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# A REVIEW IN NODAL ANATOMY FOR PLANTS

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## Abstract

Nodal anatomy reveals the number, behavior and fait of bundles in each node and internode. Firstly, three main types of nodes represented by the one trace- one gap, the three trace-three-gaps, and the multi-traces- multi gaps in plants were proposed. Then the fourth types of nodes, represented by two- multi traces - one gap , was added to nodal types, while the fifth type (split –lateral) has been proposed, where a single trace associated with numerous leaves by splitting as found in different families from Angiosperms.Branches traces are distinct from leaf ones, and it represented of one or several bundles formed in axillary of leaves, commonly branch trace and middle leaf trace formed with the same gab,One of the important facts of studying nodal anatomy is the relationship between nodal structure and leaf base referring to stipules and sheathing base as well as the phyllotaxy. In monocot plants leaves characterized by sheathing bases, So the leaves nodes appeared with numerous leaf traces separated from different stem bundles, in Dicots plant different nodal types recognized.the studies of nodal anatomy are considered as an important features in taxonomical studies and phylogenetic studies on Dicots plant, most the studies revealed the di-traces and tri-traces nodes considered as primitive type while the uni-trace or multi-traces node are the advanced and it was proposed either by reduction or amplification.

**Keywords**: Nodal Anatomy, Gap, Trace, Angiosperm, Gymnosperm.

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## Introduction

Nodes and internodes represented one of the attractive feature in advanced angiosperms plants stems, composed of nodes and internodes, anatomically, the nodes can be distinguished from the other part of stem by traces departures which is usually appear as a gap in vascular cylinder (pant &Mehra, 1964) and known as uni-lacunar, tri-lacunar, or multi-lacuner depending on the numbers of gaps (Metcalfe & Chalk, 1979)

plant nodes represents the area in which strips of vascular tissue of the stem cylinder are separated to form the so-called leaf trace and are replaced by a group of parenchyma cells to form the so-called gap, As it occurs at each node of the stem nodes with the formation of the leaf primordia, an extension of the procambial strands (from the xylem and phloem) below the bases of the leaves and as an extension of the vascular tissue from the vascular cylinder of the stem, then those strands extend within the primordia of the leaves and developed within them, and for this it is noted in the longitudenal sections of the stem node The bending and protrusion of the vascular tissue to the outside to form the vascular tissue of the leaf and this is called the leaf trace.As shown in Figure (1)

