Plants and Plant Adaptations

EARTH 444

BIOLOGY 462

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What is a wetland plant?

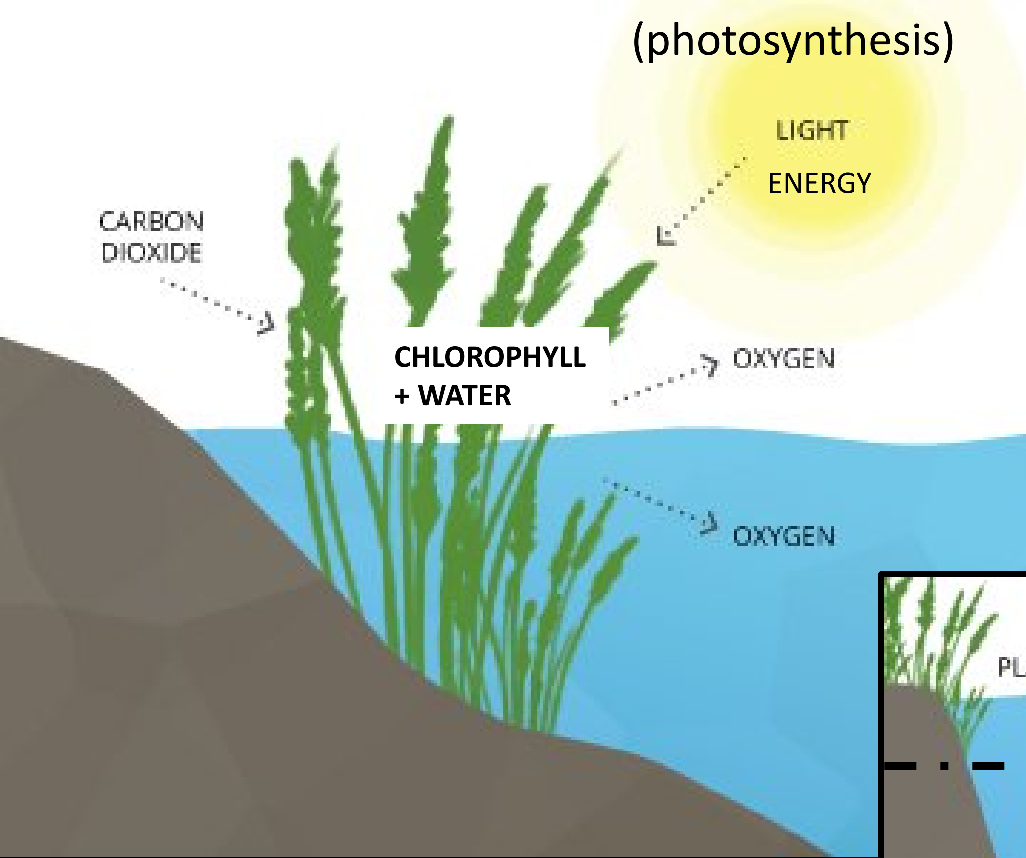
- **Hydrophyte**: any plant growing in water or on a substrate that is at least periodically deficient in oxygen as a result of excess water content (Cronk and Fennessey 2001)
- Includes both herbaceous and woody species but not mosses and algae
  - Emergent
  - Floating-leaved plants
  - Submerged plants

