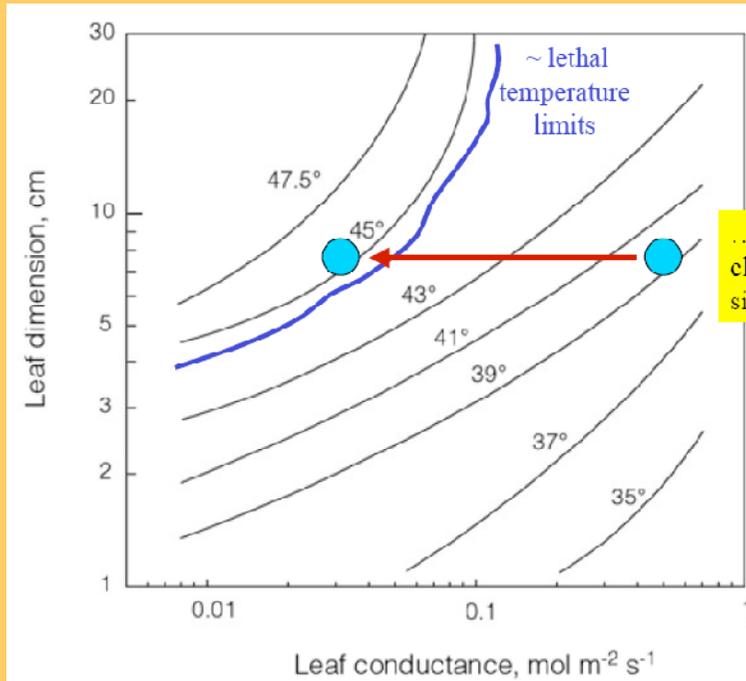
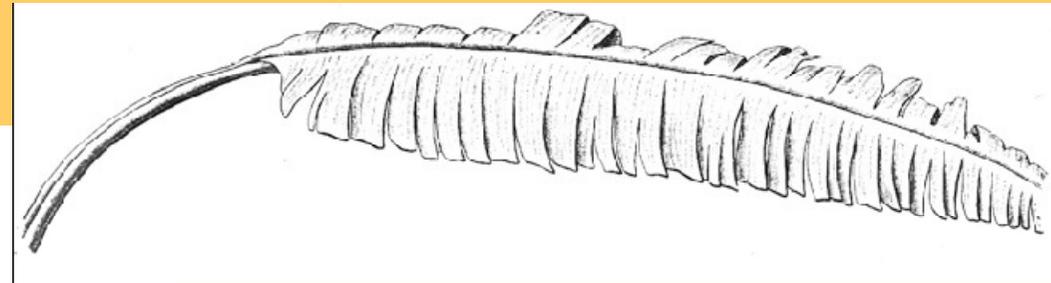
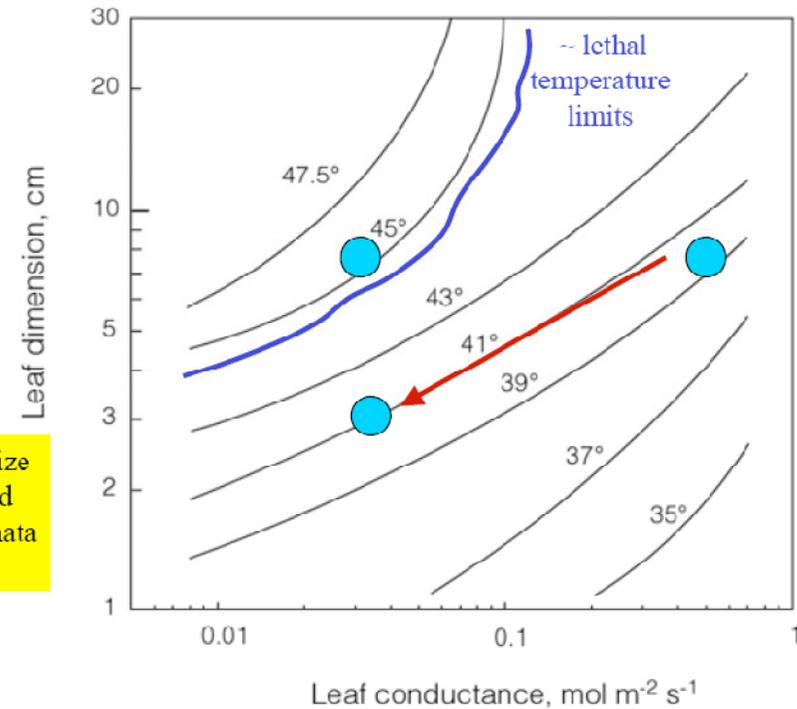


O balanço entre o acoplamento convectivo e a transpiração determinam a integridade fisiológica de folhas de bananeira.



... if the stomata closed and leaf size remained large

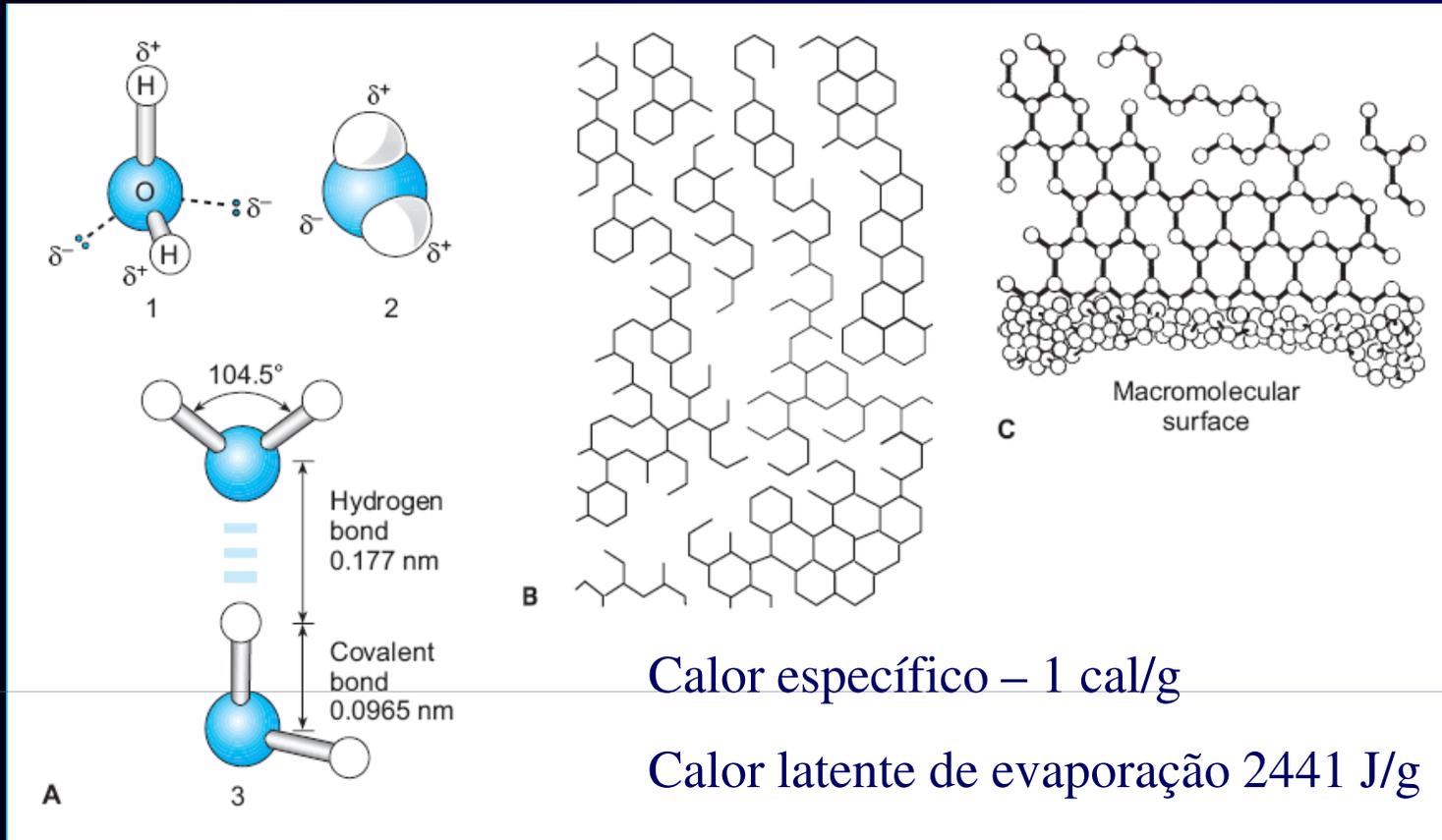


... if leaf size is decreased as the stomata closed

A água no meio aéreo

O conteúdo de água na atmosfera pode ser representado de diversas formas :

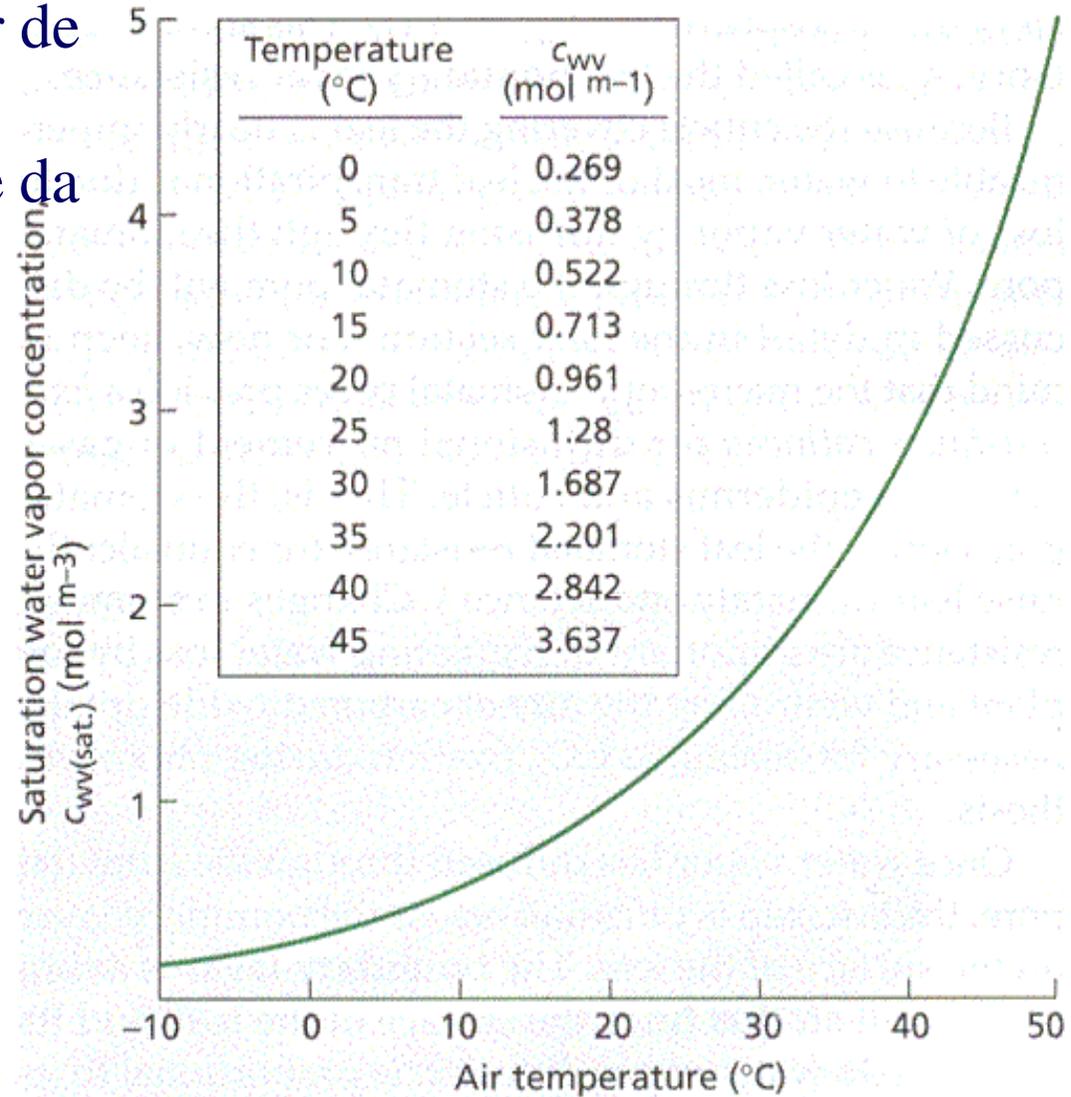
Concentração por volume	c_{wv}	mol m^{-3}
Pressão de vapor (pressão parcial de vapor d'água)	e_a	kPa
Umidade Relativa $= (e_a/e_s) * 100$, onde e_s é a pressão de vapor no ponto de saturação.	UR	%
Déficite de pressão de vapor $= e_s - e_a$	VPD	kPa



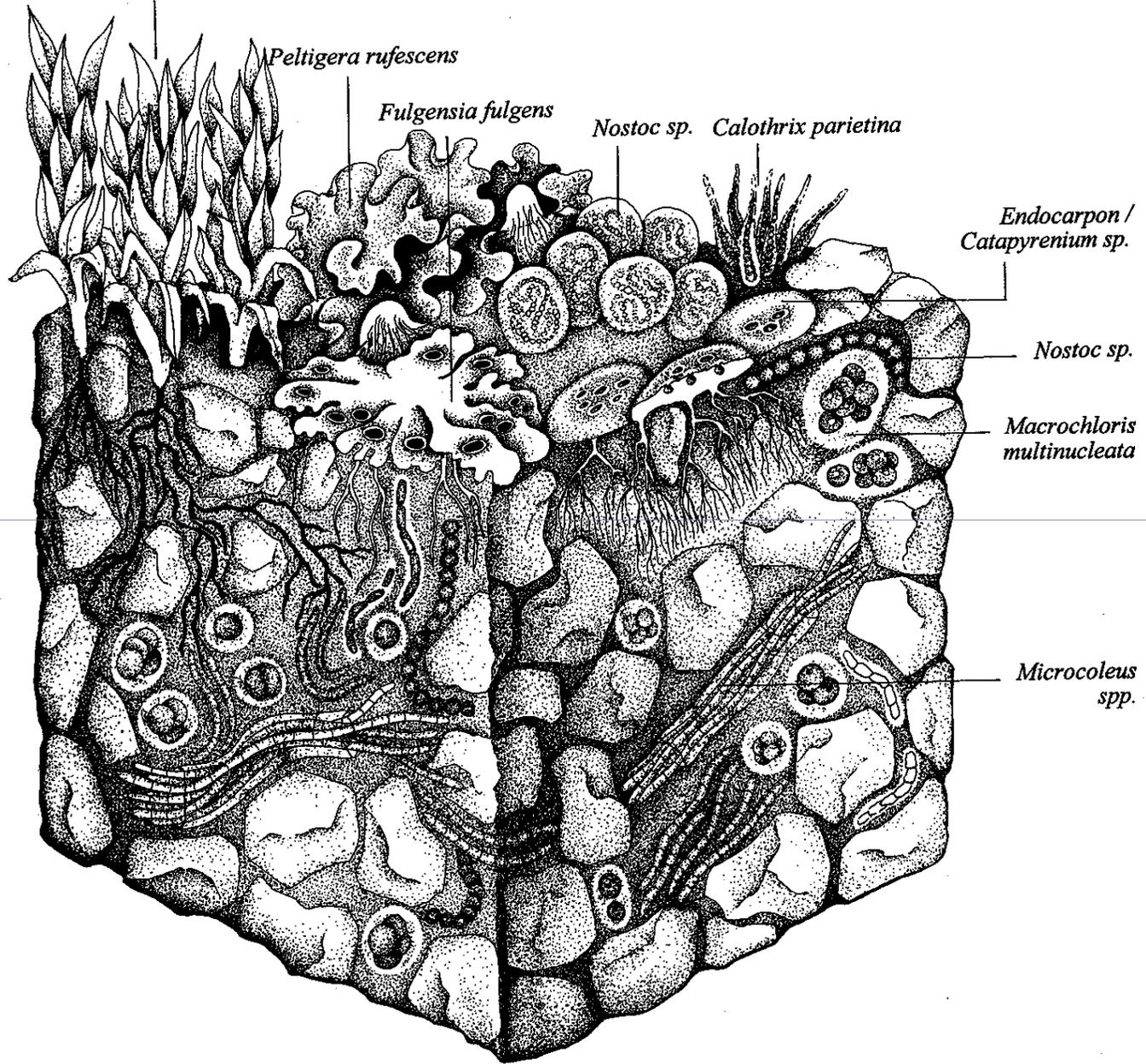
A interação da água com o balanço de energia é associada com as características peculiares desta substância, dadas pelo arranjo de elétrons do Oxigênio e sua interação com o Hidrogênio.

No sistema planta-atmosfera, o regime de temperaturas é compatível com as mudanças de estado da água. Desta forma, a água constitui o elo mais eficiente entre o fluxo de massa e de energia. Entretanto, a limitação de sua disponibilidade no ambiente terrestre e seu papel na manutenção da estrutura da planta e em funções fisiológicas básicas, parecem restringir o sucesso do uso de suas propriedades de dissipação de energia nas plantas terrestres.

A solubilidade do vapor de água na atmosfera depende principalmente da temperatura.



Bryum bicolor agg./ *Brachymenium* *exile*



Peltigera rufescens

Fulgensia fulgens

Nostoc sp. *Calothrix parietina*

Endocarpon / Catapyrenium sp.

Nostoc sp.

Macrochloris multinucleata

Microcoleus spp.

Angiospermas
típicas

Cenozoic Era
(65 mya to today)

Quaternary (1.8 mya to today)
Holocene (11,000 years to today)
Pleistocene (1.8 mya to 11,000 yrs)
Tertiary (65 to 1.8 mya)
Pliocene (5 to 1.8 mya)
Miocene (23 to 5 mya)
Oligocene (38 to 23 mya)
Eocene (54 to 38 mya)
Paleocene (65 to 54 mya)

Pteridófitas e
Pteridospermas

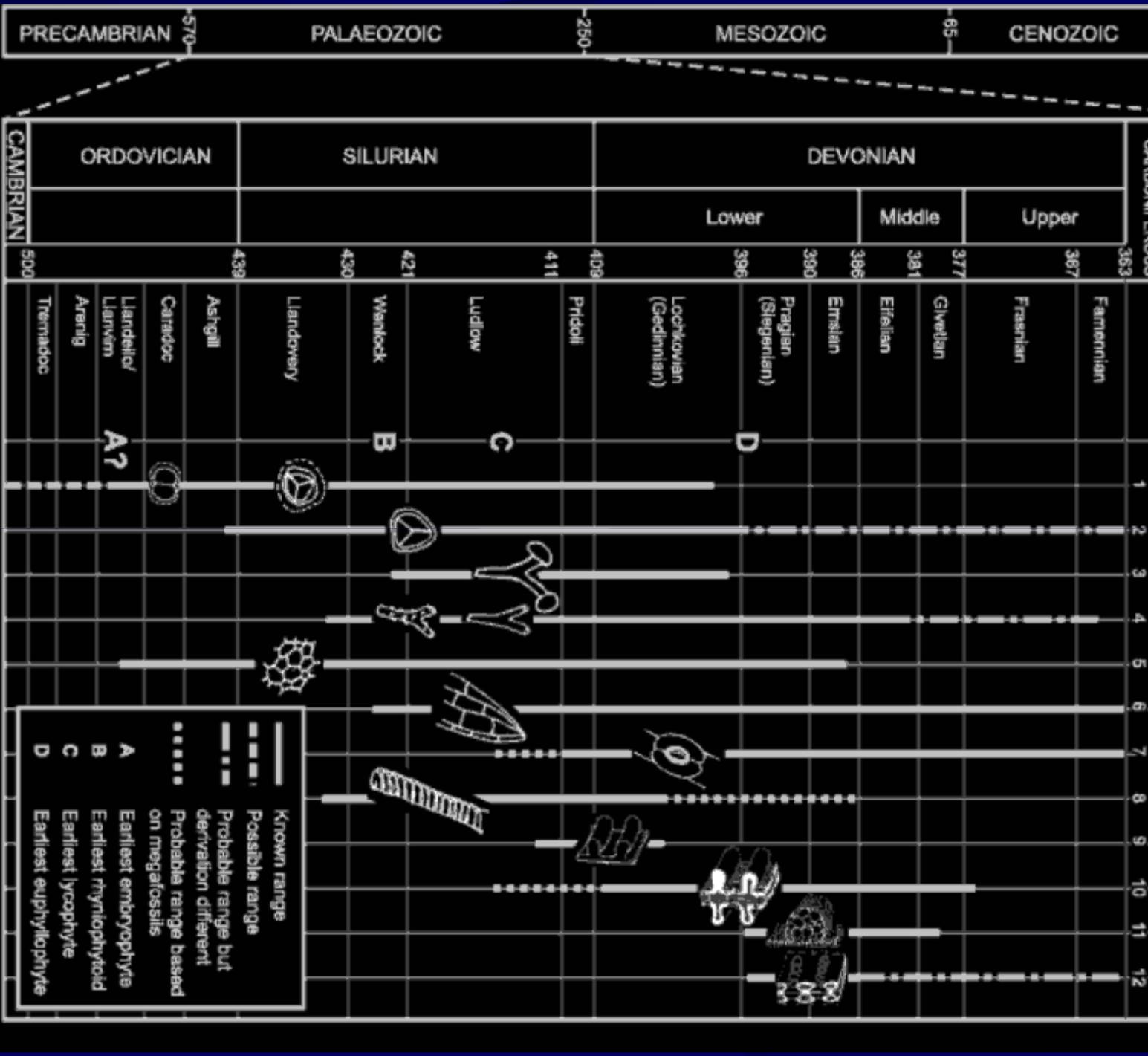
Mesozoic Era
(245 to 65 mya)

