

SPERMATOPHYTA

"GIMNOSPERMAS"



Loconte & Stevenson 1990

CLADOSPERMAE

MESOSPERMAE

CYCADOPHYTA GINKGOPHYTA PINOPHYTA GNETOPHYTA ANGIOSPERMAS

- gemas axilares
- folhas simples
- megastrobilo composto
- dioicia
- sementes platispérmicas
- pólen monossulcado
- formação do tubo polínico
- óvulo unitegumentado ortótropo
- sementes com sarcotesta e esclerotesta
- embrião com 2 cotilédones

Loconte & Stevenson 1990

Gifford & Foster (1989)

Mauseth (1995)

Progymnospermophyta (fóssil)

Pteridospermophyta (fóssil)

Cycadeoidophyta
(=Bennettitales) (fóssil)

Cycadophyta

Ginkgophyta

Pinophyta (=Coniferophyta)

Gnetophyta

CLASSIFICAÇÕES

GIFFORD & FOSTER 1989 MAUSETH 1995 Filos	BRESINSKY et al. 2012 Subdivisão Spermatophytina	CHASE & REVEAL 2009 Classe Equisetopsida (=Embryopsida)
Progymnospermophyta Pteridospermophyta Cycadeoidophyta Cycadophyta Ginkgophyta Pinophyta (=Coniferophyta) Gnetophyta	 Cl. Cycadopsida Cl. Ginkgopsida Cl. Coniferopsida	 Subcl. Cydadidae Subcl. Gynkgooidae Subcl. Pinidae Subcl. Gnetidae

PINOPHYTA
viventes:
PINALES
630 espécies



Triássico 200 m.a.

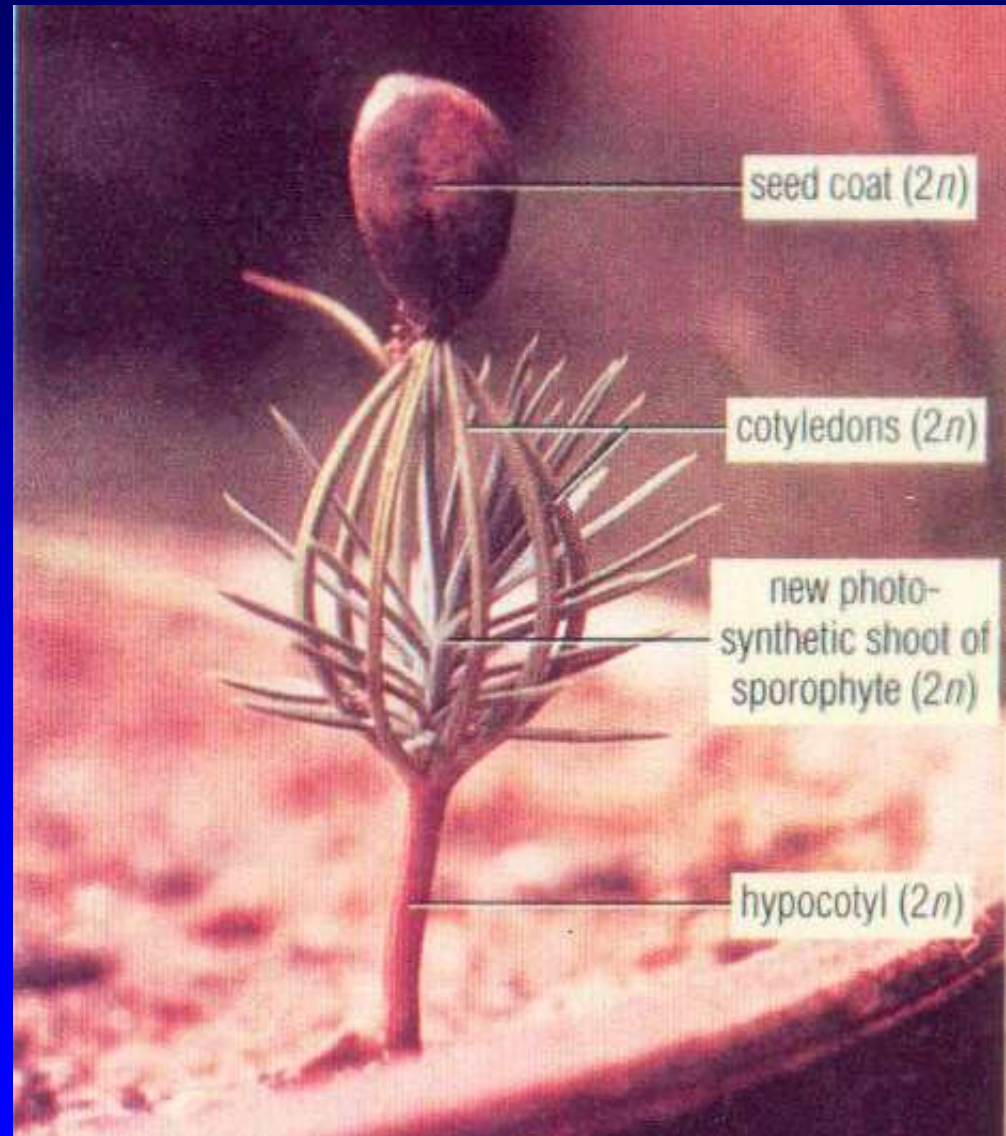
Coníferas dominantes

**Atualmente - Floresta Boreal
(Taiga)**



NOVIDADES EVOLUTIVAS (sinapormorfias de Mesospermae)

- ♦ germinação epígea

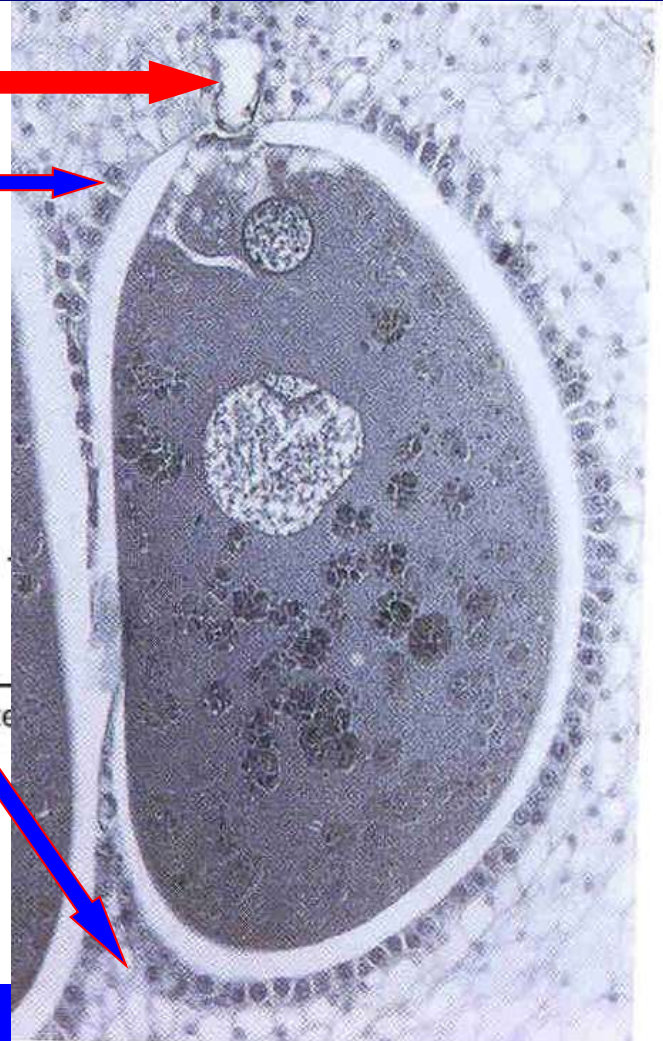
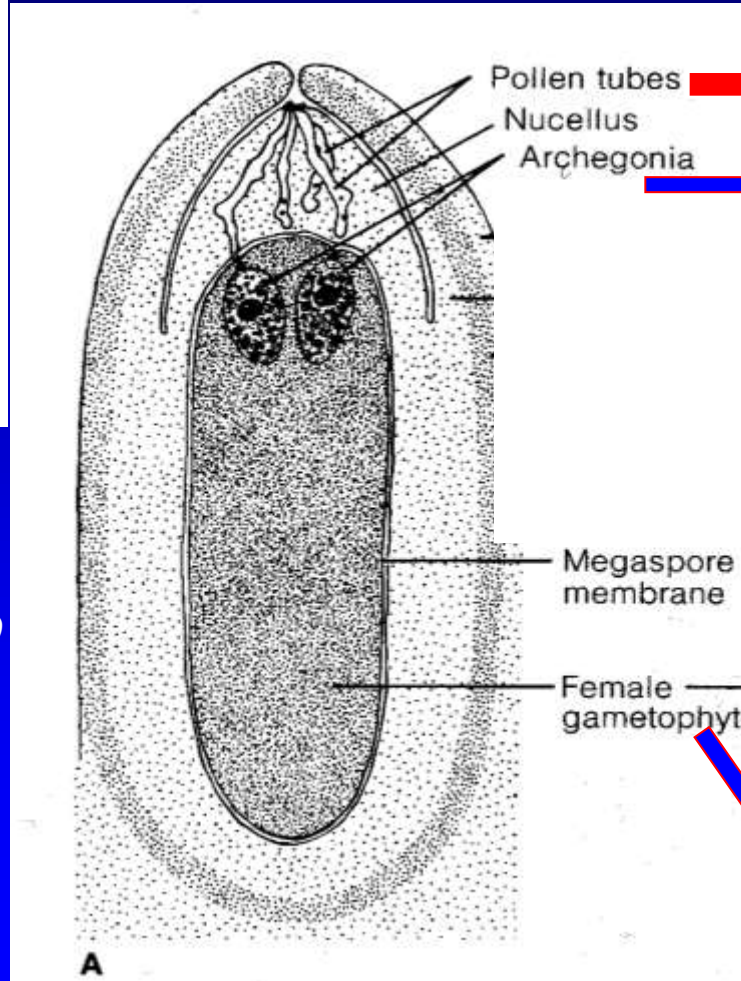
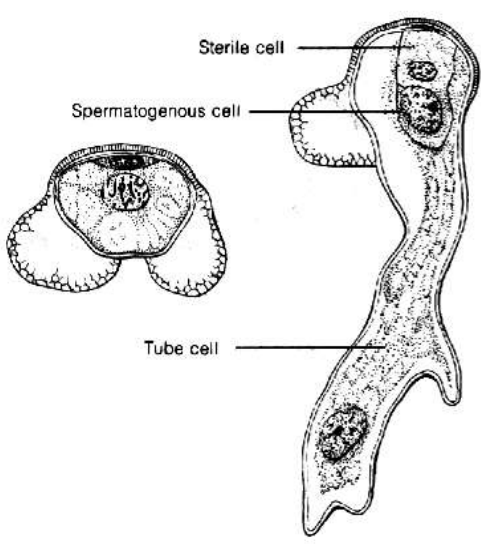


Perry & Moton 1996

NOVIDADES EVOLUTIVAS

♦ sifonogamia

♦ gametas masculinos não flagelados (células espermáticas)

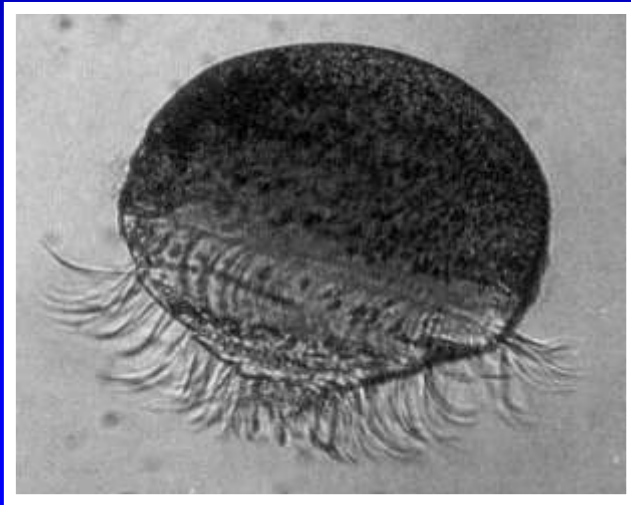
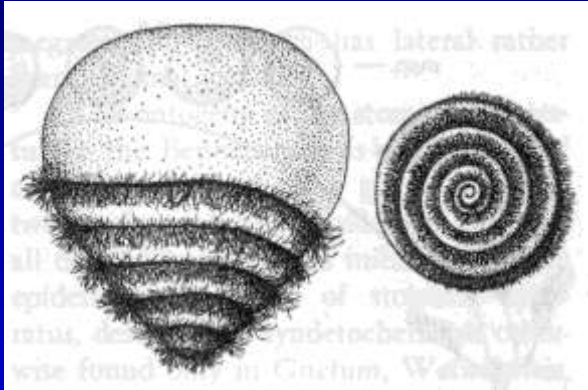


Tubo polínico em
Pinus nigra
Gifford & Foster 1989

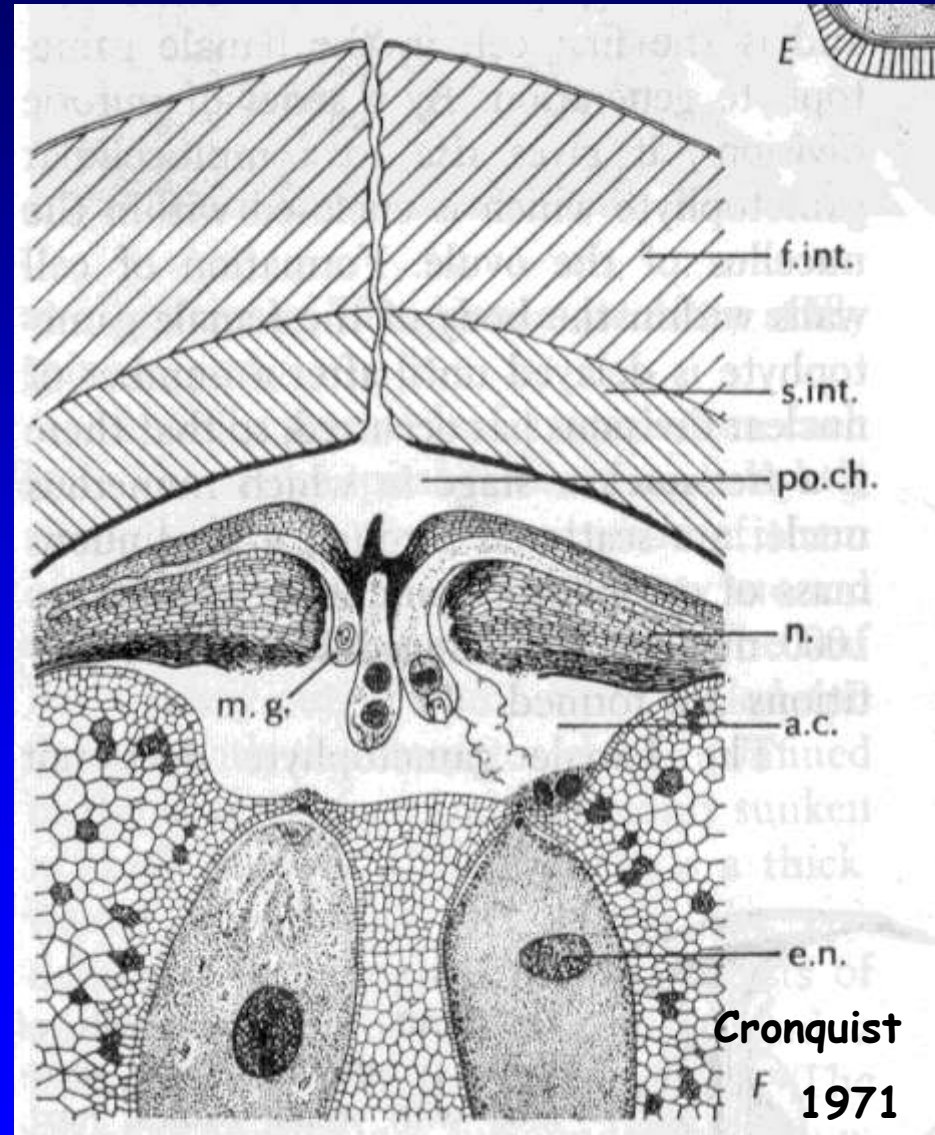
CYCADOPHYTA -

assifonogamia

- óvulos com câmara polínica e câmara arquegonial
- anterozóides multiflagelados



Gameta masculino de *Zamia integrifolia* (Gifford & Foster 1989).

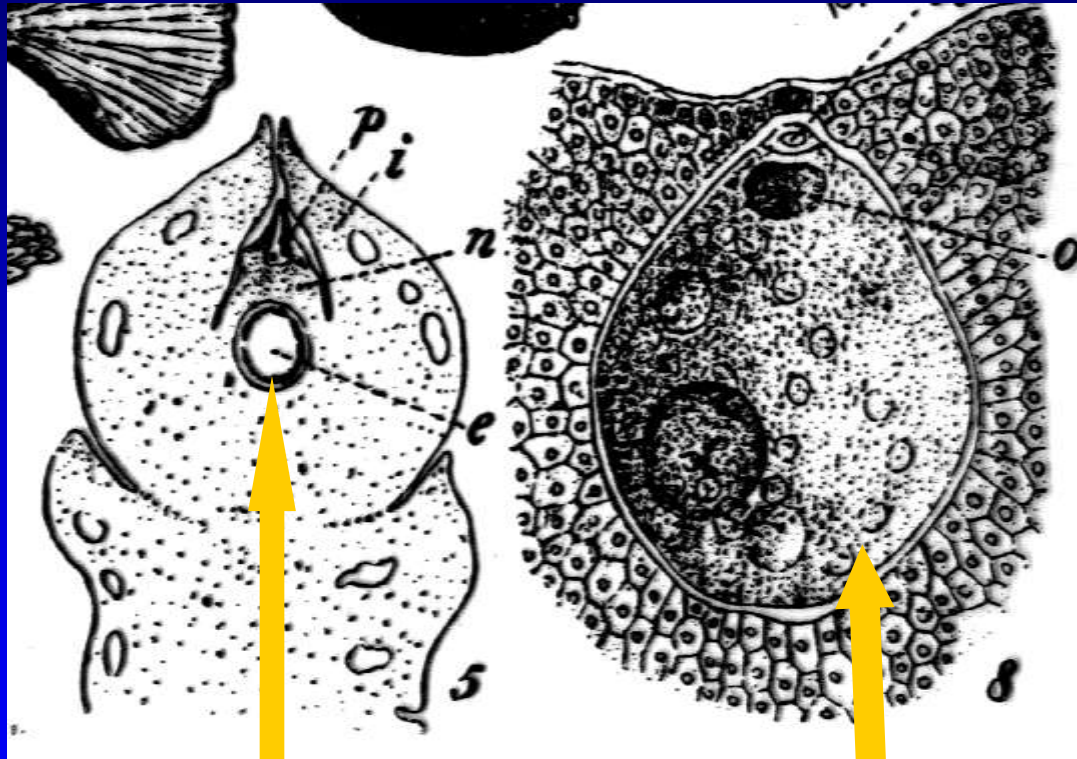


Cronquist
F 1971

- Óvulo unitegumentado
- Câmaras polínica e arquegonial
(assifonogamia)

