is limited because a welldefined tunica occurs only in a few taxonomic groups.

Apices of many gymnosperms have no tunica.
Gymnosperm apex be considered as a naked corpus when the tunica is absent.

Tunica-corpus theory was proposed for describing a type of growth, with emphasis upon orientation of planes of cell division (Schmidt 1924), and does not provide a basis for classification of tissue types or zones within the meristem.

Gradually there arose a concept of cytohistological zonation within the gymnosperm shoot apex.

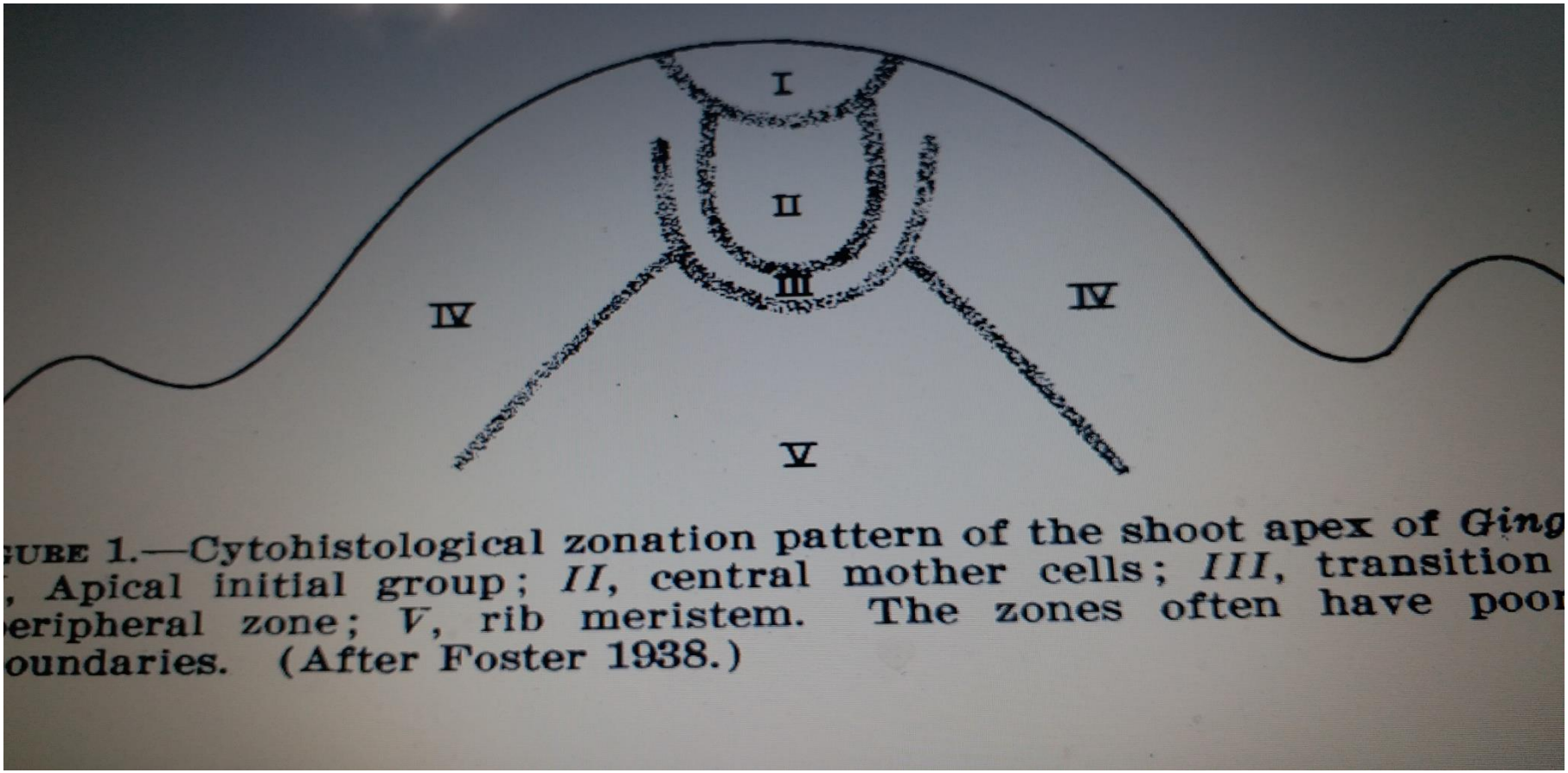
This idea depends upon the existence, within the meristem, of zones distinguishable from one another by –