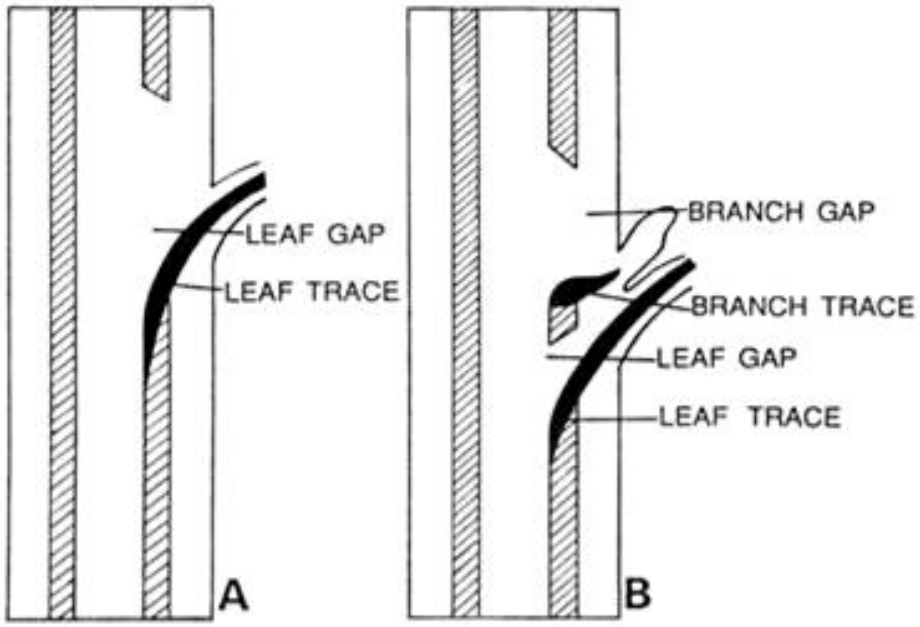


**Fig. 1: leaf and branch traces. A: L.S. in node through leaf trace and gab, B: L.S. in node through branched trace.**

In the study of the stem nodes sections, the number of vascular bundles emerging from the stem and the fate of each bundle of these bundles is identified, as some of these bundles split into secondary bundles for entering the petiole and some merge to form a continuous vascular cylinder and some others enter into the stipules and not the petiole, as well as wide variations. Others include bundle separation sites, number of gaps, and axillary bud bundle separation method. As shown in Figure (2,3)

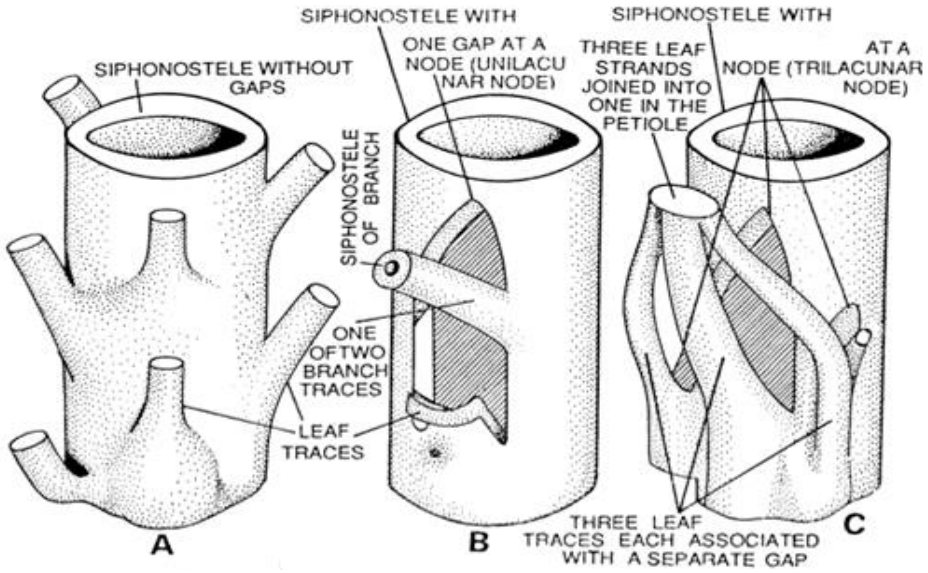


**Fig. 2: primary vascularization system, A. siphonstelic type without leaf gap (as in *Selaginella)*, B. unilacunar node, siphonstelic type with one leaf gap, C. trilacunar node, siphonstelic type with one leaf gap.**

**History, Types, and differences**

Sinnott (1914) was the first to identify the main three types of nodes represented by the one trace- one gap, the three trace- and three-gaps, and the multi-traces- multi gaps in plants by studying 164 Plant families, suggesting that, the unilacunar node has been organized from reduction of the trilacunar one either by approximation of the three to one, or by the disappearance of the lateral two bundles and its gabs; while the multilacunar node has been originated through amplification of the three original bundles and gabs in ton 5-more bundles as in monocotyledons plants nodes. (fig3)

Then the fourth type of node, represented by two- multi traces - one gap , was added to nodal types by Marsden & Bailey (1955), while the fifth type (split –lateral) has been proposed by Howard ( 1970) where a single trace associated with numerous leaves by splitting as found in different families from Angiosperms.(fig4)