GINKGOPHYTA

gametas masculinos
flagelados



Arquegônio com oosfera

Gametófito feminino



Gifford & Foster 1989

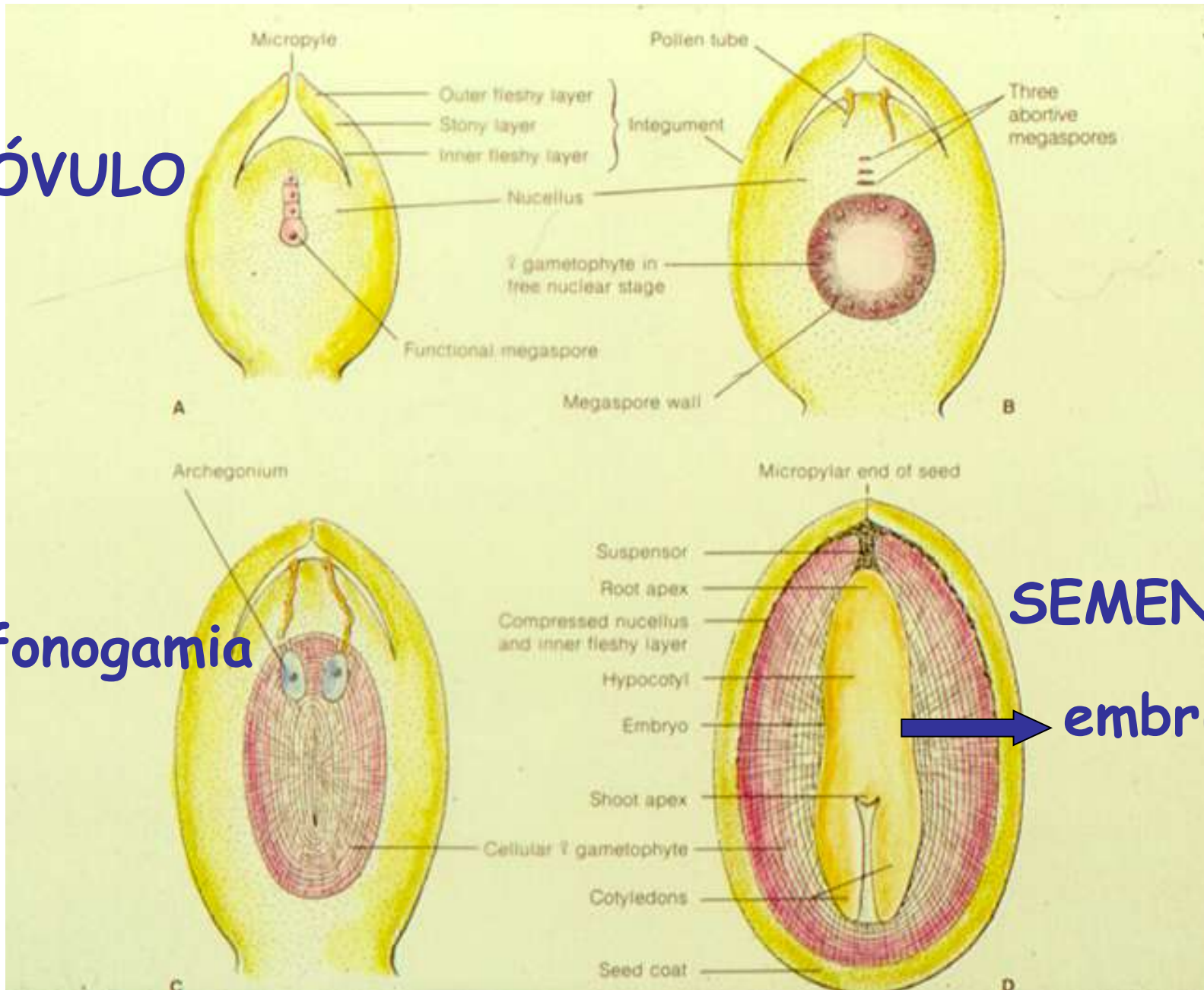
Do óvulo à semente - Pinófitas

ÓVULO

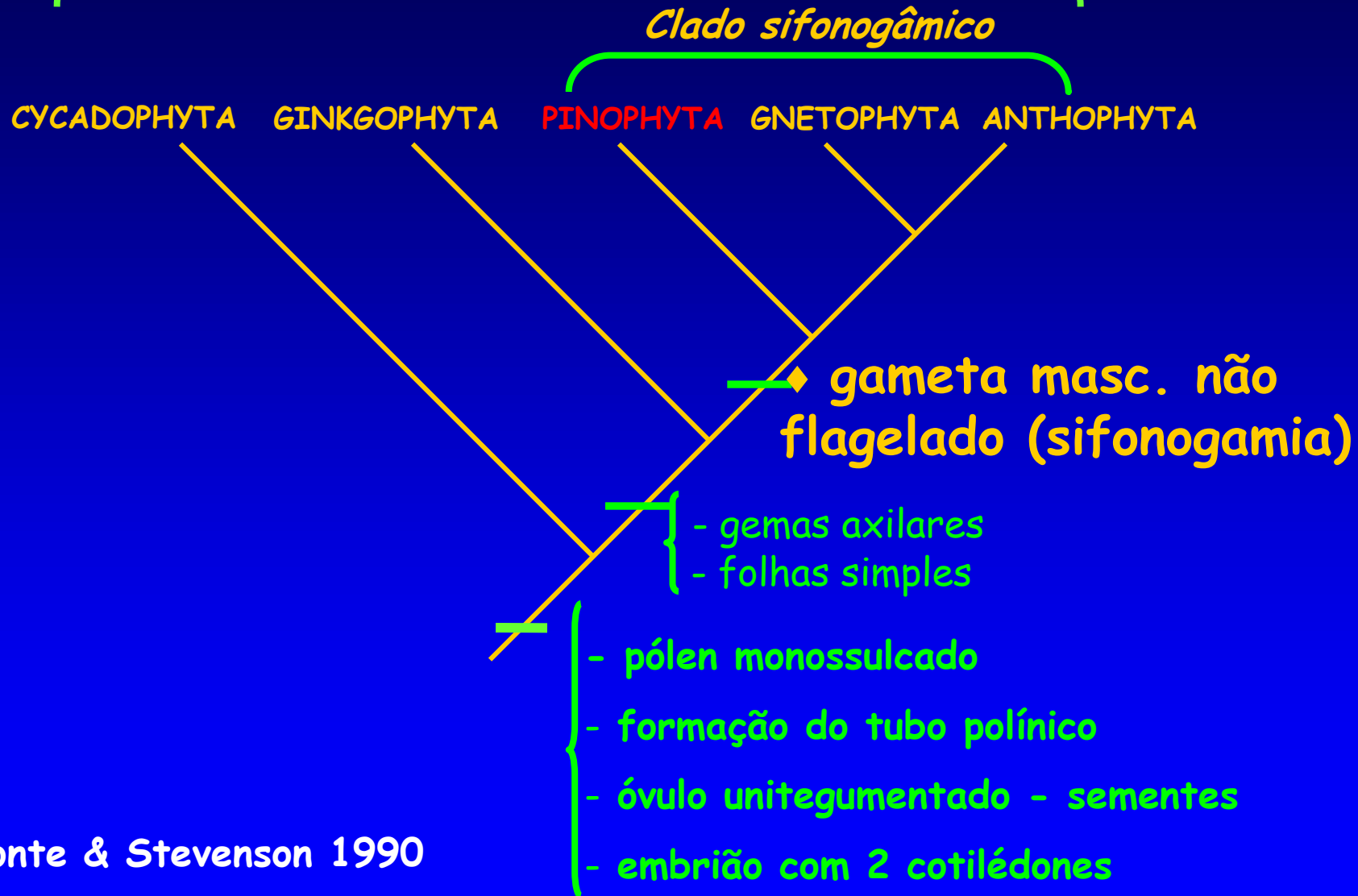
sifonogamia

SEMENTE

embrião



ESPERMATÓFITAS



Loconte & Stevenson 1990

NOVIDADES EVOLUTIVAS

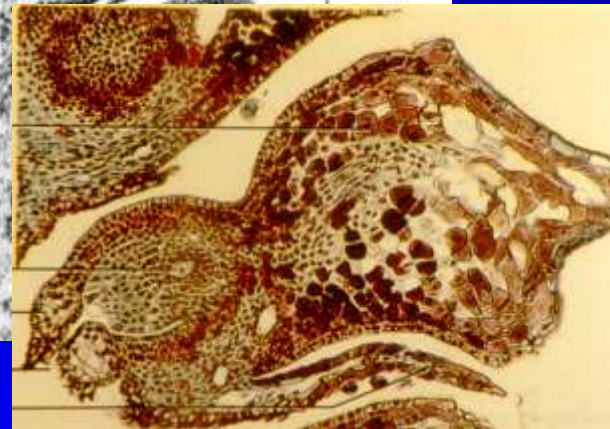
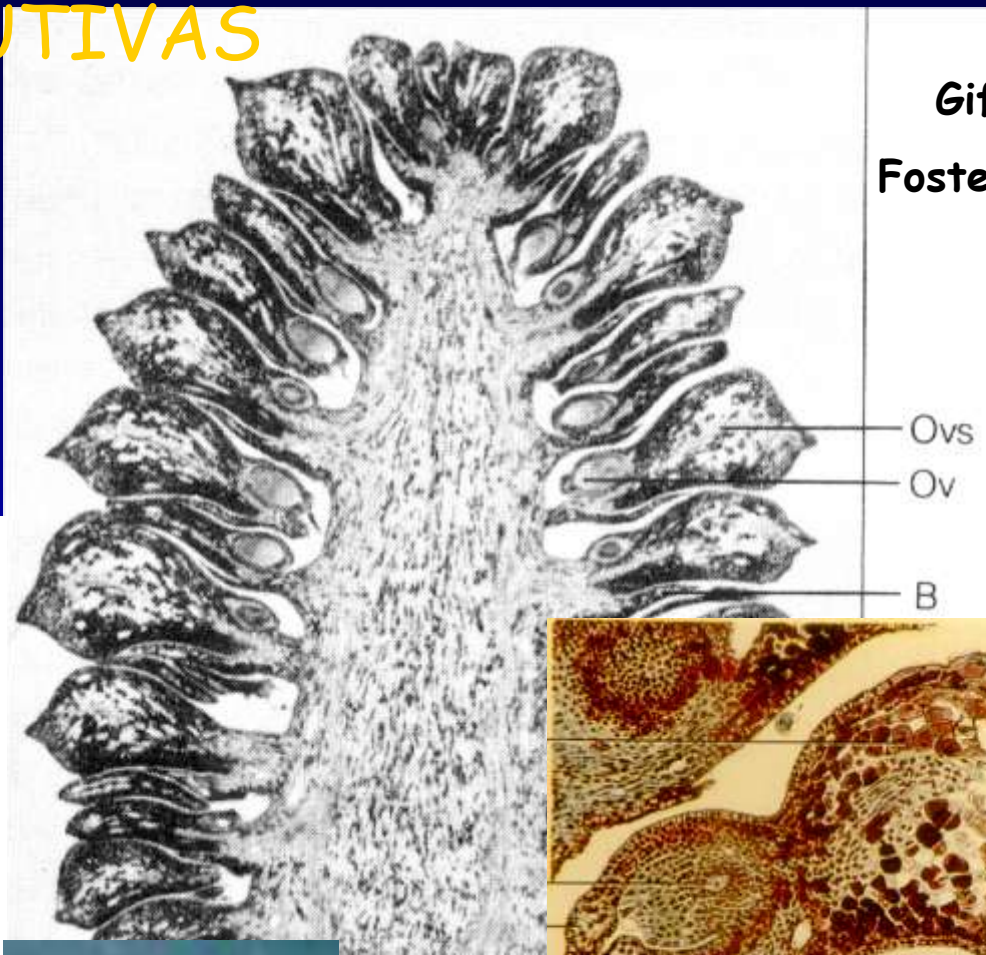
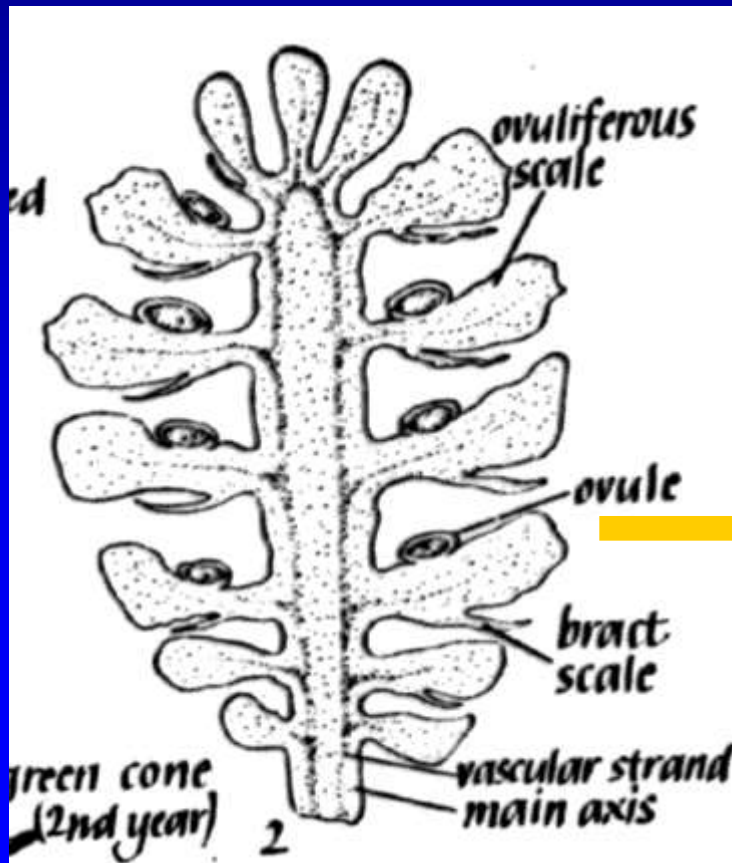
♦ megastróbito
composto = CONE

(eixo com escamas ovulíferas
e bracteais)

Pinus

Gifford &

Foster 1989



PINOPHYTA (=CONIFEROPHYTA)

3 ordens

CORDAITALES - Carbonífero Superior ao Permiano

VOLTZIALES - Carbonífero Superior ao Jurássico

PINALES (=CONIFERALES) - Triássico ao Recente

Cordaitales (PINOPHYTA)

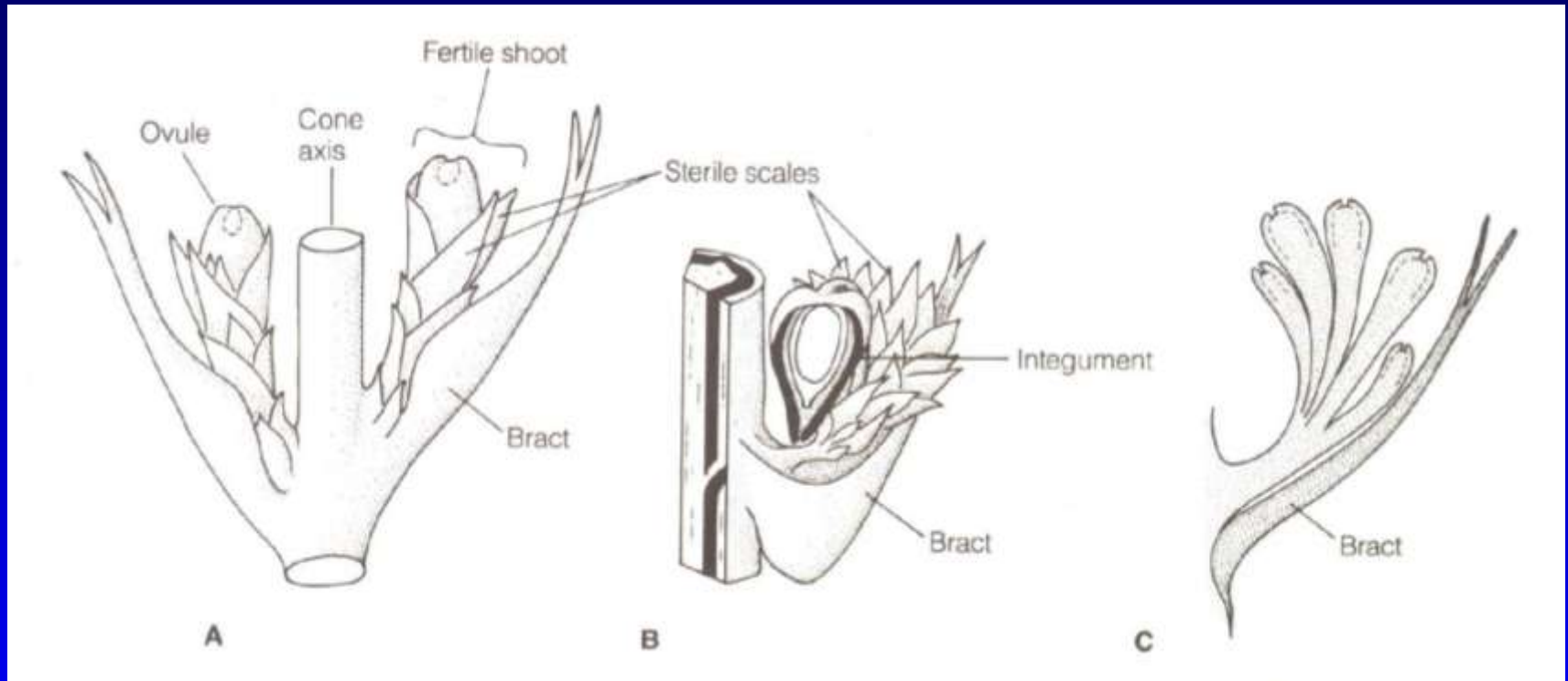


Cordaites



Carbonífero 300 m.a.

Megastróbilo composto (**CONE**): origem



A, B. Lebachia

C. Ernestiodendron

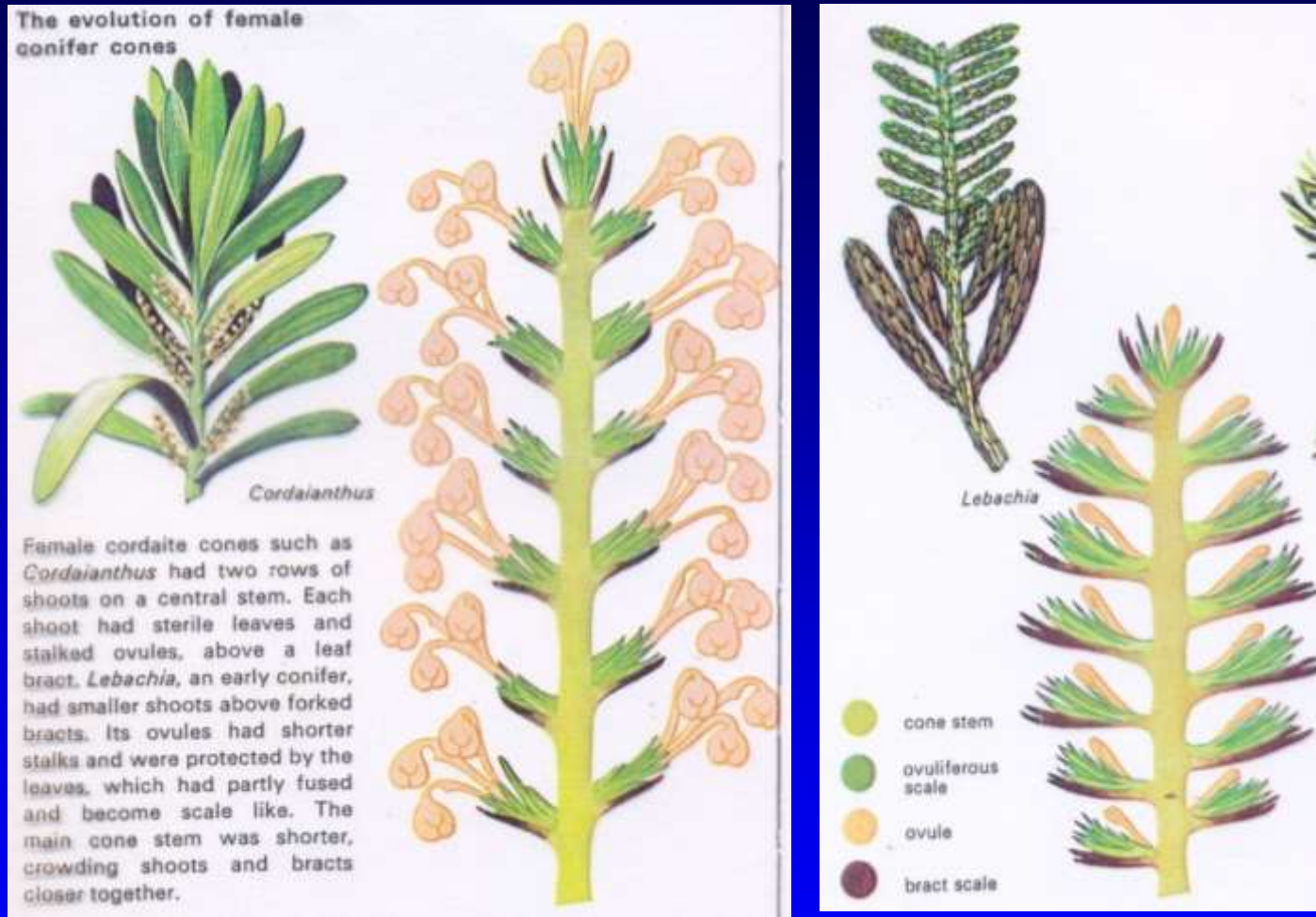
Gifford & Foster 1989

Voltziales

PINOPHYTA

extintas

Megastróbilo composto (CONE): origem



Cordaitales – PINOPHYTA extintas

Mauseth1989

Escama bracteal = folha modificada

Escama ovulífera = ramo fértil reduzido

PINALES



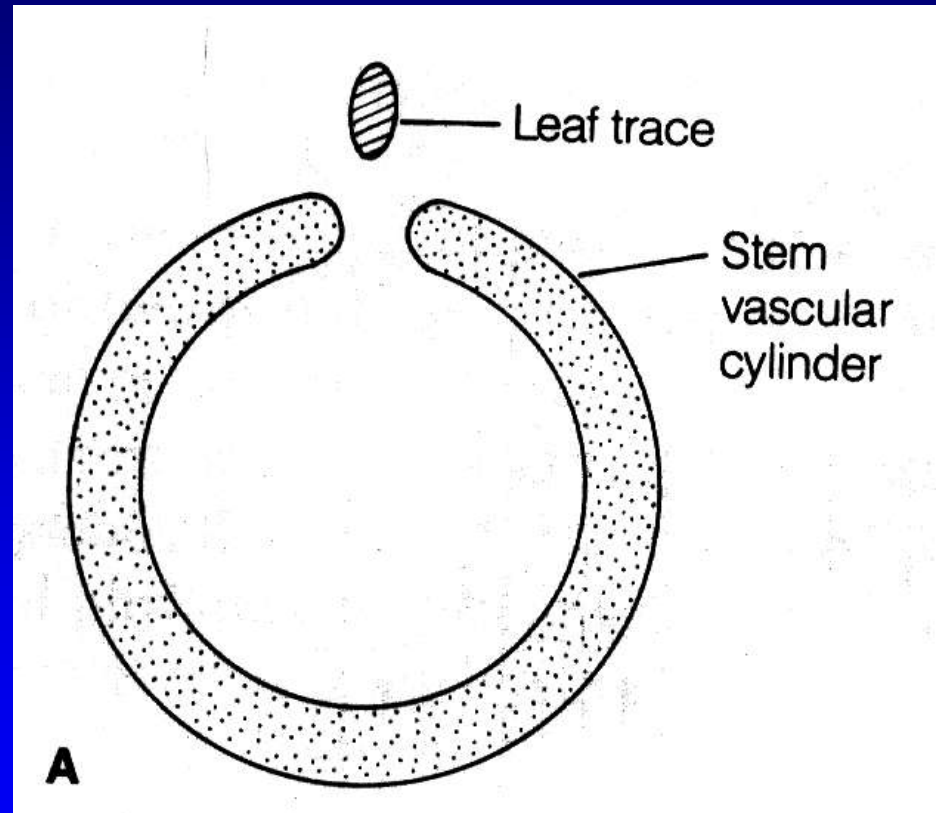
Triásico 200 m.a.

Coníferas dominantes

PINALES

POSSÍVEIS SINAPOMORFIAS

- ♦ nós unilacunares

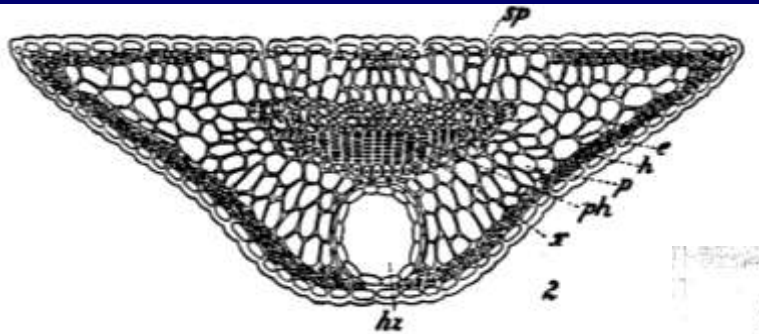


Gifford & Foster 1989

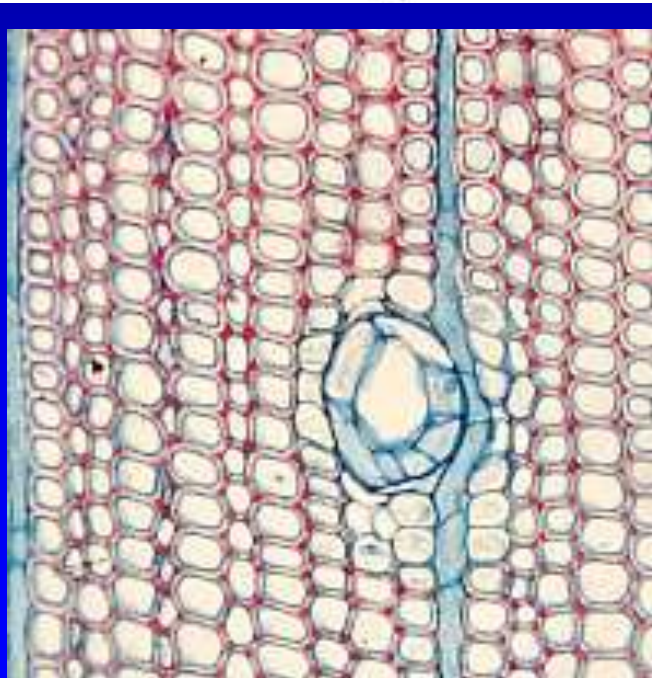
PINALES

SINAPOMORFIAS

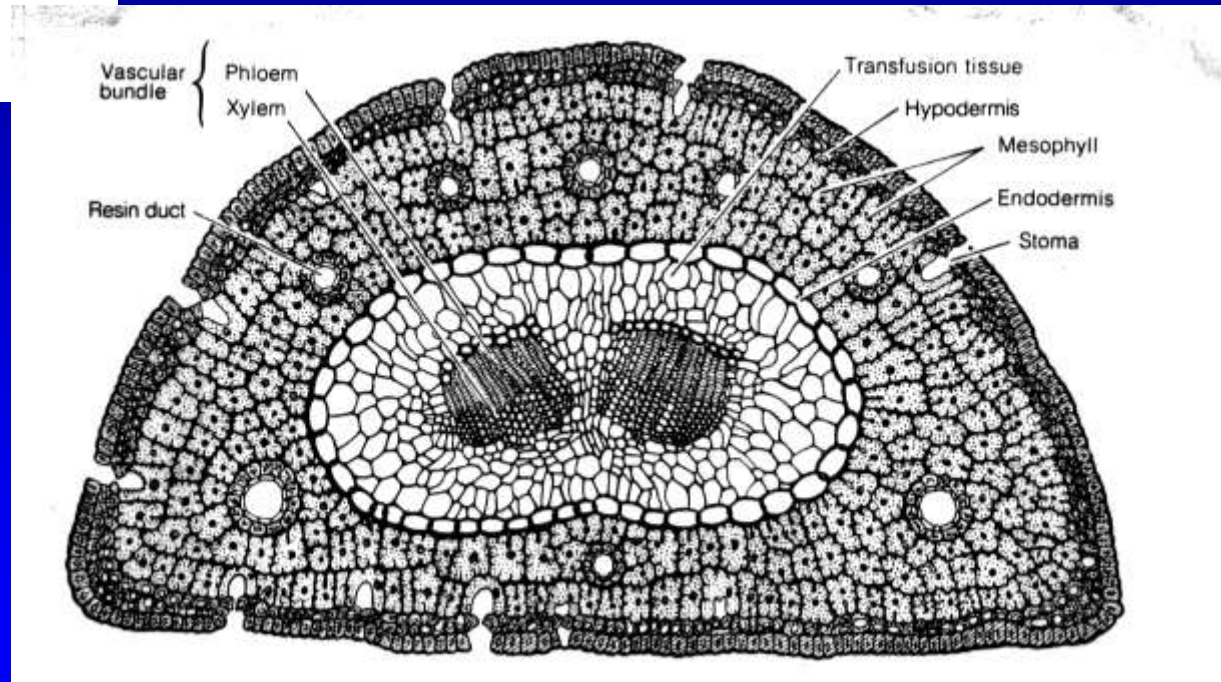
◆ canais resiníferos
no lenho e folhas



*Juniperus
communis*



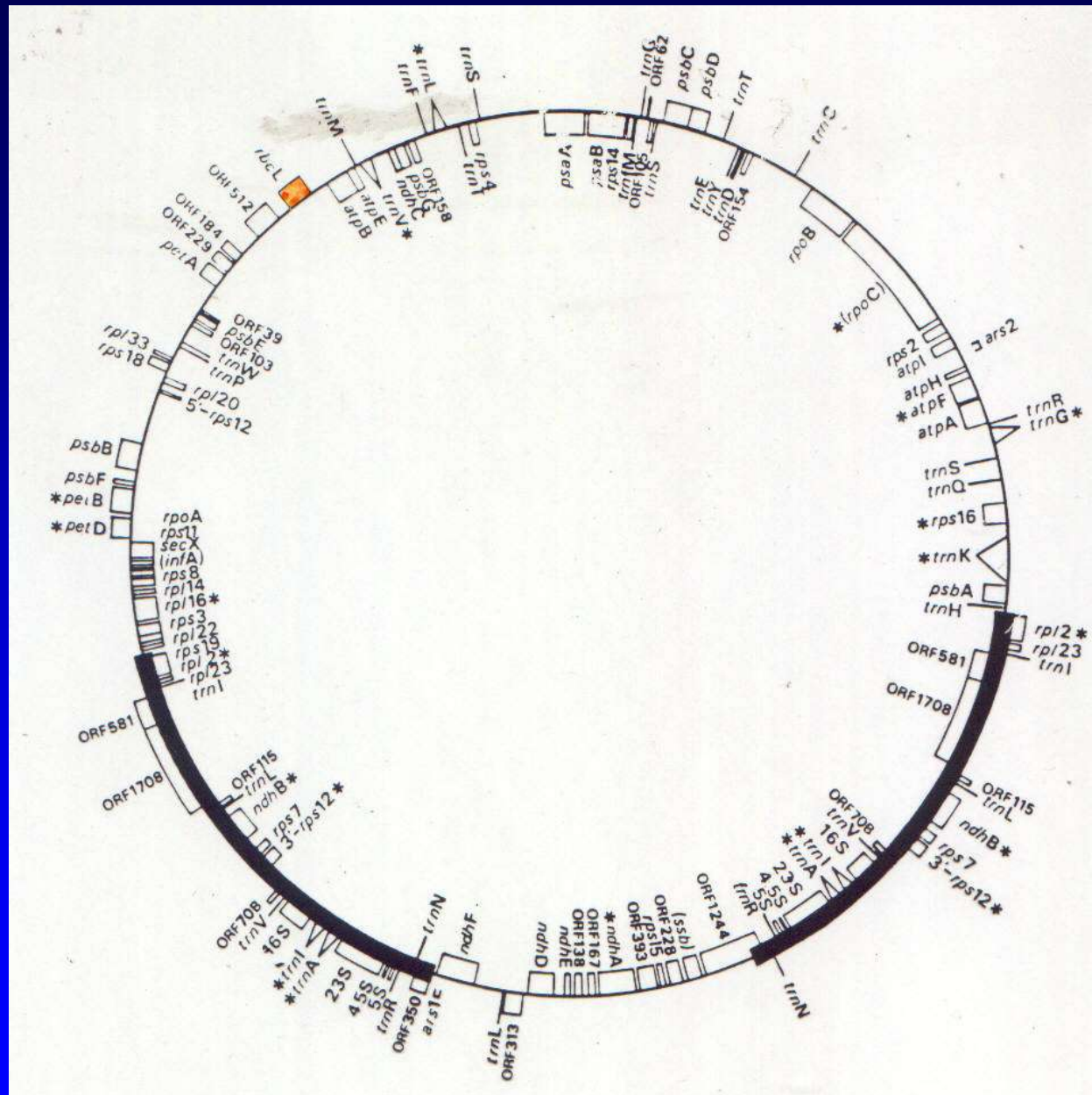
Lenho de *Pinus*



Corte transversal de folha de *Pinus nigra*
(Chamberlain 1935)