Cretaceous (146 to 65 mya)
Jurassic (208 to 146 mya)
Triassic (245 to 208 mya)

Primeiras
plantas
vasculares

Paleozoic Era
(544 to 245 mya)

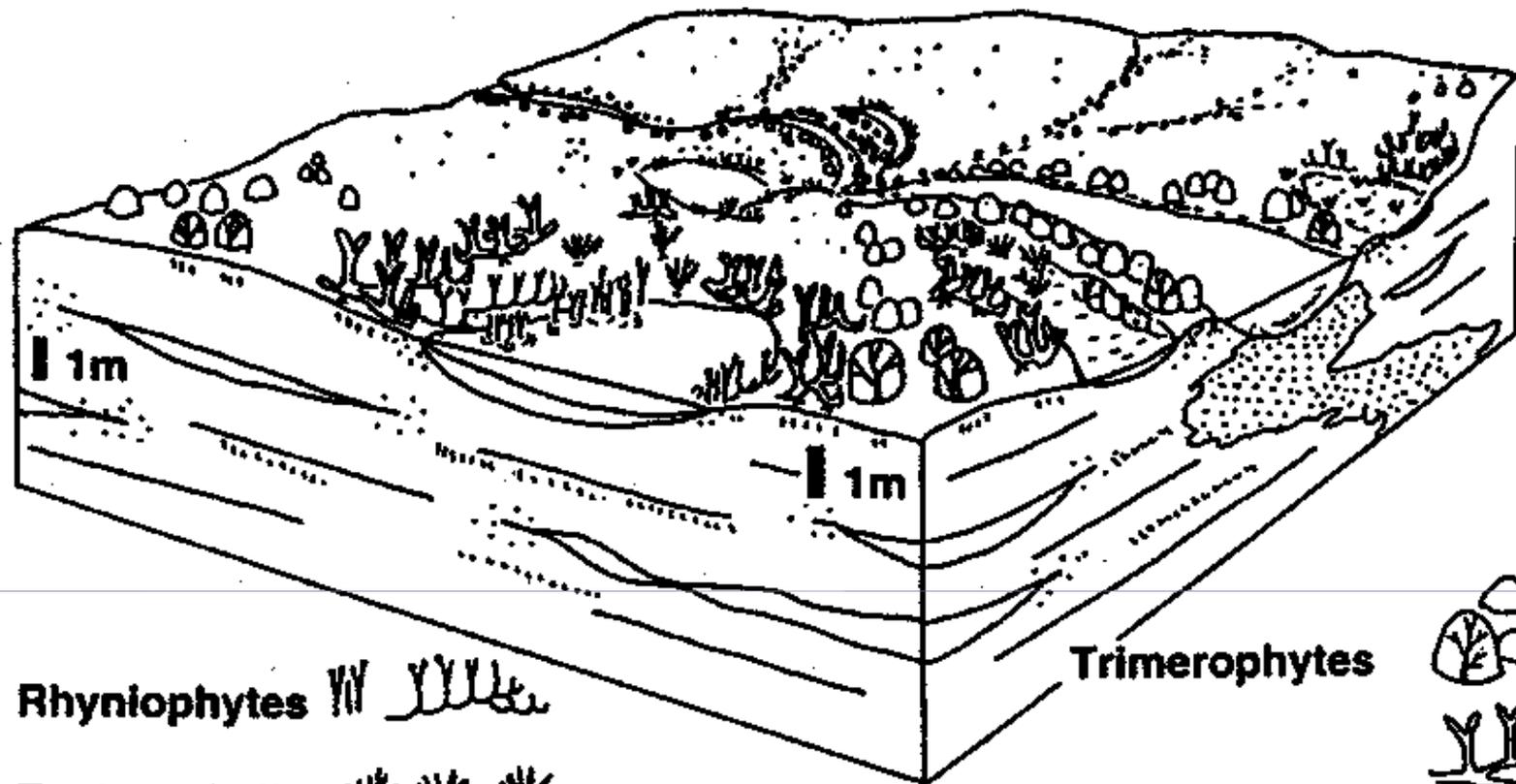
Permian (286 to 245 mya)
Carboniferous (360 to 286 mya)
 Pennsylvanian (325 to 286 mya)
 Mississippian (360 to 325 mya)
Devonian (410 to 360 mya)
Silurian (440 to 410 mya)
Ordovician (505 to 440 mya)
Cambrian (544 to 505 mya)



390 million years ago

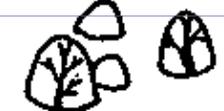


MAP KEY	Ancient landmass	Modern landmass	Ice caps & glaciers	Subduction zone (▼ direction of subduction)	Sea floor spreading ridge



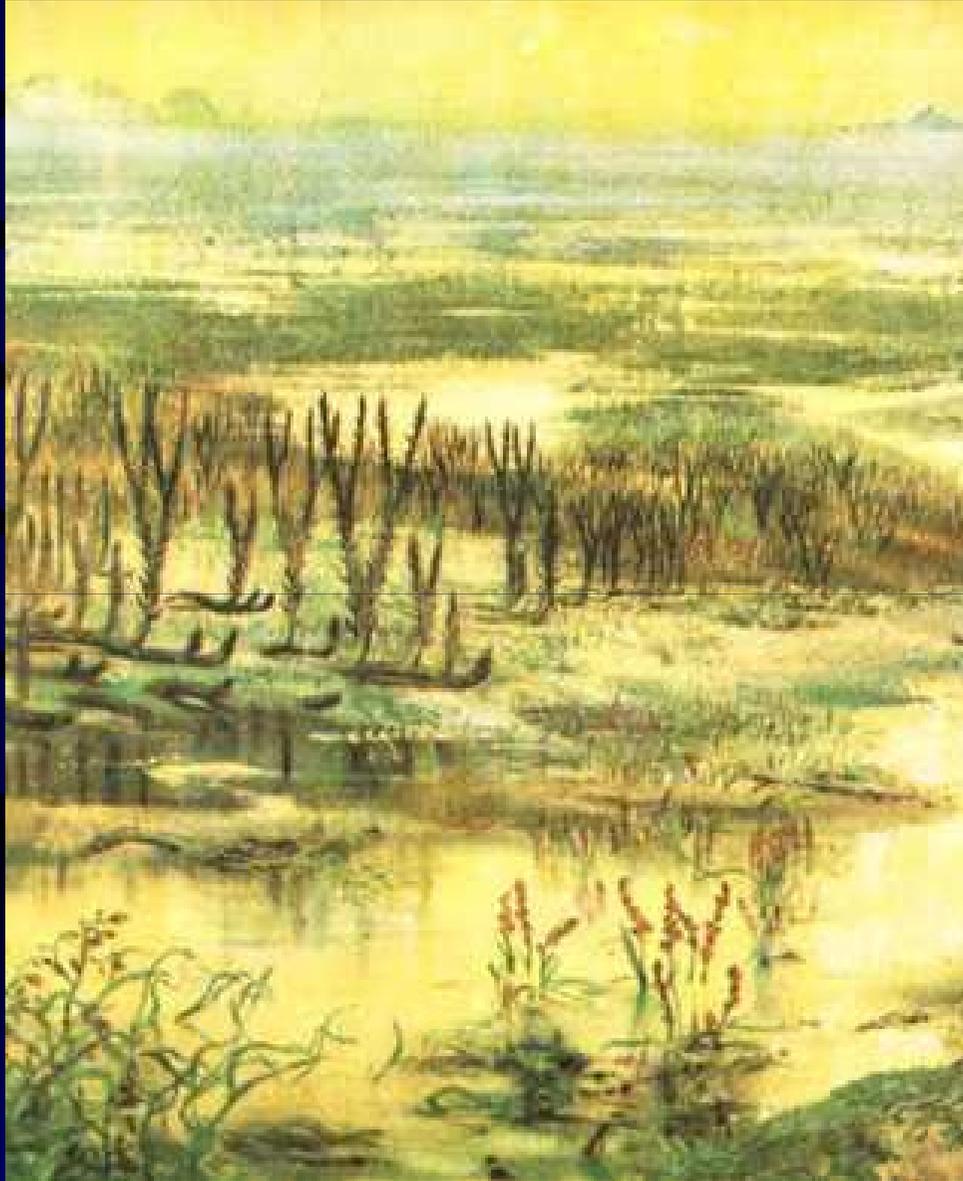
Rhyniophytes 

Zosterophylls 

Trimerophytes 

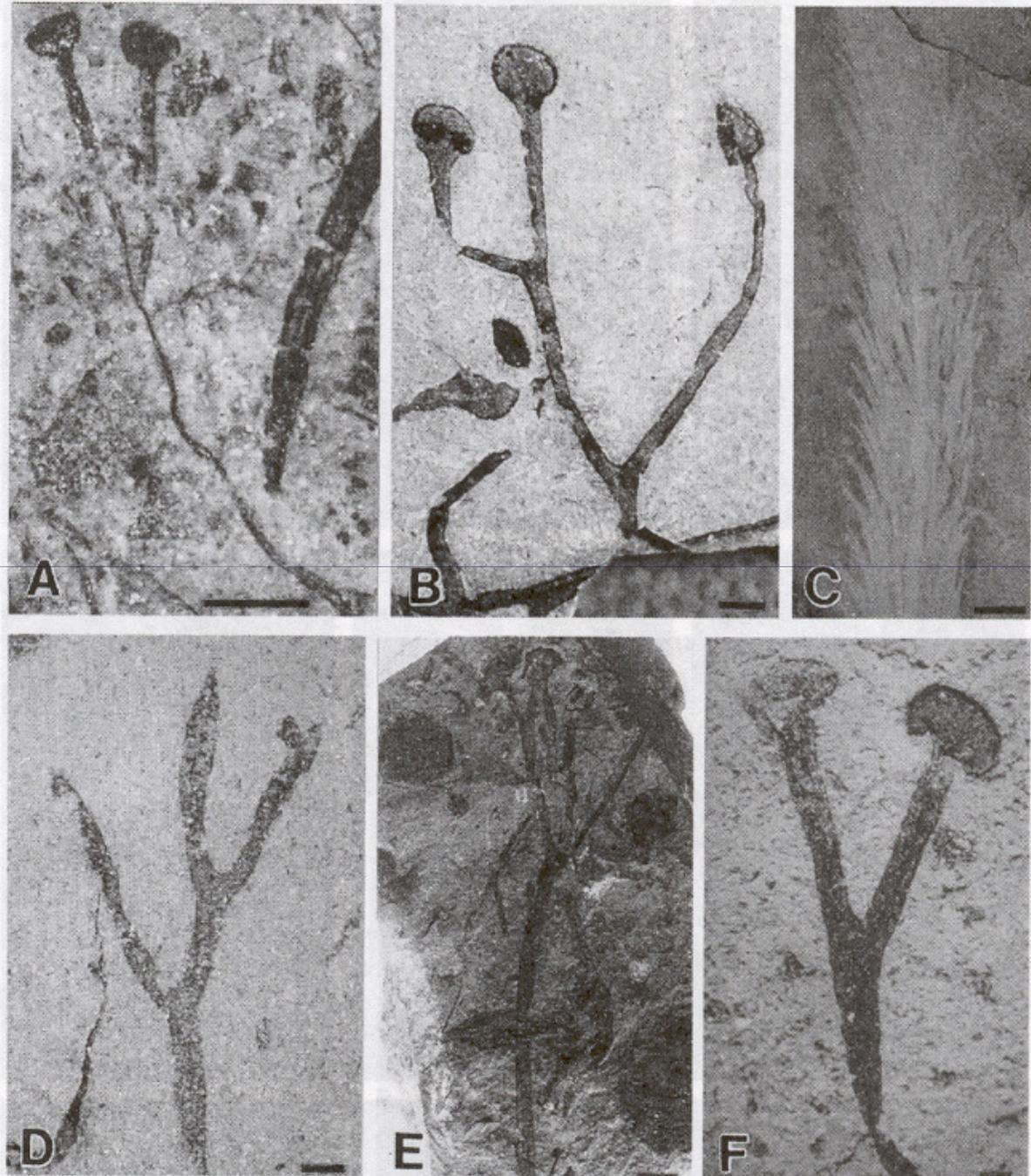
Drepanophycean
lycopsids 

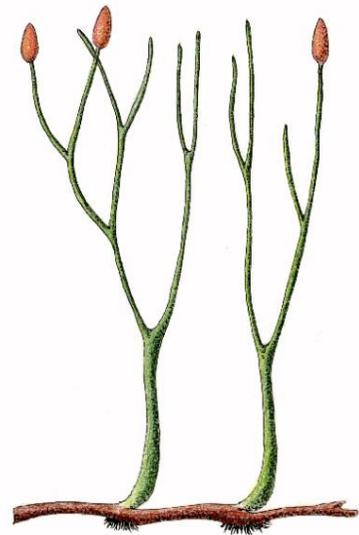
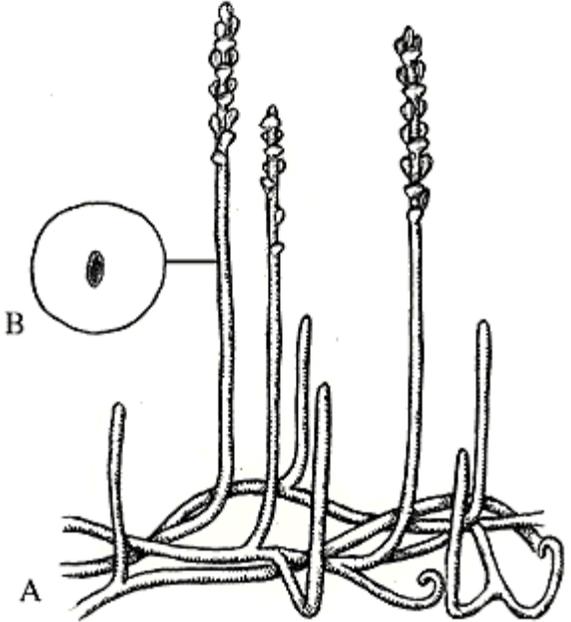
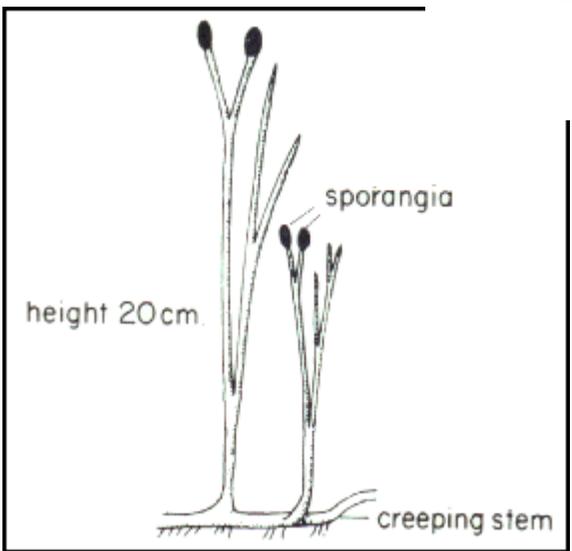
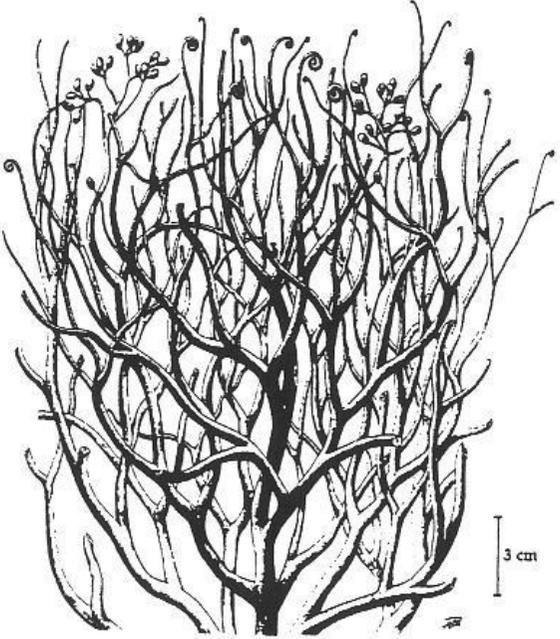
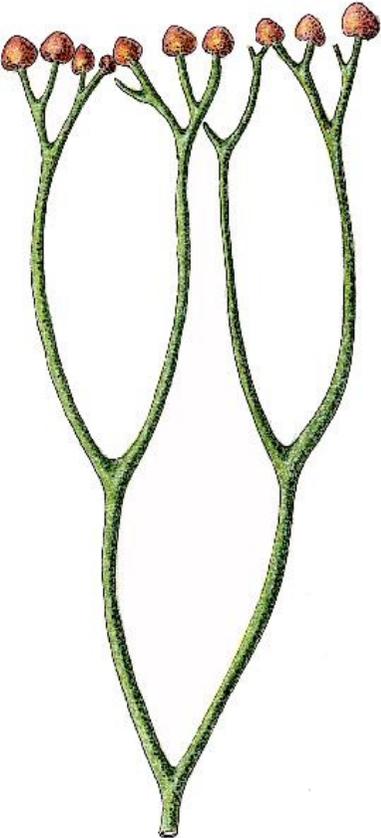
A Early Devonian (Siegenian/Pragian - Emsian)