(1)Cell size and degree of vacuolation,
(2) nuclear volume,
(3) staining characteristics,
(4) frequency of cell division,
(5) relative cell wall thickness, and
(6) orientation of planes of cell division

Foster recognized **five zones** in the *Ginkgo apex .*
Cytohistological zonation was a definite advance in understanding the organization of shoot apices.

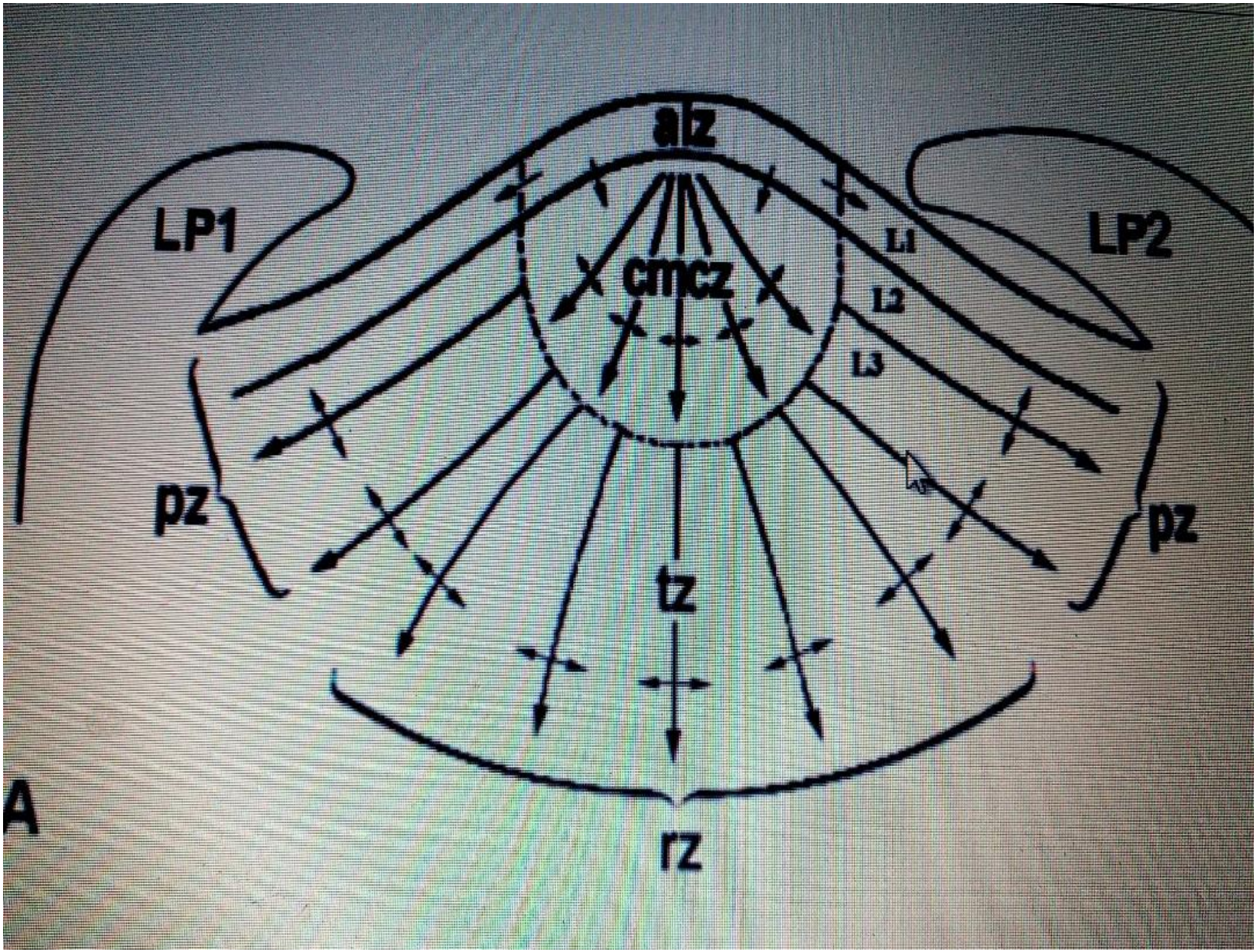
Apical initial group (Zone I),—
The apical initials occupy the summit (top) of the meristem and are larger than other cells of the surface layers.