**PERDA da sequência
repetida invertida do
DNA plastidial**

**Olmstead & Palmer
1991, baseado em
Shinozaki *et al.* 1986**



PINALES

CARACTERES DIAGNÓSTICOS

- plantas lenhosas

Pinus longaeva - árvore
mais velha do mundo

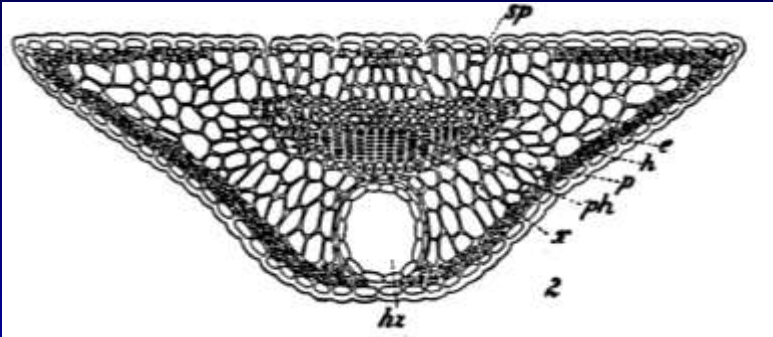


*Araucaria
angustifolia*



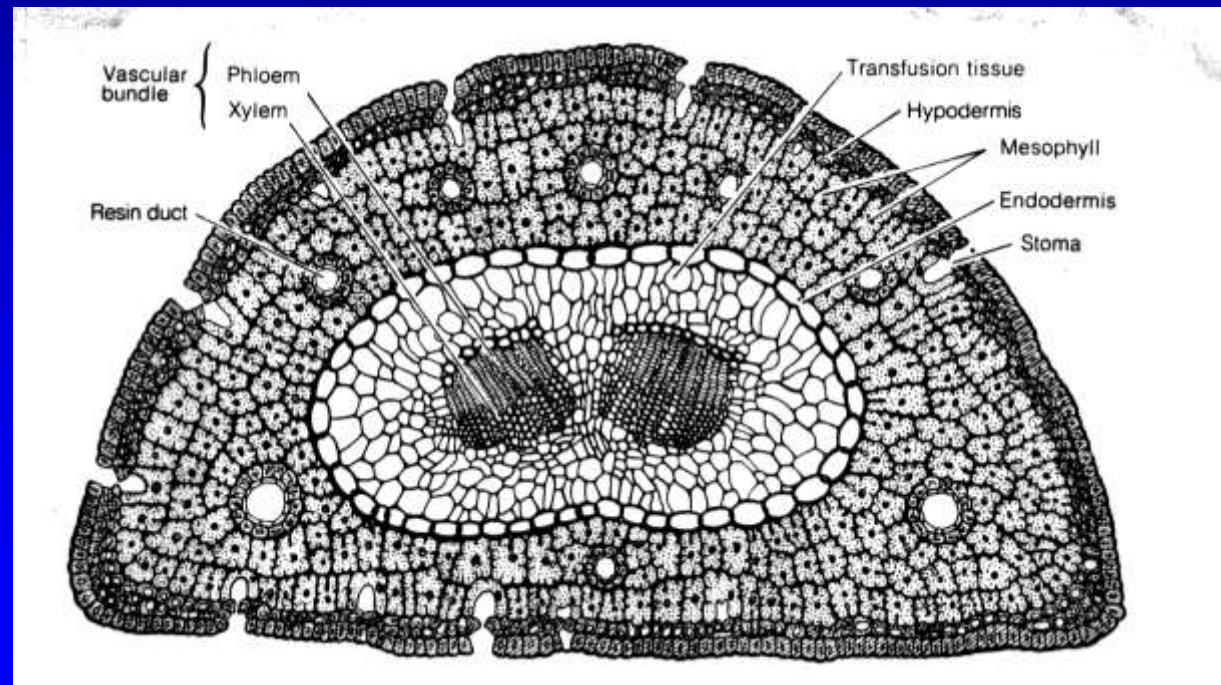
*Cupressus
sempervirens*

PINALES



Corte transversal de folha de *Juniperus communis*

♦ folhas escleromorfas,
geralmente uninérveas

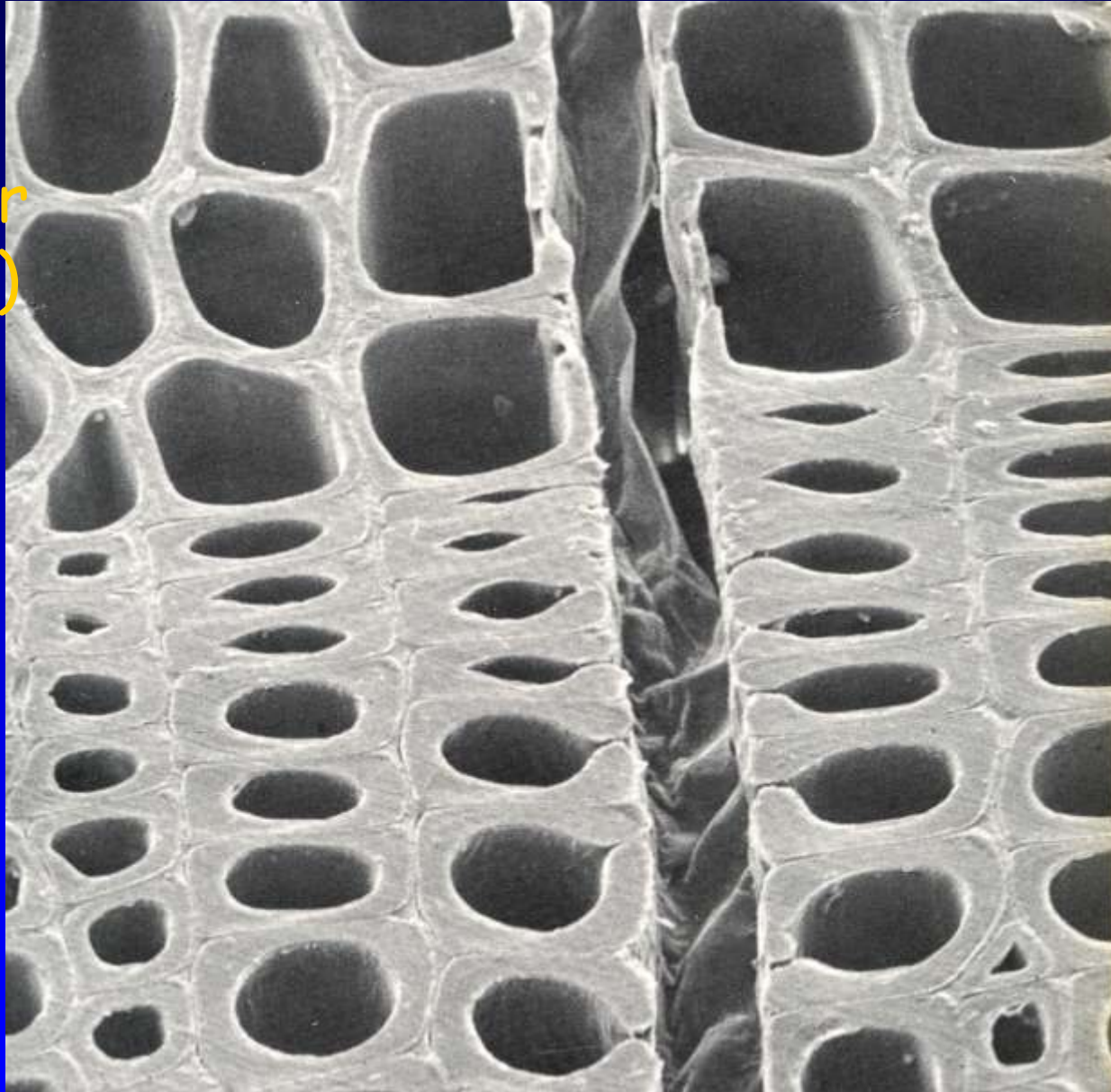


Corte transversal de folha de *Pinus nigra*
(Chamberlain 1935)

PINALES

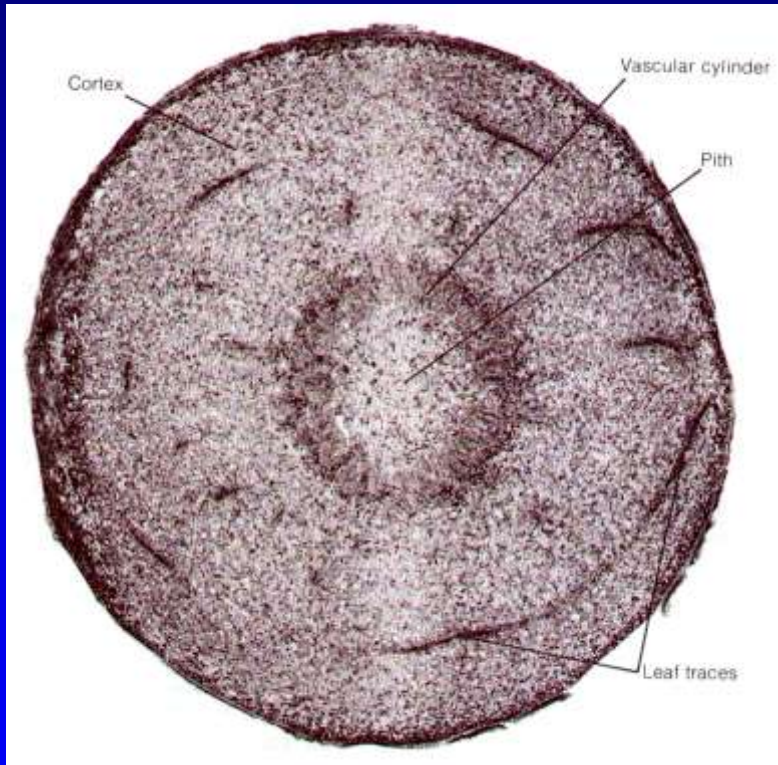
Raios unisseriados
no sistema vascular
(pouco parênquima)

Caráter
compartilhado
com
Ginkgófitas

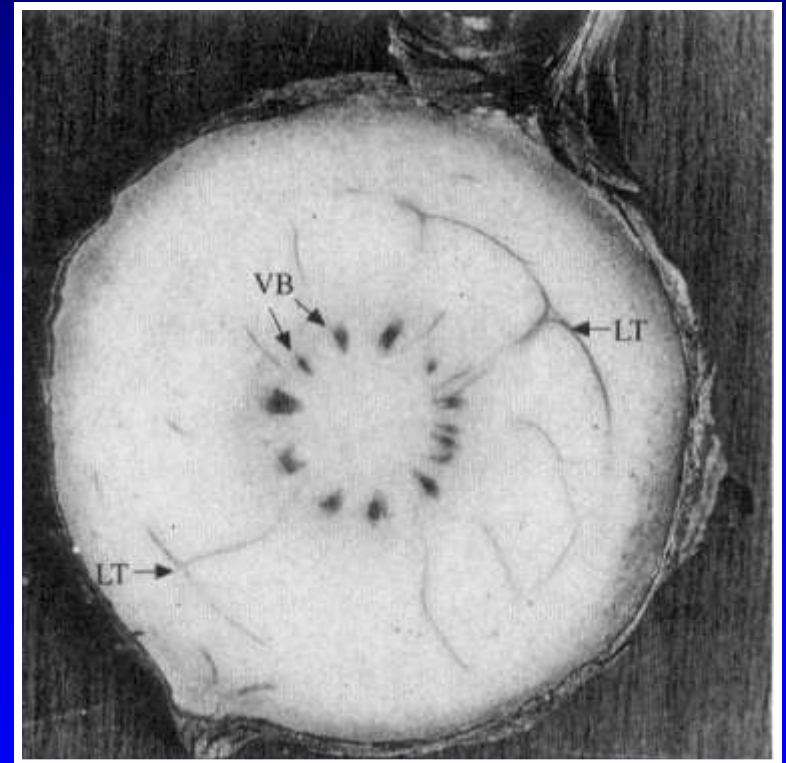


Lenho de Pinófitas e Ginkgófitas em forte contraste com CYCADOPHYTA:

↓ caule com muito parênquima



Corte transversal de caule de *Zamia* sp. (Gifford & Foster 1989)



Corte transversal de um caule de *Zamia integrifolia* (Norstog & Nicholls 1997)

PINOPHYTA

PINALES



- Araucariaceae
- Cephalotaxaceae
- Cupressaceae
- Pinaceae
- Podocarpaceae
- Taxaceae

PINOPHYTA, PINALES

PINACEAE

Família dos pinheiros
10 gêneros/220 spp.

Pinus (100 spp.)

Abies (40)

Picea (40)

Larix (10)

Tsuga (10)

Pseudotsuga (5)

- Limitadas ao Hemisfério Norte, clima temperado



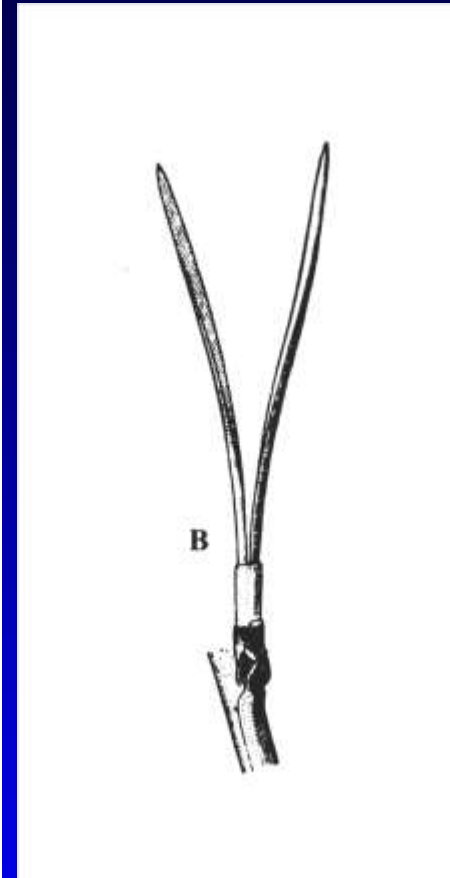
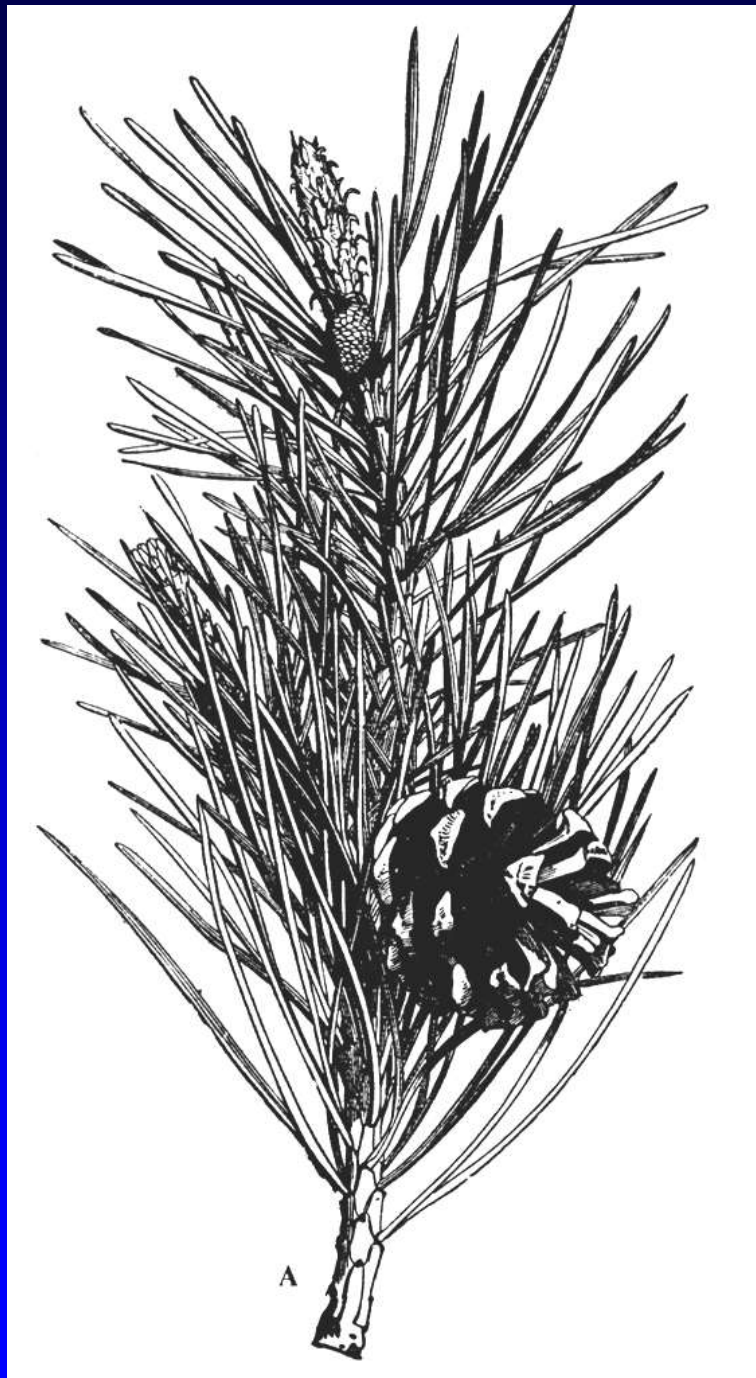
Distribuição geográfica do gênero *Pinus* (Krüssman 1995)

PINACEAE

CARACTERES DIAGNÓSTICOS

- árvores ou raramente arbustos
- ramos verticilados ou opostos (raramente alternos)

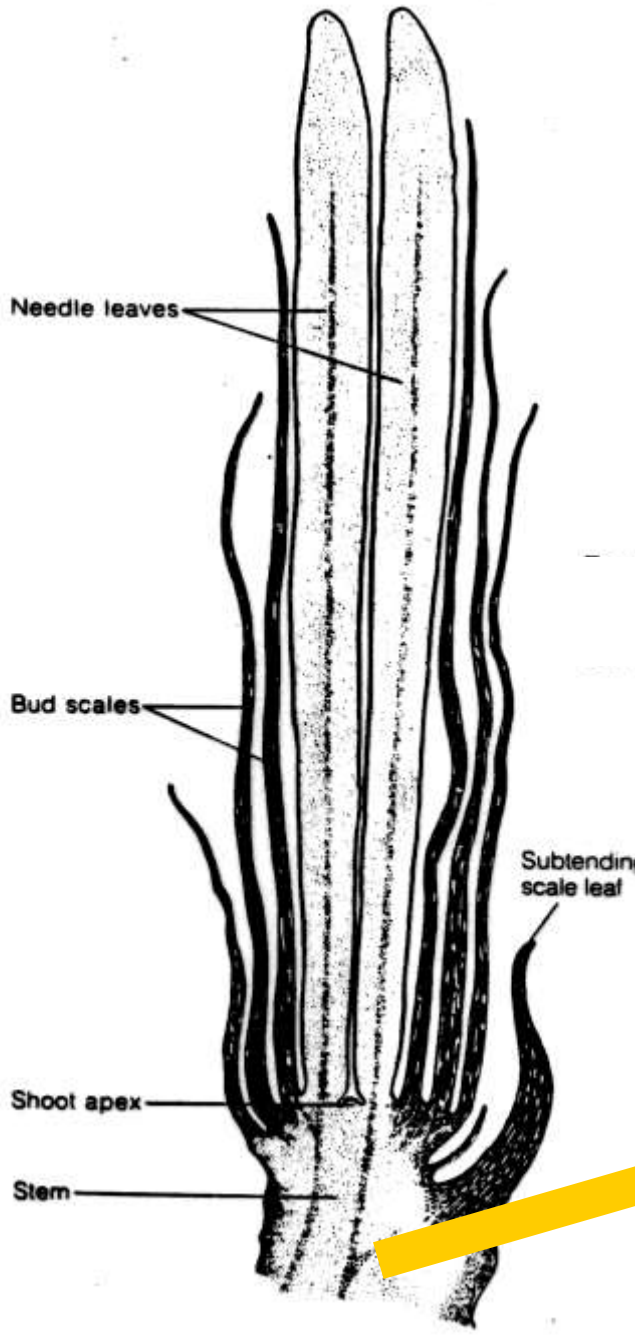
Kubitzki 1990



PINACEAE

- folhas simples, lineares a aciculares (raramente estreito-ovadas), alternas (folhas agrupadas de 2-5 em *Pinus*)

- canais resiníferos

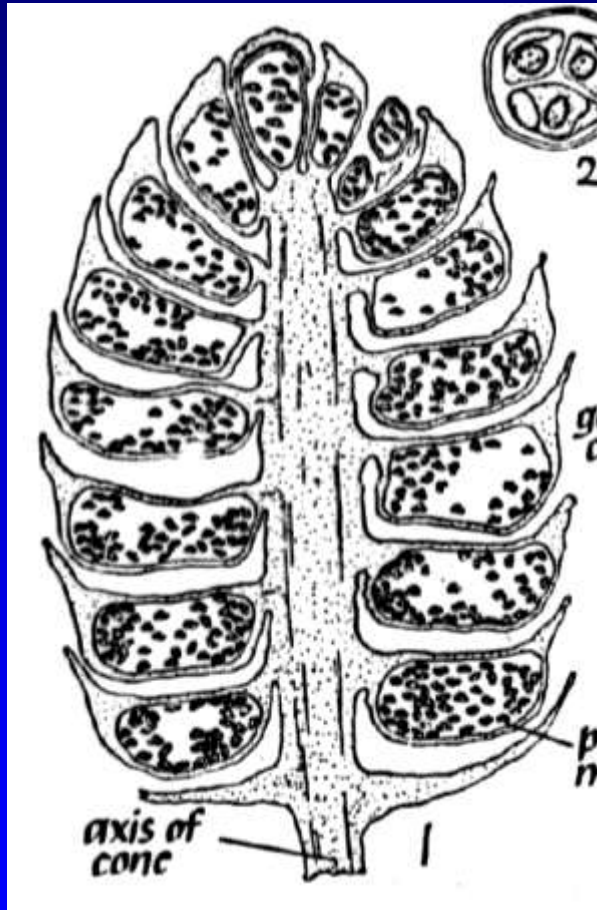


braquiblasto

Chamberlain 1935

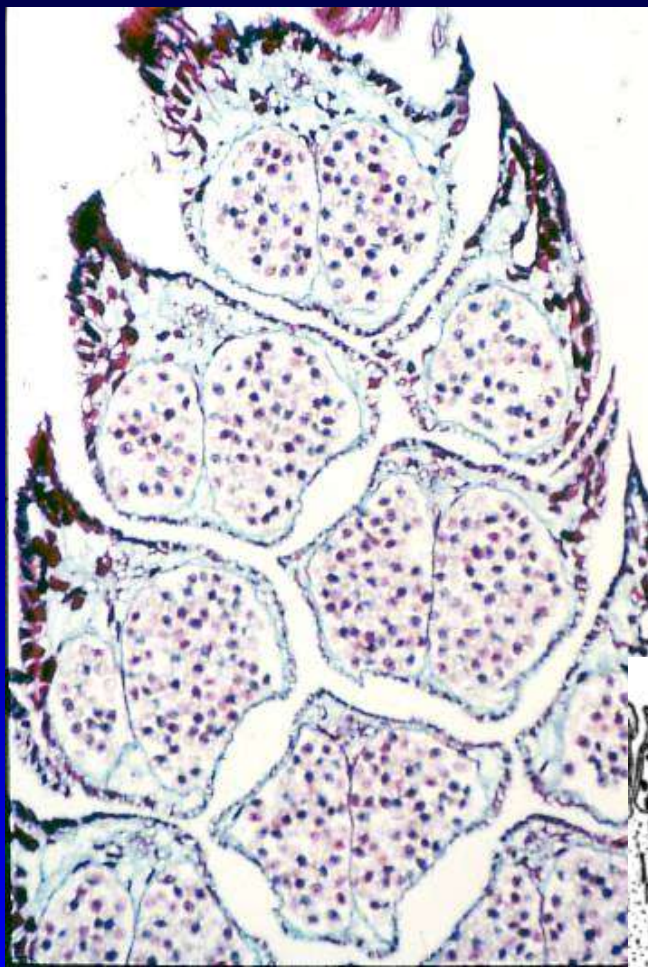
PINACEAE

- monóicas

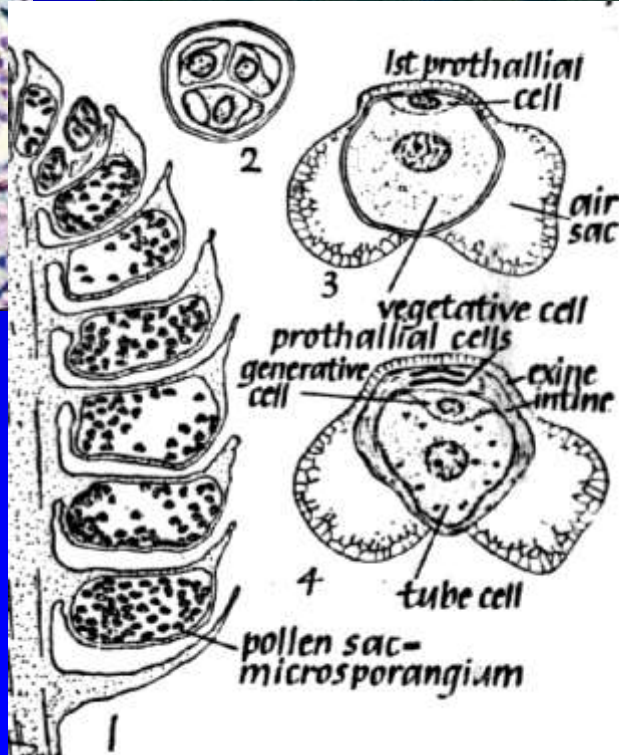


- microstróbilos com microsporofilos
espiralados

PINACEAE



- microsporofilos com 2 microsporângios
- anemofilia

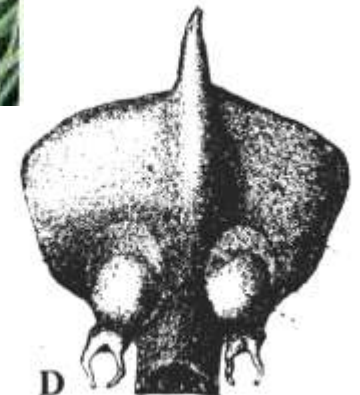
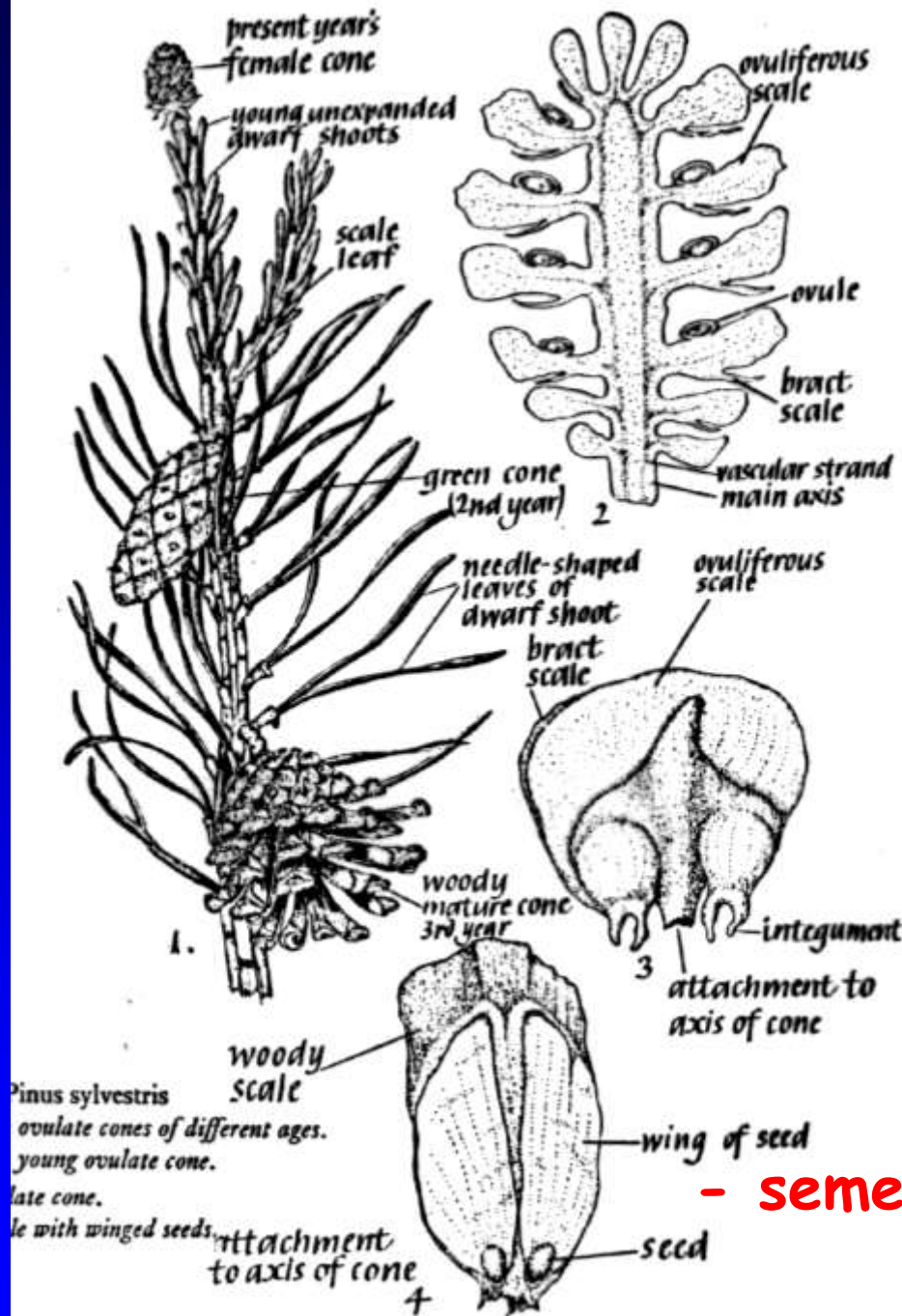