Cooksonia e
Baragwanathia

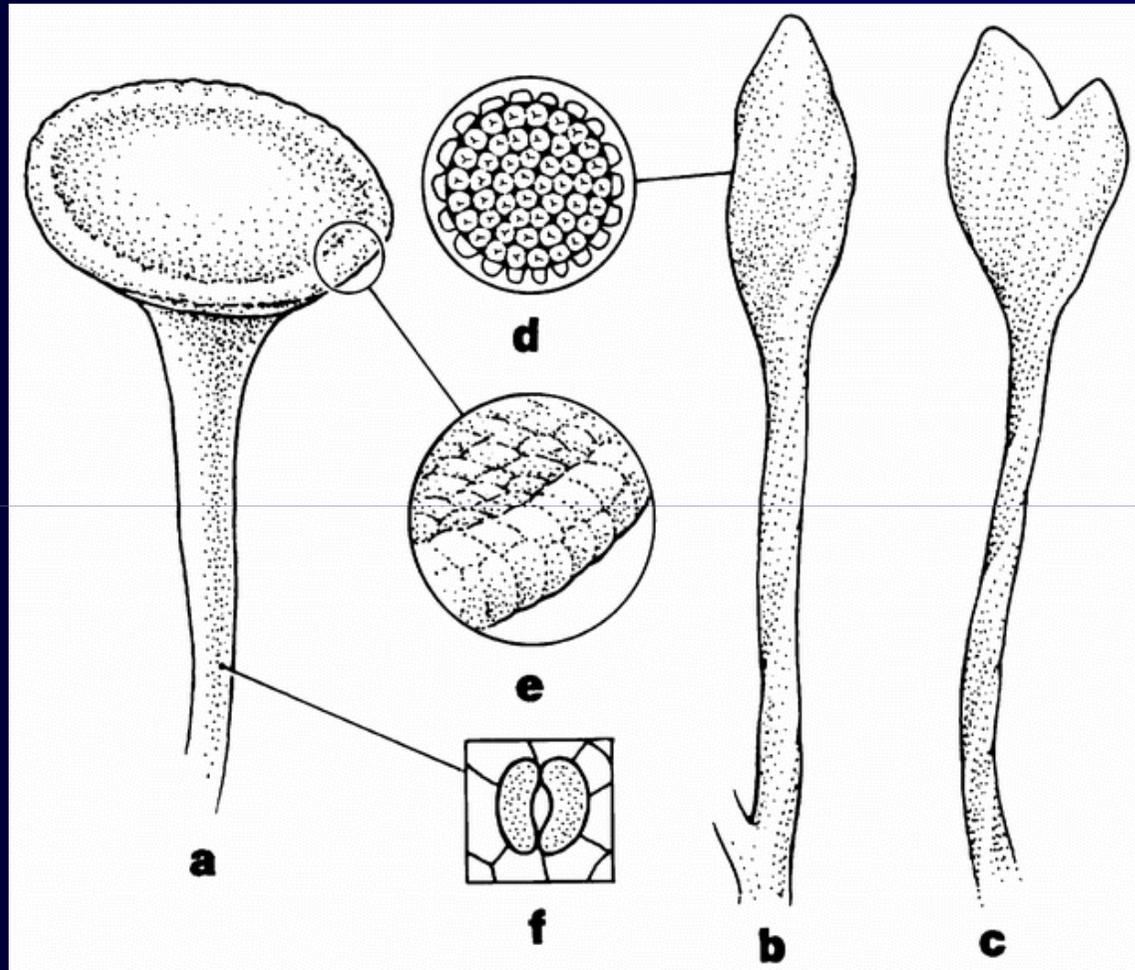
Siluriano

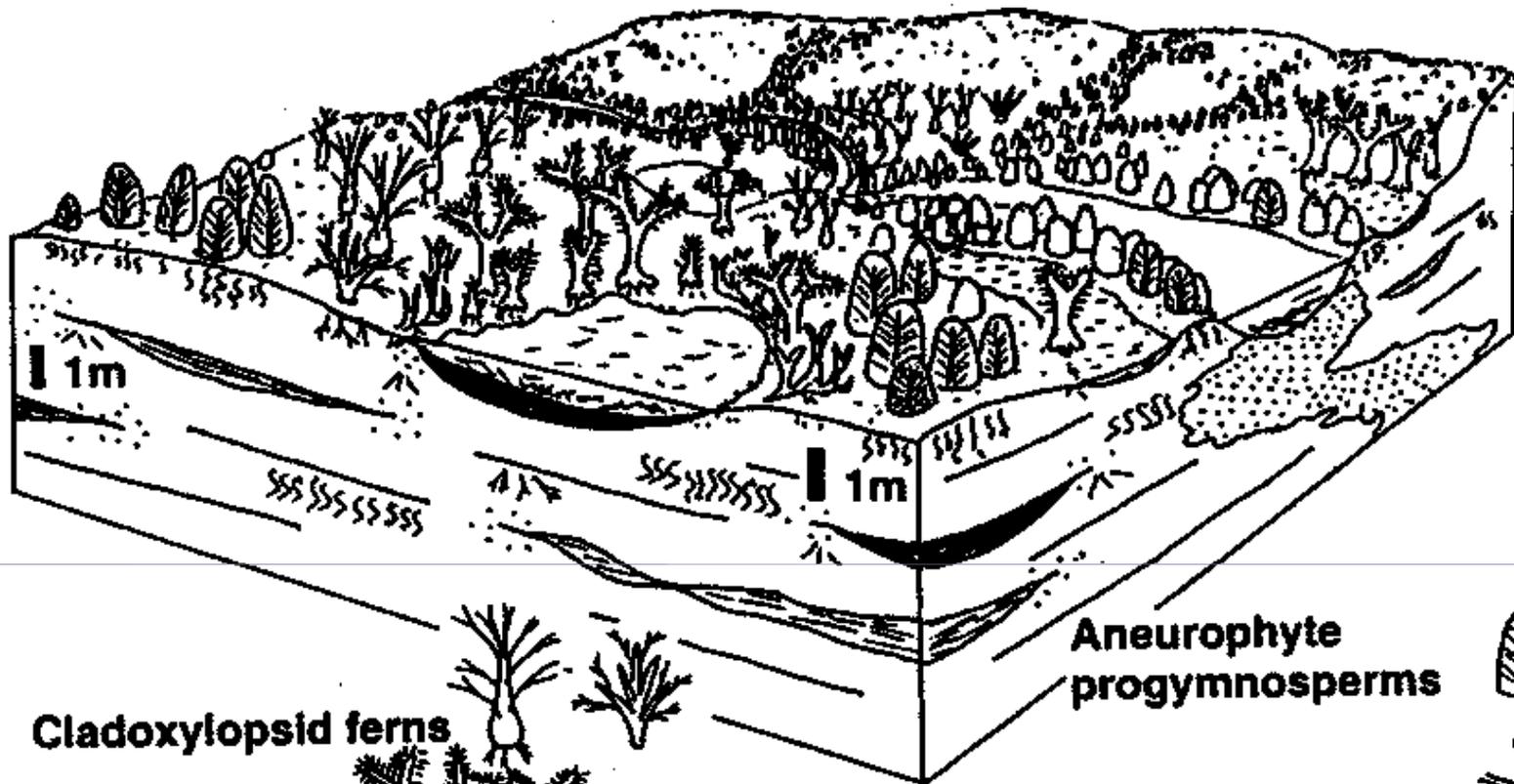




Estruturas reprodutivas nas extremidades expostas ao fluxo de ar capaz de produzir a turbulência necessária à dispersão por longas distâncias.

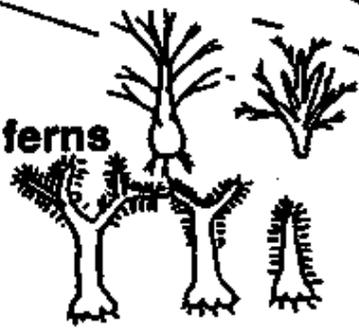
O grau de exposição provavelmente condicionava o controle de trocas gasosas através de estômatos.





Cladoxylopsid ferns

Tree lycopsids



Aneurophyte
progymnosperms

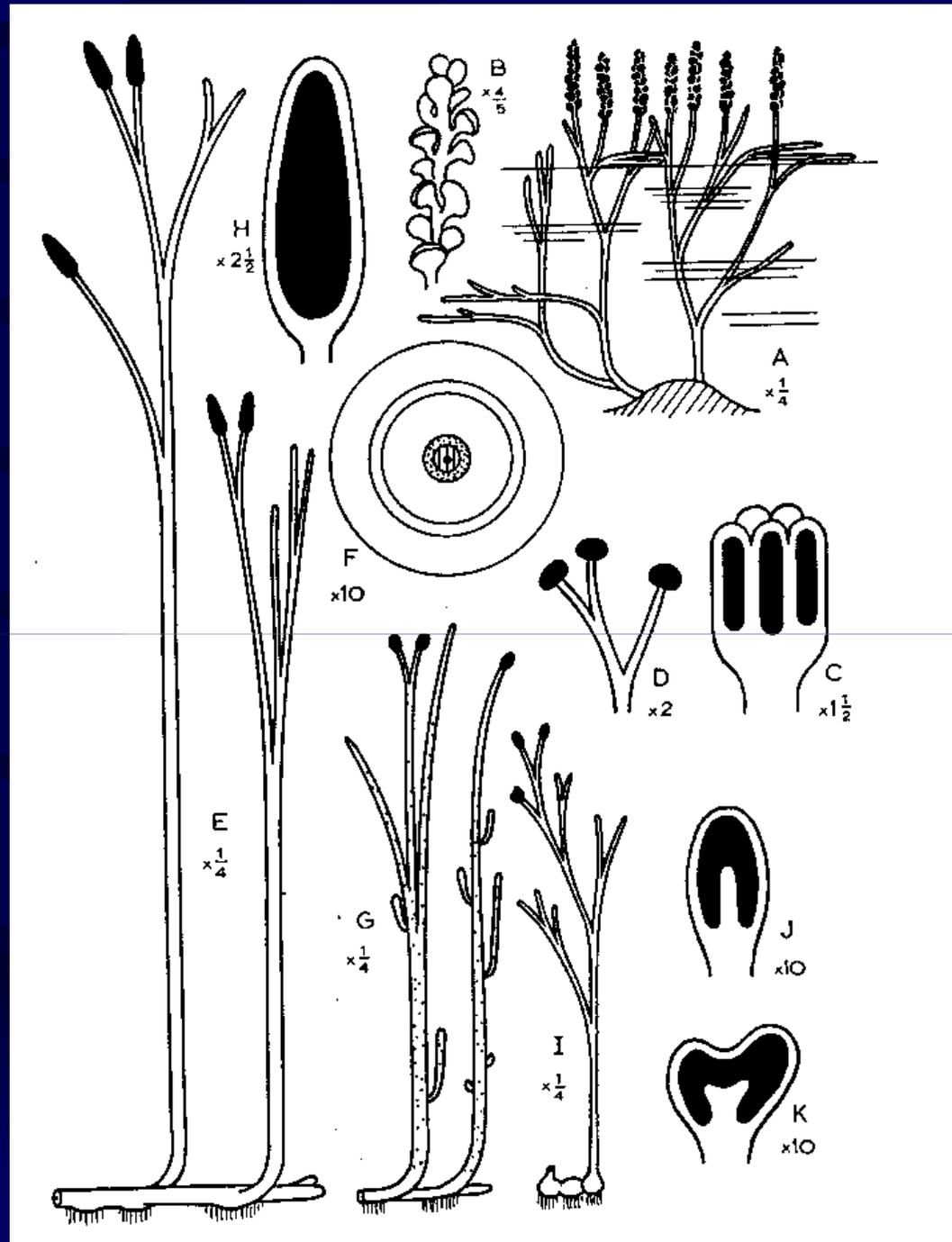
Drepanophycalean &
Leclercqian lycopsids

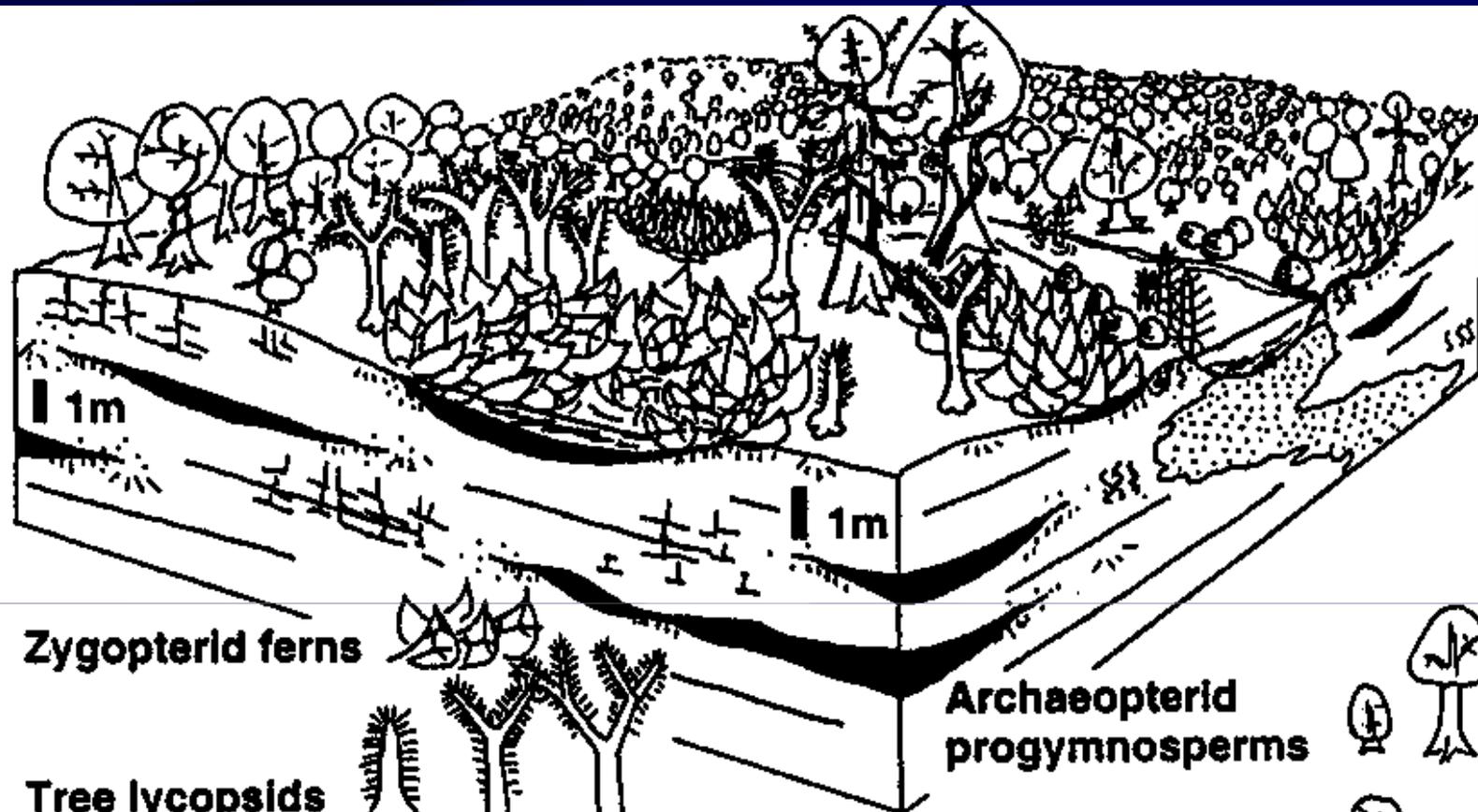


B

Middle Devonian (Eifelian - Givetian)

Rhyniophyta do Devoniano médio





Zygopterid ferns

Tree lycopsids

Pseudobornean trees

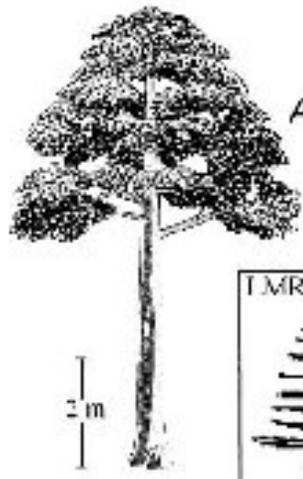
Archaeopterid
progymnosperms

Gymnosperms

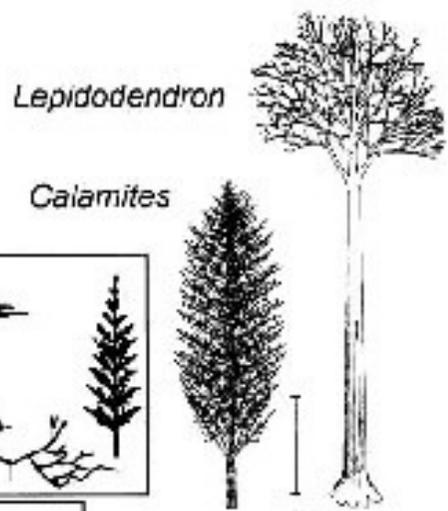
Sphenophyll vines
Cladoxylopsid vines

C

Late Devonian (Famennian)



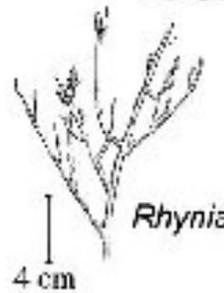
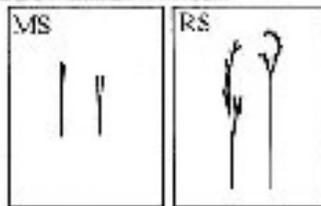
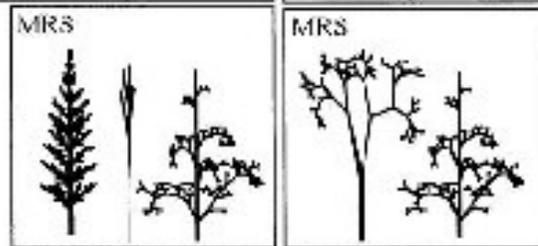
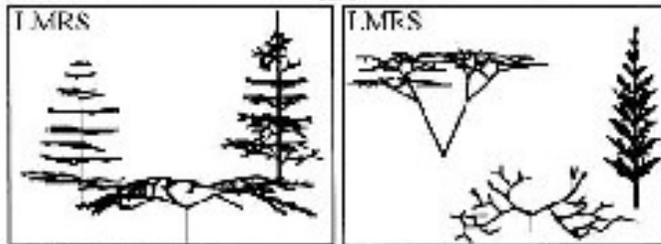
Archaeopteris



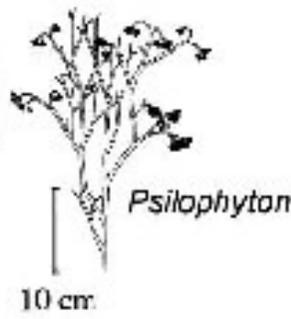
Lepidodendron

Calamites

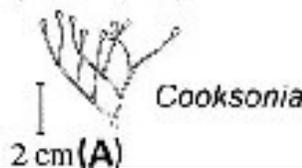
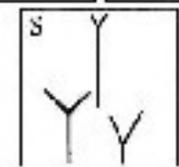
(B)



Rhynia

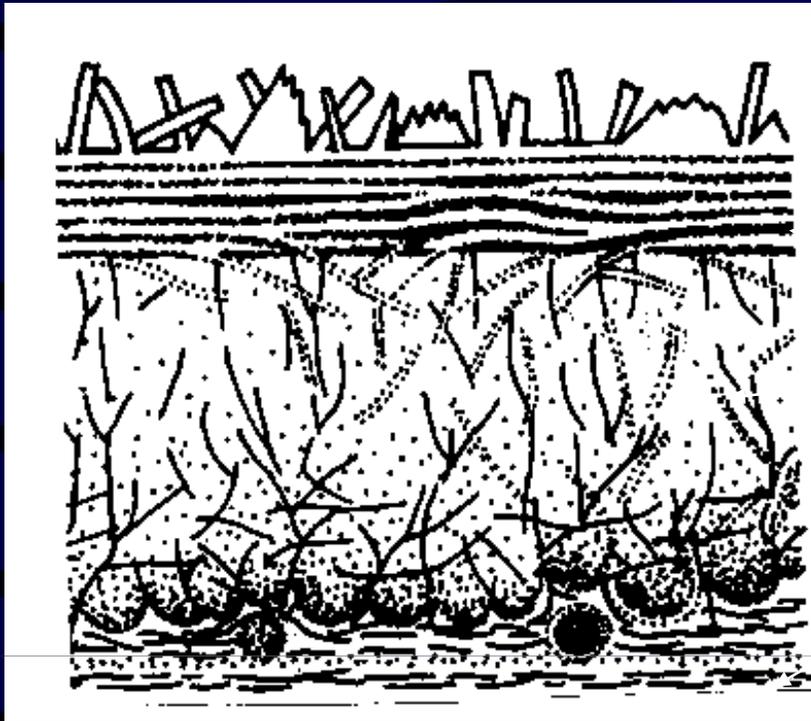


Psilophyton



Cooksonia

2 cm (A)