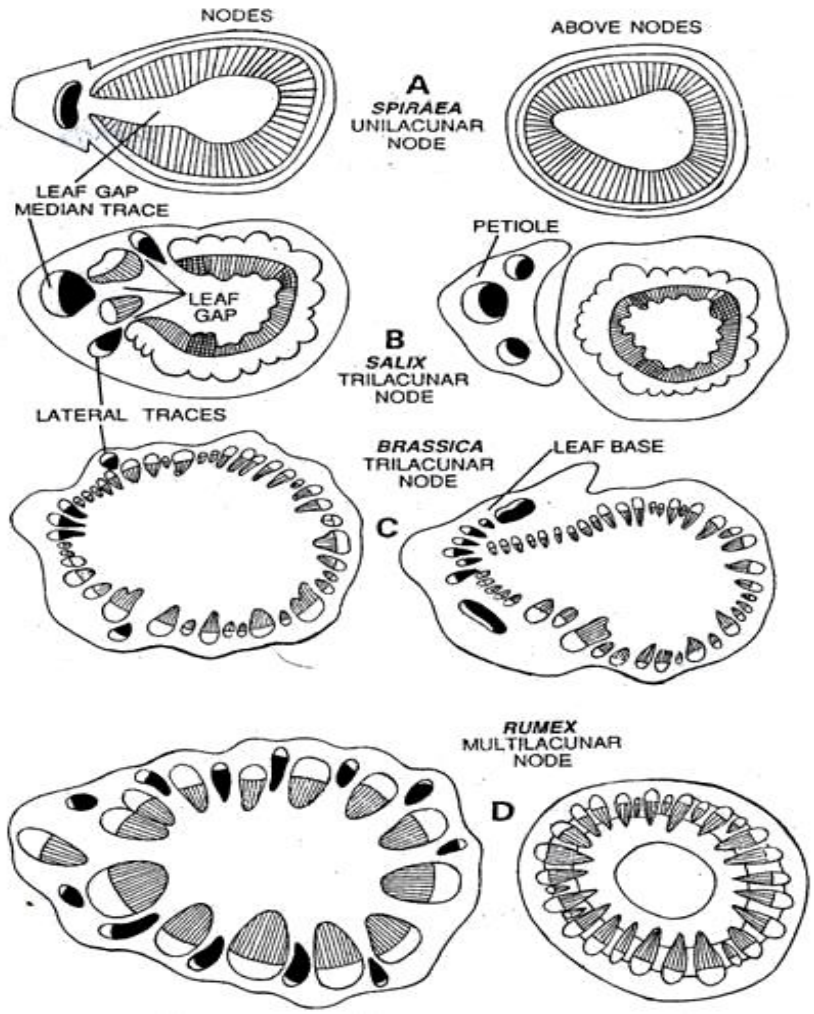


**Fig. 3: Nodal types, A. unilacunar node (one trace and one gap), B,C. trilacunar node (three traces and three gaps), D. multilacunar node (many traces and many gaps)**

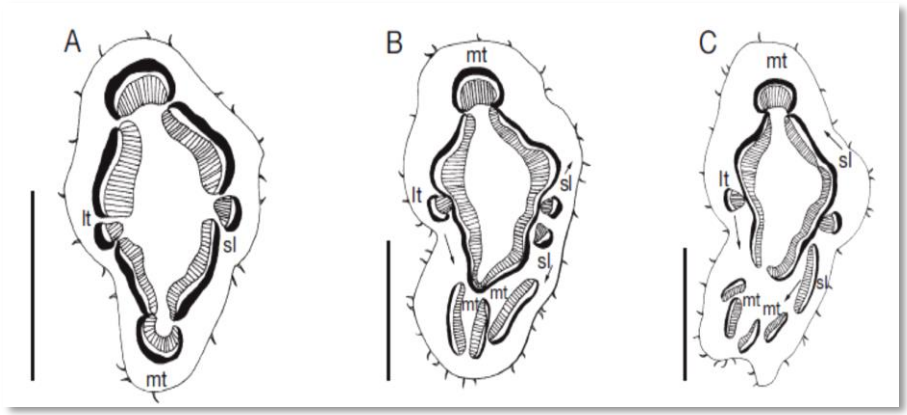


**Fig.4: split-lateral type, middle trace(mt) and lateral traces (lt,sl) splitting and associated to form the stele of each opposite leaves.**