pólen com 2 sacos aéreos



PINACEAE

- escama ovulífera com 2 óvulos

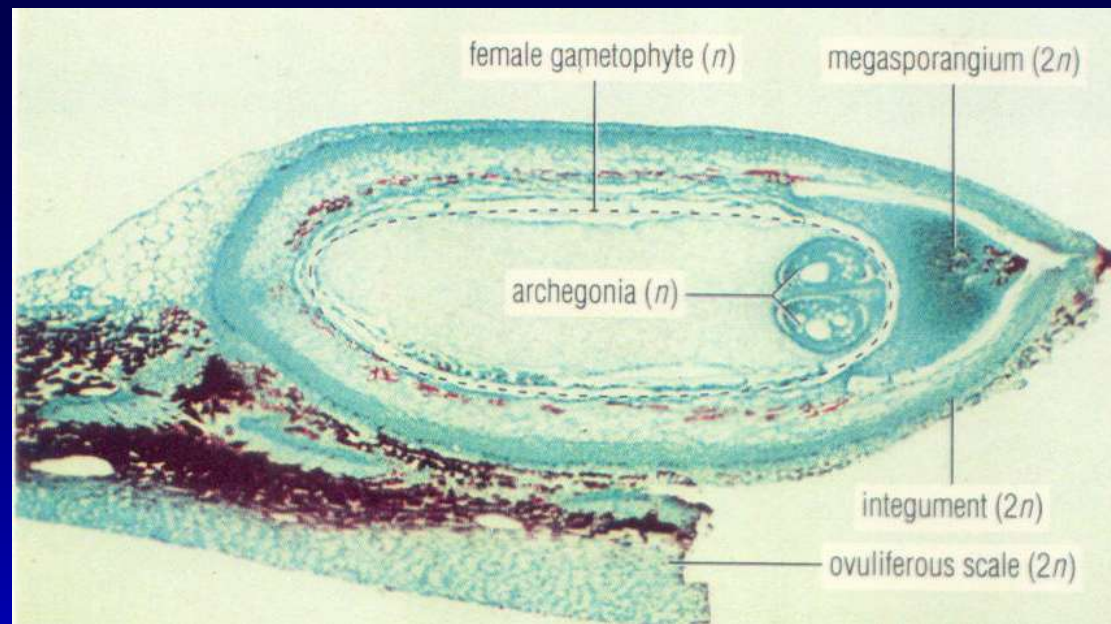


- semente alada

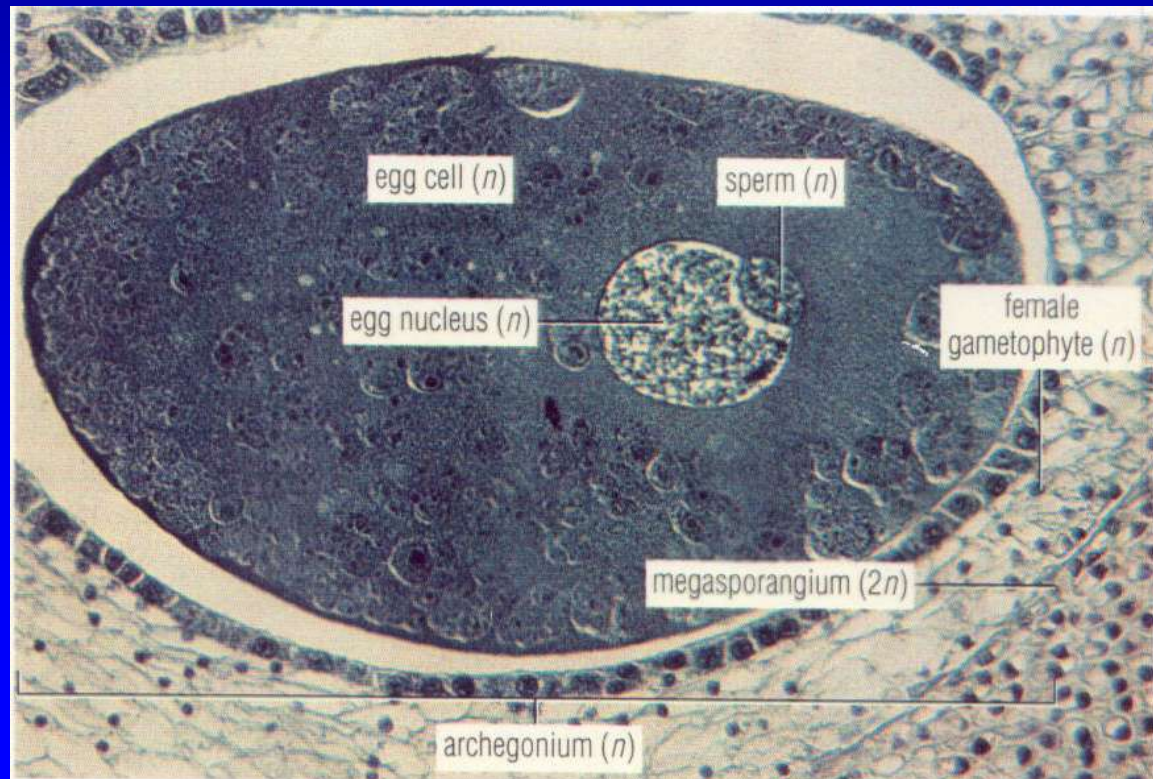
PINACEAE

Pinus

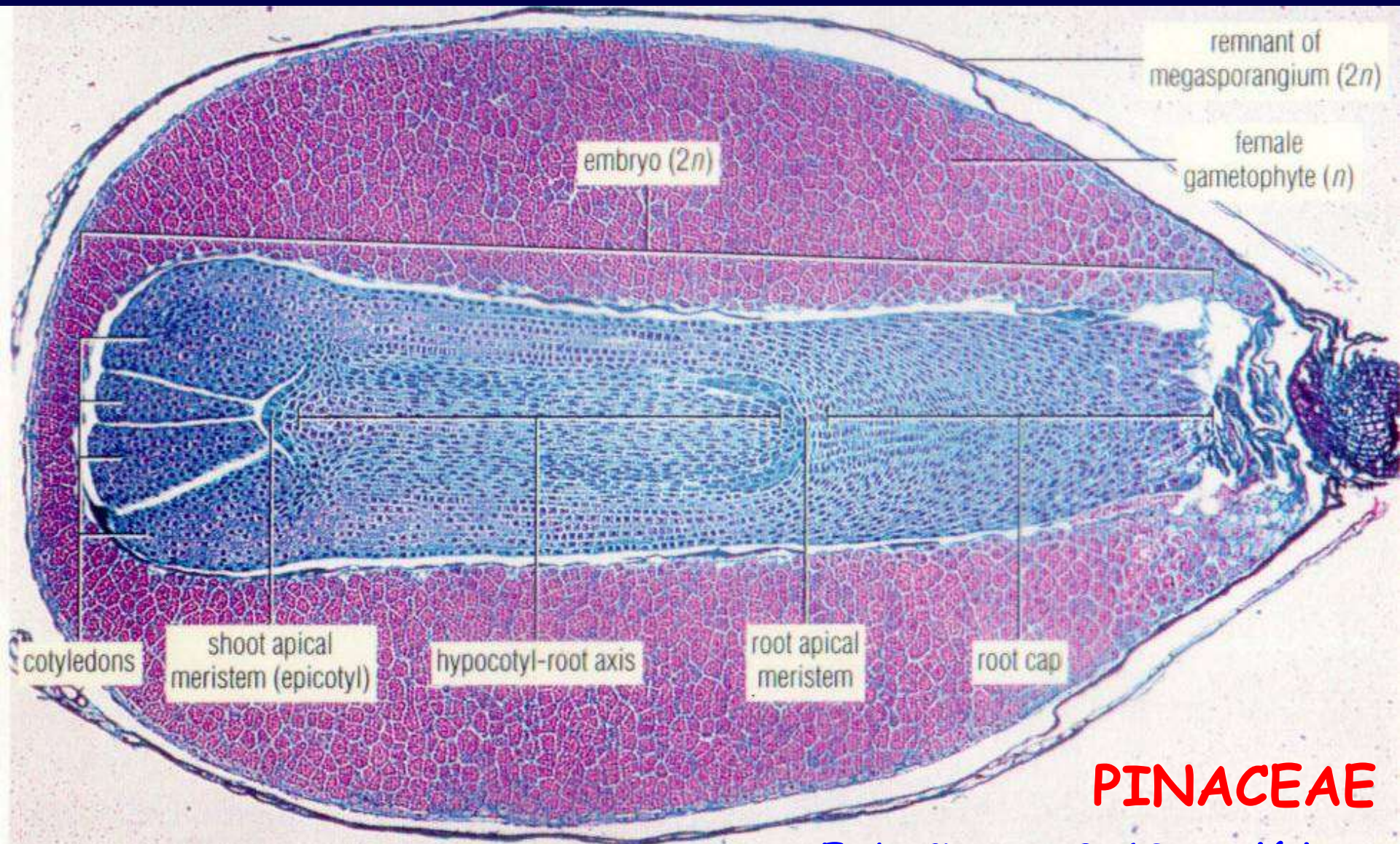
óvulo



fecundação da oosfera



Perry & Morton 1996



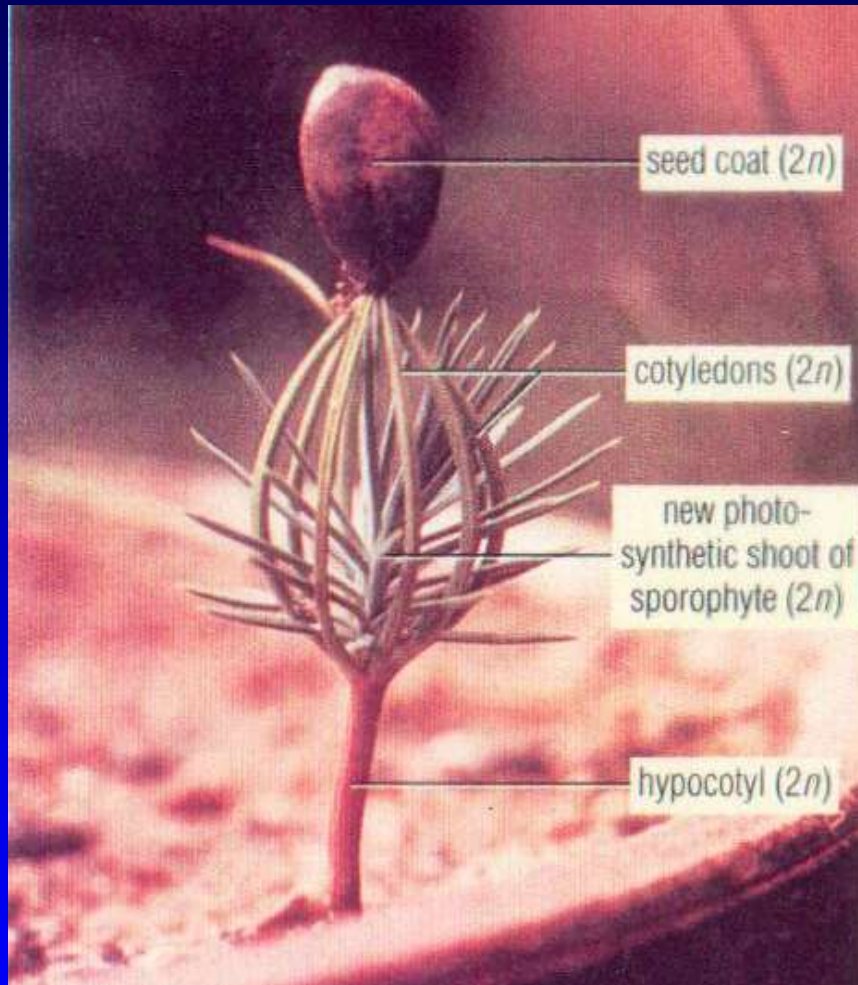
PINACEAE

Embrião com 2-18 cotilédones

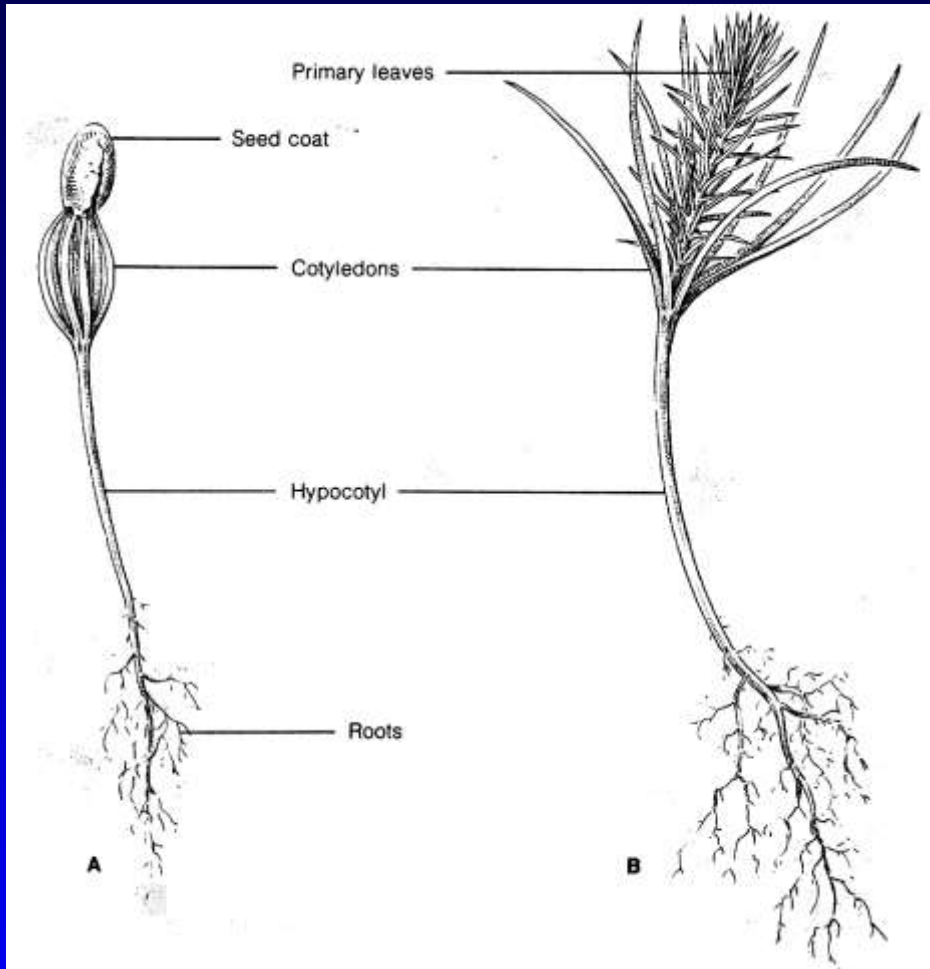
Perry & Morton 1996

Figure 57d *Pinus*, seed containing embryo. The hard seed coat was removed during slide preparation (prep. slide, l.s., 30 $\times$). (Photo courtesy Biodisc, Inc.)

PINACEAE

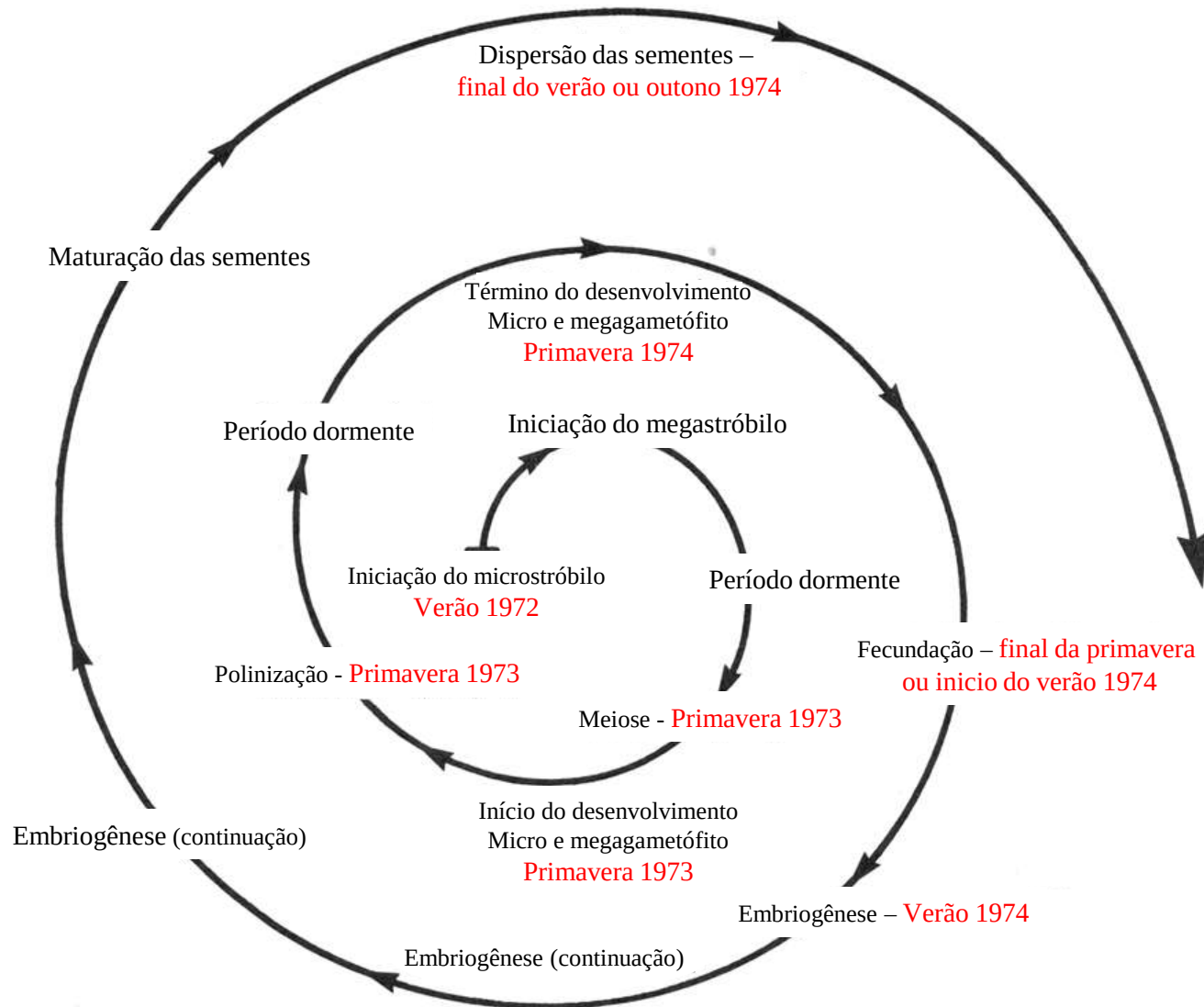


Perry & Morton 1996



Plântulas de *Pinus edulis*
(Gifford & Foster 1989)

Etapas da reprodução - *Pinus*



Modificado de Gifford & Foster 1989

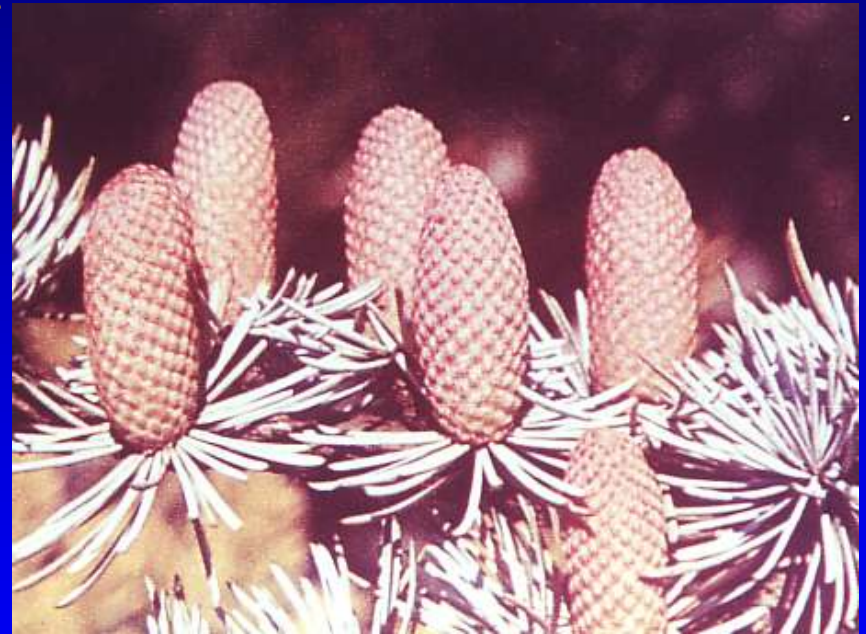
PINACEAE - importância econômica:

-madeiras úteis (*Pinus*, *Pseudotsuga*, *Picea*, *Tsuga*, *Larix* e *Abies*)

-celulose

- muito cultivadas como ornamentais

Larix sp.



Cedrus libanii

PINACEAE

importância econômica



Pinus

coleta de
resina



PINOPHYTA, PINALES

CUPRESSACEAE

Família dos
ciprestes e das
sequóias

29 gêneros/130 spp.

Juniperus (50 spp.)

Callitris (15)

Cupressus (13)

Chamaecyparis (8)

Thuja (5)

Taxodium (3)

Sequoia (1)

Sequoiadendron (1)



Cupressus sempervirens

- Família de climas quentes a frios

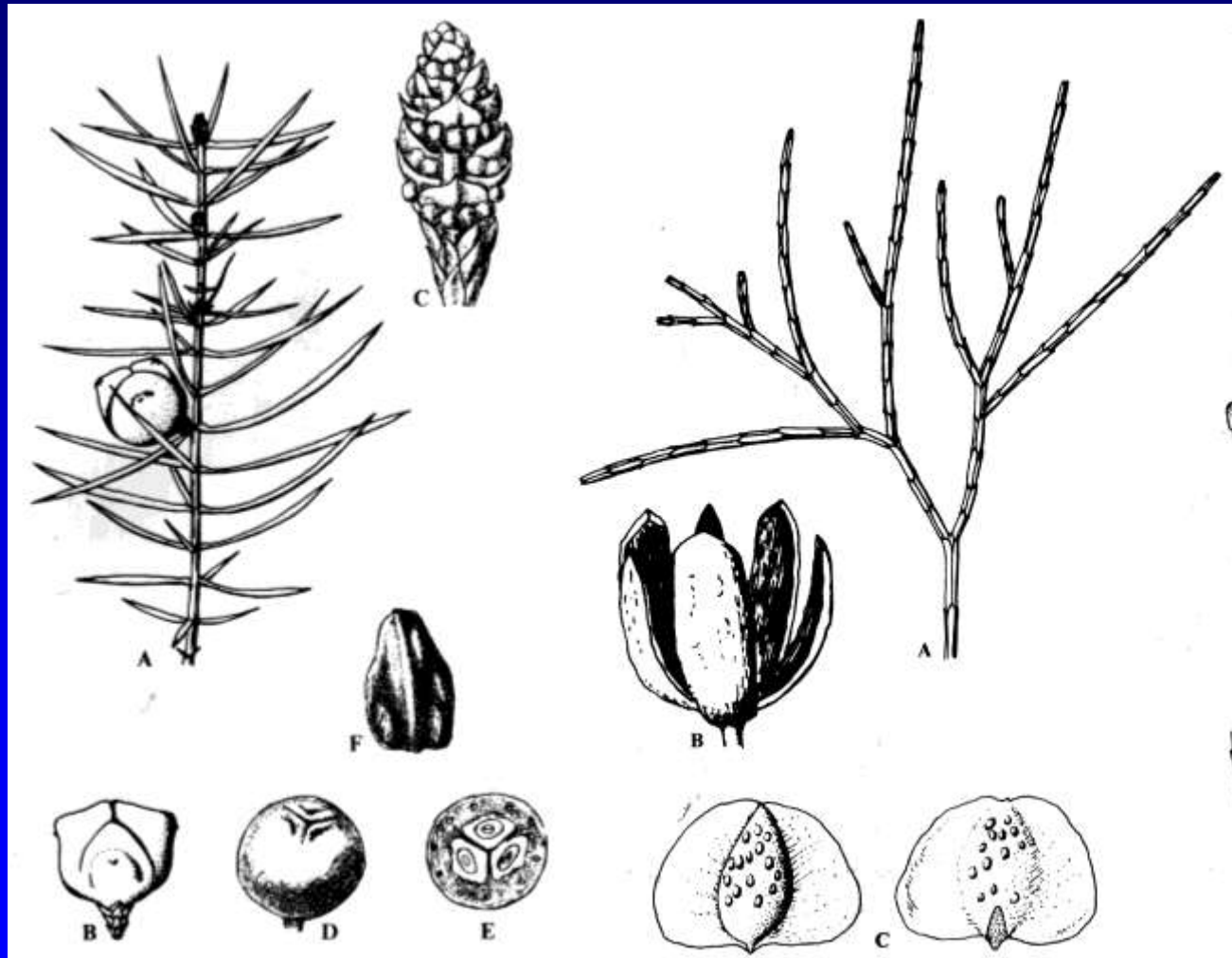


Sequoiadendron giganteum

CARACTERES DIAGNÓSTICOS - CUPRESSACEAE

- árvores ou arbustos; madeira e folhagens geralmente aromáticos
- folhas alternas, opostas ou verticiladas, escamiformes ou lineares.

- plantas
monóicas (dióicas
em *Juniperus*)



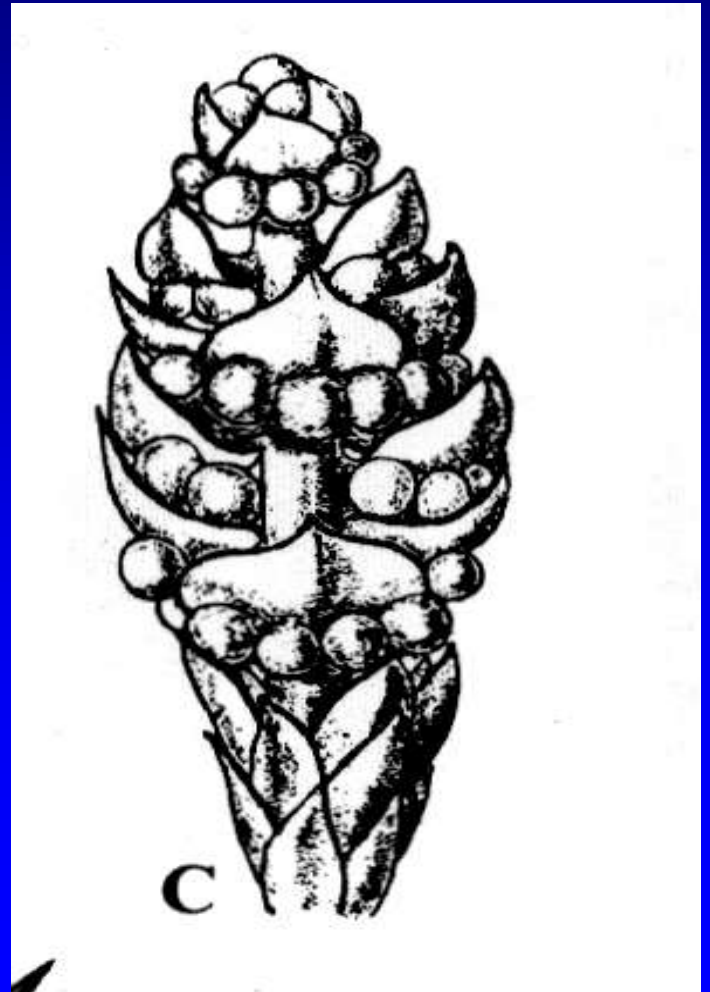
Espécies de *Juniperus* e
Callitris (Kubitzki 1990)