Adaptations

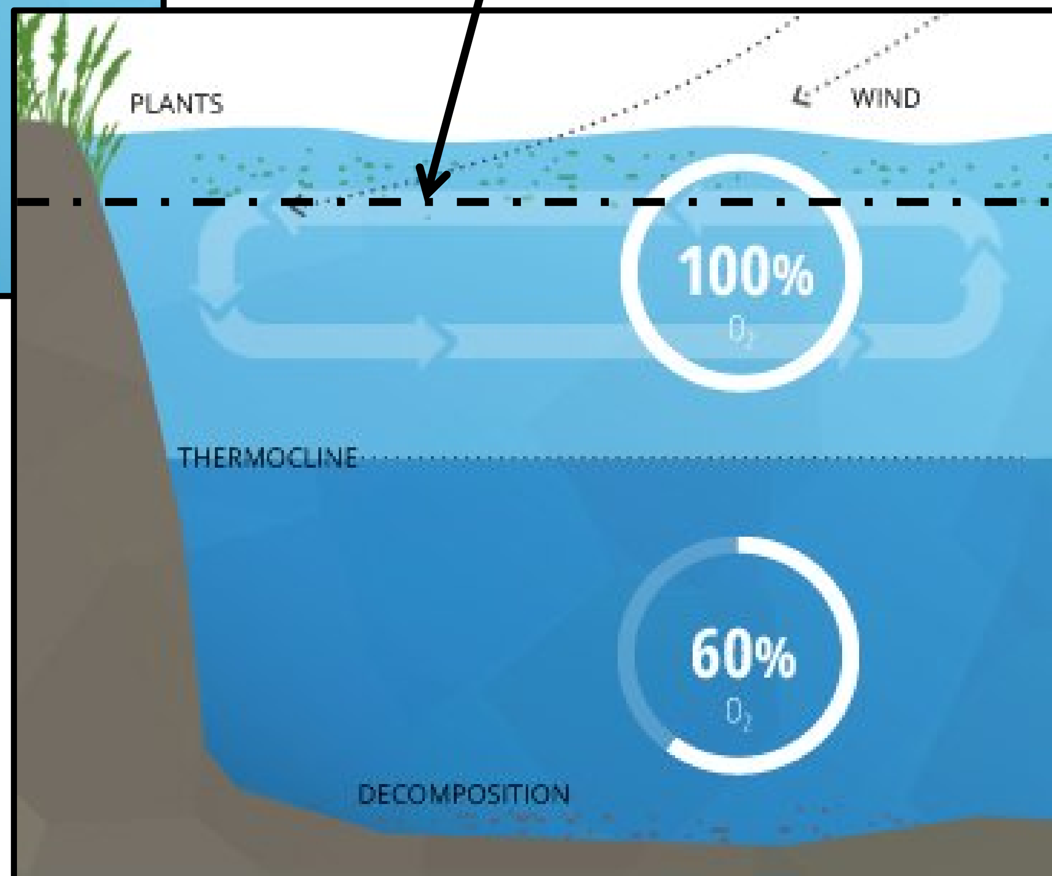
- Morphological
  - aerenchyma; buttressed tree trunks; polymorphic leaves
- Physiological
  - rhizosphere oxidation; changes in various metabolic pathways
- Reproductive
  - Prolonged seed viability; seed germination in low oxygen conditions; underwater pollination and germination

Adaptations to Anoxia (oxygen-poor conditions)

- Structural Adaptations: aerenchyma
  - Rooted wetland plants form internal gas-transport systems of large gas-filled lacunae; lacunae are together in porous tissue called aerenchyma
  - aerenchyma increases with increased reduced conditions
    - 10-12% root X-sectional area in flood intolerant plants
    - 50-60% root X-sectional area in flood tolerant plants
  - Allows gases to be stored (e.g. cattails nearly ½ total leaf volume is gas spaces and CO_2 may be up to 18X greater than in atmosphere)