- The nuclei are large and the cytoplasm somewhat vacuolated.
- The cells are only lightly stained by safranin.
- There is no single or permanent apical cell, and no clear regularity of cell division.
- Divisions occur with varying frequency and in various planes.
- The apical initials contribute directly to the peripheral zone and to the central mother cell zone.
- They are the ultimate, but perhaps remote, source of all cells of the shoot.



URE 1.—Cytohistological zonation pattern of the shoot apex of Ging
, Apical initial group; *II*, central mother cells; *III*, transition
eripheral zone; *V*, rib meristem. The zones often have poor
oundaries. (After Foster 1938.)

1.—Cytohistological zonation pattern of the shoot apex of *Qingko biloba* :
/, Apical initial group; //, central mother cells; ///, transition zone; *IV*,
peripheral zone; *V, rib meristem.*
The zones often have poorly defined
boundaries. (After Foster 1938.)


alz
LP1
LP2
cmcz
L1
L2
L3
pz
pz
tz
rz
A

Central mother cell zone (Zone. II)—

This zone occupies **a roughly spherical volume in the upper central region of the shoot apex just beneath the apical initials.**

- **Its component cells were called "central mother cells" by Foster (1938) because he believed the zone to function as a common area of propagation of cells,**

- **This after further multiplication comprise most of the internal tissues of the apex.**

- **The central mother cells are the largest cells of the apical meristem.**

- **Their nuclei are large and are only lightly stained with safranin.**

- **The cytoplasm is less dense and more vacuolated than in the peripheral zone.**

- **Growth of the cells is primarily in volume with no regular pattern. This results in highlv irregular cell arrangement.**

- **An additional distinctive feature or central mother cells is wall thickening, presumably temporary, which sometimes resembles that of collenchyma cells.**

- **Mitosis are apparently infrequent except near the transition zone.**

Transition zone (Zone III)—

The transition zone comprises **the lateral and basal margins of the central mother cell zone.**

- **It is a zone of renewed mitotic activity. In cross section the zone appears cambium-like.**
- **The zone contributes cells to the peripheral zone and to the rib meristem.**

- ***Foster did not speculate on the rate at which dividing*** **cells of the transition zone are themselves replaced by derivatives of the central mother cells.**

- **There is no evident reason why such replacement need to be frequent.**

- **Because a well-defined transition zone is lacking in many gymnosperm apices it is sometimes omitted from discussions of cytohistological zonation.**

Peripheral tissue layers (Zone IV),—

The peripheral tissue **layers occupy most of the total volume of the apex and surround the central tissues with a dome-like mass carrying the apical initial zone at its apex.**

- **All cells of the peripheral layers are small and divide frequently.**

- **Their dense protoplasts are deeply stained by safranin.**

- **Although the different layers of the peripheral zone have different origins, cellular characteristics are markedly uniform throughout.**

- **The outer layer of the zone originates from anticlinal divisions of the apical initials, but it is never discrete because periclinal divisions occur throughout its extent. This is why there is no tunica layer.**

- **The inner layers are continually augmented by daughter cells from the cambium-like transition zone.**

- **Ultimately the peripheral tissue layers give rise to the epidermis, lateral appendages, cortex, and probably also the vascular tissue of the shoot axis.**

Rib Meristem (Zone *V*)-

In *Ginkgo the rib meristem arises from cells of the* basal part of the transition zone in which there is a renewal of mitotic activity and decrease in cell size relative to the lower cells of the central mother cell zone.