*Chamaecyparis
lawsoniana*



CUPRESSACEAE

-microstróbilos:
2-10 microsporângios
na face abaxial





Sequoiadendron giganteum

Sequoia sempervirens

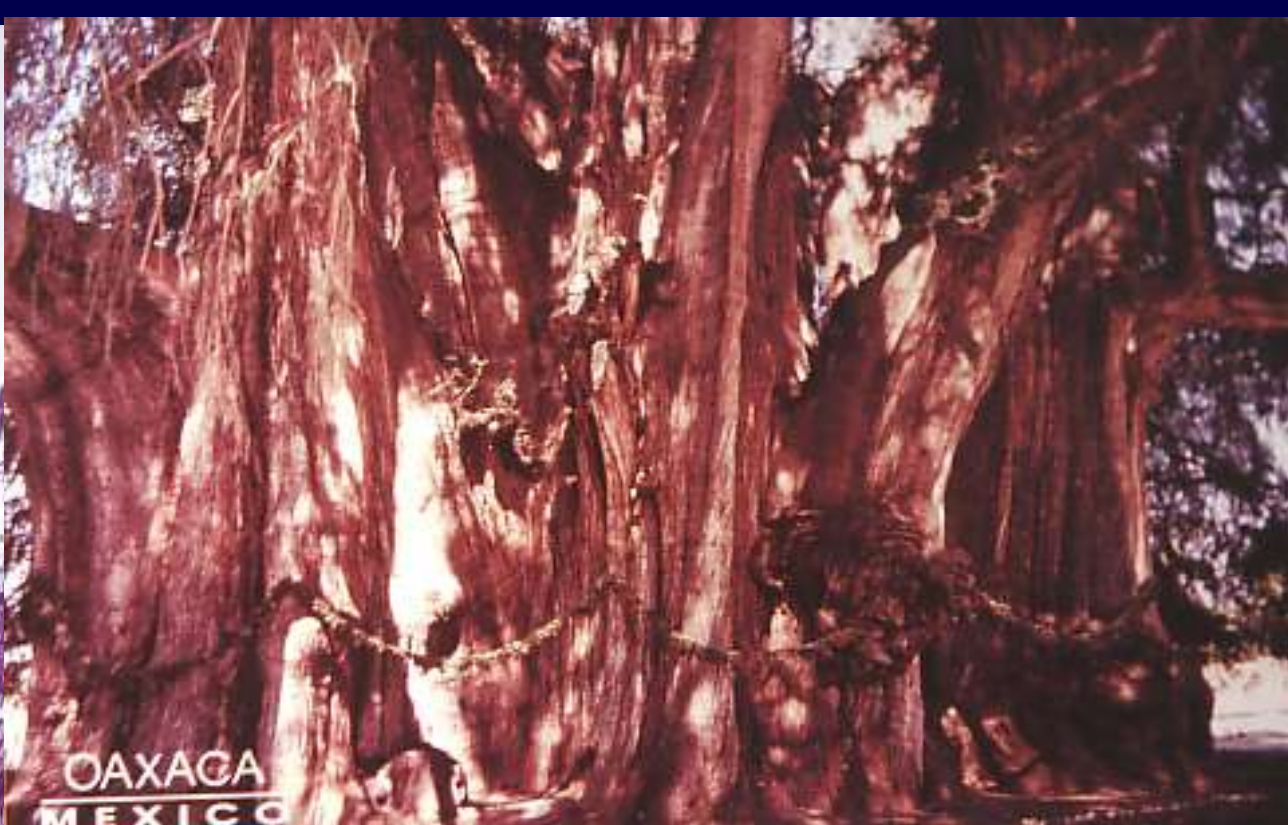
CUPRESSACEAE

PINALES, PINOPHYTA

Plantas mais altas e compactas da Terra



J. G. Rando



Taxodium distichum
CUPRESSACEAE

Cone com
escamas fundidas

Cupressus

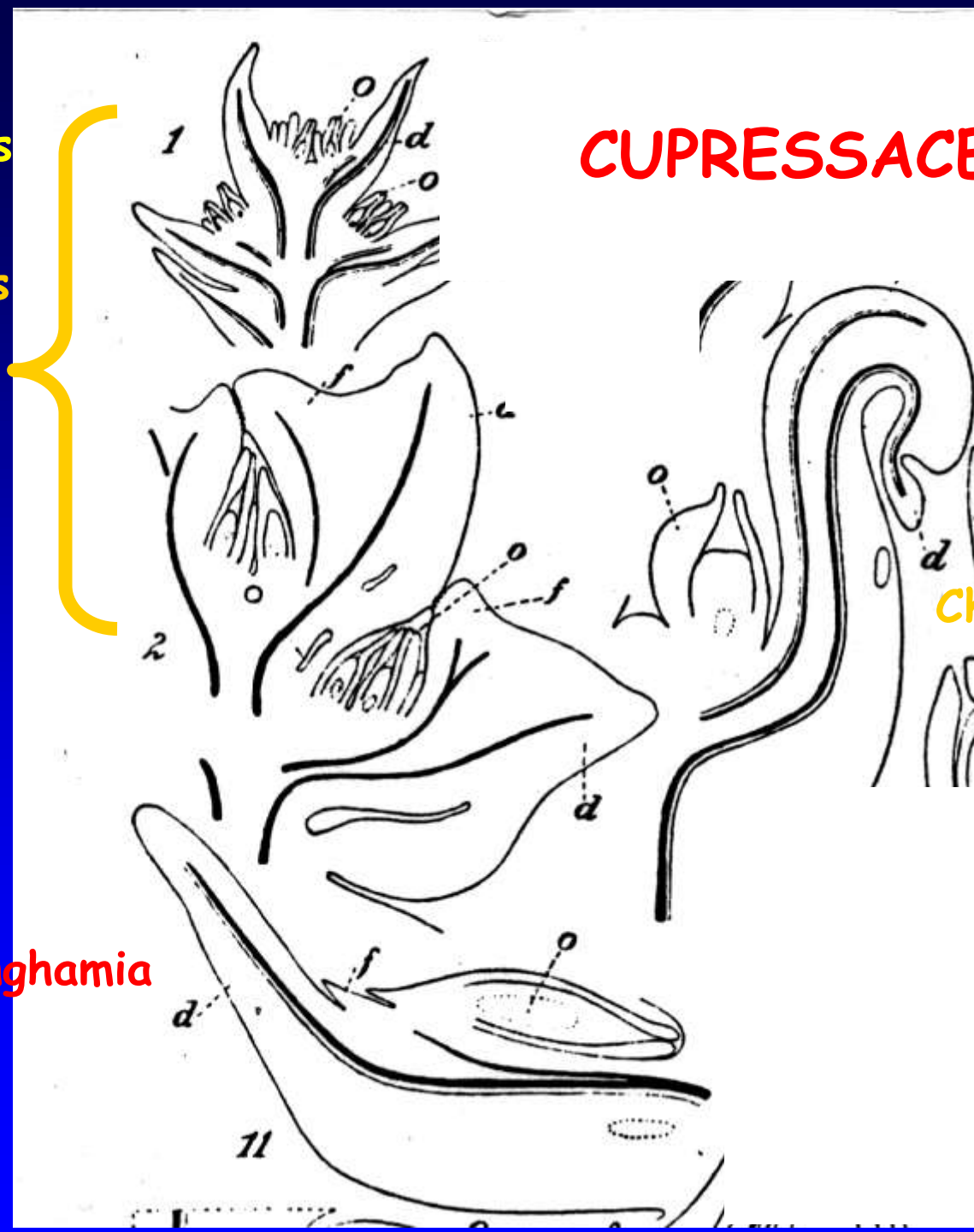
CUPRESSACEAE

Chamaecyparis

-escama ovulífera
com 1-20 óvulos

Cunninghamia

Gifford &
Foster
1989



CUPRESSACEAE

Juniperus



-Importância econômica:

- ornamentais:

Cupressus, Juniperus, Thuja

- madeira valiosa (*Cryptomeria, Juniperus, Sequoia, Taxodium, Thuja*)

PINOPHYTA, PINALES

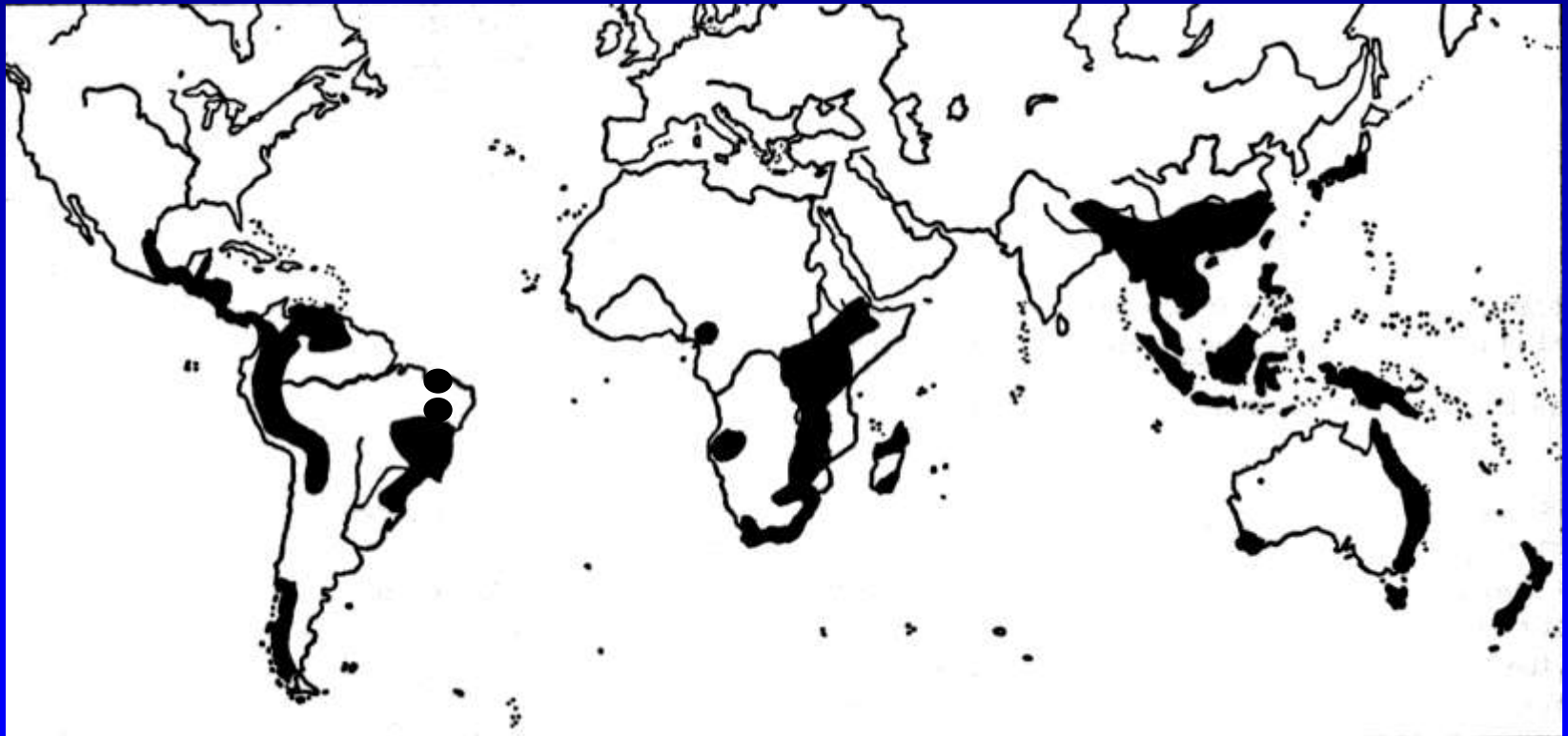
PODOCARPACEAE

17 gêneros/170 spp.

Podocarpus (100 spp.)

Dacrydium (20)

- Plantas tropicais e subtropicais, especialmente no Hemisfério Sul e no Velho Mundo



Distribuição geográfica de *Podocarpus* (Krüssman 1995)

PODOCARPACEAE

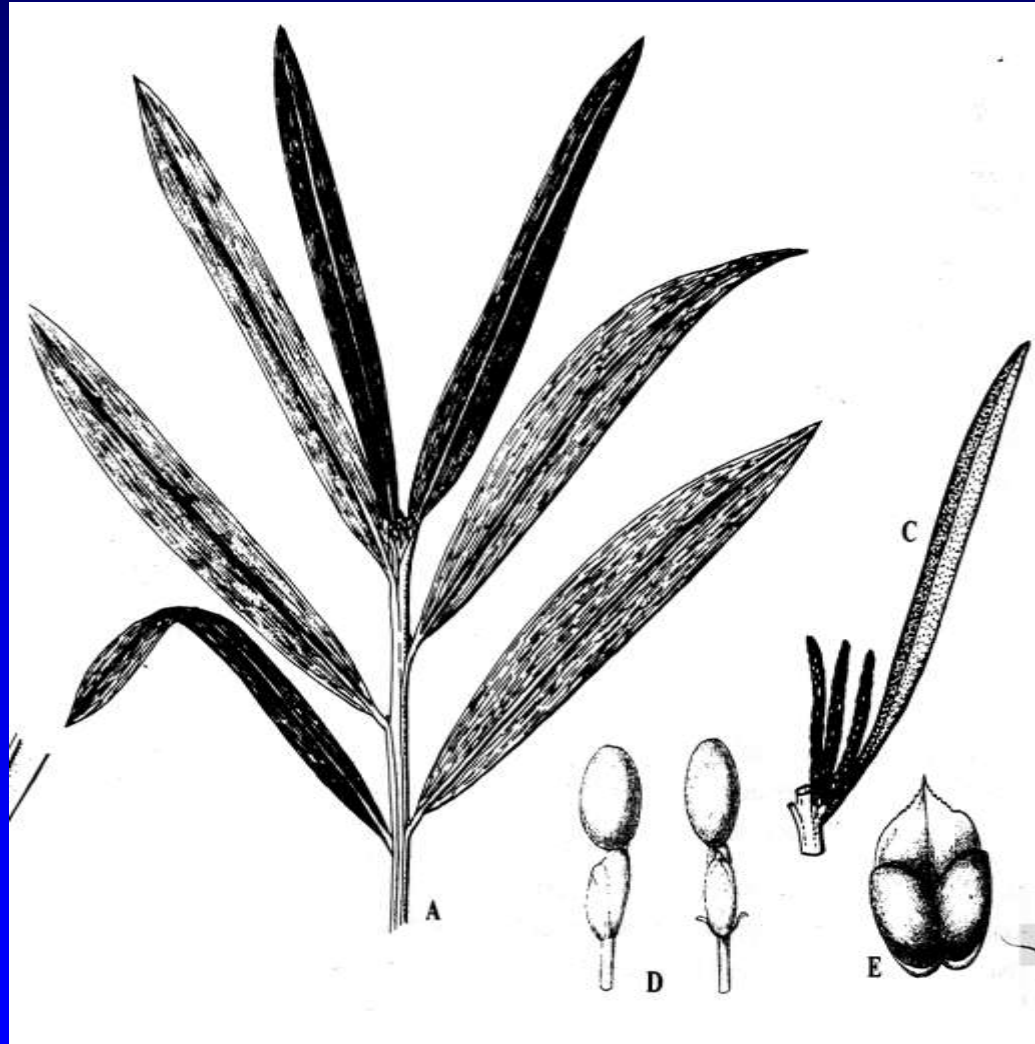
CARACTERES DIAGNÓSTICOS

- arbustos ou árvores; folhas simples, alternas, lineares a escamiformes

- plantas dióicas (raramente monóicas)

- microstróbilo cilíndrico

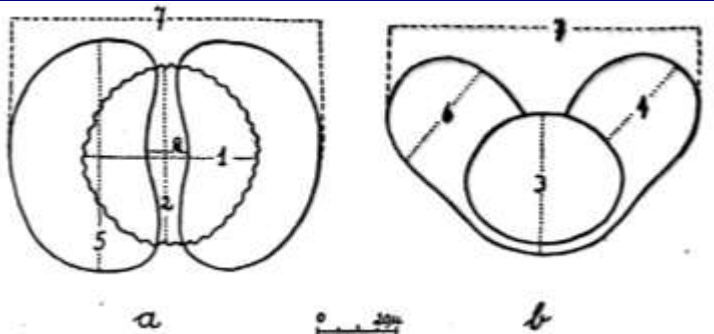
- madeira valiosa (*Dacrydium* e *Podocarpus*)



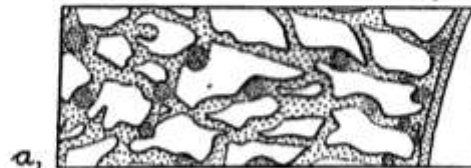
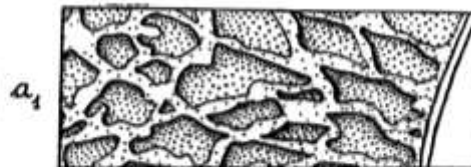
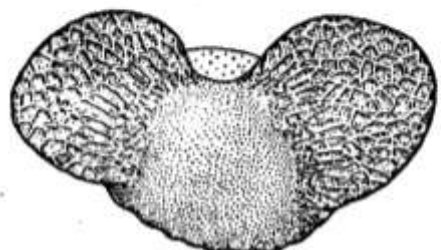
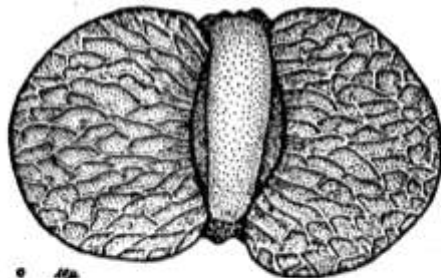
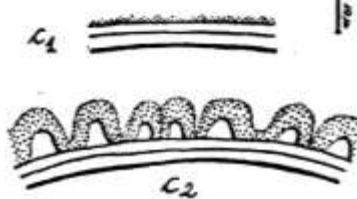
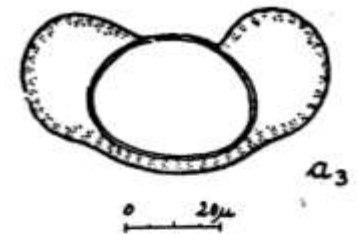
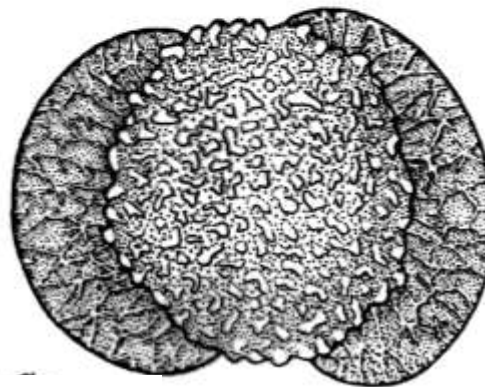
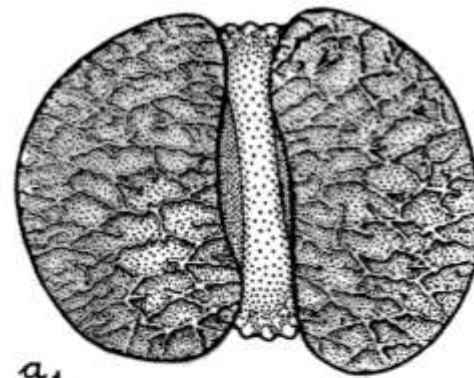
A-D. *Podocarpus macrophyllus*; E. *P. sellowii* (Kubitzki 1990)

PODOCARPACEAE

pólen com 2 sacos aéreos

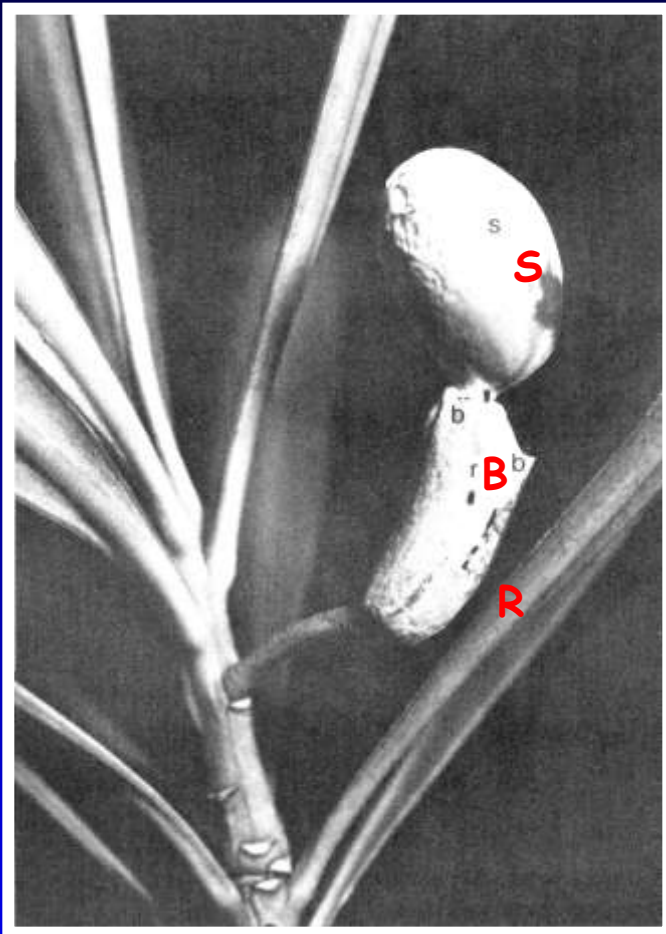


Podocarpus sellowii



Podocarpus lambertii

Barth 1962

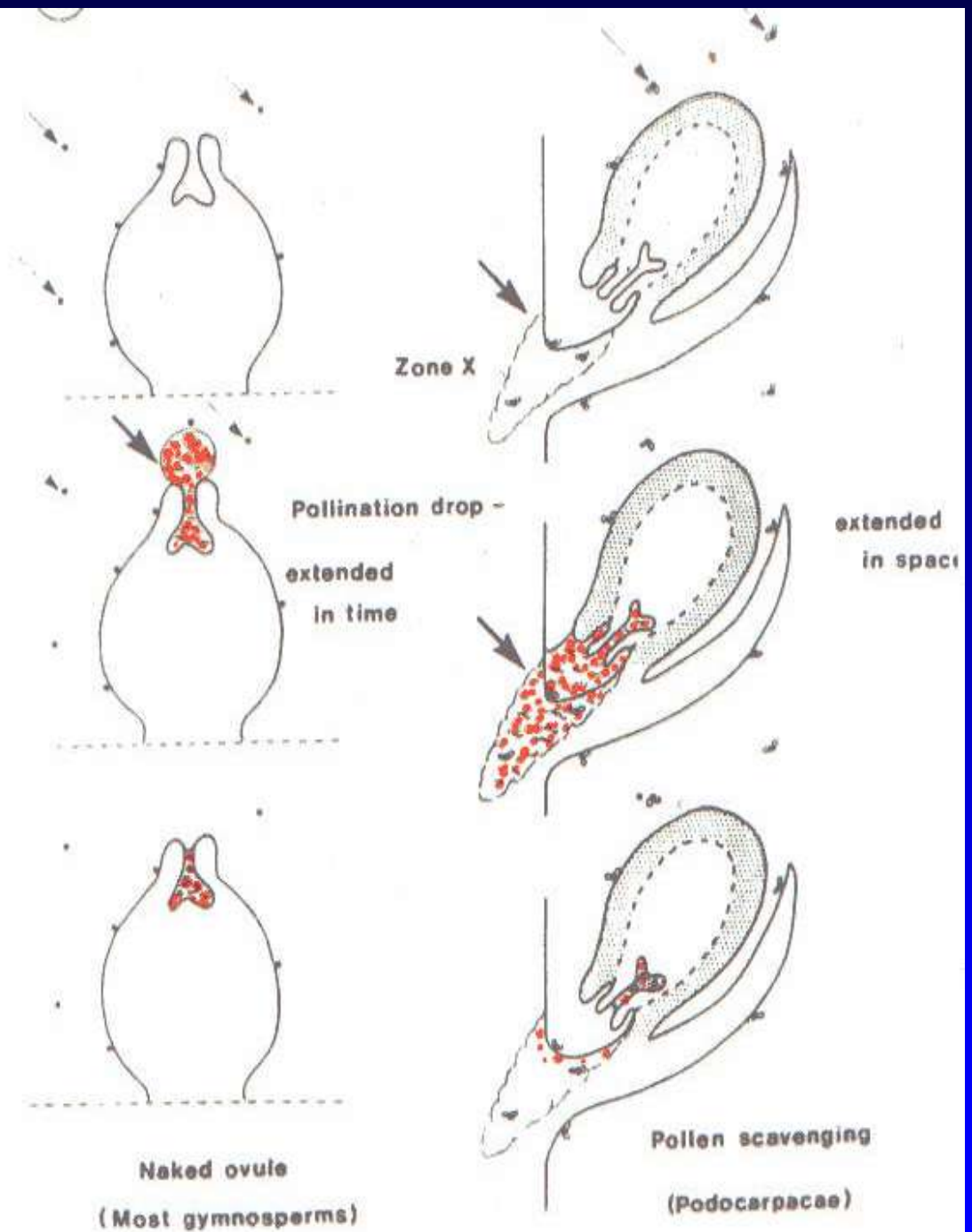


Cone maduro de *Podocarpus*

Gifford & Foster 1989

-escama ovulífera com 1
óvulo

Tomlinson *et al.*
1991



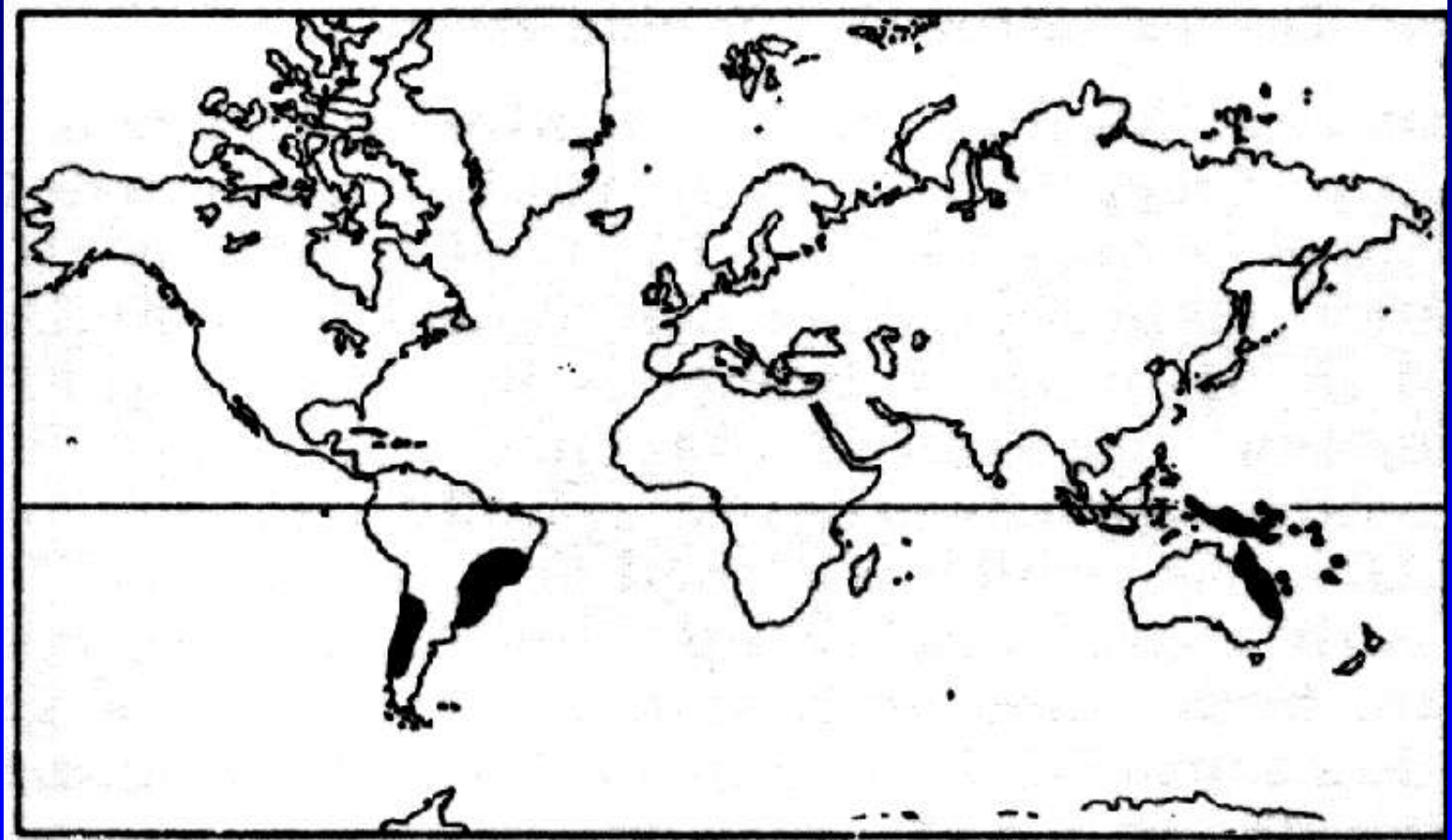
PINOPHYTA, PINALES

ARAUCARIACEAE

Araucaria

Agathis

- Restritas ao Hemisfério Sul



Distribuição geográfica do gênero *Araucaria* (Krüssman 1995)

ARAUCARIACEAE

Araucaria bidwillii

Araucaria angustifolia





PINOPHYTA, PINALES - ARAUCARIACEAE
Araucaria angustifolia



ARAUCARIACEAE

CARACTERES DIAGNÓSTICOS

- árvores com folhas lineares ou largas, opostas ou espiraladas

- plantas dióicas

- escamas ovulíferas e bracteais soldadas, recobrimdo o óvulo e formando o "pinhão"

- microsporofilos com 8 microsporângios



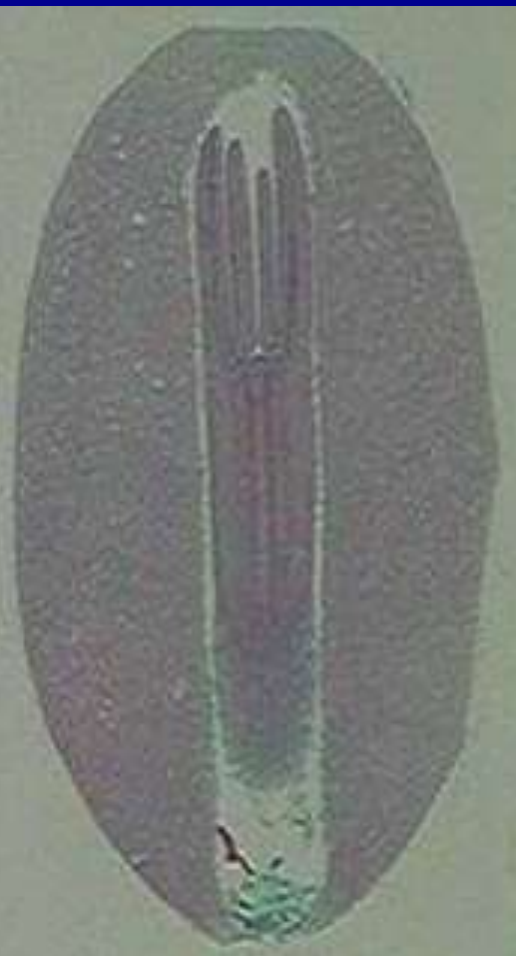
Araucaria angustifolia



Araucaria bidwillii



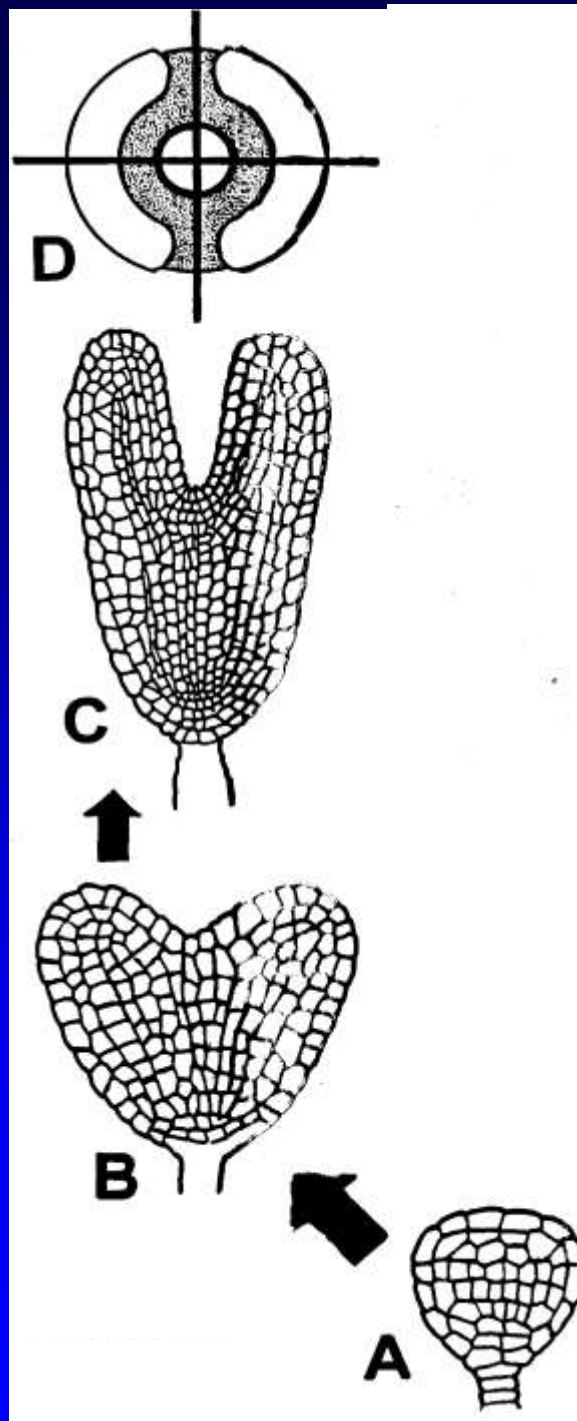
→ pinhão = semente



A porção
comestível
corresponde a
quais estruturas?