depth in wetlands

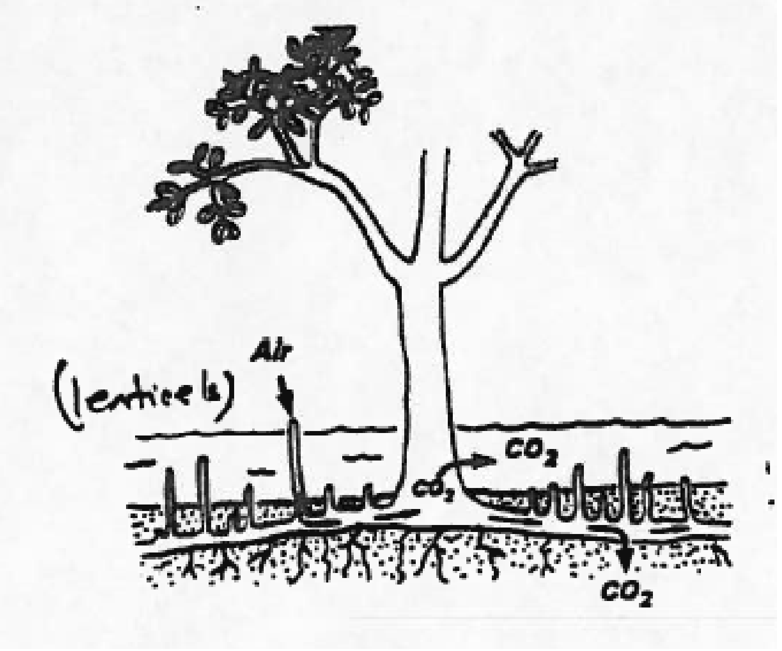



arenchyma

Adaptations to Anoxia (oxygen-poor conditions)

- Root Adaptations
  - Adventitious roots = new roots that form laterally from the main stem within days of flooding; forms in oxygen-rich water and less root biomass; plant hormone auxin
  - Shallow rooting: both woody and herbaceous plants tend to have shallower roots than in terrestrial conditons; gives root access to oxygen and nitrate

Adaptations to Anoxia (oxygen-poor conditions)



- Root Adaptations
  - Pneumatophores: modified erect roots that grow upward from roots = knees
  - Height corresponds to maximum water height
  - Take in O_2 and releases 3-22% more CO_2 than equivalent trunk area

Adaptations to Anoxia (oxygen-poor conditions)

- Root Adaptations
  - Prop and drop roots
    - Develop from lower part of stems and branches; grow outward toward substrate
    - Covered with lenticels that allow oxygen to diffuse into plant
    - Help with anchoring plant

Adaptations to Anoxia (oxygen-poor conditions)

- Stem Adaptations
  - Rapid underwater root extension: brings plant near or above water surface for light, O_2 & CO_2; hormone ethylene
  - Hypertrophy: swelling at stem base in response to flooding in herbaceous and woody plants; due to accelerated cell expansion caused by cell separation and rupture; buttress tree trunks
  - Stem buoyancy: for taking up O_2 and CO_2; slime

Adaptations to Anoxia (oxygen-poor conditions)

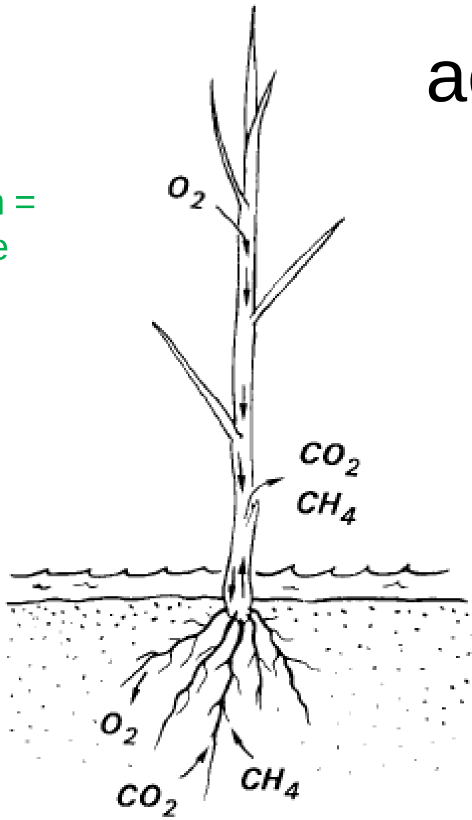
Gas transport mechanisms: enhance gas diffusion & enable plant to live in anoxic