Cutícula

Cera epicuticular

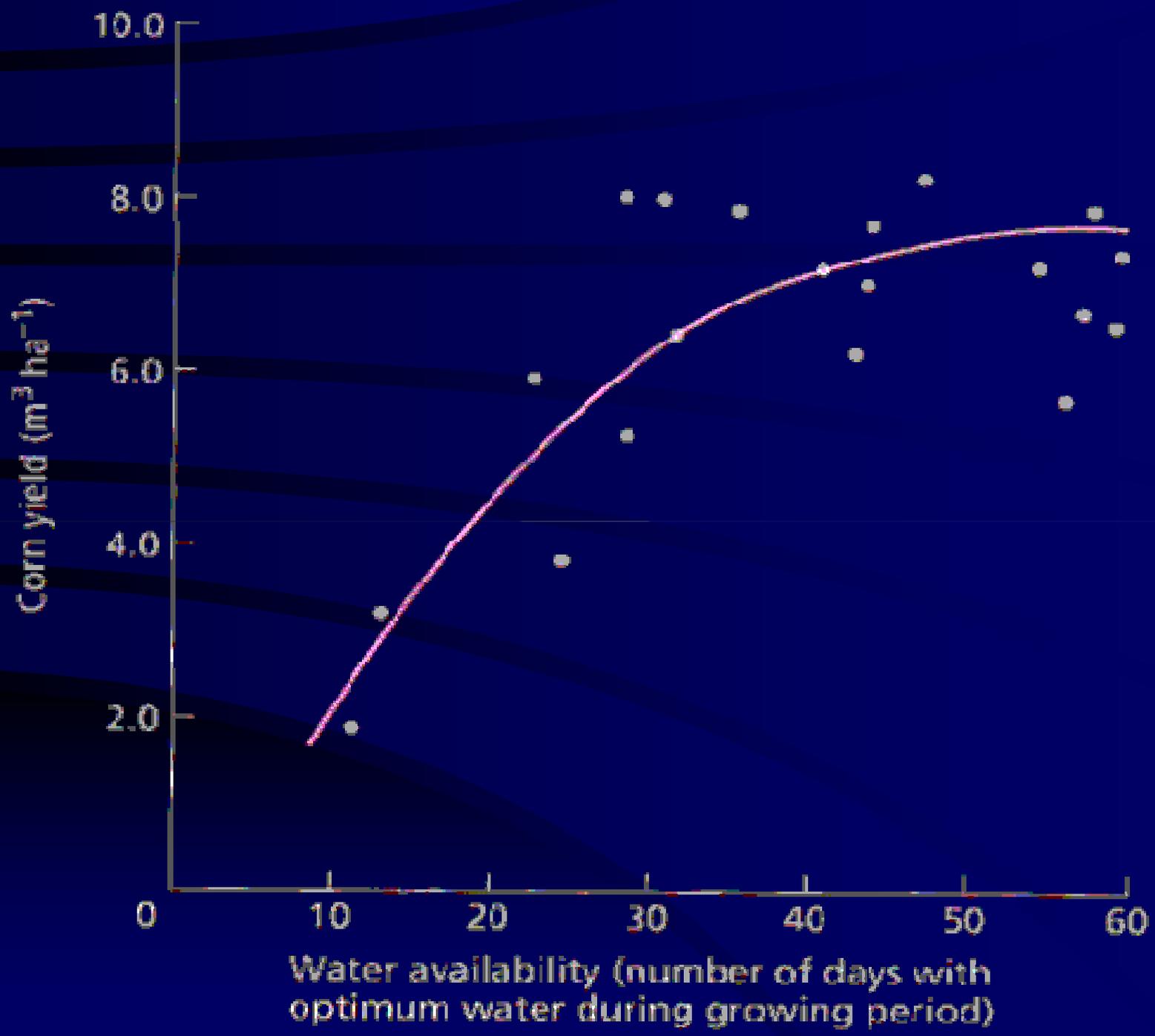
Camada de Cutina

Camada com predominio de pectina

Parede de uma célula epidérmica

Estômatos





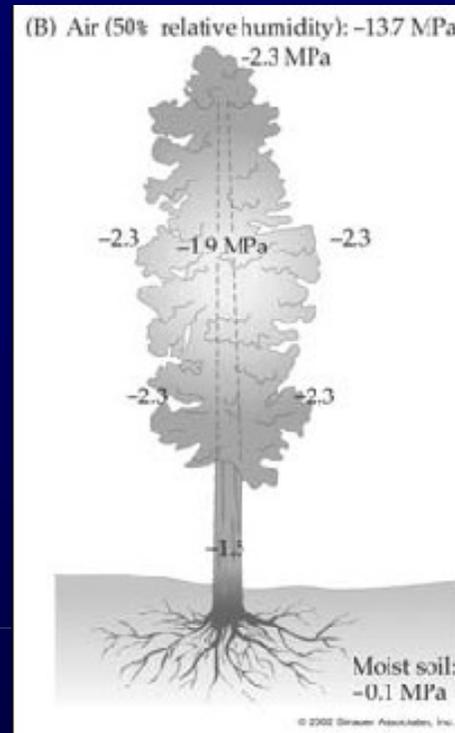
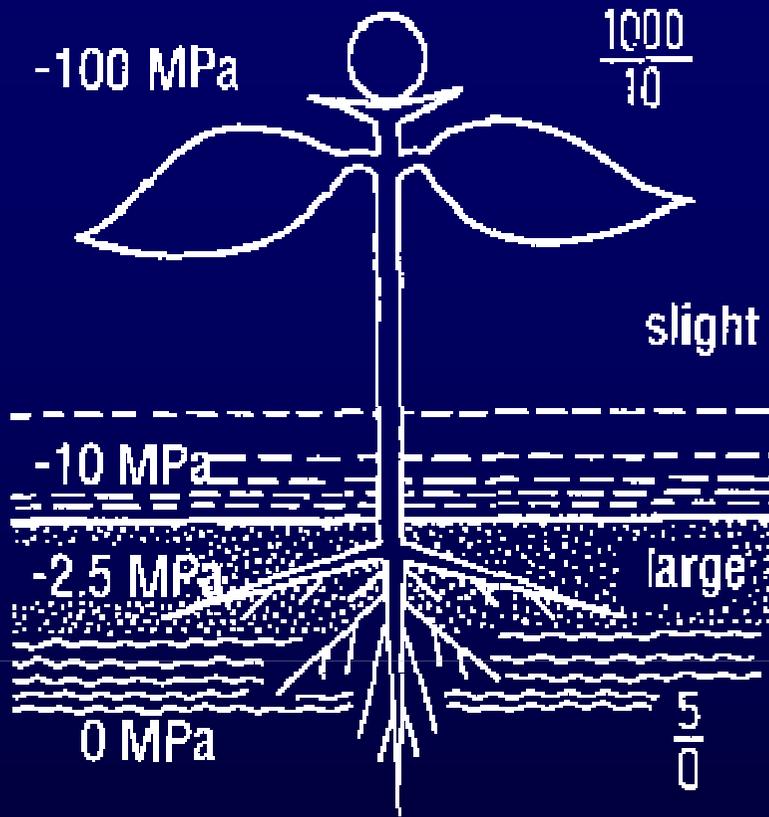
$$\Psi_{\text{H}_2\text{O}} = \Psi_{\text{osmótico}} + \Psi_{\text{pressão}} + \Psi_{\text{gravitacional}} + \Psi_{\text{mátrico}}$$

- *Potencial hídrico*
- Água pura = 0Ψ
maior potencial químico possível, correspondente ao máximo em energia livre associada com a água.
- Solutos, pressão, potencial eletroquímico, força gravitacional etc. interferem na energia livre da água e portanto reduzem o potencial hídrico $-\Psi < 0 \Psi$.

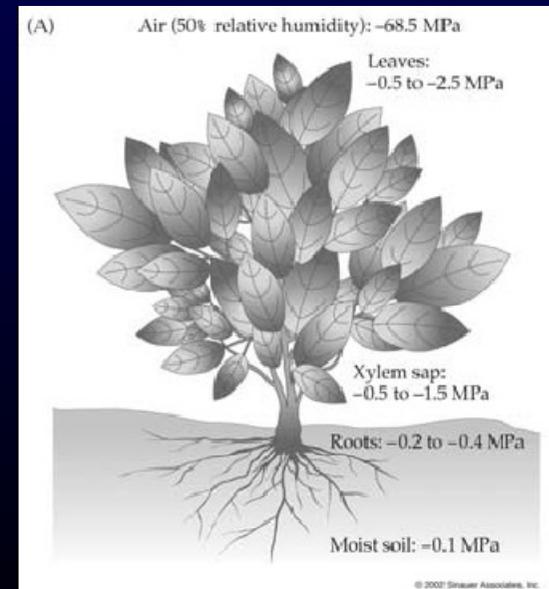
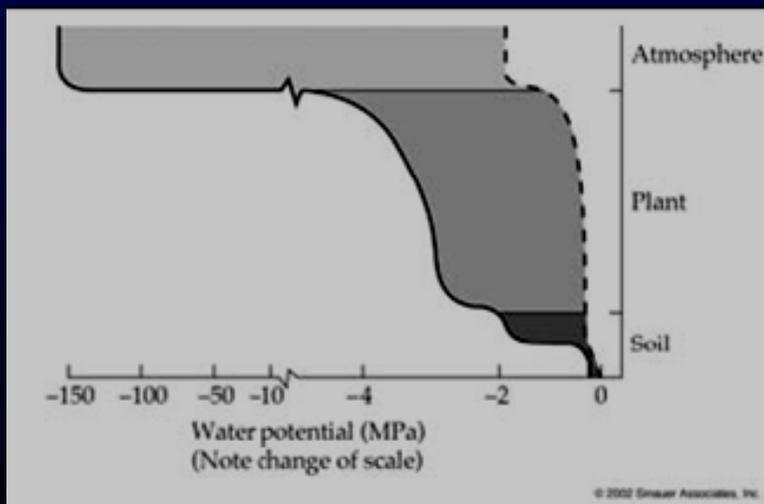
$$\Psi_{\text{osmótico}} - \text{efeito dos solutos dissolvidos. } \Psi_s \\ = -RTc_s$$

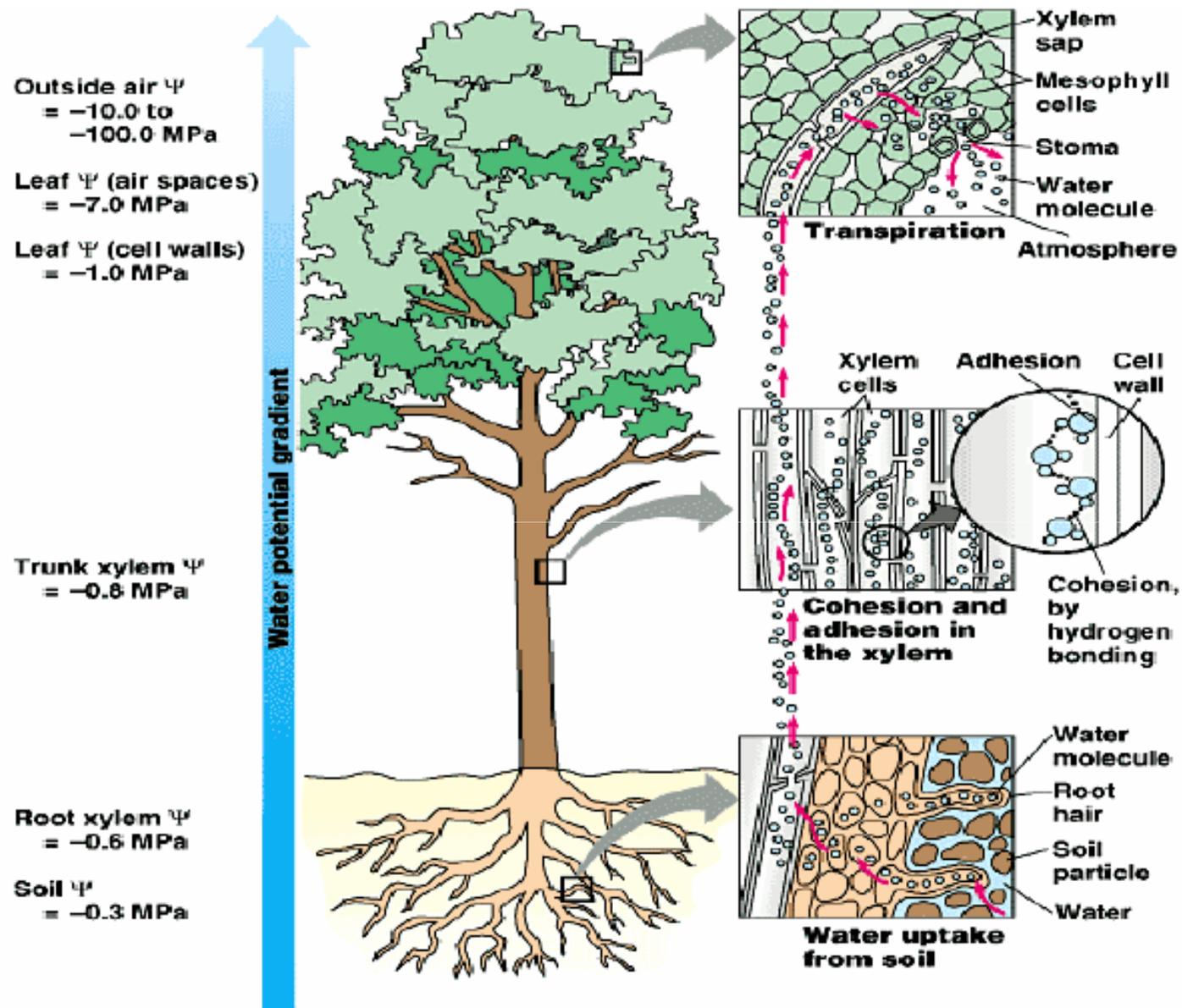
$\Psi_{\text{pressão}}$ - pressão de turgor originária da parede (positiva ou negativa).

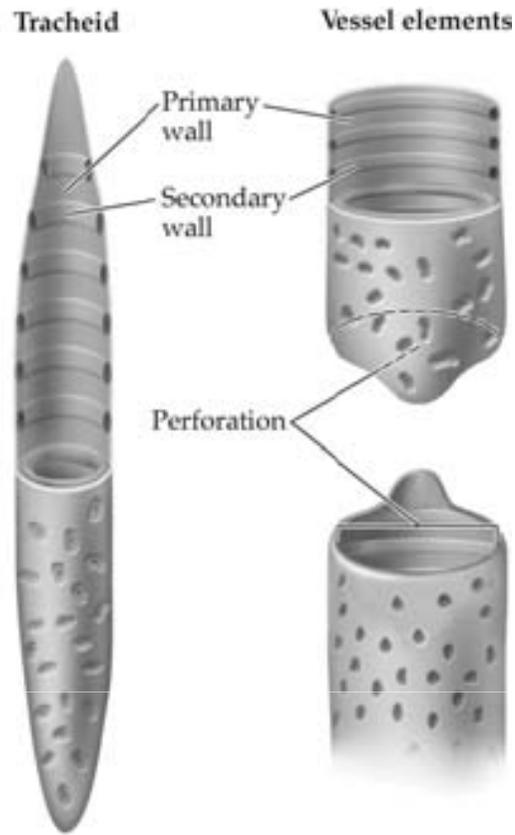
$\Psi_{\text{mátrico}}$ - efeitos de adesão e adsorção das superfícies em contato com a água.



- Potenciais nos compartimentos do continuum solo-planta-atmosfera.







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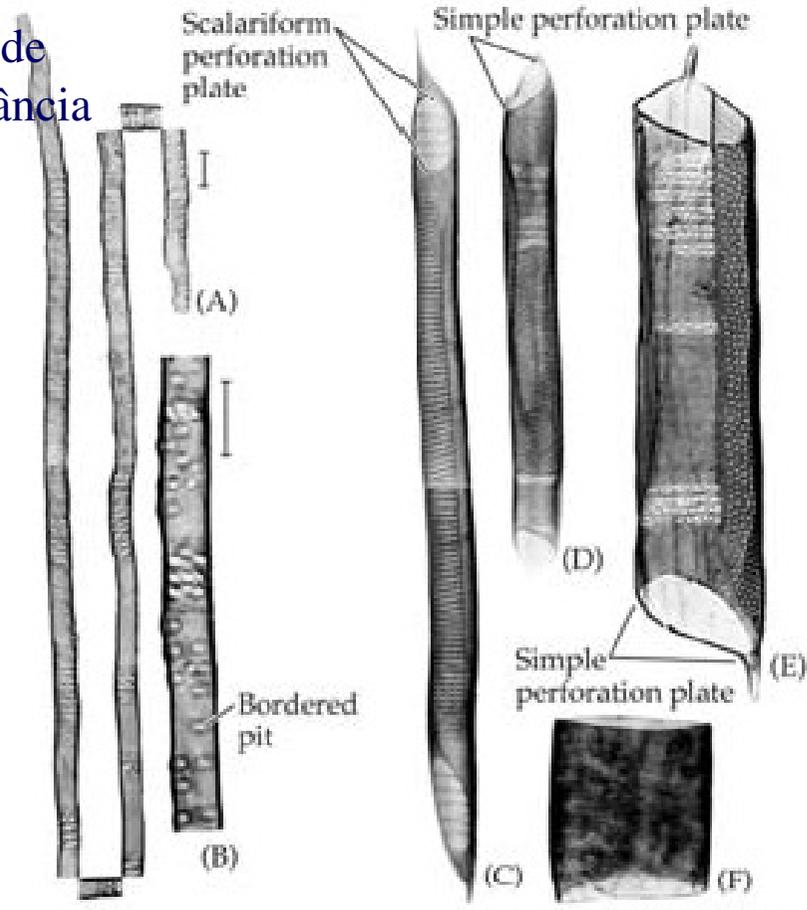
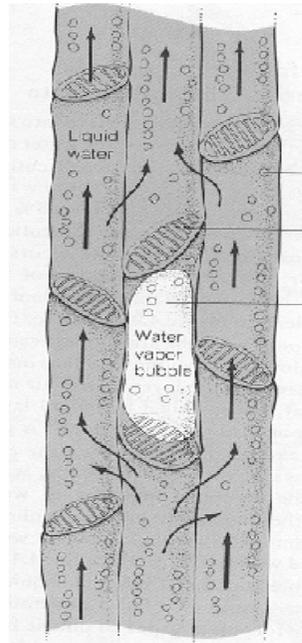
Fluxo através do vaso

$$= \frac{\pi r^4}{8n} \frac{\Delta P}{L}$$

r = raio

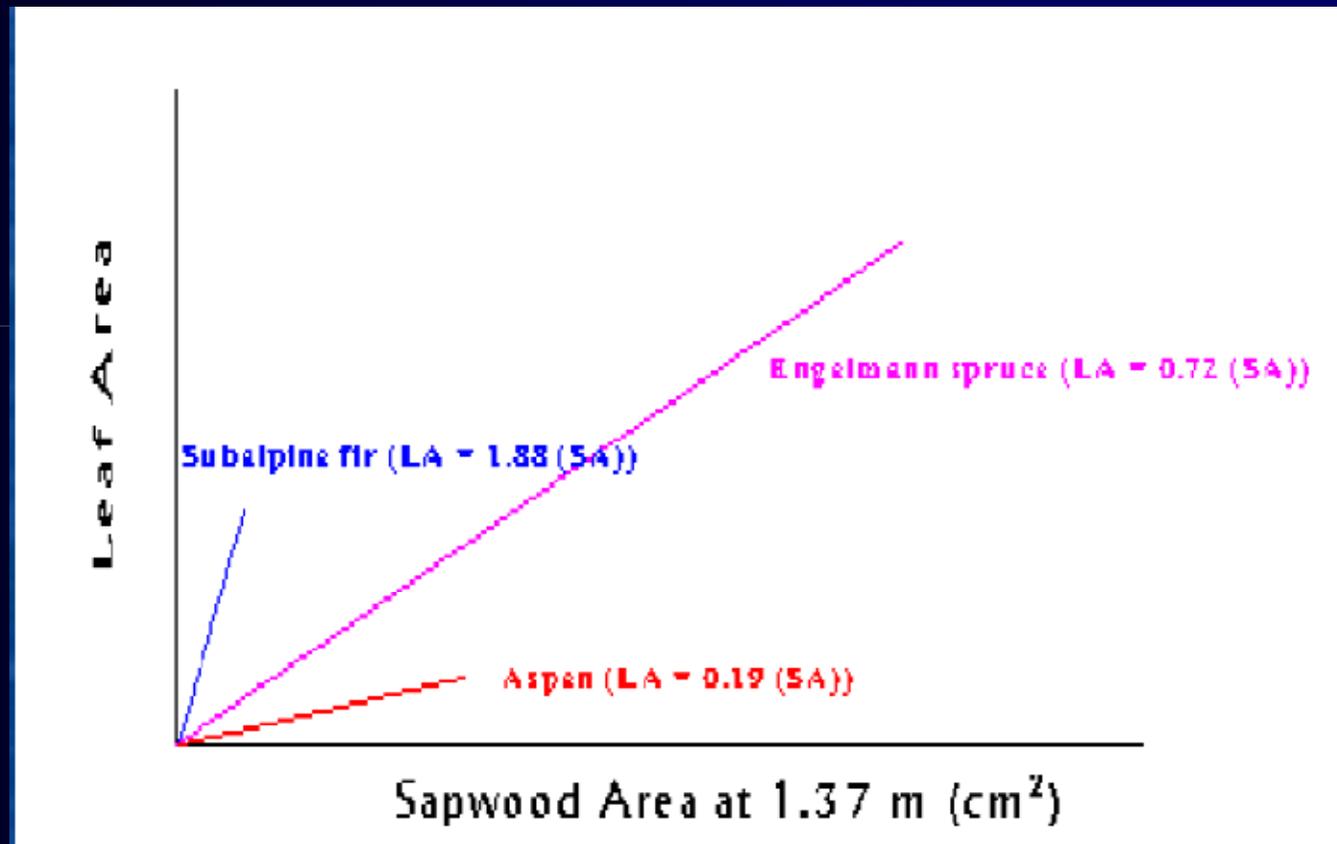
n = viscosidade

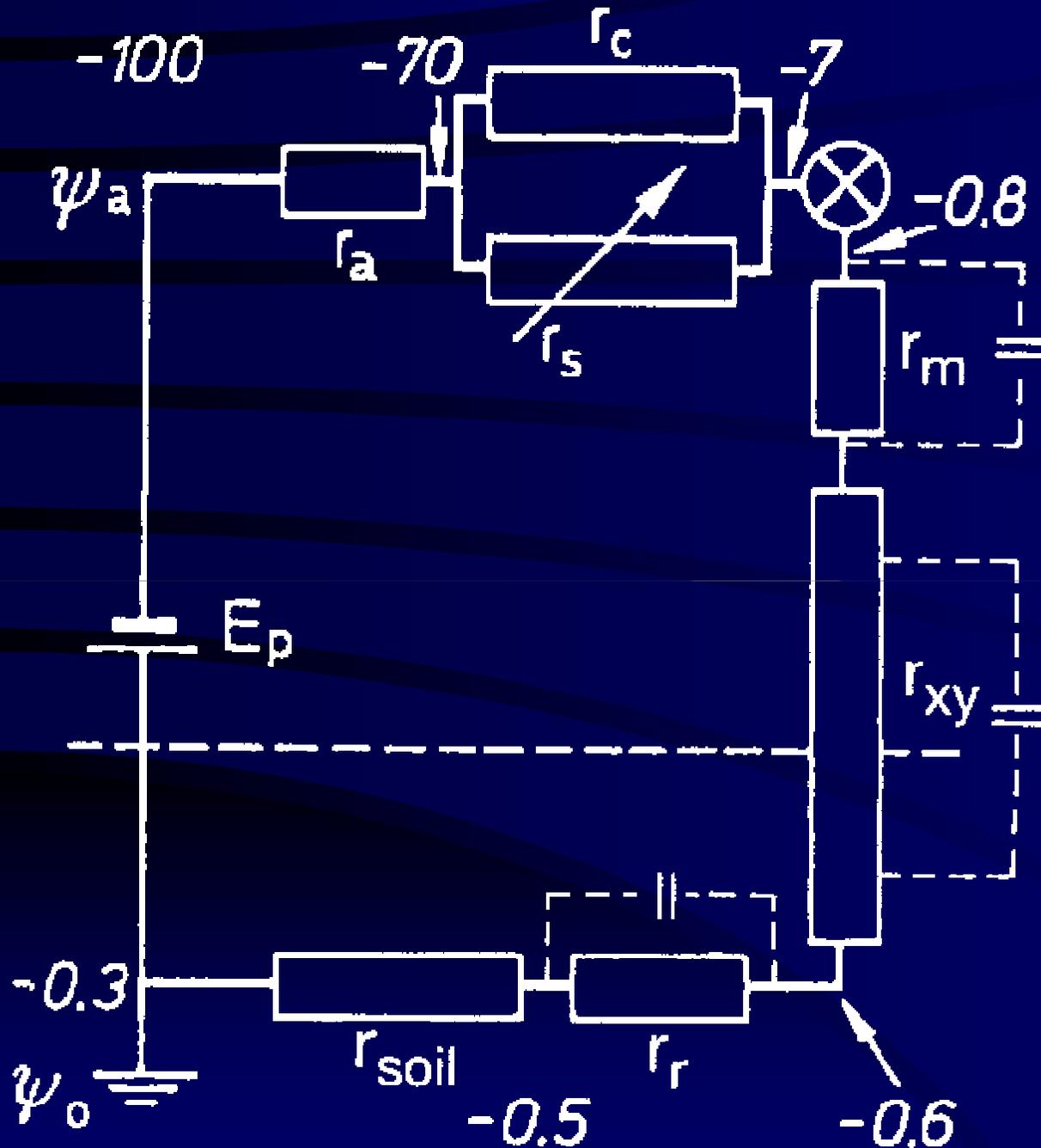
DP/L = diferença de potencial por distância