Embrião nas espermatófitas

Gifford & Foster 1988,
Yamashita 1976



PINOPHYTA, PINALES

TAXACEAE

Taxus baccata



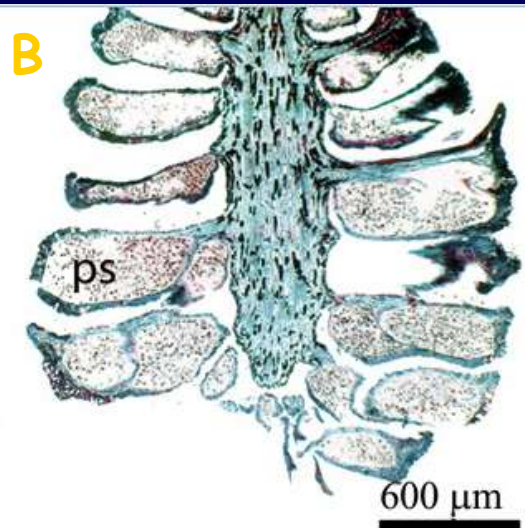
Pinus johannis, PINACEAE



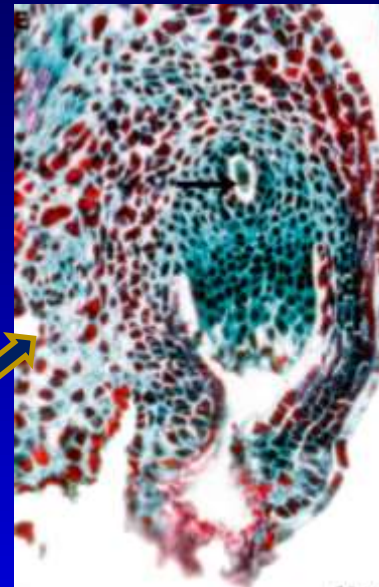
Fig. 1. Disposition of pollen, ovulate, and bisporangiate cones of *Pinus johannis*. (A) Cluster of pollen cones. (B) Ovulate cones develop on the tip of whorled lateral shoots. (C) Bisporangiate cones (arrows) interspersed with cluster of microstrobili of an individual initially monoecious predominately male. (D) Bisexual cone (arrow) originated at the top of the shoot alongside megastrobili in individual initially monoecious predominately female.

Pinus johannis, PINACEAE

A,B: microstróbilo "normal"

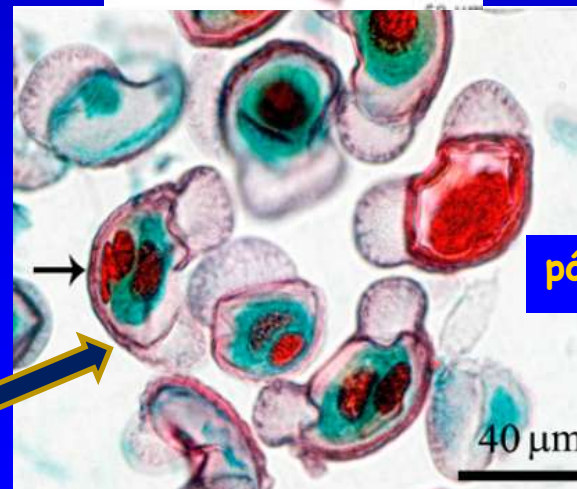
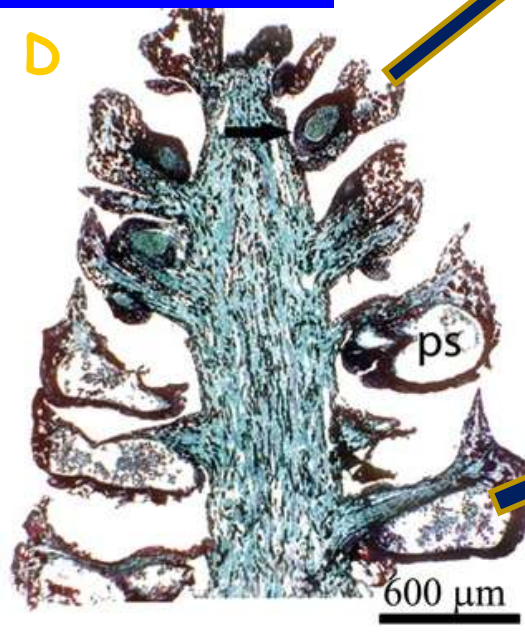


Distribuição espacial e viabilidade de órgãos produtores de pólen ou de óvulos em muitos gêneros de gimnospermas sugere existência de um mecanismo comum a todas espermatófitas (presença de genes homólogos com os das angiospermas?).



óvulo

C,D: estróbilo bisporangiado (ou monoclino)



pólen

Flores-Rentería et al. 2011

Gifford & Foster (1989)

Mauseth (1995)

Progymnospermophyta (fóssil)

Pteridospermophyta (fóssil)

Cycadeoidophyta
(=Bennettitales) (fóssil)

Cycadophyta

Ginkgophyta

Pinophyta (=Coniferophyta)

Gnetophyta



Loconte & Stevenson 1990

NOVIDADES EVOLUTIVAS

(sinapormorfias de *Gnetófitas* + *Angiospermas*)

- ◆ células iniciais cambiais curtas

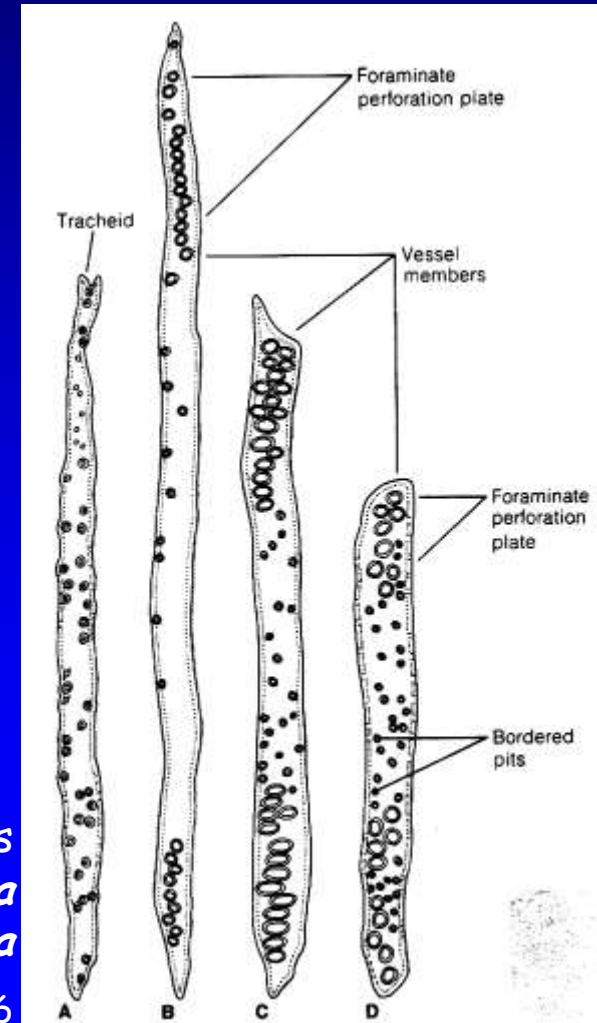
- ◆ elementos de vaso



Corte de caule de
Gnetum, uma liana
foto V. Angyalossy

Elementos traqueais
de *Ephedra*
californica

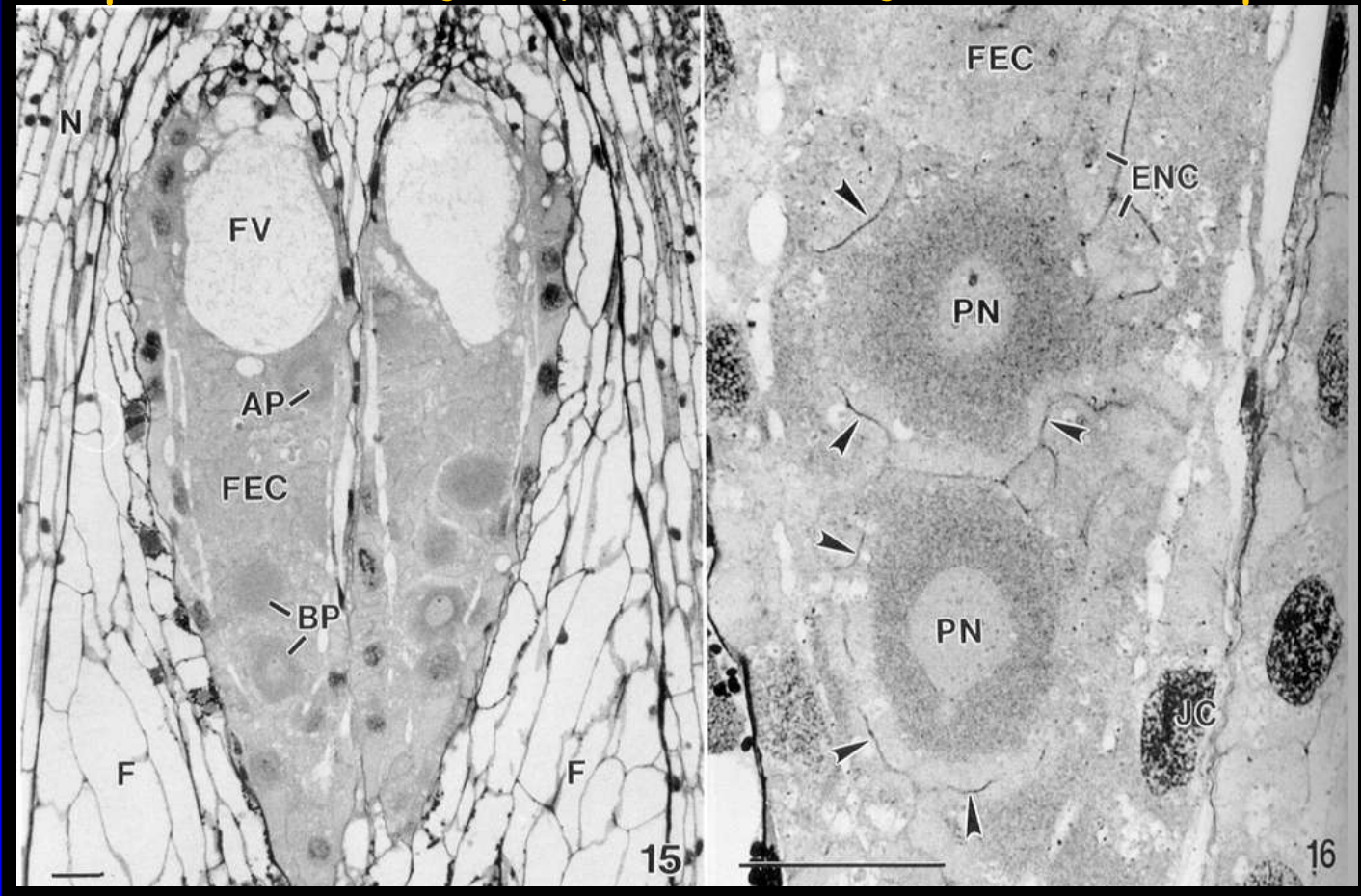
Gifford & Foster 1986



NOVIDADES EVOLUTIVAS

(sinapormorfias de Gnetófitas + Angiospermas)

- ♦ dupla fecundação (sem formação de endosperma)



1. Dois arquegônios em *Ephedra trifurca*; 2. Dois dos 8 zigotos num óvulo de *E. trifurca* (AP= proembrião basal derivado da dupla fecundação e BP= proembrião derivado da primeira fecundação (Friedman 1994)

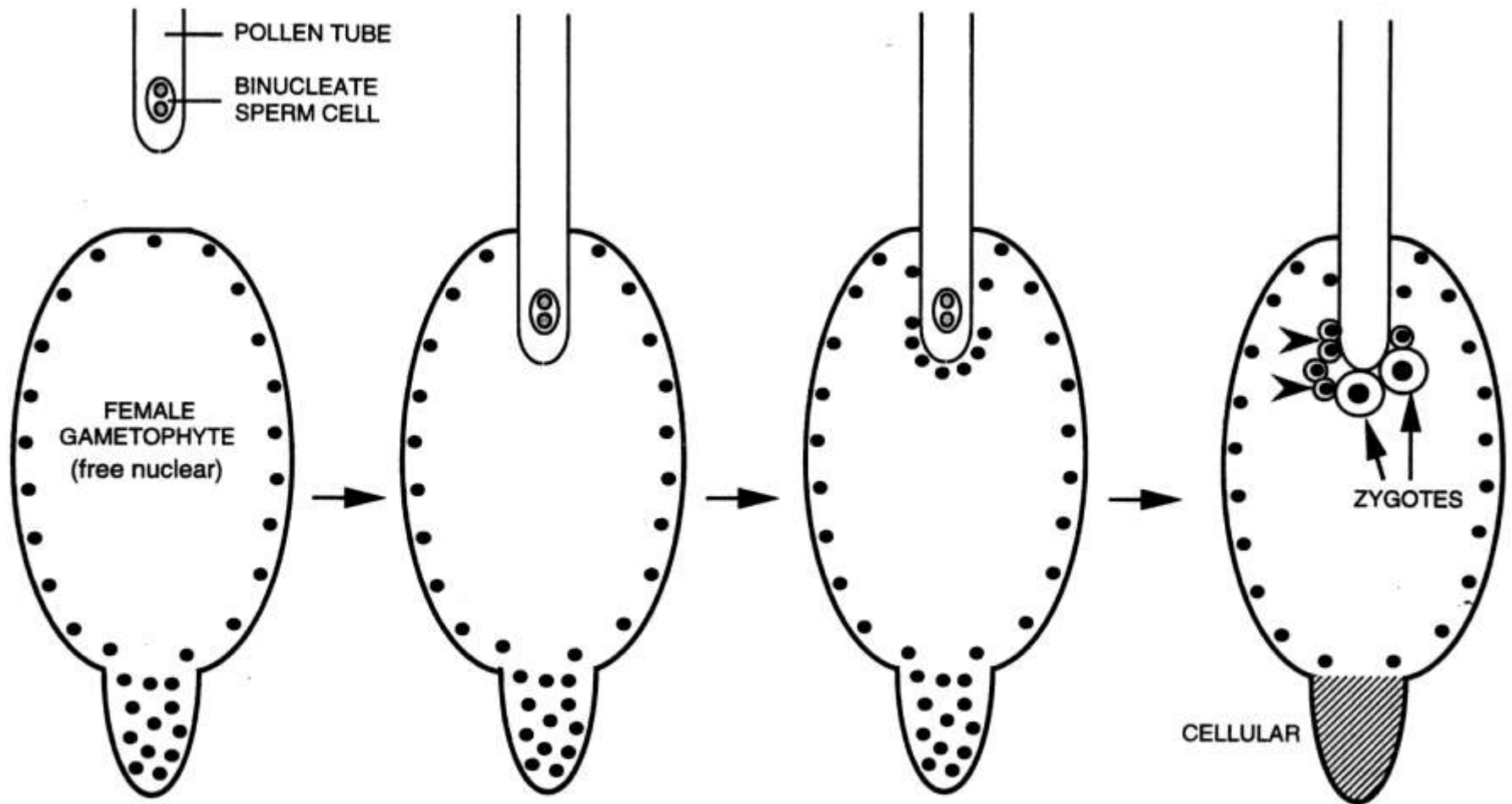


Fig. 33. Diagram illustrating double fertilization in *Gnetum gnemon*. Binucleate sperm cells are produced within pollen tubes that enter a coenocytic female gametophyte. Shortly after pollen tubes enter, free nuclei within the female gametophyte migrate around the tips of pollen tubes. None of the female nuclei differentiate as eggs and all represent potential gametes. Pollen tubes discharge both sperm nuclei into surrounding female cytoplasm and each sperm nucleus fuses with a separate female nucleus. Double fertilization results in the formation of two viable zygotes. Although unfertilized female nuclei may become cellular (arrowheads), they are clearly distinguishable from diploid zygotes. Concurrent with fertilization, the chalazal region of the female gametophyte becomes cellular and will eventually enlarge and serve to nourish developing embryos. As many as six pollen tubes may fertilize a single female gametophyte.

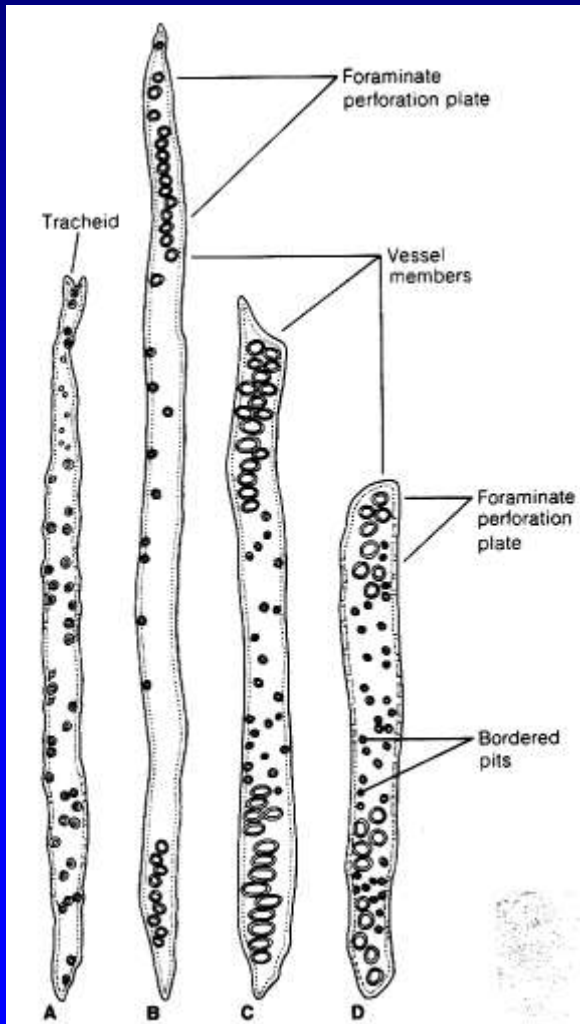
GNETOPHYTA - Permiano ao Recente

3 ordens {
EPHEDRALES
GNETALES
WELWITSCHIALES

- Gnetophyta + Angiospermas =
Hipótese das ANTÓFITAS

POSSÍVEIS SINAPORMORFIAS

- ♦ elementos de vaso com perfurações foraminadas



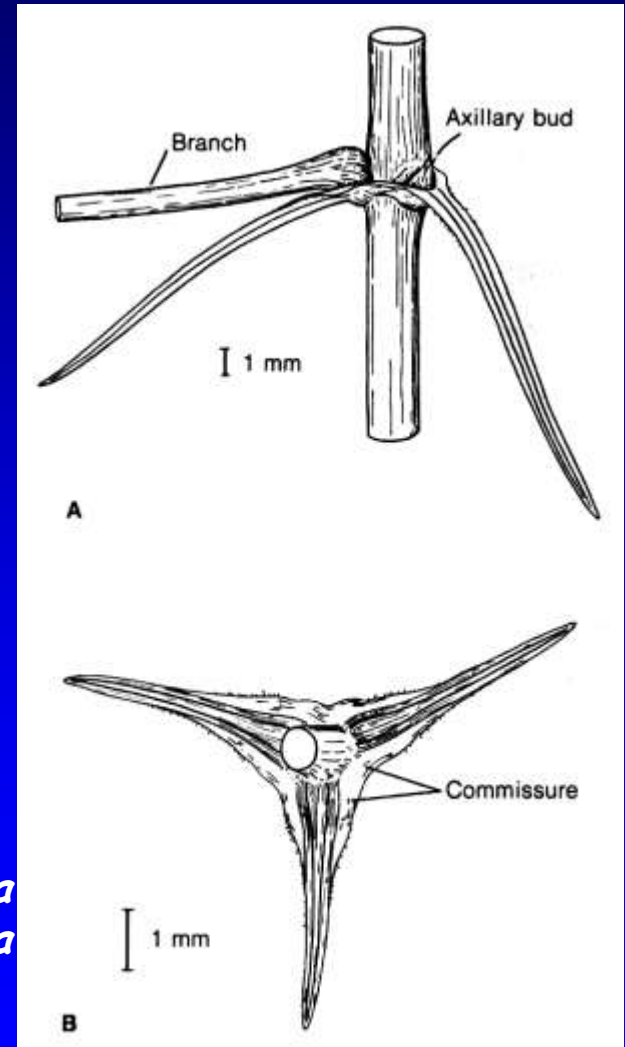
Elementos traqueais de *Ephedra californica*

- ♦ folhas com bainha

Folhas de *Ephedra foliata*

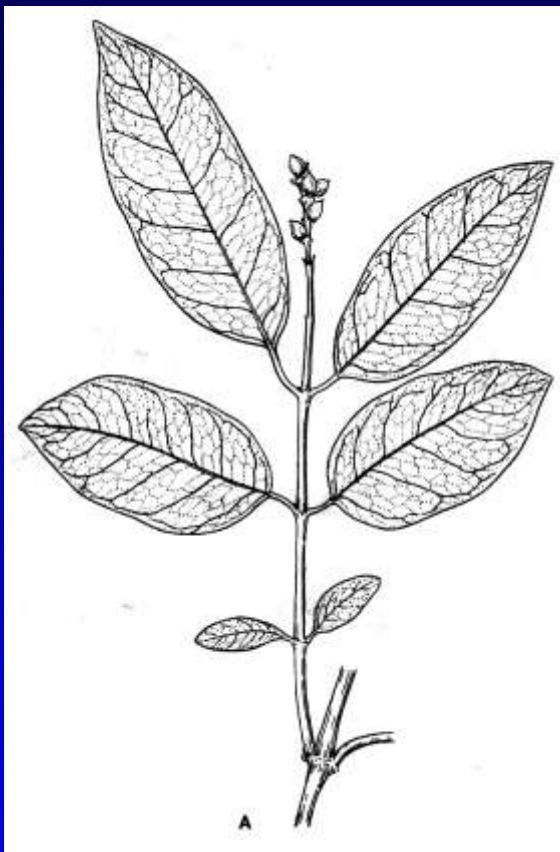
Gifford & Foster 1989

- ♦ múltiplas gemas axilares



♦ folhas opostas

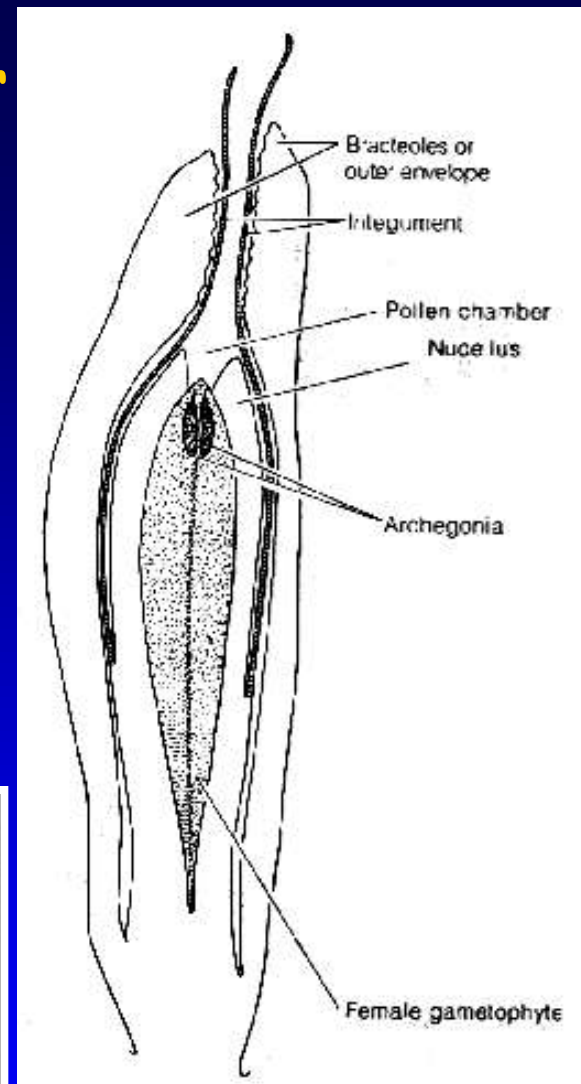
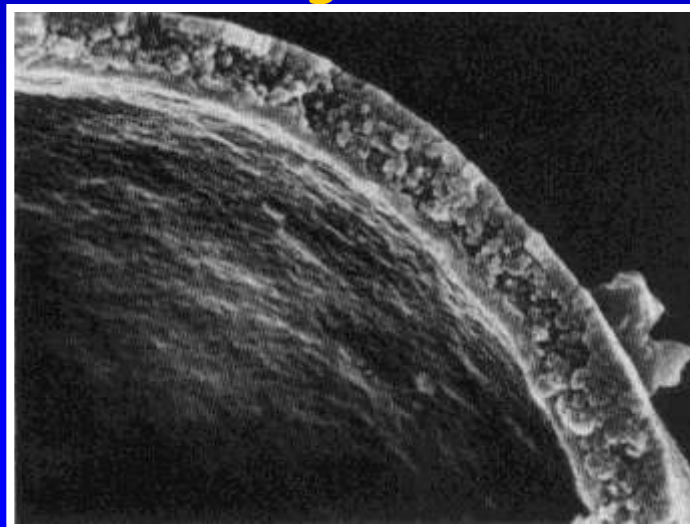
♦ micrópila tubular