- The rib meristem consists of files of cells in which transverse divisions and extension growth predominate.

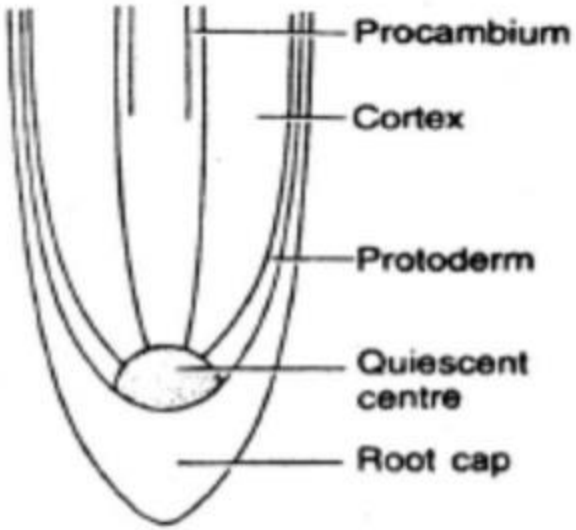
- Occasionally new files of cells are introduced by periclinal or oblique divisions.

- The rib meristems of long and short shoots of *Ginkgo exhibit* pronounced differences in behavior.

- *In the short shoot rib meristem* activity is ephemeral (short period). It gives rise to maturing pith cells only a short distance below the transition zone. Consequently there is little internodal elongation.

- The extensive internodal elongation of long shoots partly results from much more persistent rib meristem activity.

Quiescent Centre



Root apex organization acording to quiescent centre concept

THE QUIESCENT CENTER,

It is located subterminally in the apical meristem of elongating roots, was described by Clowes (1956a) as a population of cells which is metabolically inactive and which shows very low rates of cell division

The quiescent centre A region in the apical meristem of a root where cell division proceeds very slowly or not at all, but the cells are capable of resuming meristematic activity should tissue surrounding them be damaged.

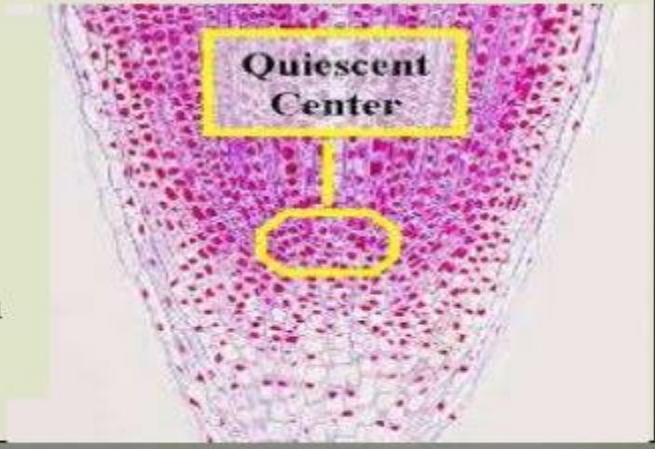
The **quiescent centre** is a group of cells, up to 1,000 in number, in the form of a hemisphere, with the flat face toward the root tip. Quiescent centre is situated at the pole of cortex and stele and consists of four cells (e.g. Arabidopsis) or as high as 600 cells that have very low mitotic activity.