Branches traces are distinct from leaf ones, and it represented of one or several bundles formed in axillary of leaves, commonly branch trace and middle leaf trace formed with the same gab, in some plants the branch traces evenly coalesce to form branch stele or separated laterally to form pair of lateral traces for lateral leaf primordia.( Schwager *etal.,* 2015)

One of the important facts of studying nodal anatomy is the relationship between nodal structure and leaf base referring to stipules and sheathing base. It should be noted that previous studies revealing that unilacunar node was found in estipulated leaf while the multilacunar nod appear in less or more sheathing base (Sinnott and Bailey, 1914)

In monocot plants leaves characterized by sheathing bases, So the leaves nodes appeared with numerous leaf traces separated from different stem bundles.(fig. 6)

In monocot plant the common type is known as palm-type which is characterized by numerous traces divided consequently into large and small traces which lately be or be not merged with other lateral bundles, in some monocots with bundles arranged in rings, the node characterized similar to palm-type but differ in large traces fate which don't inter deeply in the internode position(Pizzolato & Sundberg, 2002).

leaf traces in node and their derivatives differs according to plant groups and its phyllotaxy, in the study of some Gymnoserms plant –Conifers, Namoodiri and Beck (1968) mensioned that the vascularization in some Conifers with helical leaves phyllotaxy appeared to be composed of discrete sympodia with unilateral leaf trace, and referring to the disappearing of sympodia firstly as a result of contacting with neighbor bundles as well as their undulation.

Some Angiosperm families characterized by unilacunar and uintrace node as Tliliaceae, Mtritaceae, Verbinaceae (Thanki *etal.,* 2000; Shah and Thanki,1998; Banger,2012), as well as the Lythraceae family which characterized by unilacunar node differed in trace shape among different species.(Kshirsagar, 2016;2017)

Bignoniaceae family characterized by unilacunar, unitrace node also, however some species showed unilaculat, tri-traces as a result of consequence splitting of the