Ramo de *Gnetum indicum* (Gifford & Foster 1989)

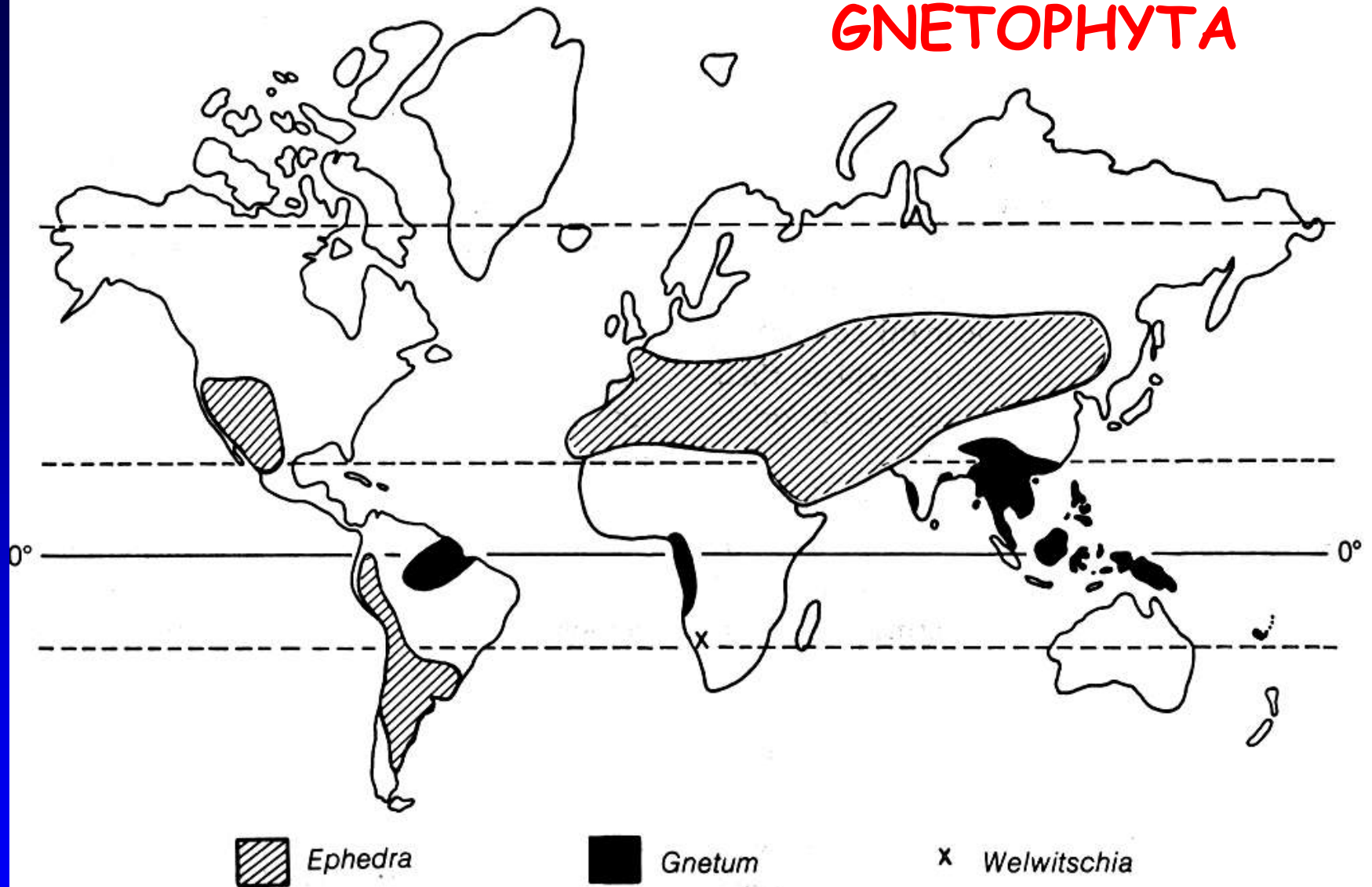


♦ pólen estriado, com ectexina granular



óvulo de *Ephedra foliata* (Gifford & Foster 1989)

GNETOPHYTA



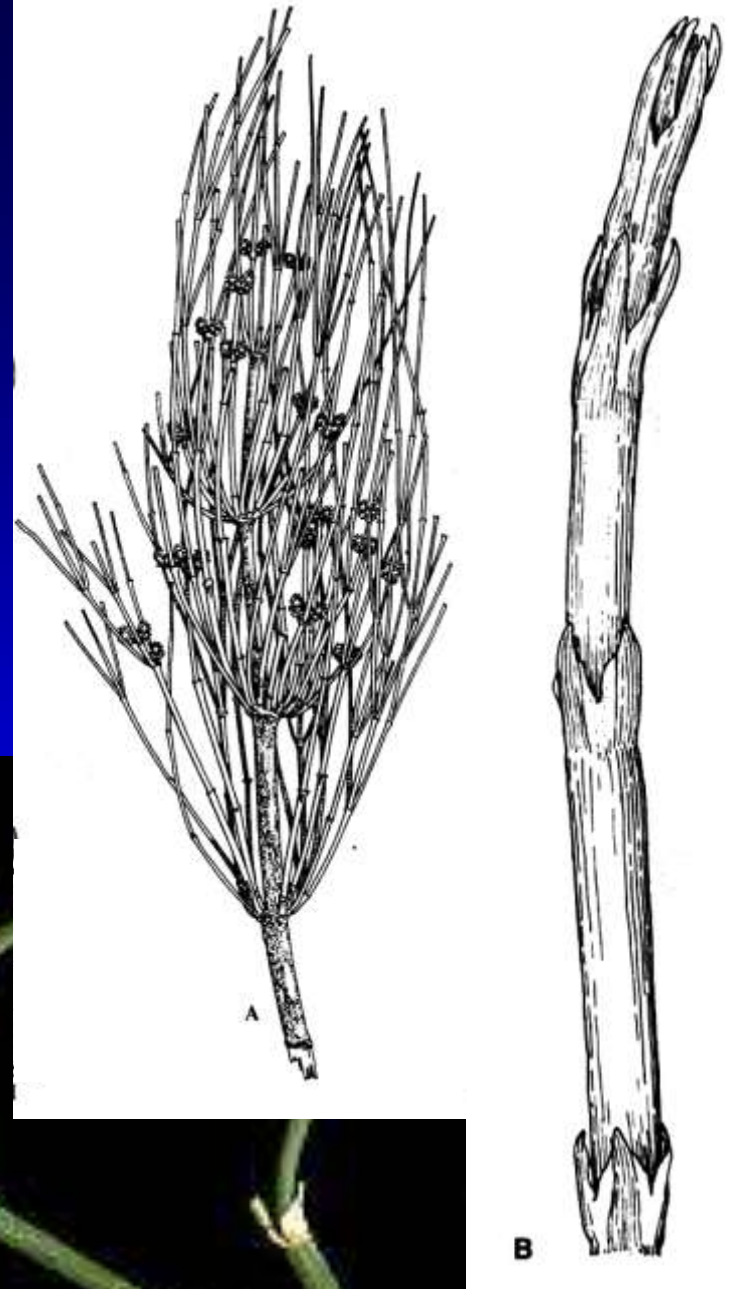
Distribuição dos gêneros *Ephedra*, *Gnetum* e *Welwitschia*
(Gifford & Foster 1989)

EPHEDRALES GNETOPHYTA

EPHEDRACEAE: *Ephedra* (50 spp.)

CARACTERES DIAGNÓSTICOS

- arbustos muito ramificados, geralmente escandentes
- ramos verticilados ; geralmente verdes e fotossintetizantes
- folhas opostas ou verticiladas, reduzidas ou escamiformes, fundidas basalmente numa bainha
- fonte da droga efedrina



EPHEDRACEAE - *Ephedra*

- plantas principalmente dióicas
- microstróbilo com agrupamentos de 1-10 anteróforos; brácteas opostas

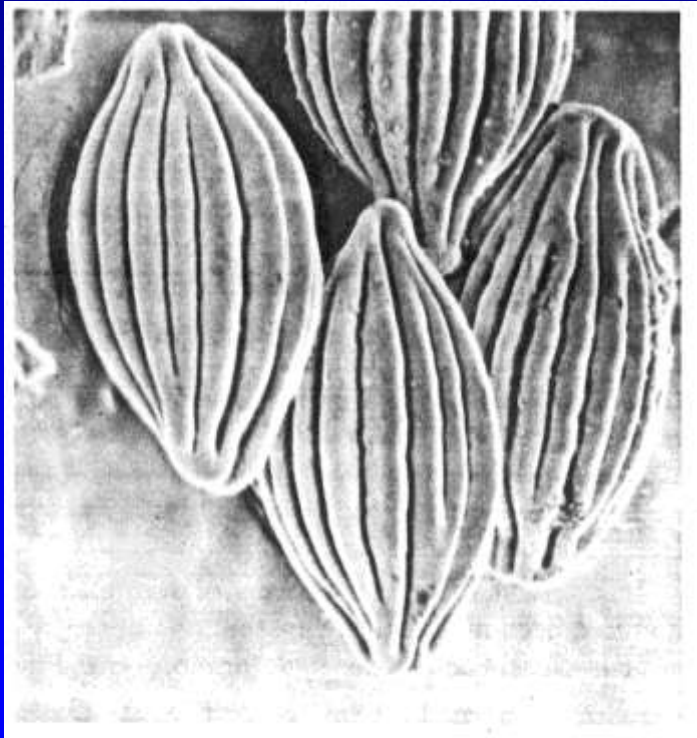
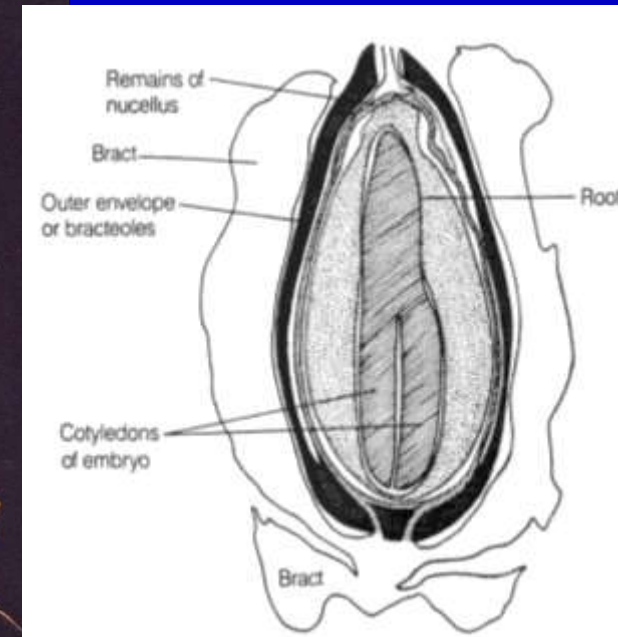
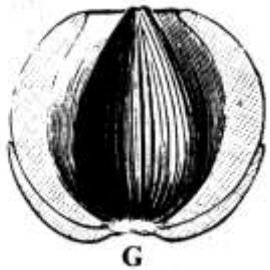
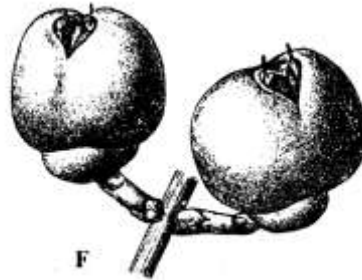
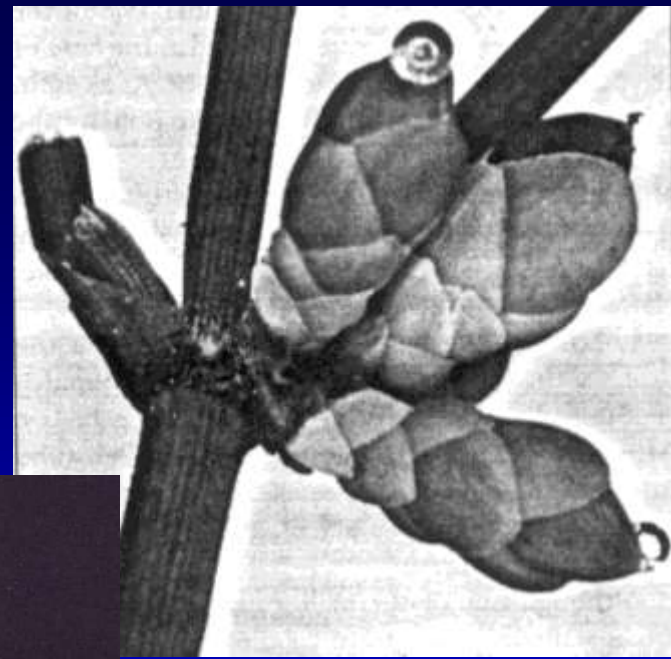


FIGURE 18-15 Scanning electron micrograph of a group of pollen grains of *Ephedra* sp. Note the prominent longitudinal (meridional) ridges characteristic of the pollen of this genus ($\times 700$).



-EPHEDRACEAE - *Ephedra*

- megastróbito com invólucro de brácteas opostas ao redor dos óvulos
- sementes 1-2(-3) por invólucro



GNETALES - GNETACEAE

GNETOPHYTA

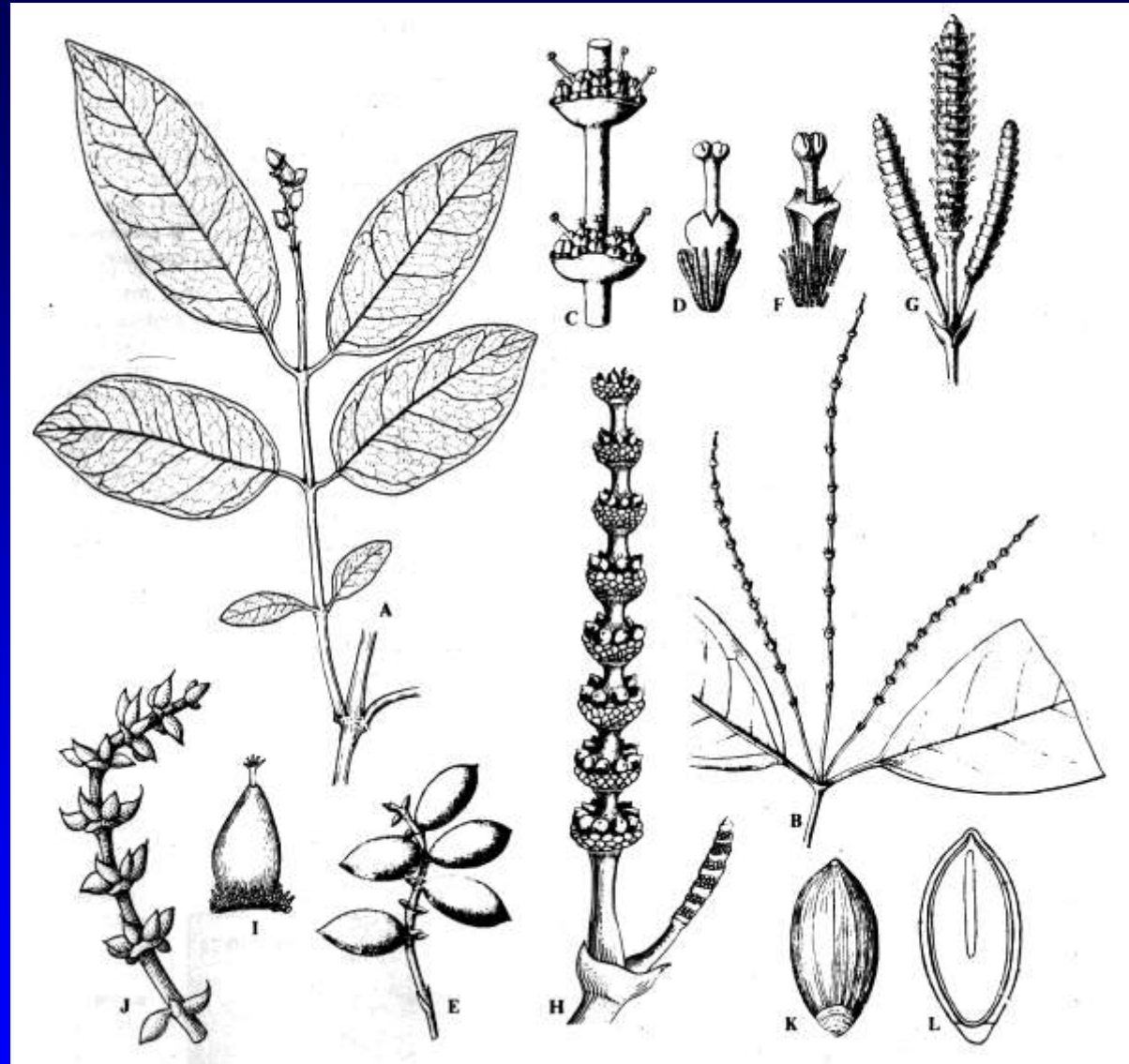
Gnetum (40 spp.)

CARACTERES DIAGNÓSTICOS

lianas lenhosas,
raramente árvores
(*Gnetum gnemon*)
ou arbustos

- folhas simples,
largas e opostas;
com nervação
reticulada

- plantas dióicas



Gnetum: A. *G. indicum*; B -E. *G. africanum*; F, *G. G. latifolium*; H-L. *G. gnemon* (Kubitzki 1990)

Microstróbilo



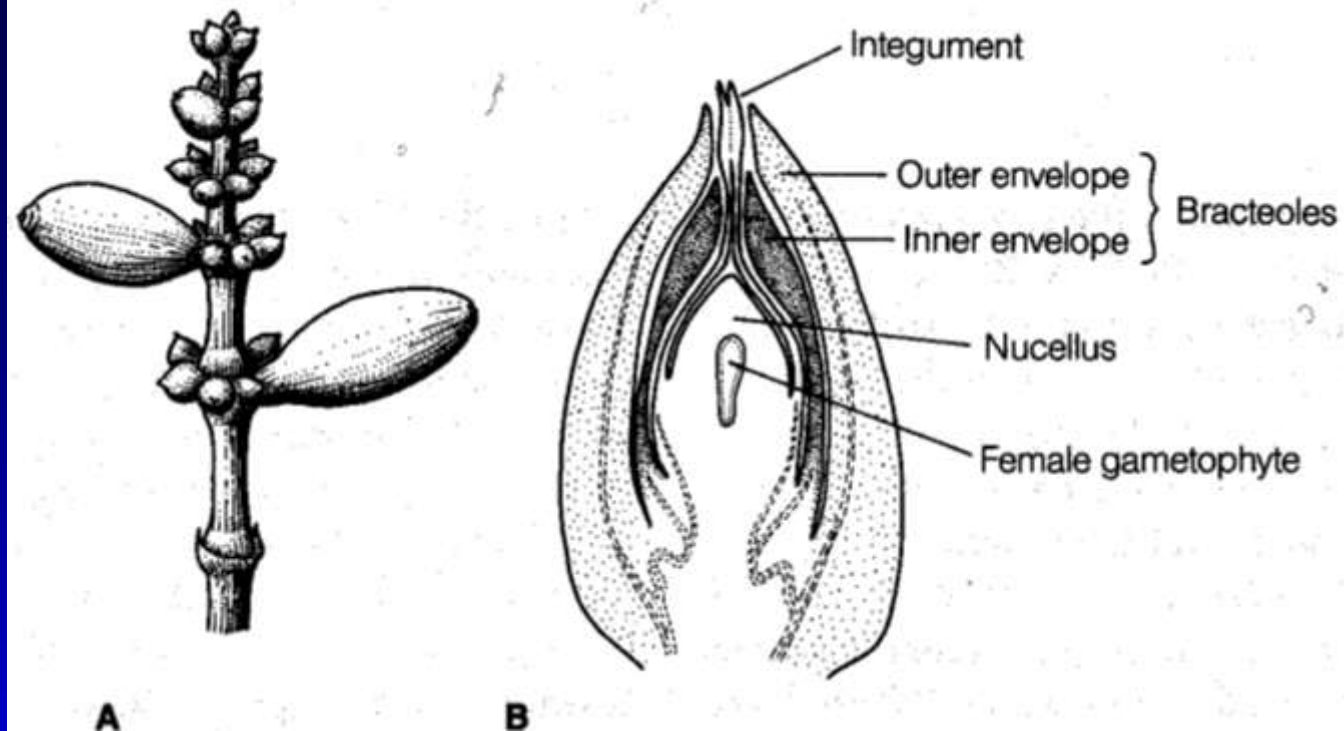
GNETOPHYTA
GNETACEAE
Gnetum 40 spp.

Lianas de
florestas
úmidas



GNETACEAE

Gnetum



megastróbito com sementes carnosas



GNETOPHYTA

Welwitschiales

Welwitschiaceae

Welwitschia mirabilis



WELWITSCHIALES

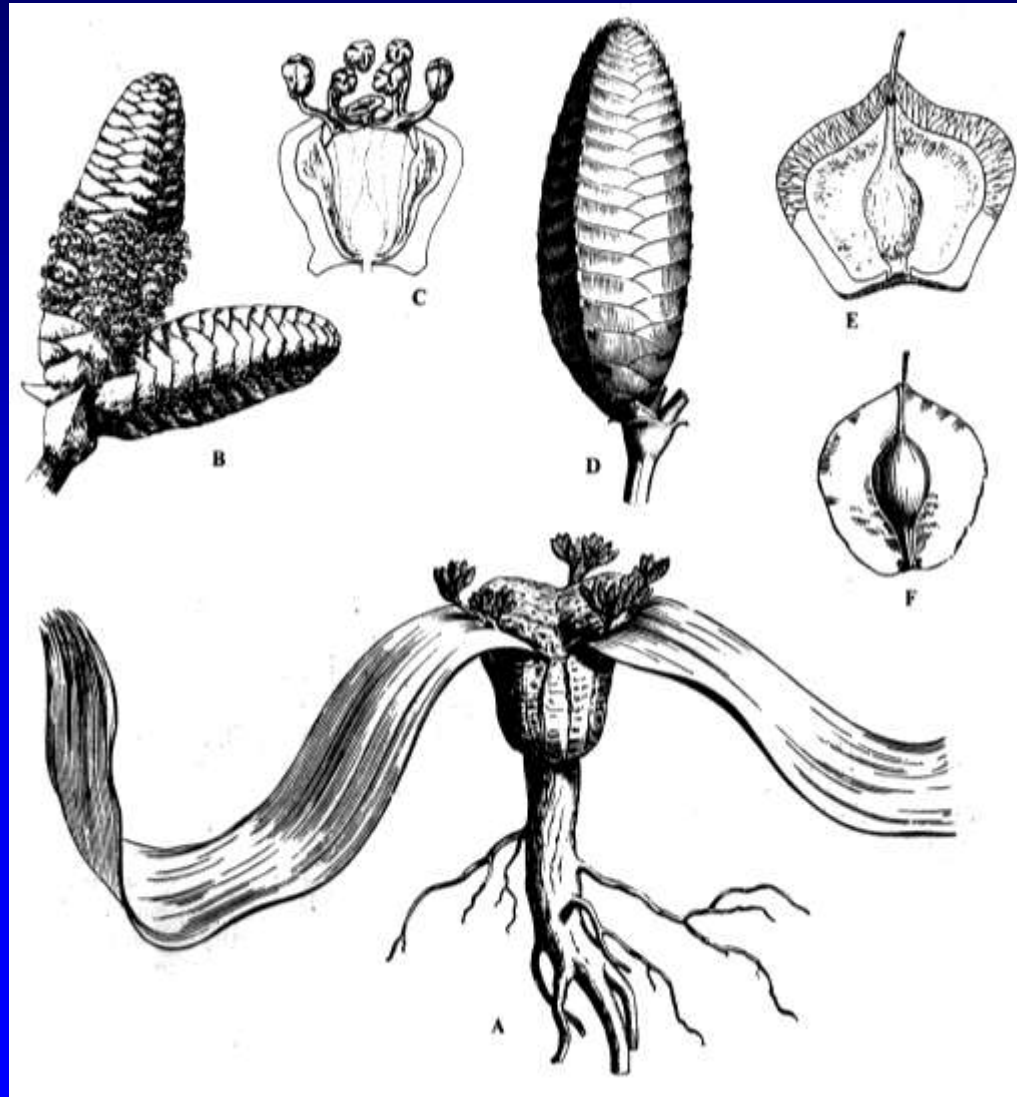
GNETOPHYTA

WELWITSCHIACEAE - *Welwitschia mirabilis*

CARACTERES DIAGNÓSTICOS

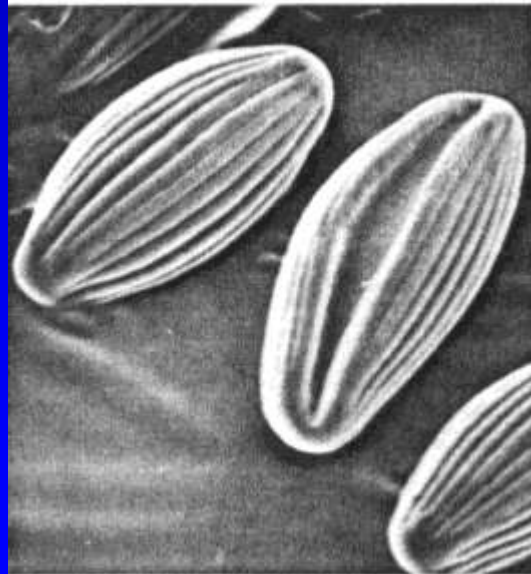
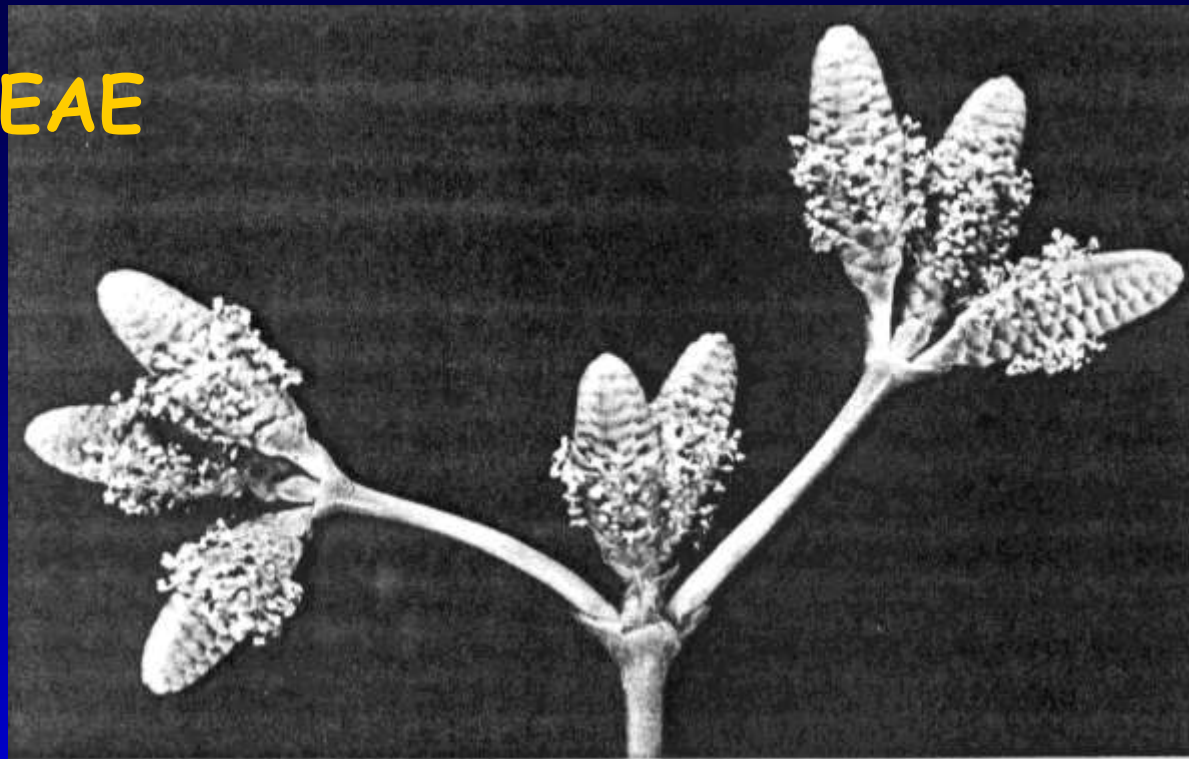
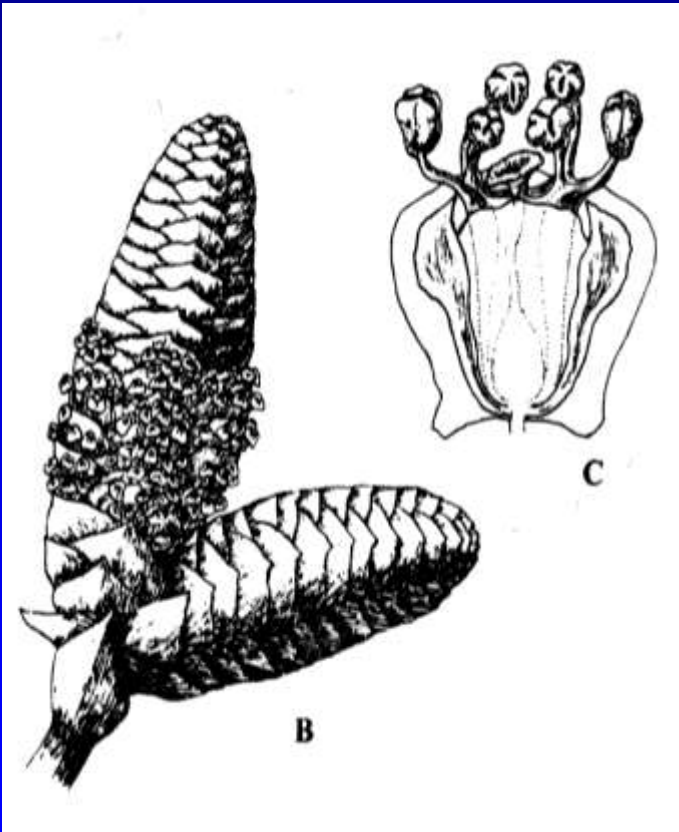
- caule curto, muito lenhoso e não ramificado
- 2 enormes folhas em forma de fita
- nervuras paralelas
- planta dióica
- óvulo envolto por brácteas

Kubitzki 1990



WELWITSCHIACEAE

Welwitschia



Welwitschia

FIGURE 18-22 *Welwitschia mirabilis*. A, portion of a microsporangiate shoot system showing strobili, bract and protruding microsporangioophores; B, pollen grain note median longitudinal furrow (sulcus) ($\times 700$). [A courtesy of Dr. D. W. Stevenson.]