- Passive molecular diffusion: most prevalent; physical process where substance moves from site of lower concentration/partial pressure to site of higher concentration/partial pressure; aerial part of plant has O_2 concentrations close to atmospheric (ie. 21%) and about 4% in rhizomes/roots

Passive gas diffusion: from high to low concentrations/pressure

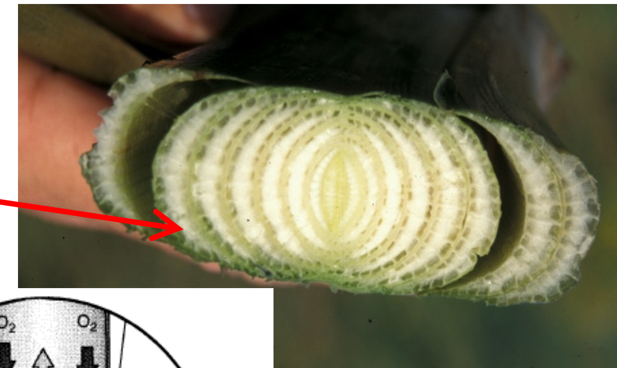
lvs & stems:
~ 21% O
concentration =
~ atmosphere

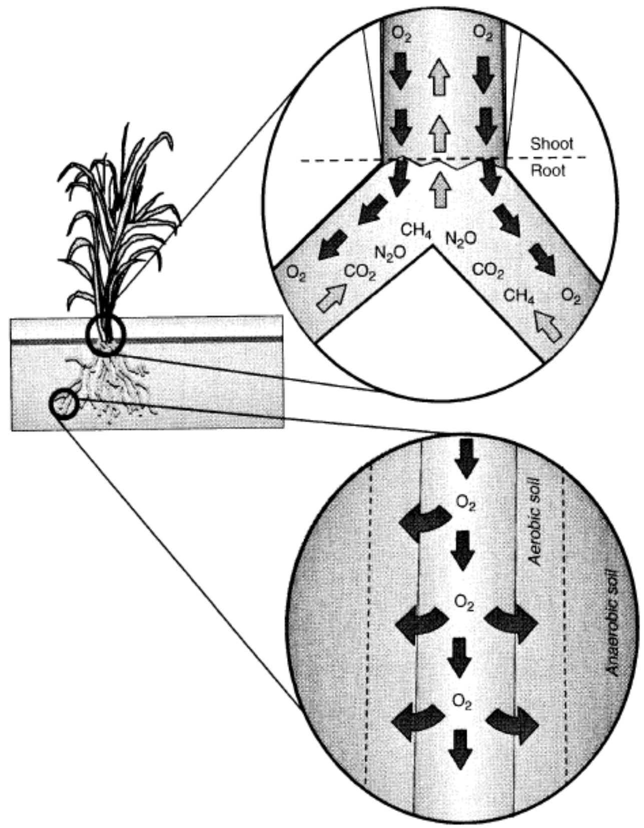
roots: ~4% O
concentration



(From Brix 1993)