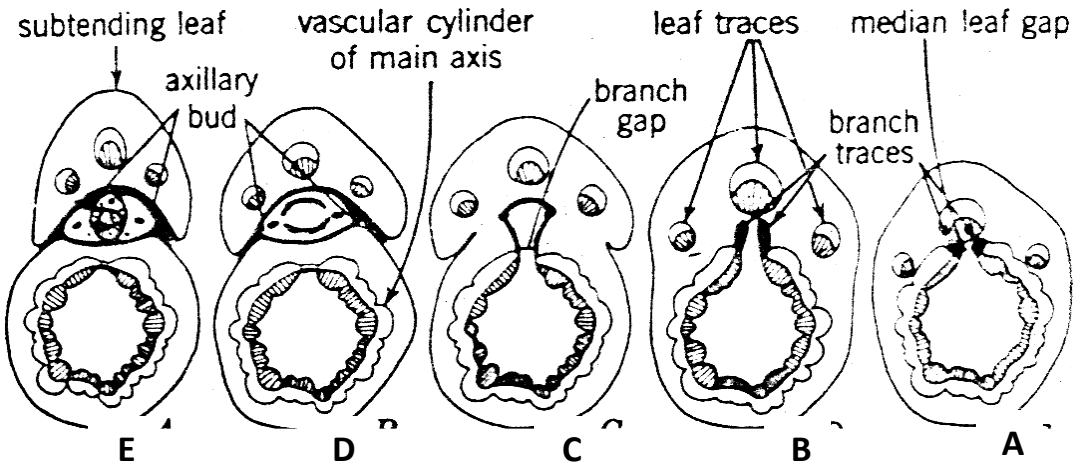


**Fig 5: Vascularization of axillary branch, represented leaf and branch traces.**

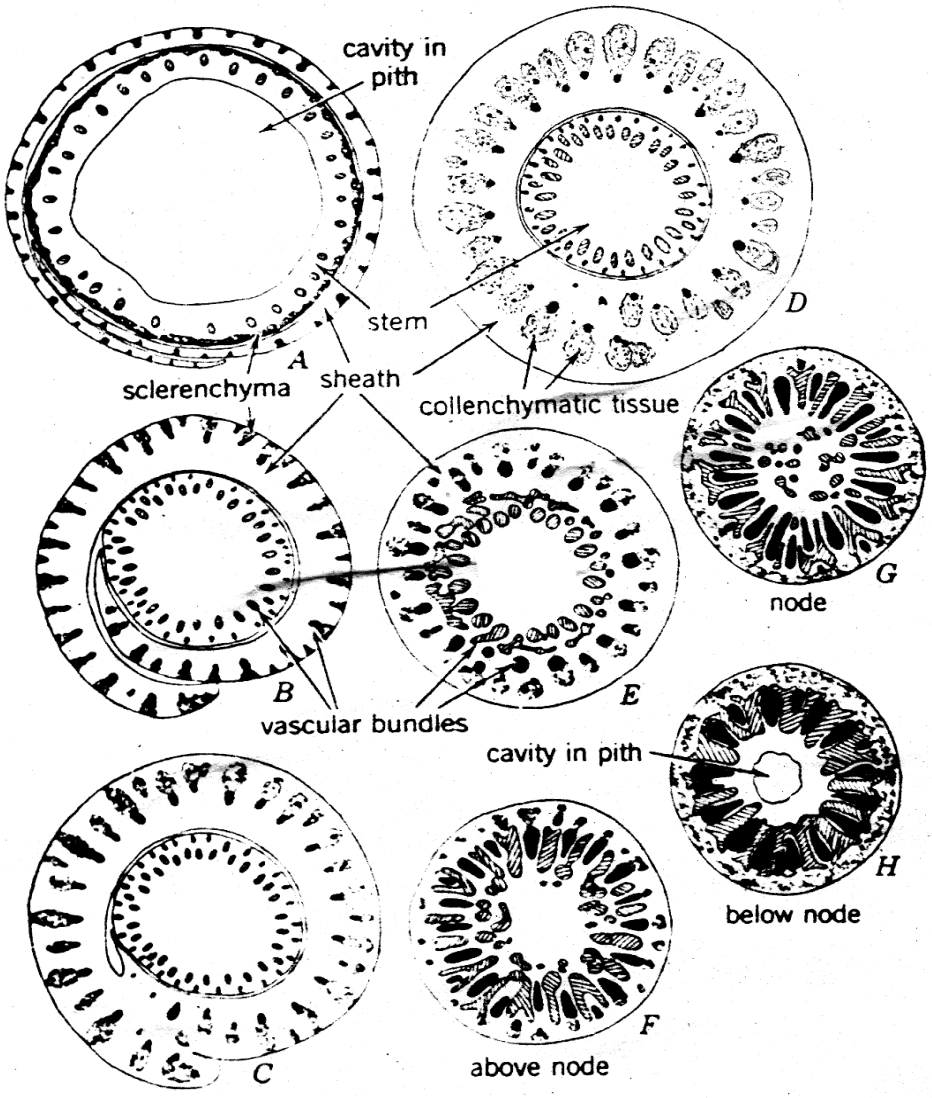


**Fig.6: Monocot nodal anatomy (*Triticum* stem), cross section in various levels beginning from the middle of internode to the next node (A-F to H), cross the node (G)**

bundle after passing the leaf base (JAIN, 1977). In other families as Lamiaceae most of studied species appeared with uni-lacunar and uni-trace in addition to presence of other species with uni-lacunar and di-traces which considered as primitive condition and developed by approximation to form uni-trace node which is the advanced one.(Gupta and Bhambie, 1977)

other plants as Rubiaceae (*Galium*) morphologically it could be described with whorled leaves phyllotaxy but according to anatomical nodal studies it was cleared that the phyllotaxy is opposite with unilacunar and uni-trace and other leaves like consider as leafy stipules. (Gharband Al-Musawi,2003)