"GIMNOSPERMAS"

ANTÓFITAS

CYCADOPHYTA GINKGOPHYTA PINOPHYTA GNETOPHYTA ANGIOSPERMAS



Loconte & Stevenson 1990

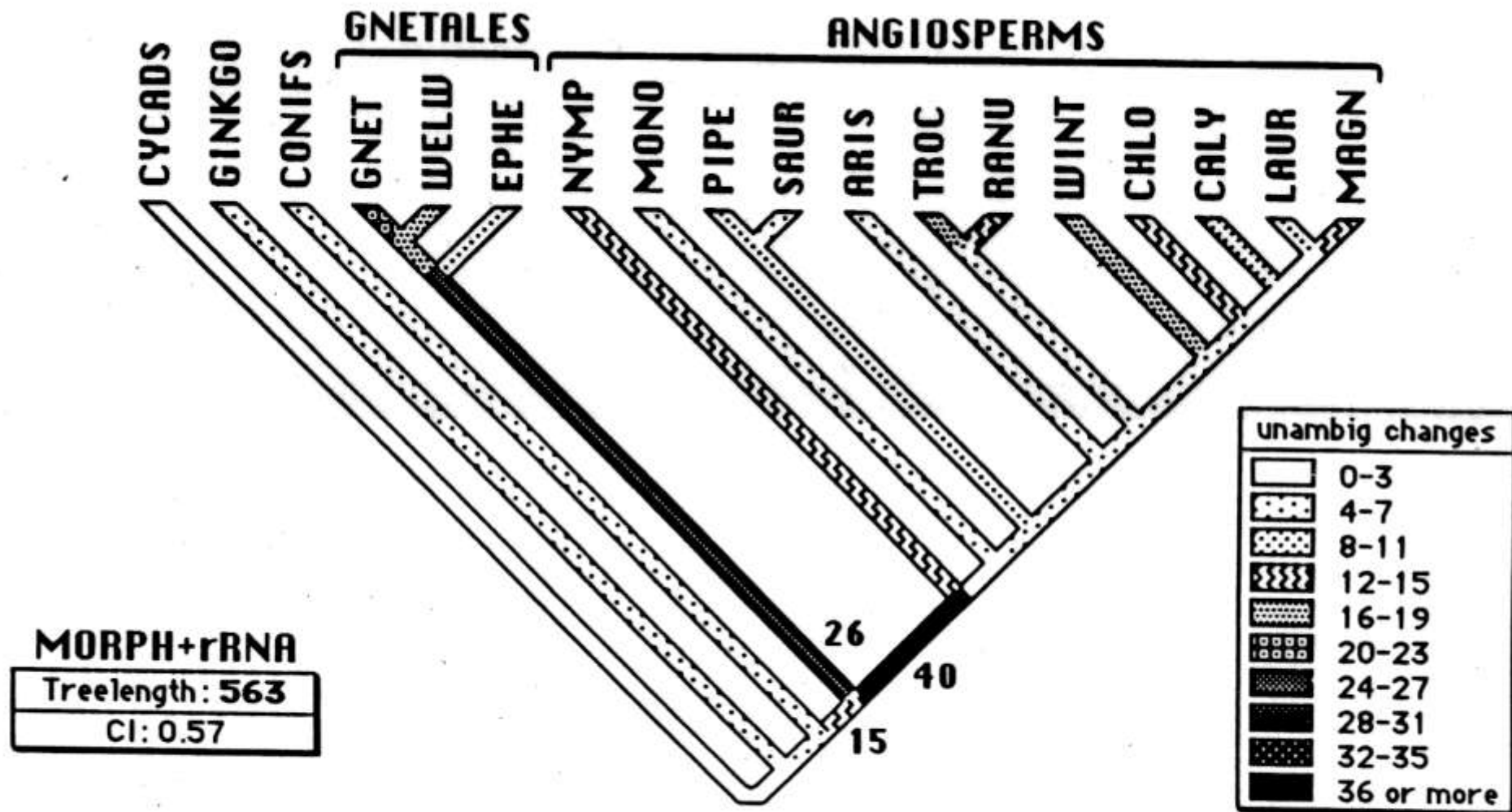
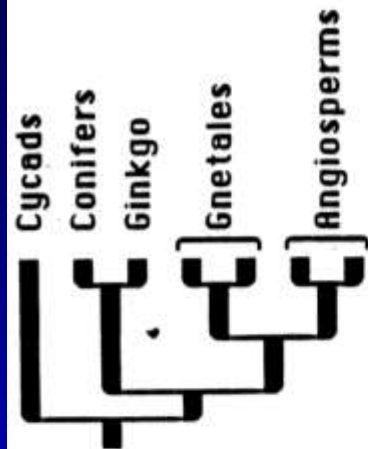
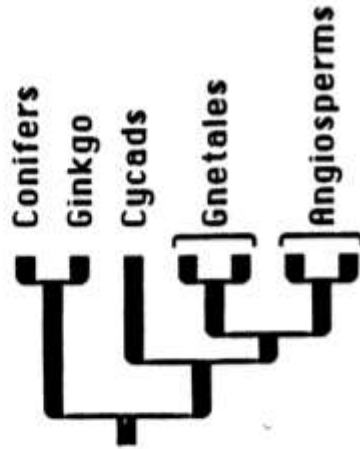


FIGURE 15. Single most parsimonious tree found in analysis of the combined morphological and rRNA data set, showing the number of unambiguous changes supporting each node. Abbreviations as in Figure 8.

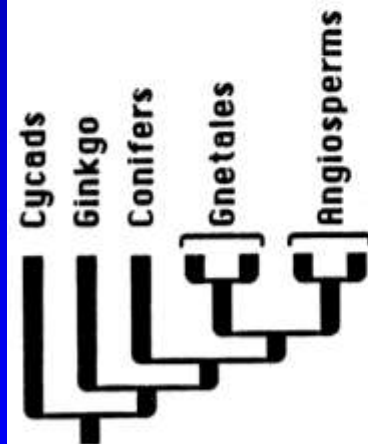
Morphology



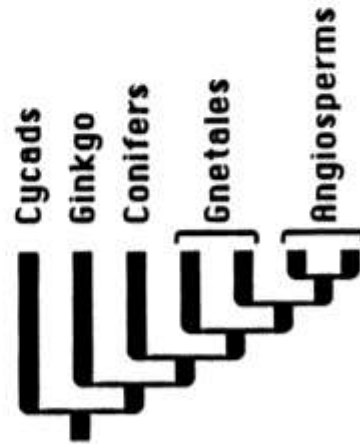
Crane 1985
Doyle & Donoghue 1986, 1992
Doyle 1996



Doyle & Donoghue 1986, 1992
Doyle 1996

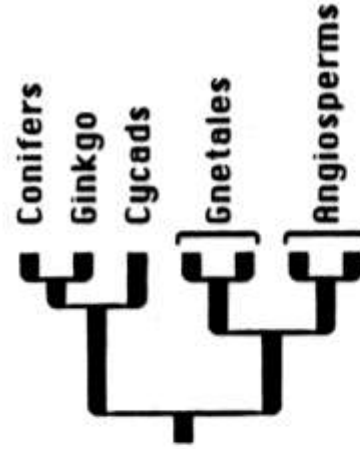


Loconte & Stevenson 1990
Doyle & Donoghue 1992 (R)

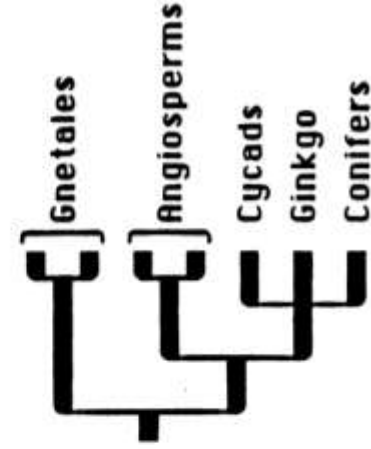


Nixon et al. 1994

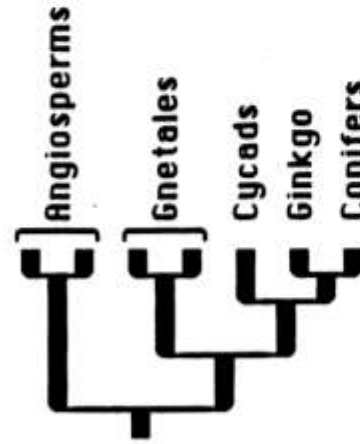
Molecular data



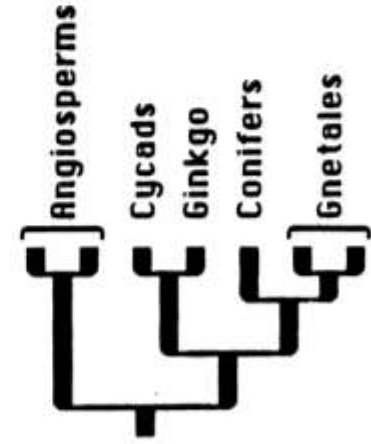
rRNA, Hamby & Zimmer 1992



rRNA, Hamby & Zimmer 1992
rbcL, Albert et al. 1994



rbcL, Hasebe et al. 1992
28S, Stefanovic 1996



cpITS, Goremykin et al. 1996
18S, Chaw et al. 1997
coxI, Bowe & DePamphilis 1997

Figure 3 Relationships among living groups of seed plants found in different analyses of morphological and molecular data

Chaw *et al.* 2000

rbcl

mt SSU rDNA

nu SSU rDNA

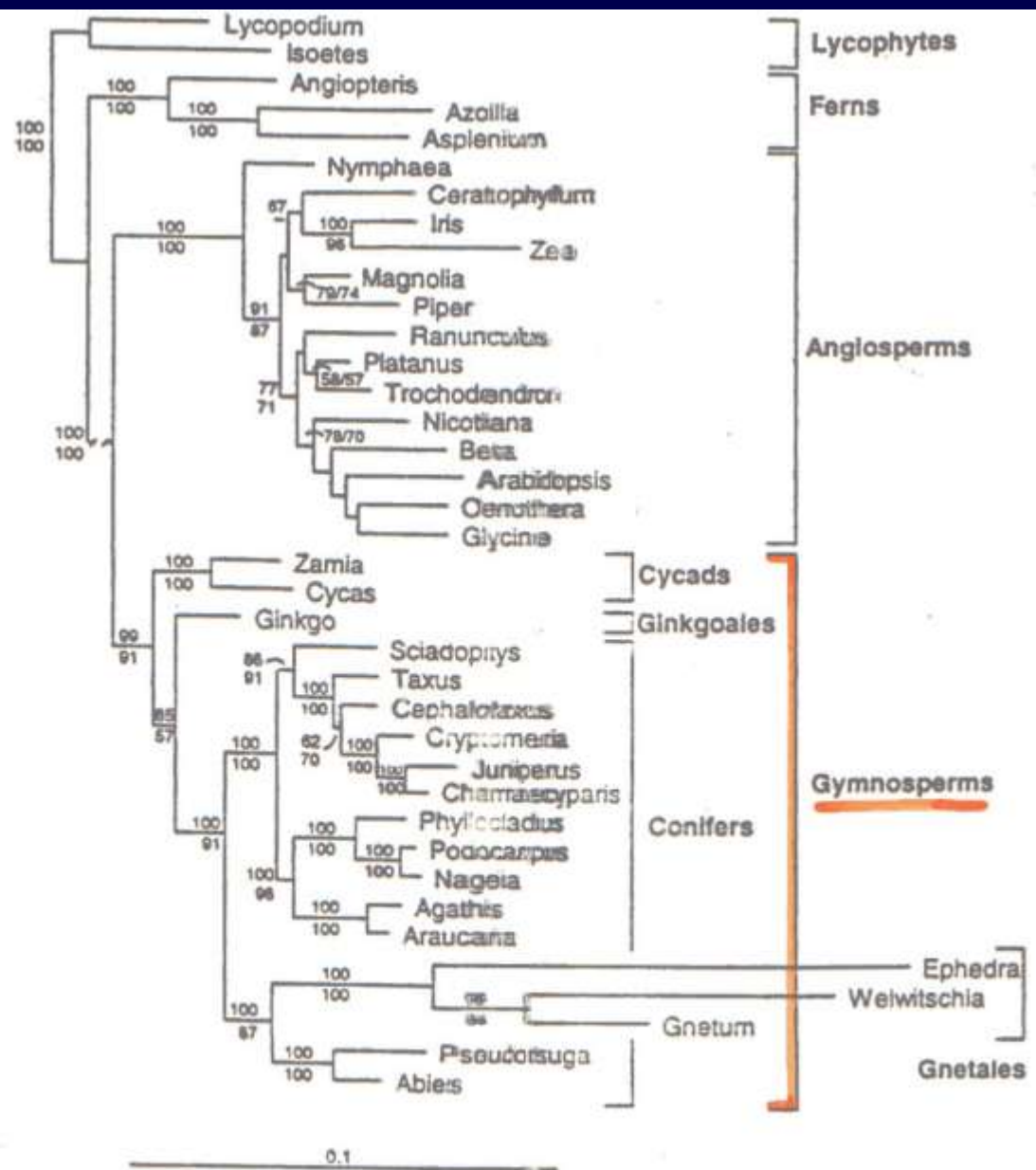
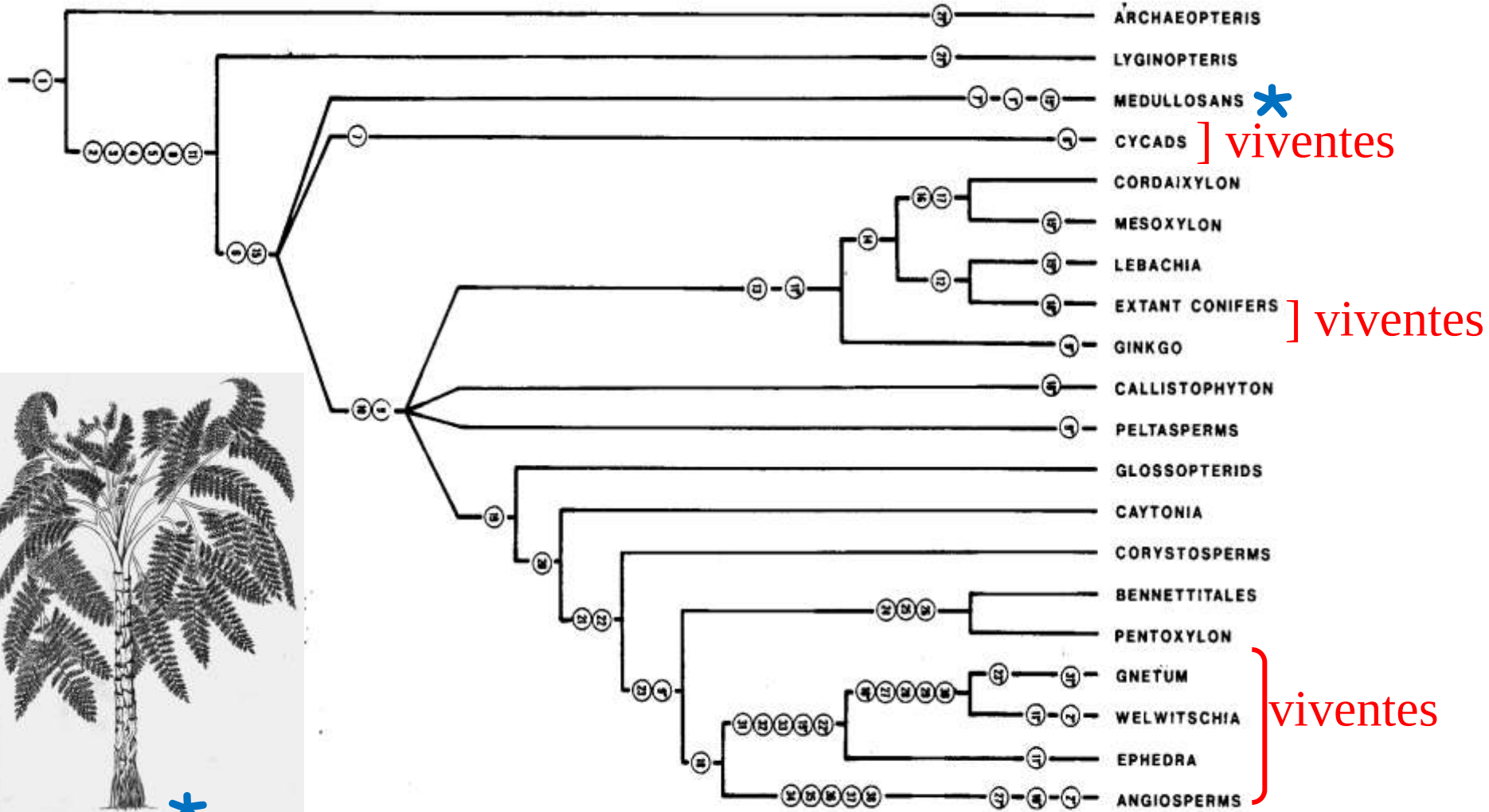


Fig. 4. Analysis of a combined dataset of all three genes. The ML tree shown has a log likelihood = -35,774.90 and was estimated by using a ti/tv ratio = 2.1. All BS values >50% are shown above (ML no-rates) and below (MP) nodes.

Acesso à informação paleontológica (campo praticamente exclusivo da morfologia)



Medullosa

Crane 1985

Specht & Bartlett
2009

baseado em Doyle
2008

e Soltis et al. 2008

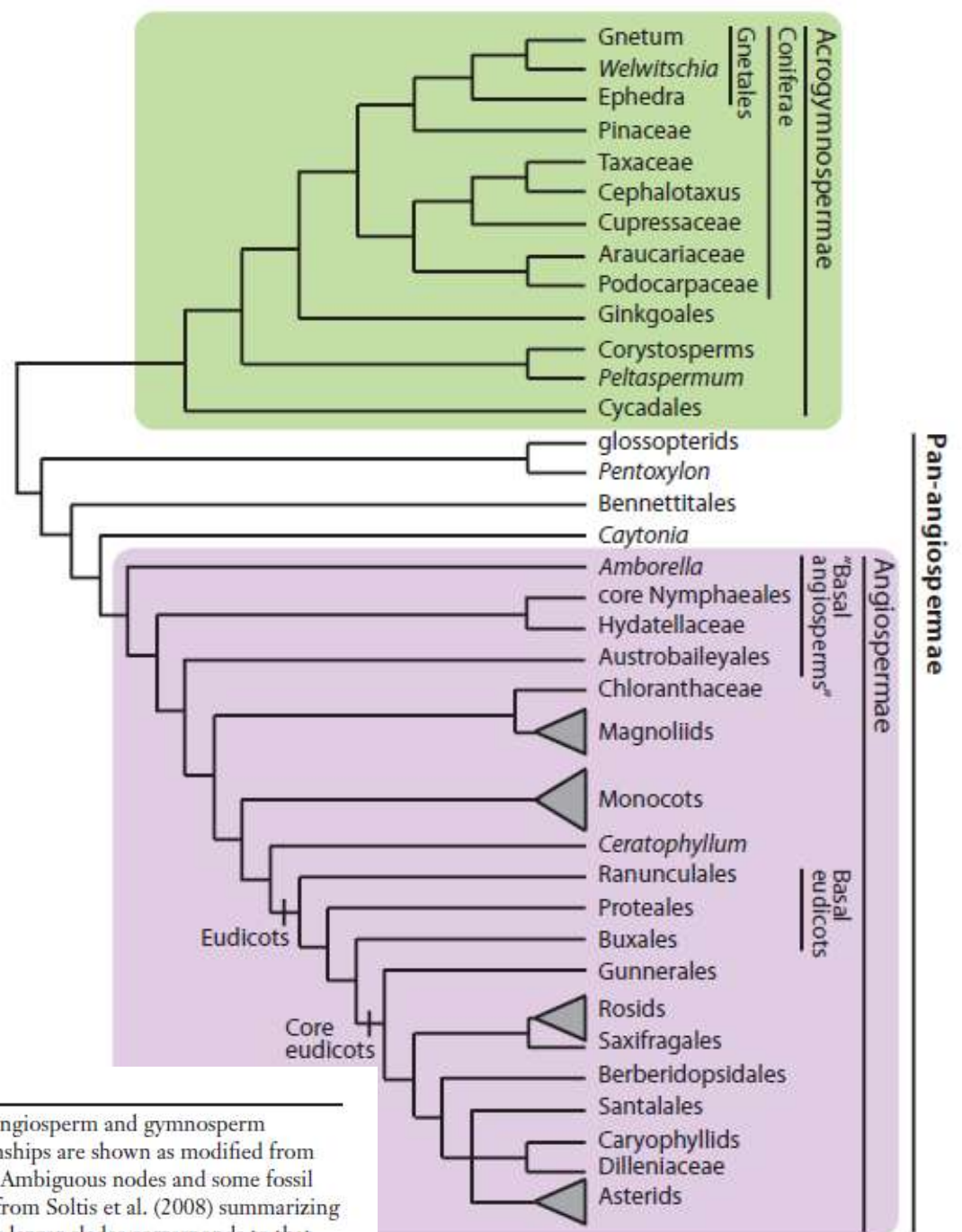


Figure 1

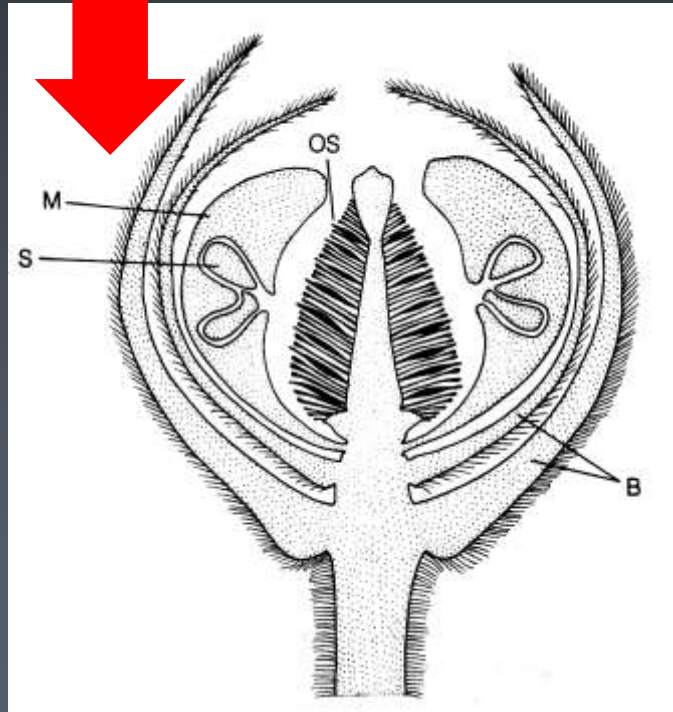
Summary topology of current views and recent advances in deep-level angiosperm and gymnosperm relationships. Acrogymnospermae and stem lineage angiosperm relationships are shown as modified from Doyle's (2008) analysis including fossil taxa with a molecular backbone. Ambiguous nodes and some fossil taxa are excluded if not discussed in text. Angiosperm relationships are from Soltis et al. (2008) summarizing Jansen et al. (2007) and Moore et al. (2007). Terminology used to define larger clades corresponds to that used throughout the text.

Grupos fósseis com sementes que compoem o clado
Pan-angiospermas segundo **Specht & Bartlett 2009**

Pentoxylum; CAYTONIALES - Permiano ao Triássico;
GLOSSOPTERIDALES - Triássico ao Cretáceo;
BENNETTITALES - Triássico ao Cretáceo

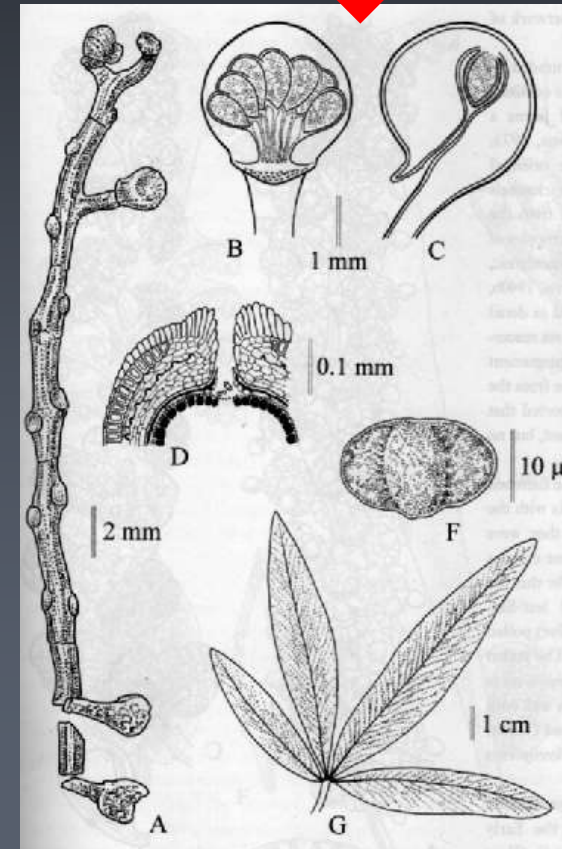


Doyle 2008 apud
Retallack & Dilcher 1981



Williamsoniella

Gifford & Foster 1989



Caytonia, Friis et al. 2011

ESPERMATÓFITAS

"GIMNOSPERMAS"