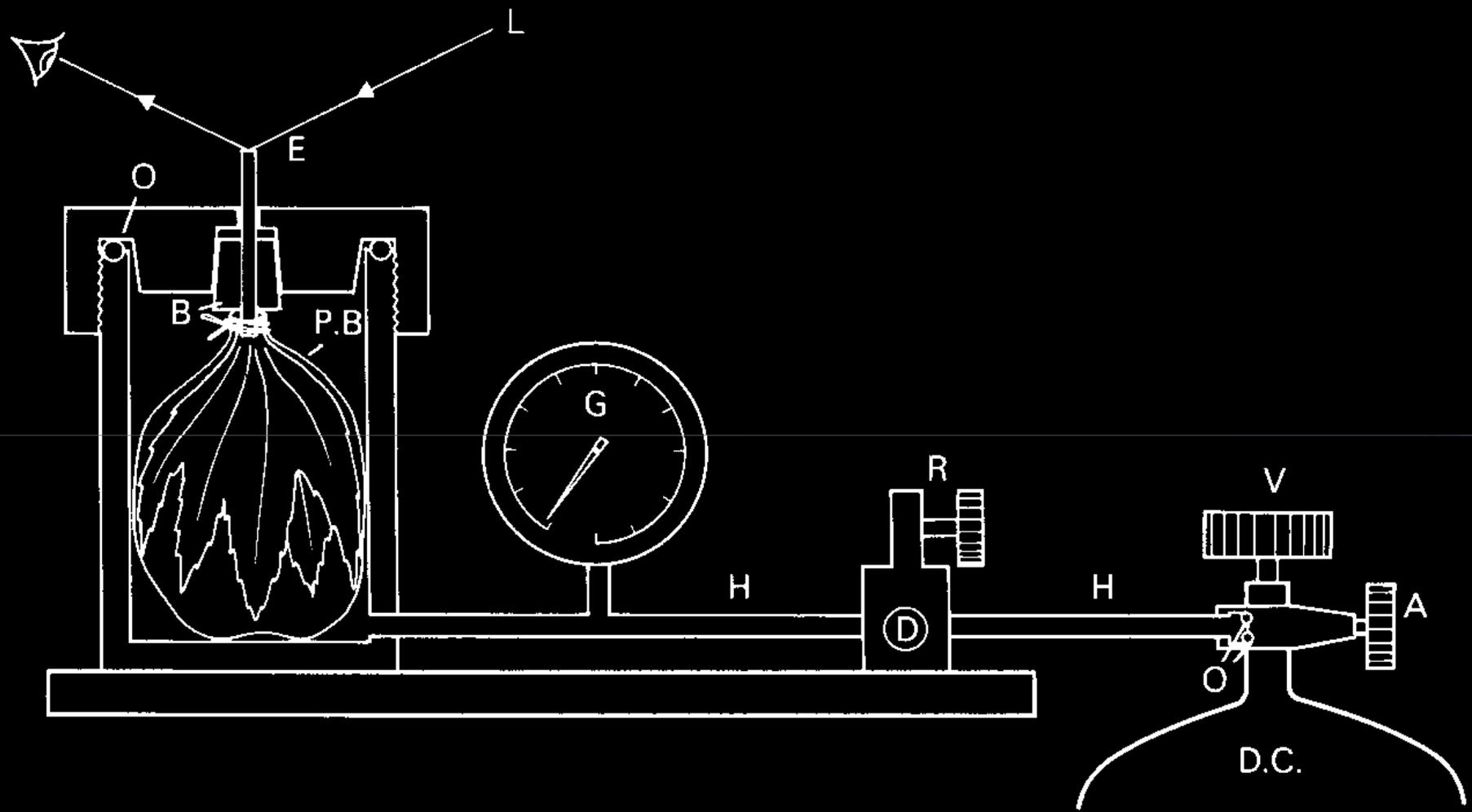
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A condutância do xilema é diretamente proporcional à área foliar.

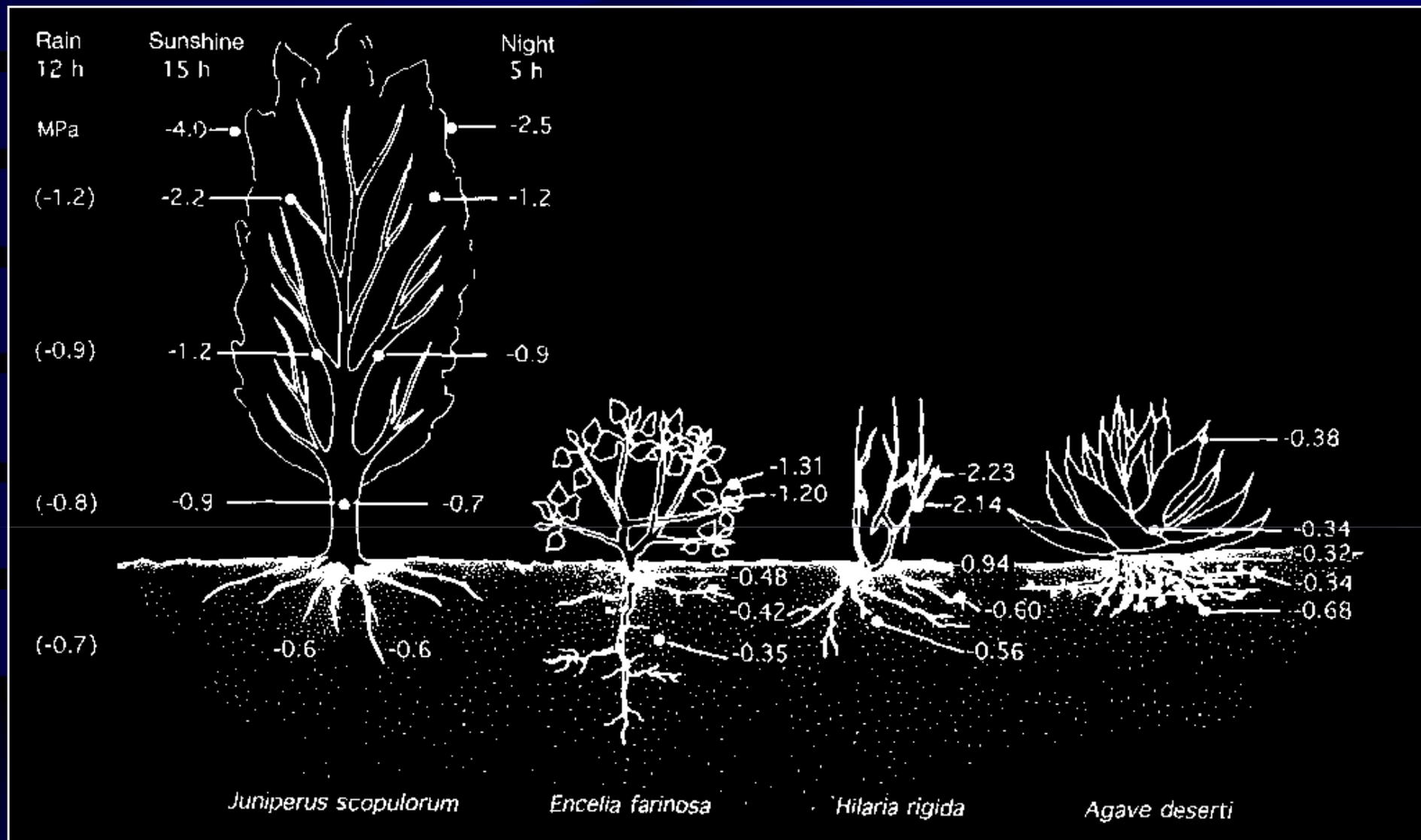




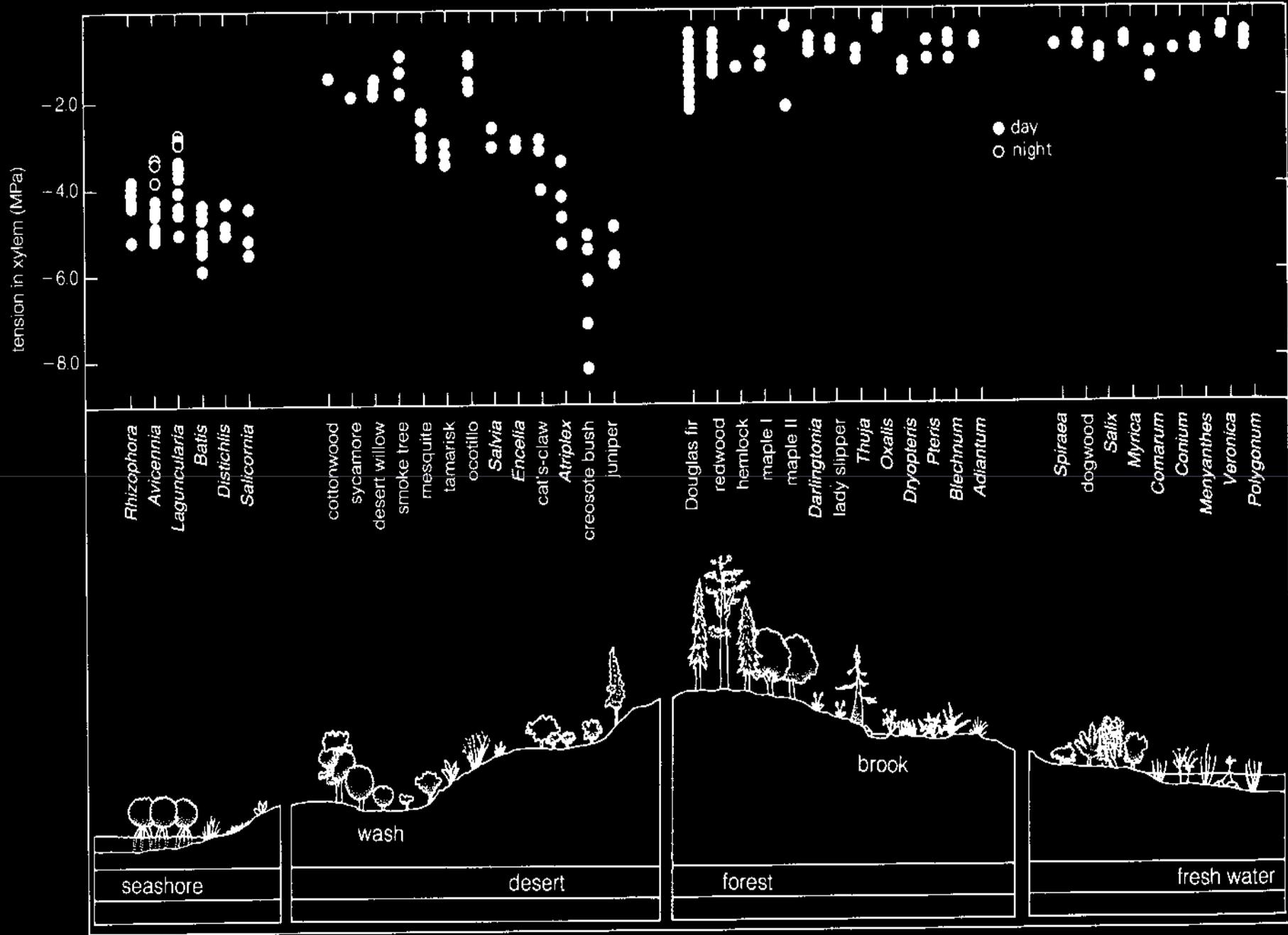
- Modelo do fluxo de água representado por um circuito de resistências e capacitâncias sob uma fonte de tensão, correspondente à diferença de potencial entre o solo e a atmosfera

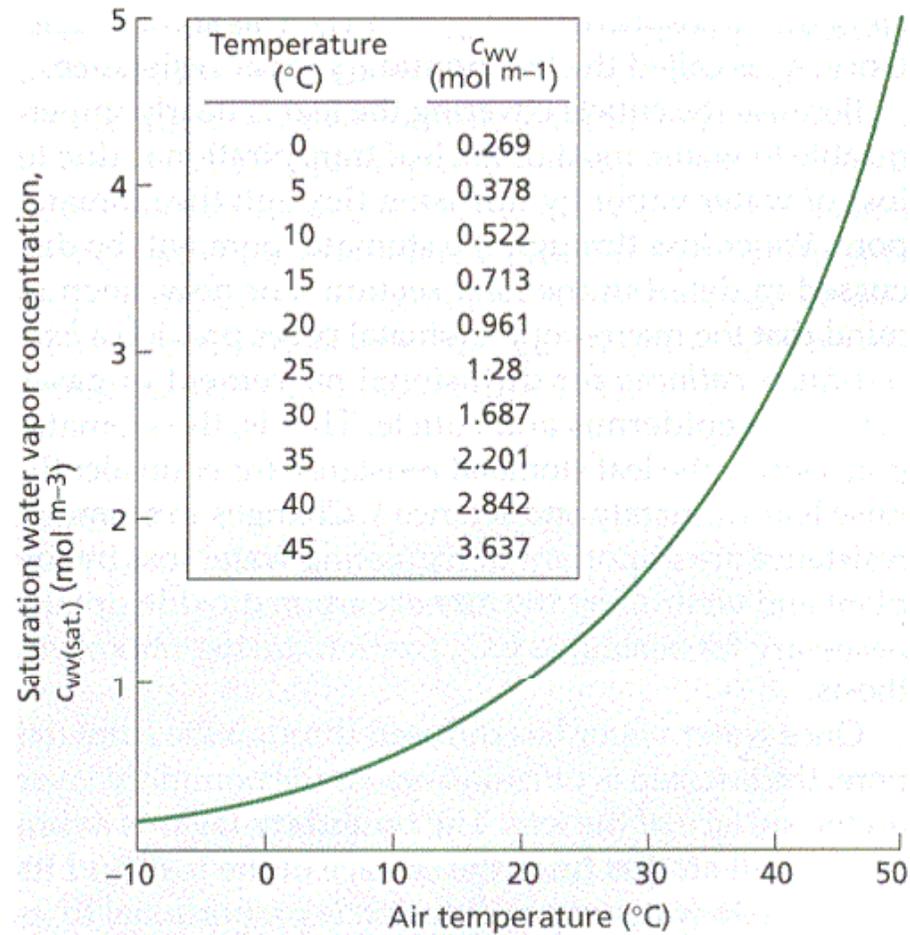






- Perfis do continuum de potenciais hídricos em plantas de regiões áridas e semi-desérticas representando várias formas de crescimento.





$$RH = e_a / e_s$$

$$VPD = e_s - e_a$$

$$e_s \text{ (Pa)} / (T) \approx 6.1078 e^{((17.269 * T) / (237 + T))}$$

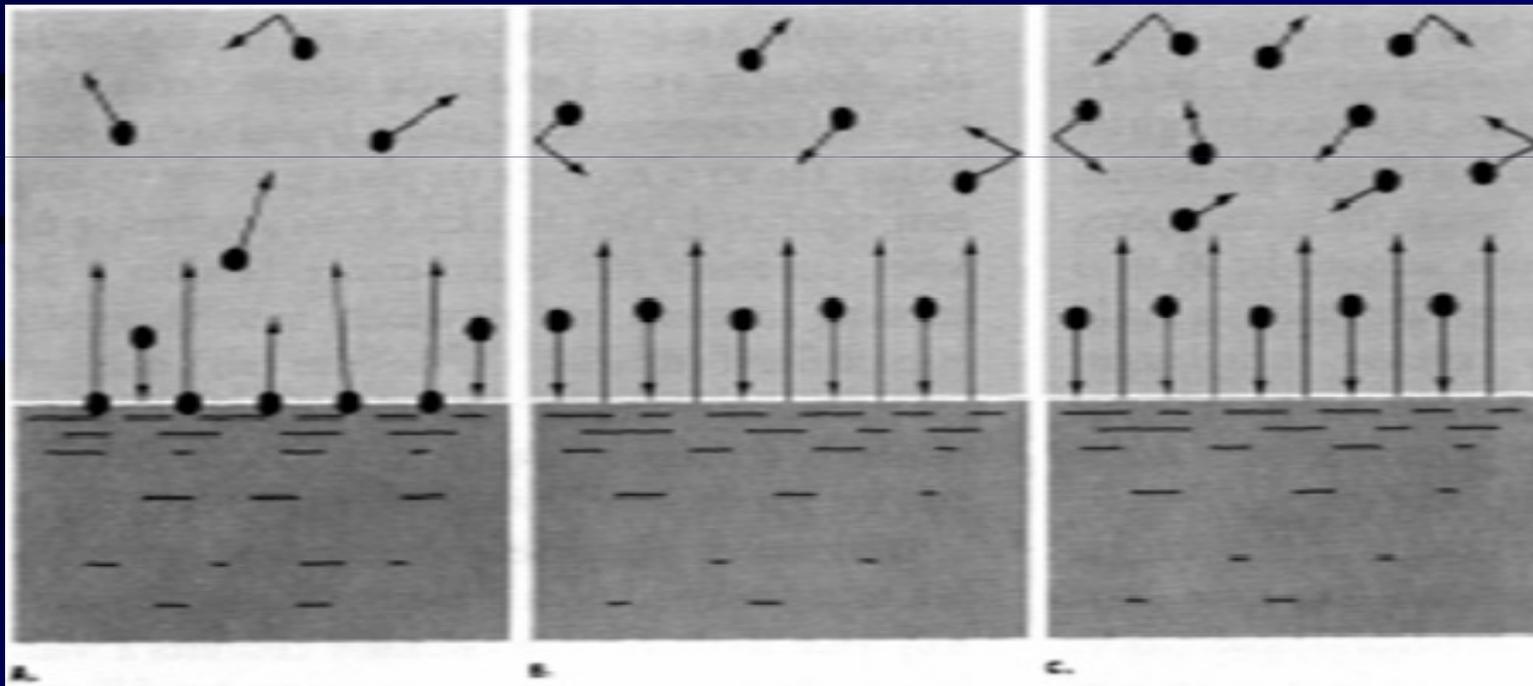
Potencial hídrico do ar associado a valores de umidade relativa e temperatura

RH	10	15	20	25	30
100	0.0	0.0	0.0	0.0	0.0
99	1.3	1.3	1.3	1.4	1.4
98	2.6	2.7	2.7	2.8	2.8
95	6.7	6.8	6.9	7.0	7.1
90	13.8	14.0	14.2	14.4	14.7
80	29.1	29.6	30.1	30.6	31.1
70	46.6	47.4	48.1	48.9	49.6
50	90.5	92.0	93.6	95.1	96.5
30	157.0	160.0	162.0	165.0	168.0
10	301.0	306.0	311.0	316.0	321.0

Pressão de Vapor da Água

$$e_s = \exp(6.41 + 0.0727 TC - 3.00 \times 10^{-4} TC^2 + 1.18 \times 10^{-6} TC^3 - 3.86 \times 10^{-9} TC^4)$$

e_s : pressão de vapor de saturação [Pa]; TC: temperatura ambiente em graus centígrados



Water vapor pressure (VP) and water pressure saturation deficit (VPD) at varied temperatures and relative humidity (R.H.)