In vascularization study of Solanaceae members the nods types was unilacunar in all studied members but differed in traces numbers which could be unitrace, ditraces or tritraces and these differences could be correlated with petioles bundles shapes (Bhati,.2015), while in Asteraceae family the nodal study revealed the nodal types were trilacunar-tritraces in all studied species characterized by continuous separated bundles through petiole or rachis.(Rawat*etal.,* 2015)

the presence of petiolar gland, stipule, tendirals, compound tri foliate, pinnatly or palmatly leaves would effect in separation of leaf traces to form some unique nodal condition, as represented in study of Tadavi & Bhadane (2014) on petiolar glands in some Euophobeaceae taxa, and the study of Bhadane & Vaikos (1999) in Meliaceae as well as the study of Khansaheb (1974) in Cucurbitaceae family to elucidated the vascularization of tendrils which receved the vascular supply from leaves traces and cauline traces leading to proposed that the tendrils are stem-leaf complex.

Other studies as the researches of Sharma and pillai (1982,1985) in paripinnate leaves and other studies which emphasized the importances of study the vascularization in stem-node-leaf as continuous system (Kshetrapal and Tyagi, 1981; Dubey *et al.,* 1990; Negi and Sharma, 2000)

Papilionaceae family characterized by stipulated compound trifoliate or compound pinnatly leaves with trilacunar and tritraces node as proposed by Devadas and Beck (1972), lately other studies showed the specific nodal type with five traces in the family as a result of middle trace splitting (Gupta, M. and Murty, 1978), recently several studies revealed the origin of five traces which are formed by multiplication of axis bundle just below the node while the stipules traces came from pair of cortical traces.(Hassan, and Heneidakm 2006)

Maity ( 2014) mentioned in his study the splitting type of nodal anatomy in Euphorbiaceae family, described the splitting pattern of each lateral and middle traces to form the stele of the opposite leaves

Phylogenetic problem can be solved by different plants studies as the vascular system studies by comparing different living plants.

The trilacunar node consider as the primitive one in both Angiosperm and Gymnosperms (Gunckel and Wetmore, 1946; Marsden and Steeves, 1955; Bailey, 1956; Fahn and Bailey, 1957)

Bailey (1956) mentioned that Dicotyledons plans vascular supply in early stage (cotyledons and cotyledons leaves) consist of double leaf traces arises from unilacunar one, and lately change to different type in mature plant, as a result of double cotyledon leaves present.

Swamy (1953) mentioned the appearance of lateral traces in pair of lateral leaves is a modification of unilacunar one, other researchers reported these traces as compound trace (Mitra and Majumdar, 1952)

Other researchers mentioned that the unilacunar double traces node is the primitive one as Marsden and Bailey (1955) and Canright (1955) which proposed evolutionary line to Angiosperms starting with unilacunar-two trace node. Fahn and Baily (1957) also suggested the same statement mentioned the development of trilocunar node from the unilacunar one.

Later Howard(1970) mentioned the term split-laterals to nodal anatomy to elucidate the splitting of lateral traces in different taxa, which was subsequently confirmed by Ghosh and Banerji (1986) whose found both tri-lacunar three traces and uni-lacunar one trace in *Ilex clerkei* and *I. dipyrene* depending on different studied part.

So, the studies of nodal anatomy are considered as an important features in phylogenetic study on Dicots plant, most the studies revealed the di-traces and tri-traces nodes considered as primitive type while the uni-trace or multi-traces node are the advanced and it was proposed either by reduction or amplification (fig. 7,8 )