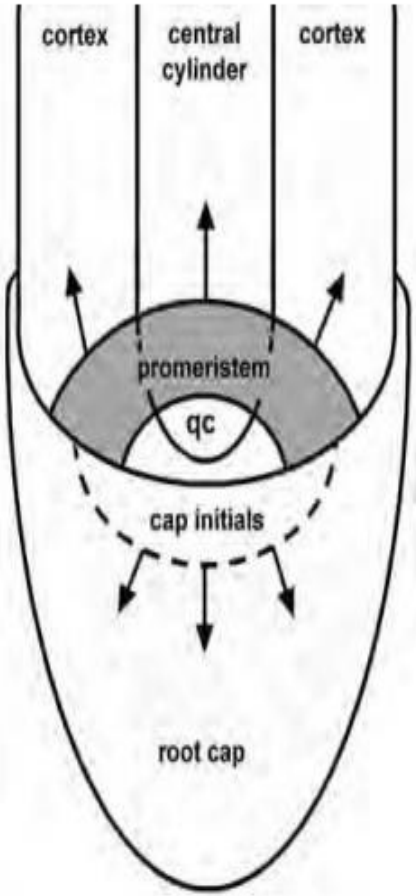
The root apical meristem is present as the tip of main root and has a quiescent centre in its centre, which is characterized by low frequency of cell division, mitosis and thus low synthesis of DNA, RNA and protein. The quiescent centre serves as reserve meristem and is most apparent in actively growing roots but disappears during dormant phase, carbohydrate starvation or root cap removal.

QUIESCENT CENTER:

Clowes(1958)studied the root tips of *Zea mays* and observed an inactive center in between root cap and active meristematic region.

- fewer mitochondria ,
- ER ,
- very small nuclei ,
- low rate of DNA synthesis and protein synthesis.





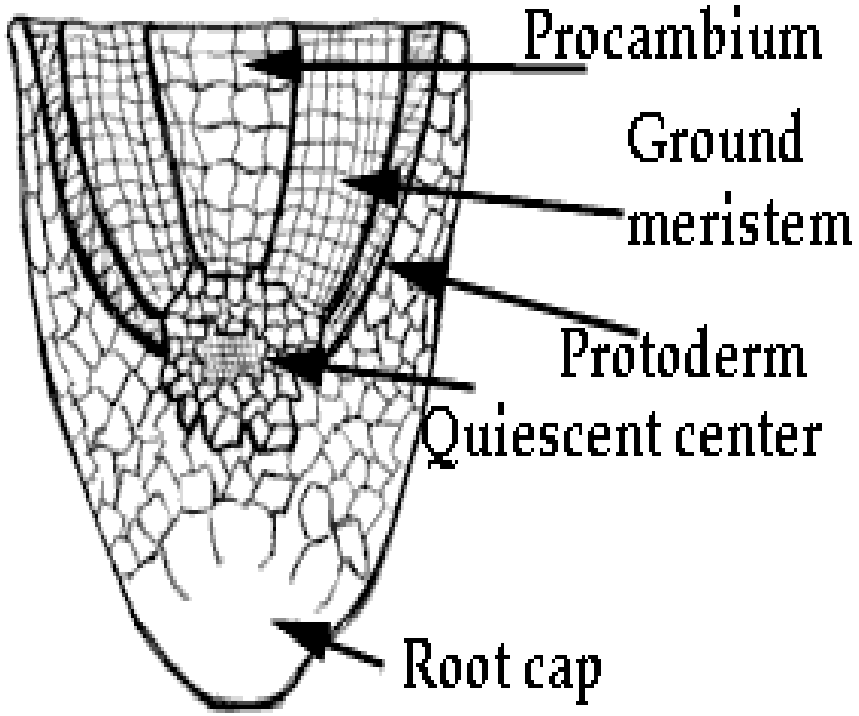


Figure 3.1 Diagram of root apical organization in *Zea mays* (Poaceae), a species with closed structure. Arrows indicate direction of displacement of cell derivatives. (Adapted from Feldman 1984).

The relatively inactive state of the quiescent center cells does not mean that they have become permanently non functional.

Quiescent center cells do divide occasionally and serve to renew the more actively dividing regions around them, the cells of which are unstable and displaced from time to time.

In roots injured experimentally by radiation or surgical treatments the quiescent center is able to repopulate the meristem

- A quiescent center arises twice in primary roots:
  1.Embryogeny 2.stages of seed germination
- The quiescent center is variable in volume:
  Thin roots- smaller or entirely absent
  long roots- distinctive centers
  short roots- no Q.c
  seedless vascular plants- it lacks qc