Temp. [C]	R.H. [%]	VP [kPa]	VPD [kPa]
10	100	1.28	0.00
	60	0.74	0.54
	20	0.25	1.03
20	100	2.34	0.00
	60	1.40	0.94
	20	0.47	1.87
30	100	4.24	0.00
	60	2.55	1.69
	20	0.85	3.39

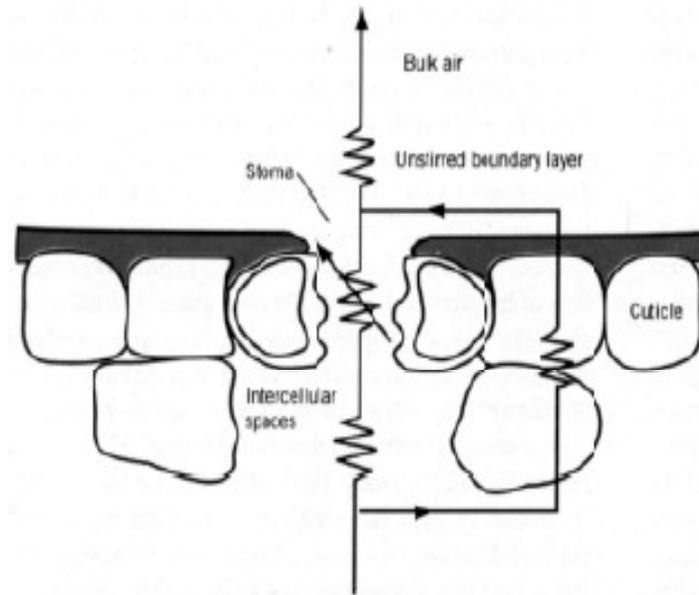
ΔW

Déficite de pressão de vapor entre a folha e o ar depende das temperaturas do ar e da folha e da umidade relativa do ar – tomando-se a UR da folha como próxima de 100%

Folha	Atmosfera	$e_{\text{folha}} - e_{\text{ar}}$
(A)		
T = 10°C	T = 10°C	
e = 1,23 kPa	e = 0,61 kPa	0,61 kPa
UR = 100 %	UR = 50 %	
(B)		
T = 20°C	T = 20°C	
e = 2,34 kPa	e = 0,61 kPa	1,73 kPa
UR = 100 %	UR = 26 %	
(C)		
T = 30°C	T = 20°C	
e = 4,24 kPa	e = 0,61 kPa	3,63 kPa
UR = 100 %	UR = 26 %	

ΔW

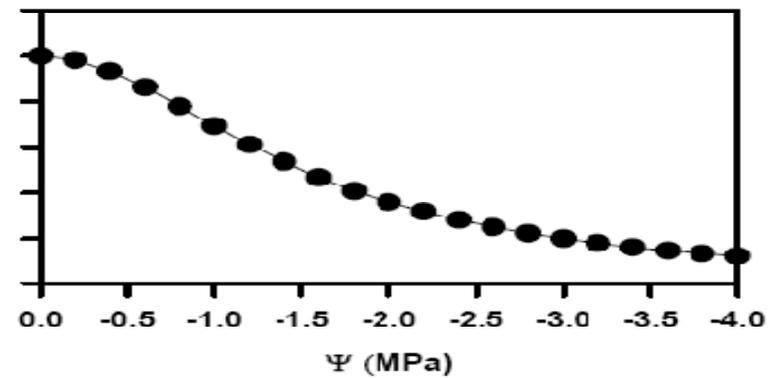
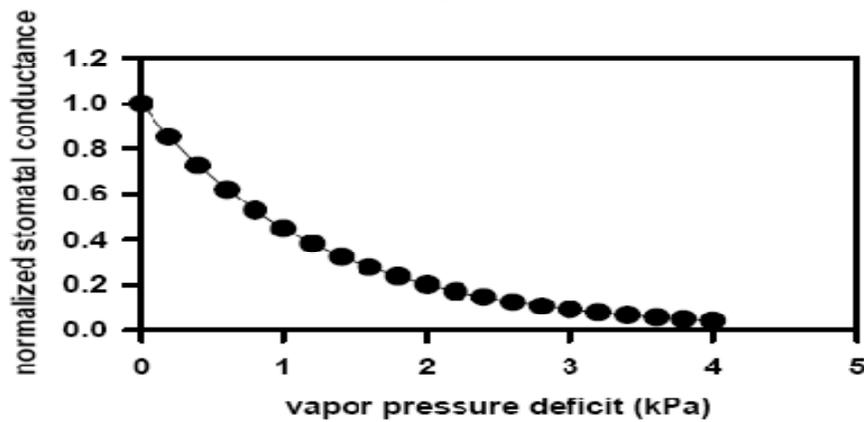
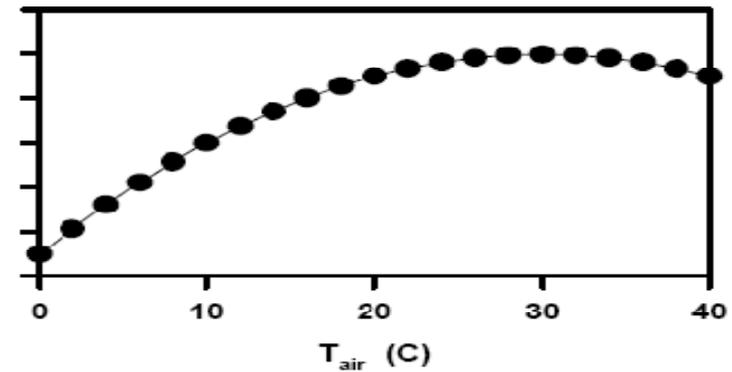
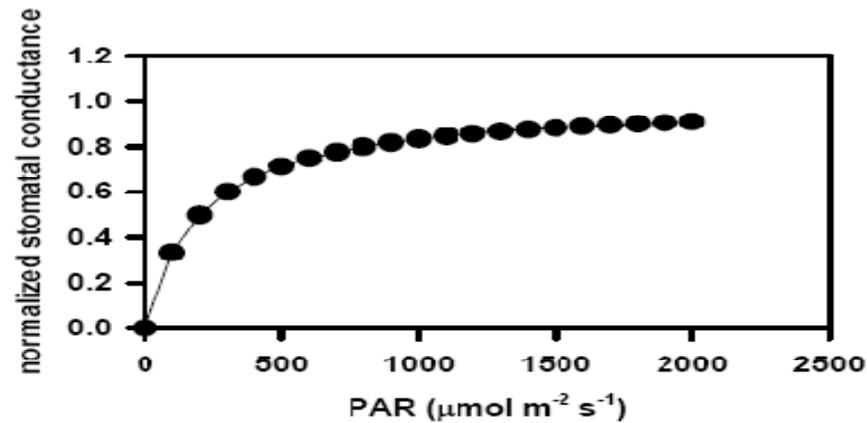
$$Tr = \frac{e_{folha} - e_{ar}}{r_{estomatica} + r_{envolvente}}$$



$$Tr = \frac{(e_{folha} - e_{ar})g}{P}$$

$$g = \frac{Tr \cdot P}{(e_{folha} - e_{ar})}$$

Modelos de Jarvis



Penman-Monteith-Gleichung

$$E = \frac{s(R_n - G) + \rho_a \cdot c_p \cdot g_H \cdot \delta_e}{\lambda \left[s + \left(\gamma \cdot g_H / g_w \right) \right]} \quad (3)$$

E = Transpiration [$\text{mol H}_2\text{O} \cdot \text{m}^{-2} \cdot \text{s}^{-1}$]

R_n = Net radiation [$\text{W} \cdot \text{m}^{-2} = \text{J} \cdot \text{m}^{-2} \cdot \text{s}^{-1}$]

G = Heat flow to soil [$\text{W} \cdot \text{m}^{-2} = \text{J} \cdot \text{m}^{-2} \cdot \text{s}^{-1}$]

ρ_a = Density of dry air [$\text{kg} \cdot \text{m}^{-3}$]

c_p = Heat capacity of air at constant pressure [$\text{J} \cdot \text{kg}^{-1} \cdot \text{K}^{-1}$]

δ_e = Water vapor deficit of air, VPD, $e_o - e$ [$\text{Pa} \cdot \text{K}^{-1}$]

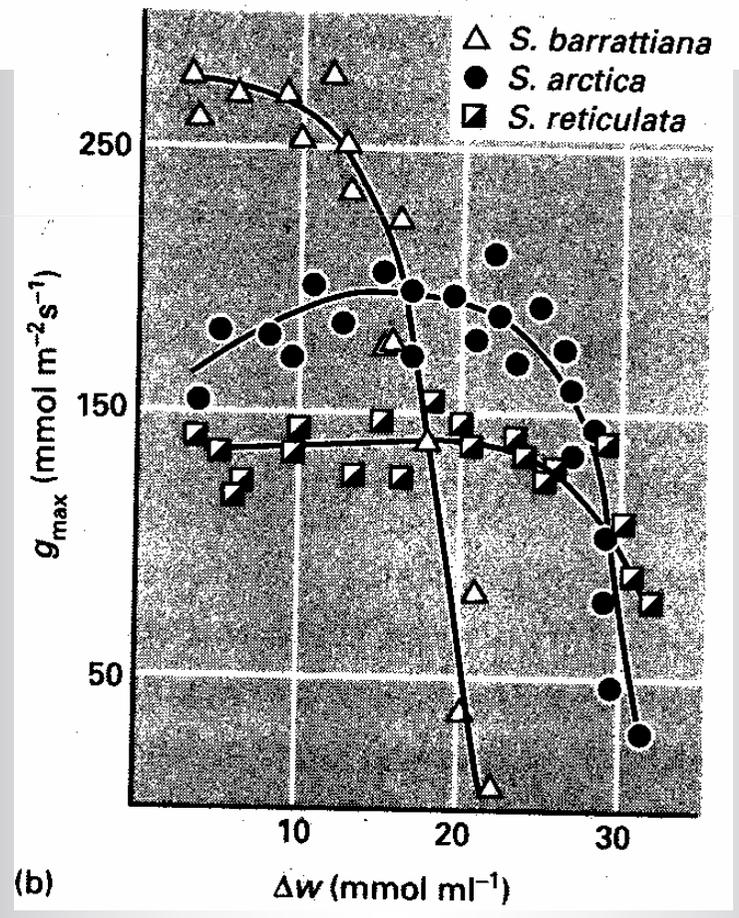
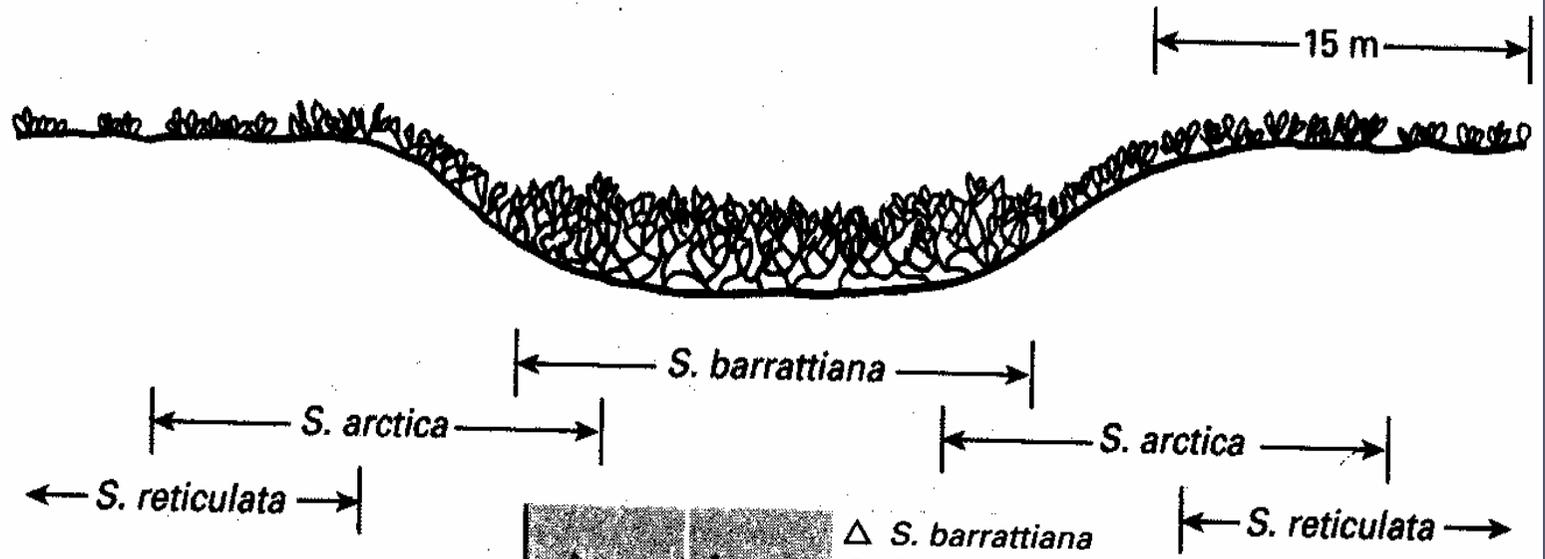
g_w = Stomatal conductance for water vapor [$\text{m} \cdot \text{s}^{-1}$]

g_H = Heat conductivity of air [$\text{m} \cdot \text{s}^{-1}$]

s = Slope of water vapor pressure curve, $e_o - f(T)$ [$\text{Pa} \cdot \text{K}^{-1}$]

→ γ = Psychrometer constant [$\text{Pa} \cdot \text{K}^{-1}$]

λ = Molar heat of evaporation of H_2O ($\approx 40 \text{ kJ/mol H}_2\text{O}$)



(b)

Stomatal resistance ($s\ cm^{-1}$)

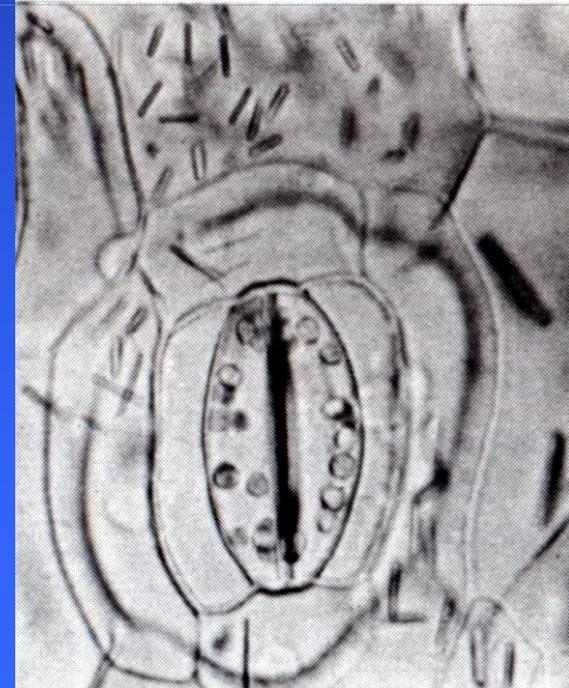
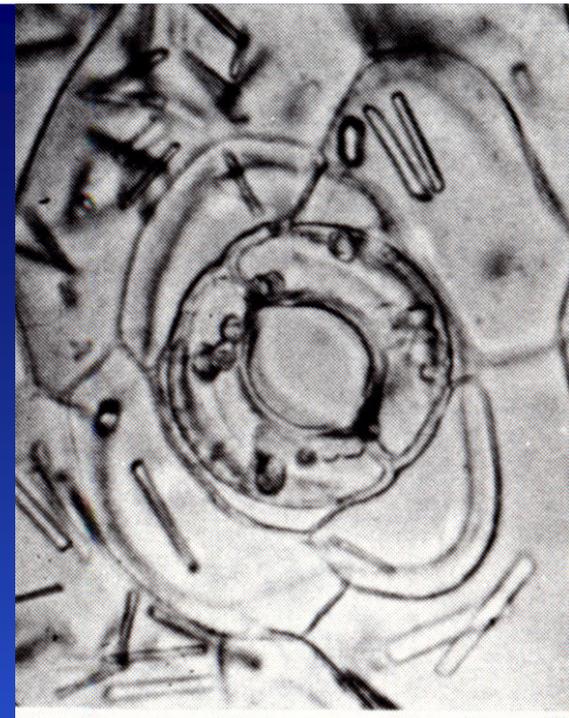
0.4 2 1.0 0.5 0.4

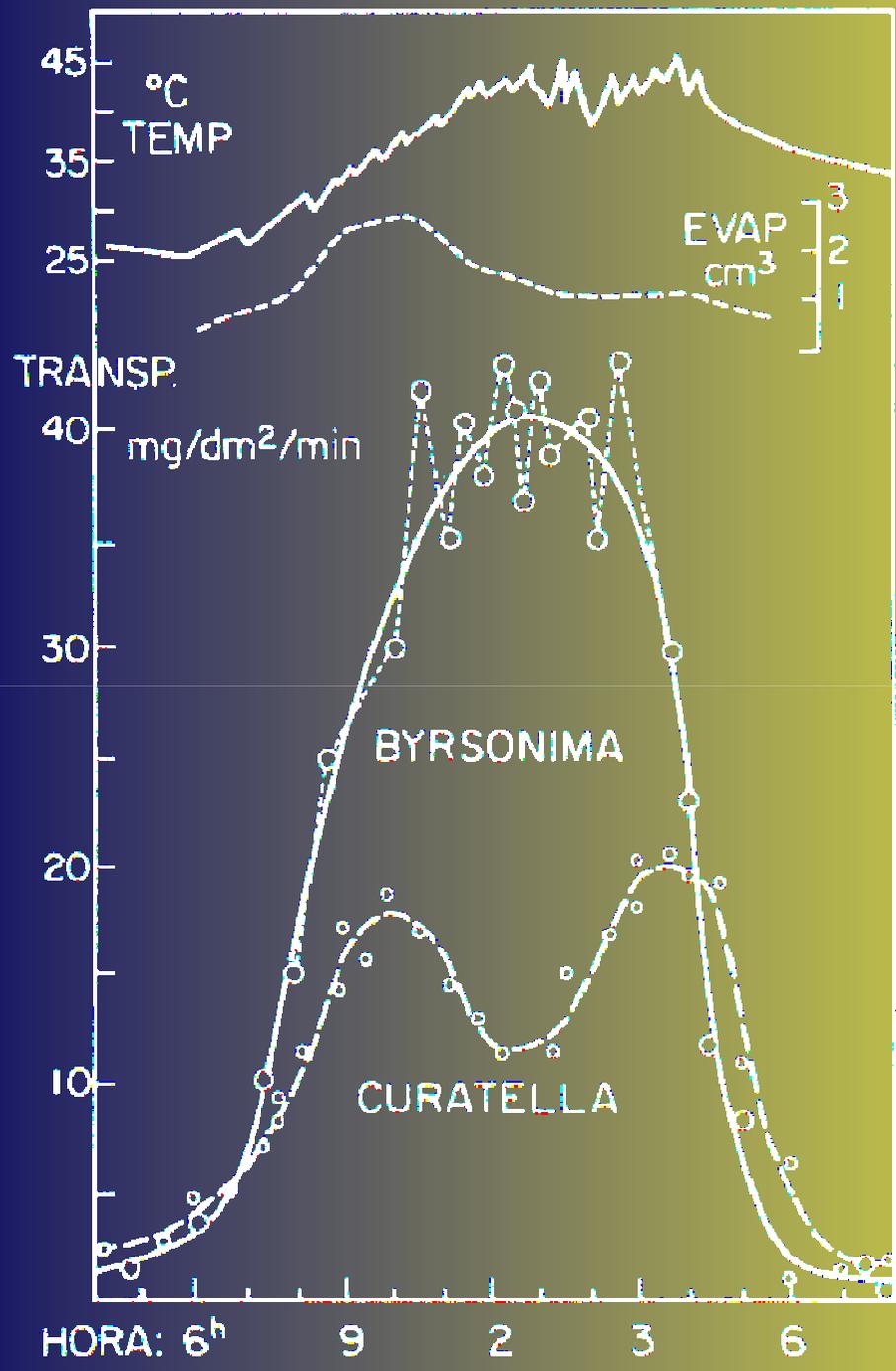


- Succulents
- Evergreen conifer
- Deciduous woody plants
- Herbs from shaded places
- Evergreen woody plants
- Desert and steppe
- Deciduous fruit tree
- Wild graminoids
- Cultivated C3 grasses
- Cultivated C4 grasses
- Herbaceous crops
- Herbs from open habitats
- Wetland plants

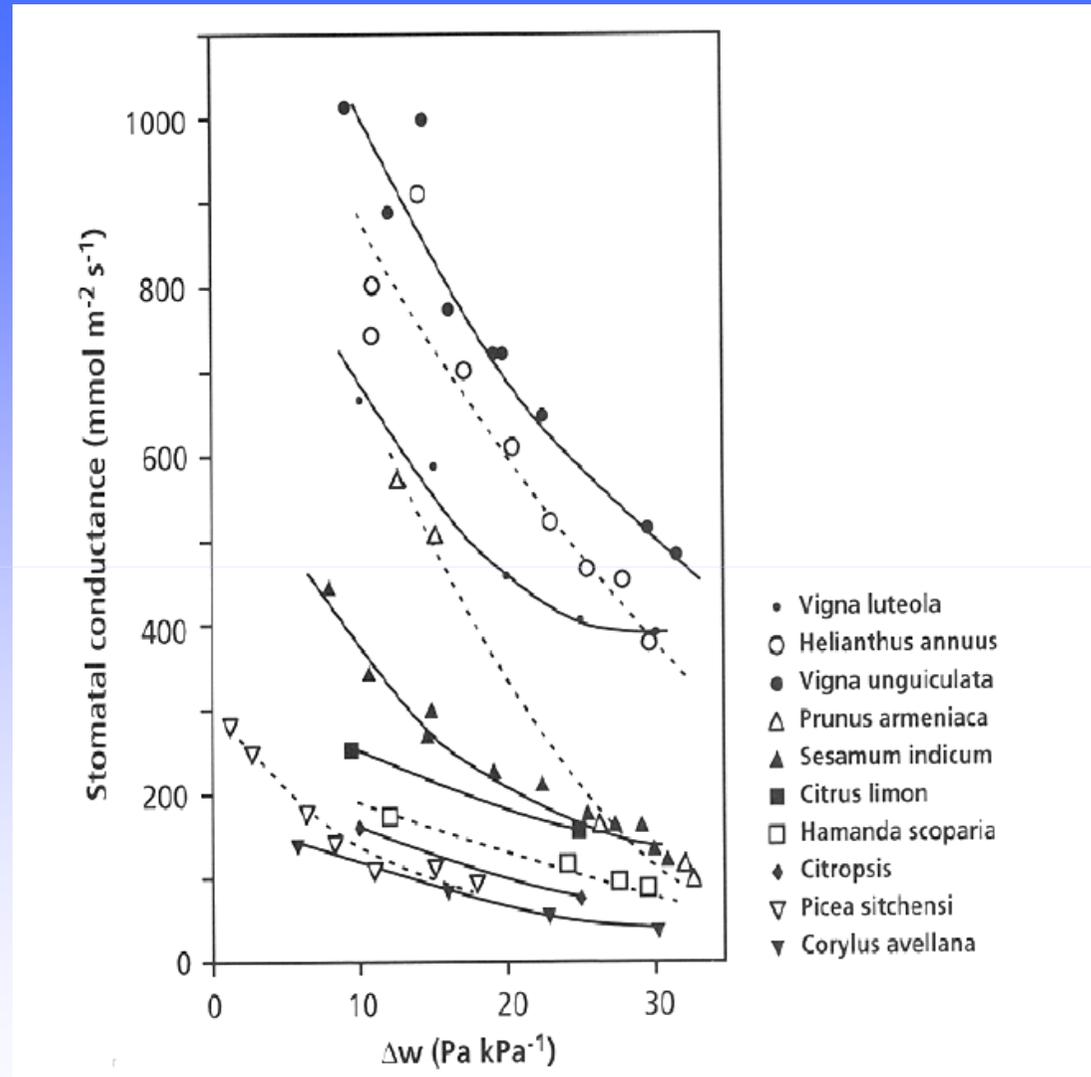


Stomatal conductance ($cm\ s^{-1}$)





Na maioria das plantas vale a expectativa de uma redução da condutância estomática com o aumento do DW. Entretanto, além de parâmetros típicos de cada espécie, estão envolvidas respostas complexas que incluem sinais internos, associados ao ABA, respostas foliares diretas e variações na condutividade hidráulica e no acoplamento com o solo.