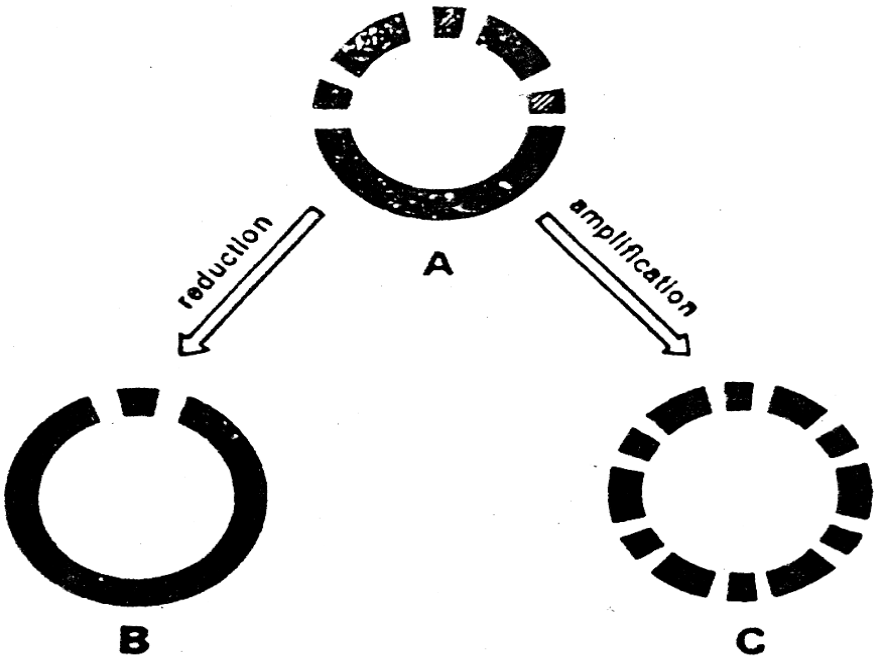


**Fig.7: Evolutionaryline of nodal vascularization according to Sinnot, (914)**

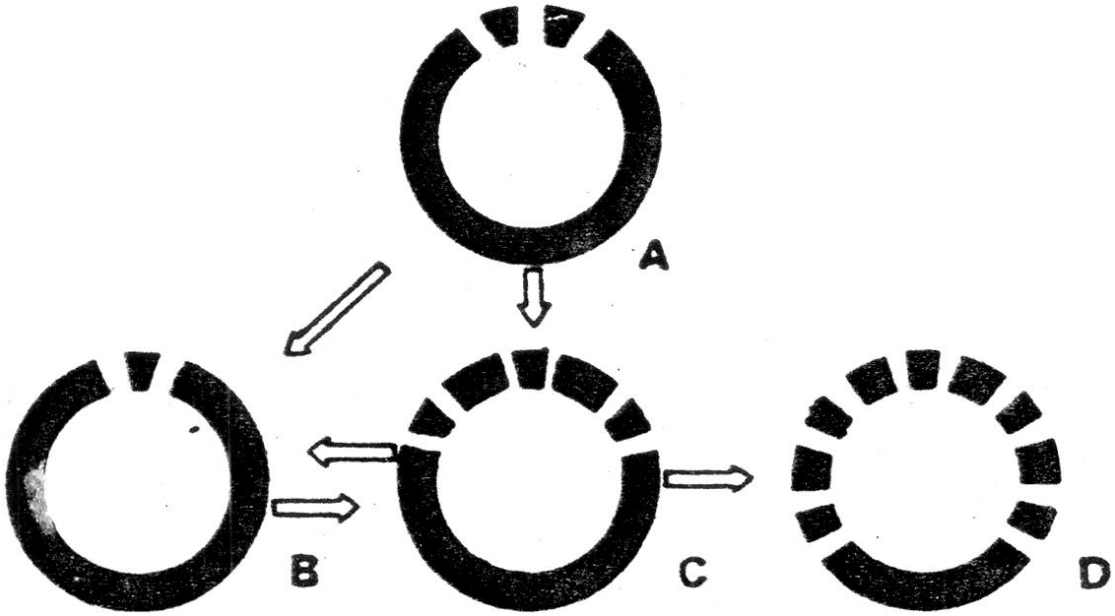


**Fig.8: Evolutionary line of nodal vascularization according to Philipson (1975)**

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