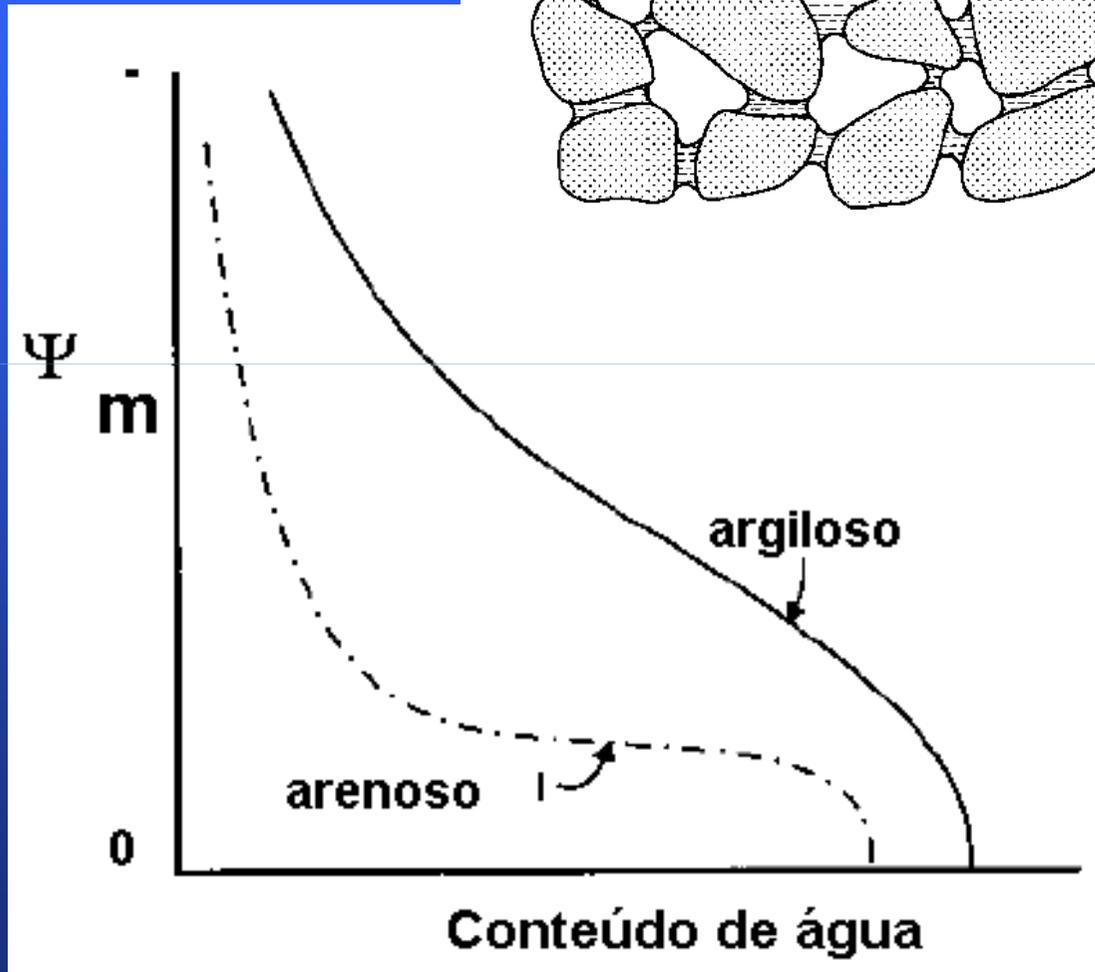
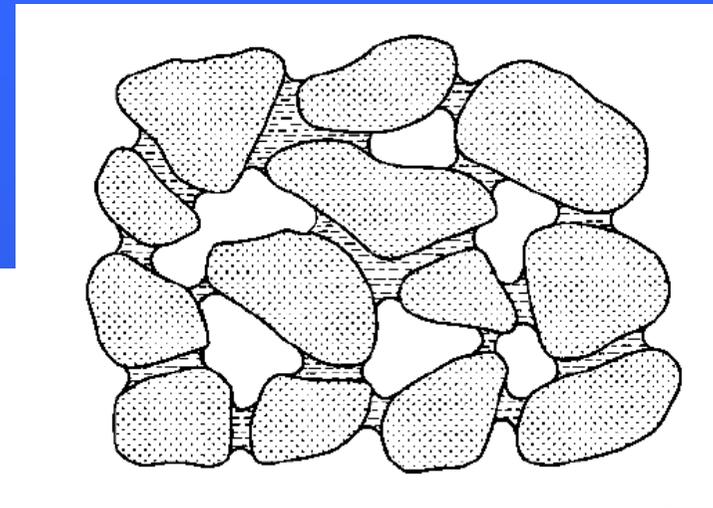
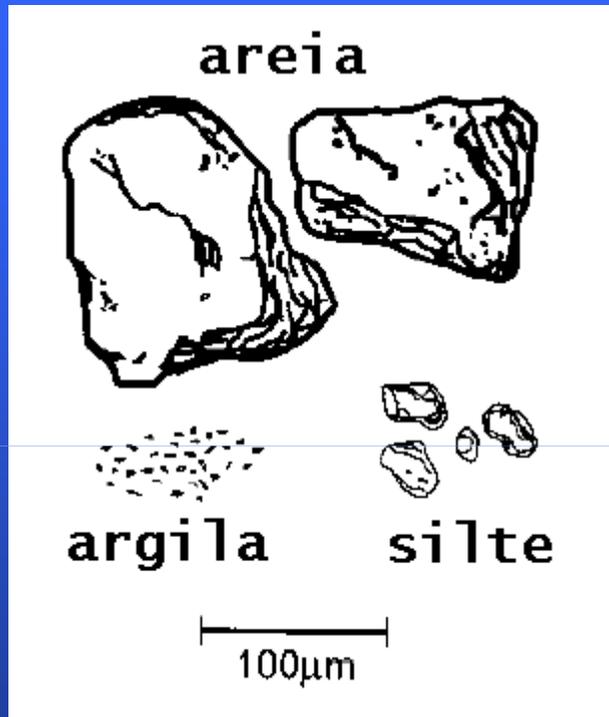
Eficiência de uso da água

$$Tr = \frac{(e_{folha} - e_{ar})g}{P}$$

$$A = \frac{(C_{folha} - C_{ar})g}{1.6P}$$

$$\frac{A}{Tr} = \frac{(C_{folha} - C_{ar})}{1.6(e_{folha} - e_{ar})}$$

Água no solo

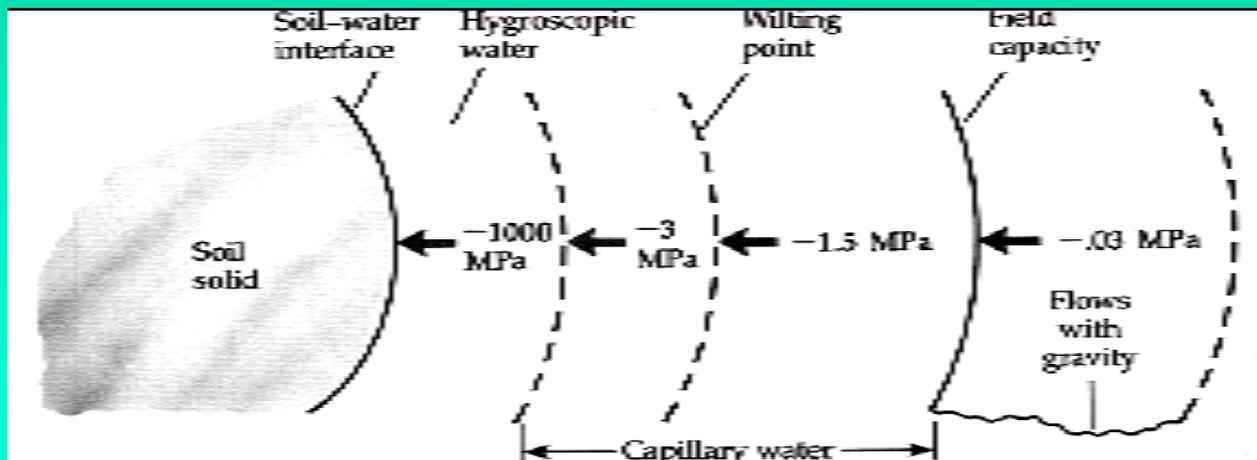
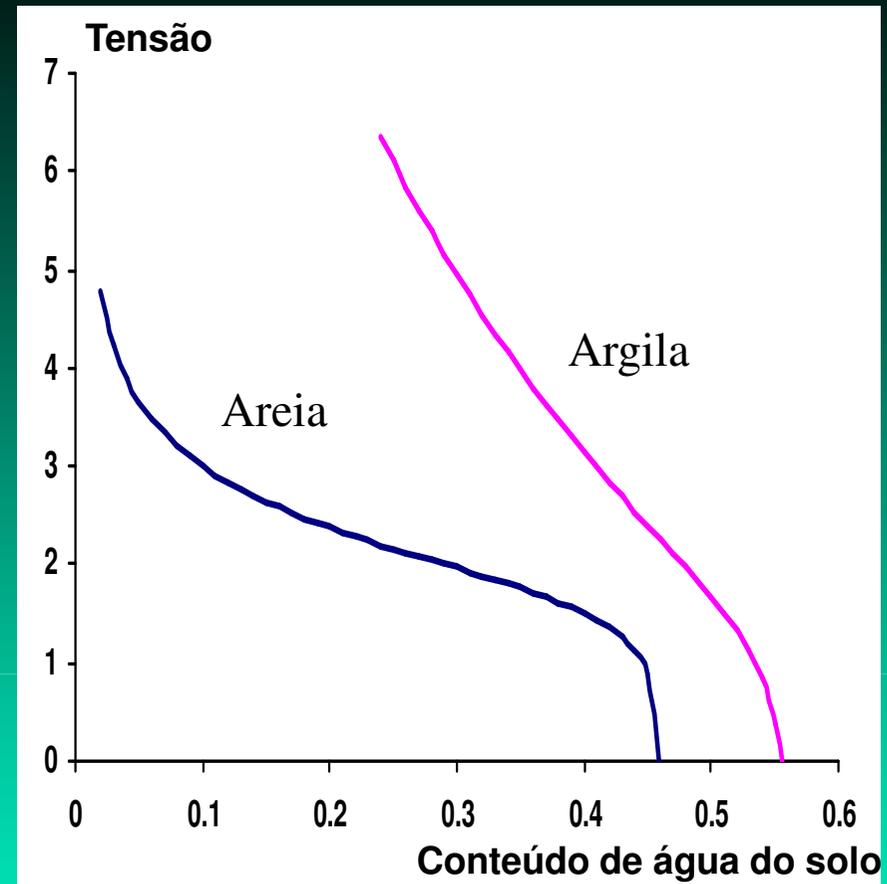


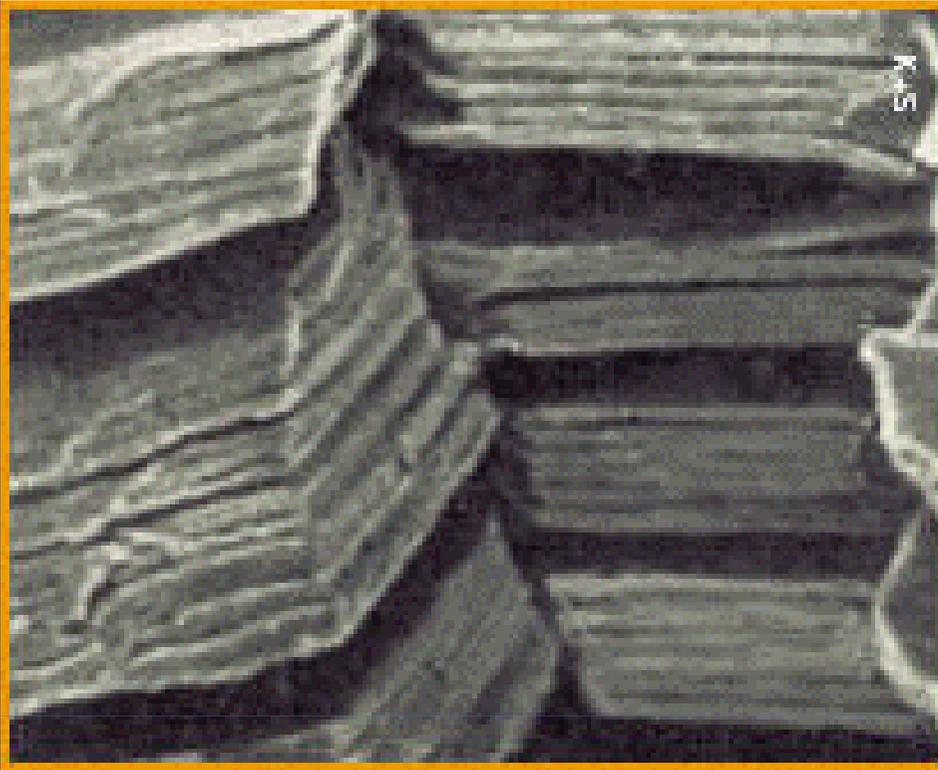
Seco, em equilíbrio com o ar

Ponto de murcha típico de muitos cultivares.

Capacidade de campo

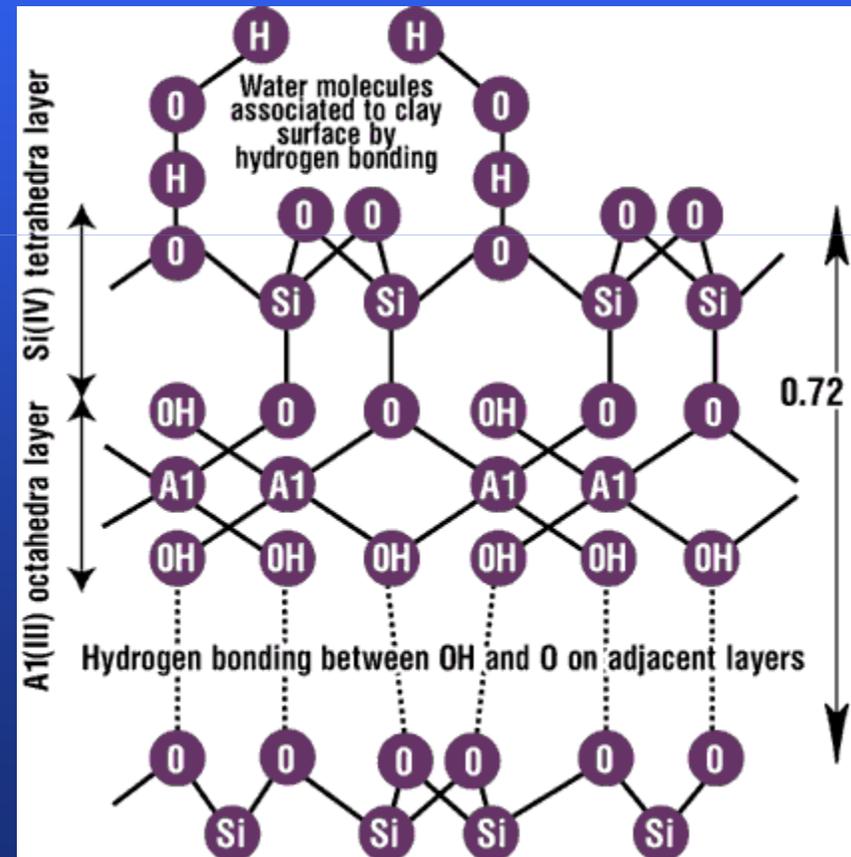
Saturado

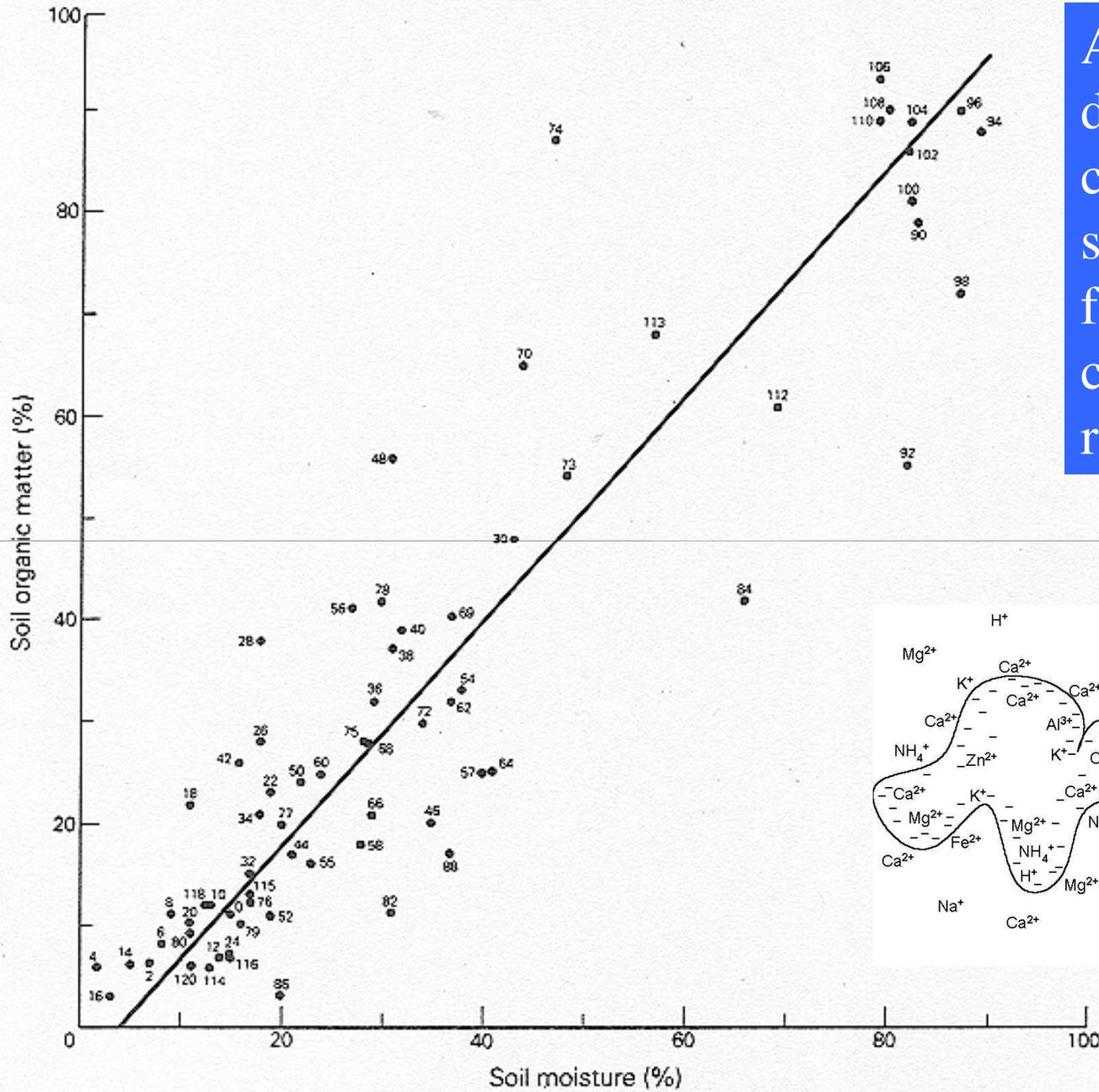




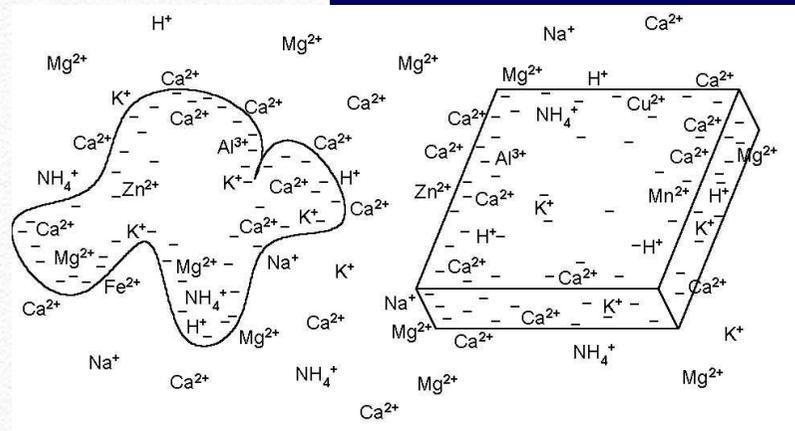
Partícula de argila

Disposição da água em relação aos silicatos da partícula de argila



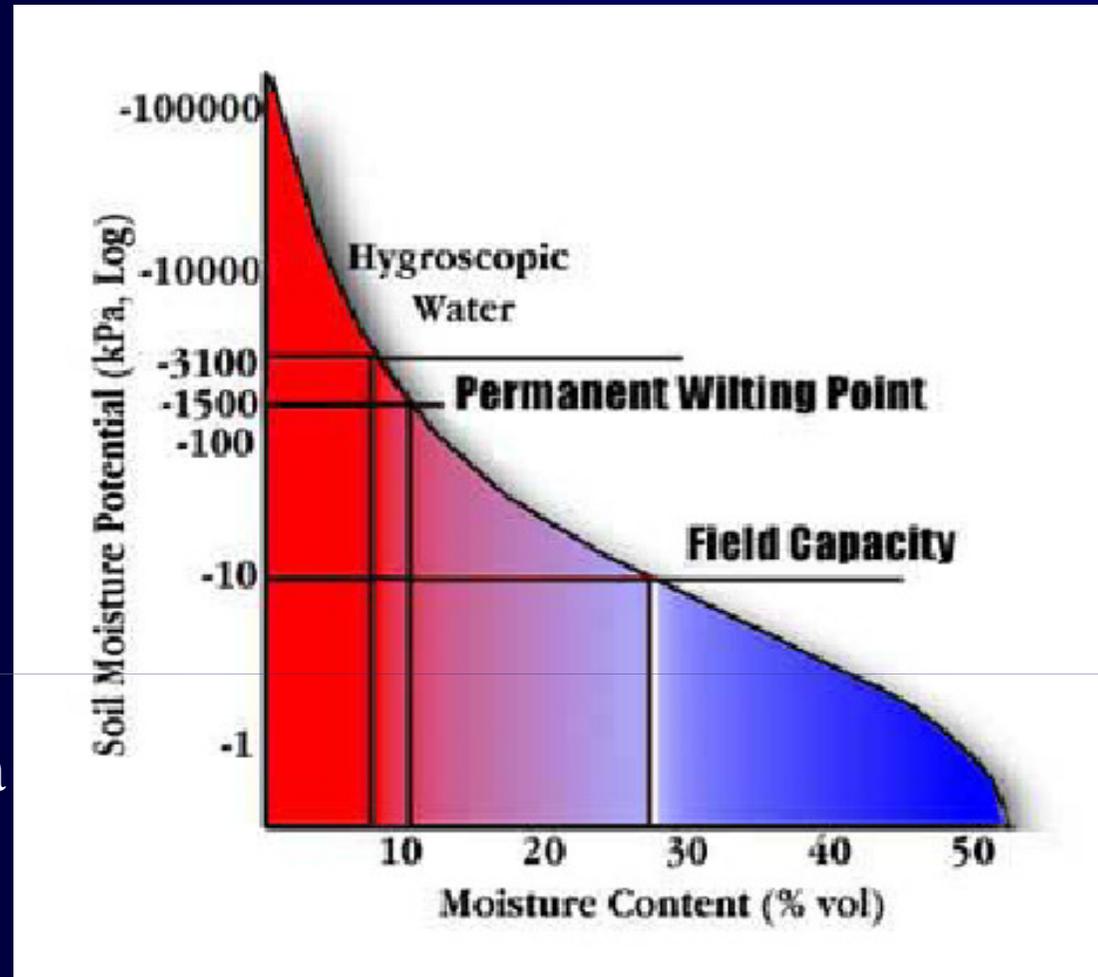


A matéria orgânica do solo se comporta de forma similar à argila, formando micelas e contribuindo para retenção de água.

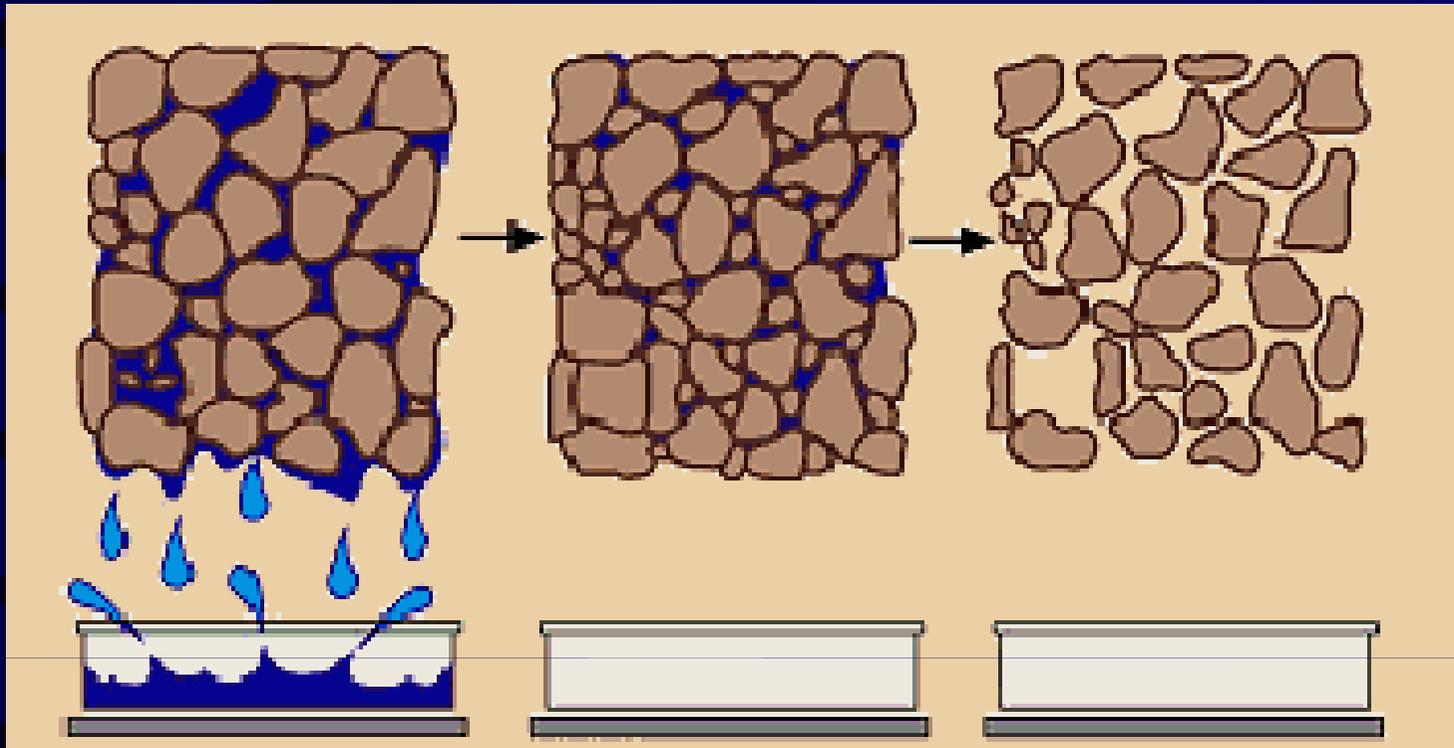


Capacidade de campo :
capacidade máxima de
retenção de água após a
drenagem gravitacional

Ponto de murchamento
permanente:
Potencial mátrico que não
pode ser vencido pela força
de sucção da planta.



Água disponível: conteúdo de água no solo verificado entre o
ponto de murchamento permanente e a capacidade de campo.



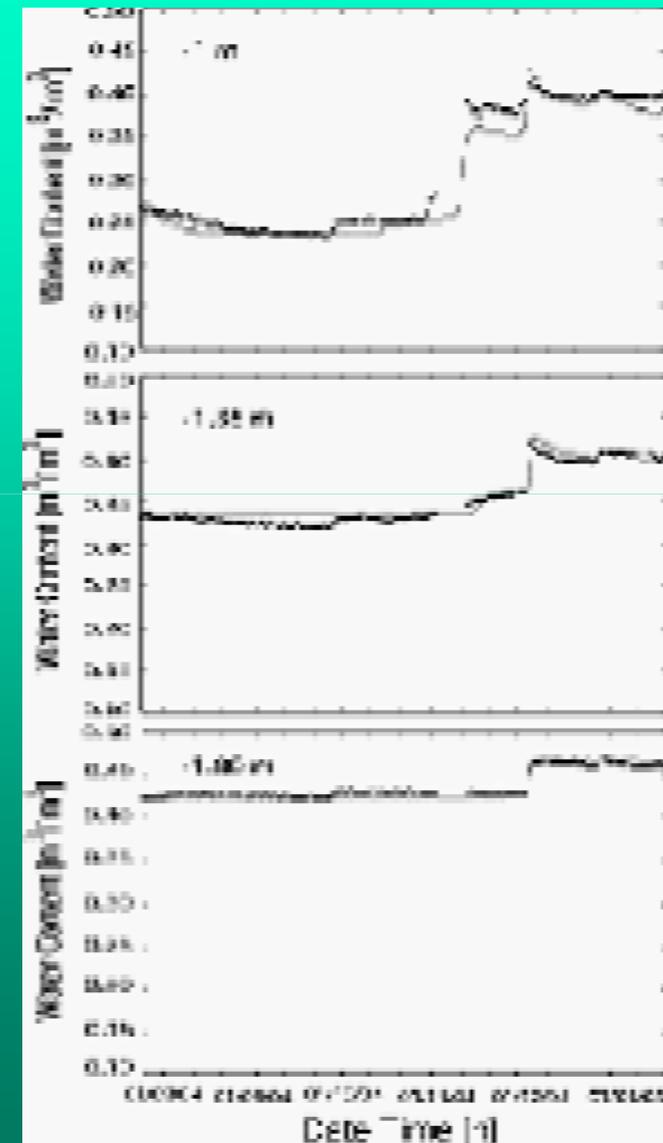
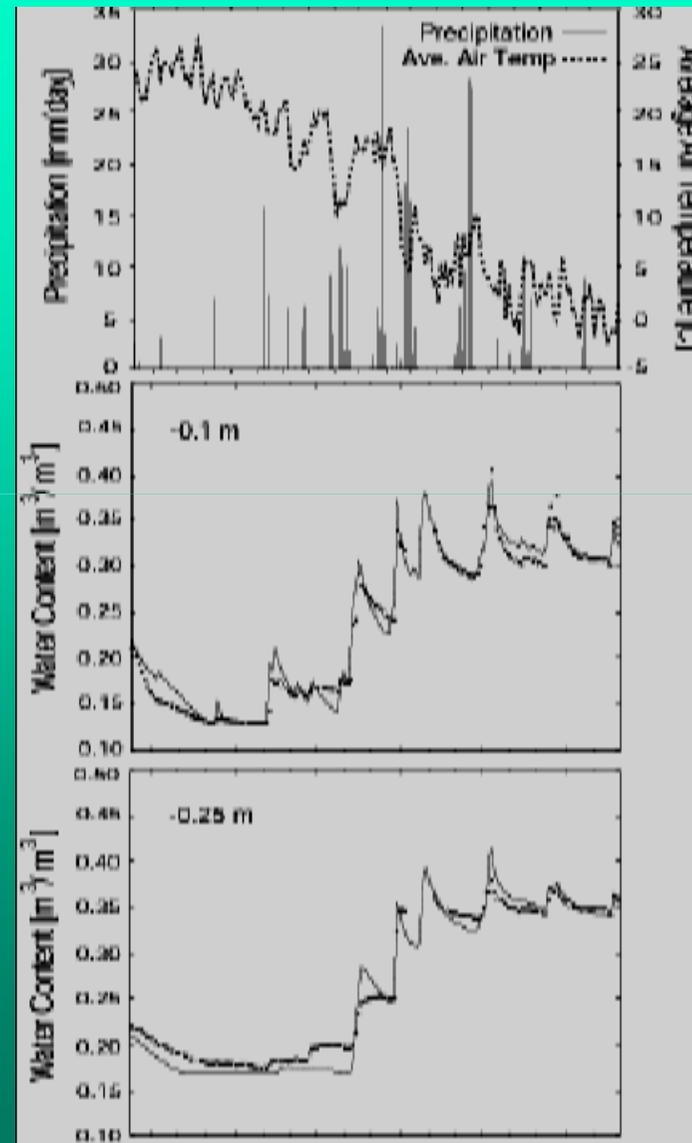
Solo saturado

Capacidade de
campo

Ponto de
Murchamento
Permanente

Água disponível para as plantas = profundidade de enraizamento (m) X capacidade de campo (m^3 / m^3)

Dados empíricos



Modelos de Priestmann- Taylor e Penman - Monteith

$$ET = \frac{(R_n - G)}{\lambda} \frac{\alpha \Delta}{\Delta + \gamma}$$

$$\lambda ET = \frac{\Delta(R_n - G) + \rho_a c_p \frac{(e_s - e_a)}{r_a}}{\Delta + \gamma \left(1 + \frac{r_s}{r_a}\right)}$$

R_n = Net Radiation

G = Soil heat flux

$(e_s - e_a)$ = vapor pressure deficit

ρ_a = air density

c_p = specific heat of air

Δ = slope of the saturation vapor pressure/temperature curve

γ = psychrometric constant

r_a = aerodynamic resistance

r_s = surface resistance

α = factor which account for the resistance term

Percolação em uma matriz.
Modelo de Richards.

$$\rho_w \frac{\delta \theta}{\delta t} = \frac{\delta}{\delta z} \left(K(\psi) \frac{\delta \psi}{\delta z} - Kg \right)$$

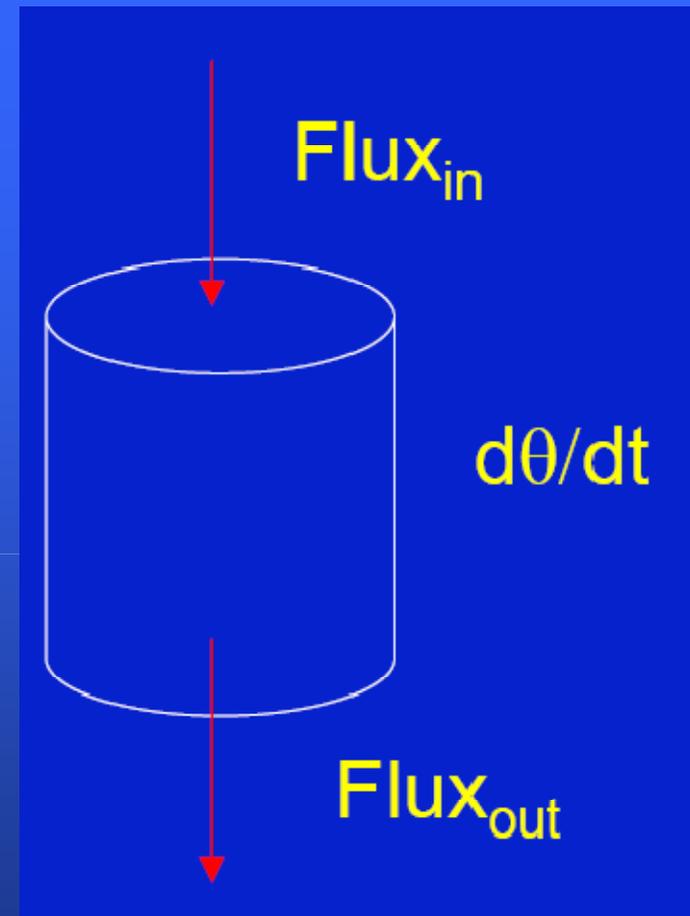
θ = volumetric soil water content ($\text{m}^3 \text{m}^{-3}$)

ψ = soil water potential (J kg^{-1})

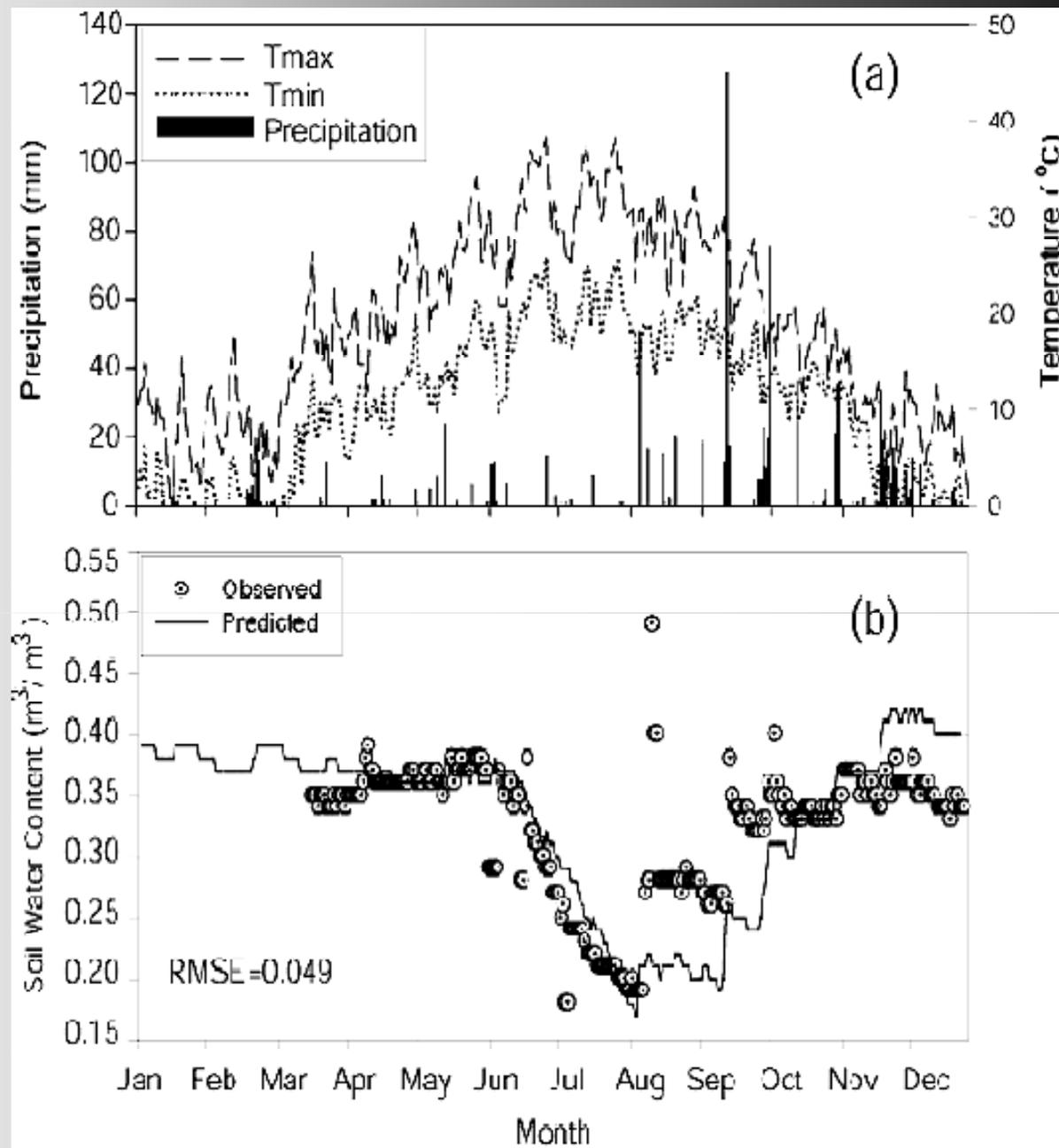
z = vertical dimension (m)

$K(\psi)$ = Hydraulic conductivity ()

g = gravitational constant ()



Dados
empíricos X
Modelo



Medidores de potencial
hídrico do solo:
←-Blocos de gesso



Tensiômetros



RESISTÊNCIA DAS PLANTAS À SECA

Plantas que escapam à seca → EFÊMERAS