aerenchyma





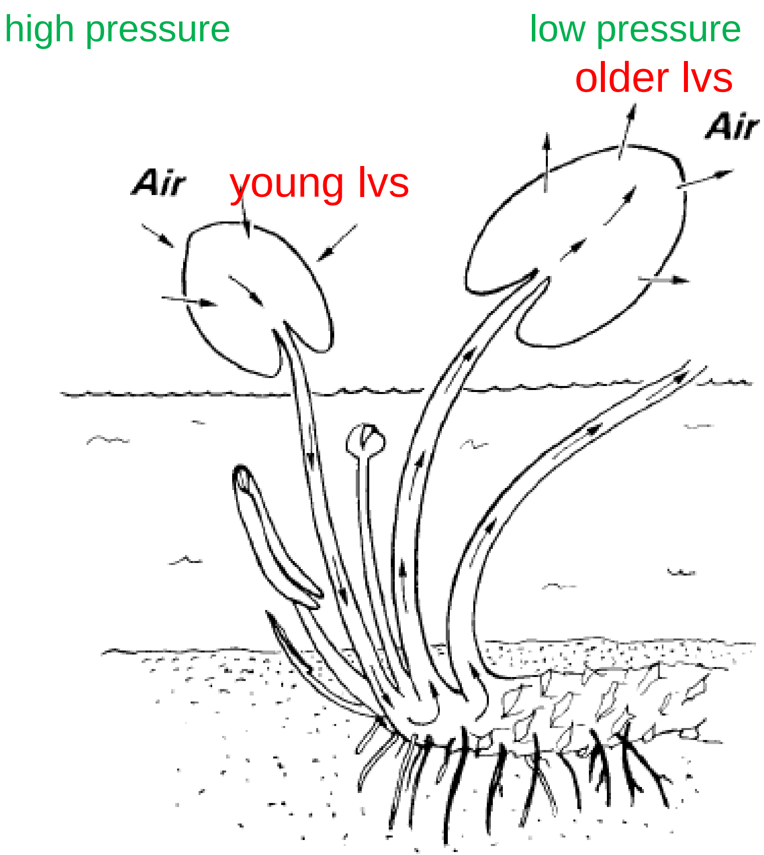
(From Reddy & DeLaune 2008)

Adaptations to Anoxia (oxygen-poor conditions)

Gas transport mechanisms:

- Pressurized ventilation: air moves into plant through stomata of younger lvs, down stems to rhizomes, then back up to older lvs and out
- youngest lvs have greater pressures because of smaller stomata, differences in humidity, water vapour than in older lvs

Pressurized Ventilation



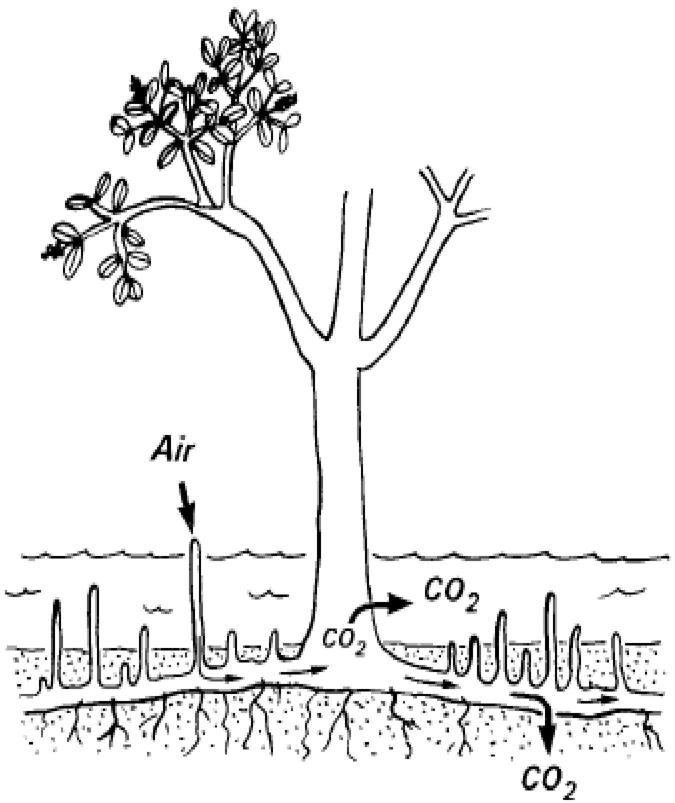
(Taken from Brix 1993)

Adaptations to Anoxia (oxygen-poor conditions)

Gas transport mechanisms:

- Underwater gas exchange: based on exchange of gases between submerged plant tissues and surrounding water; ie. pneumatophores

Underwater gas exchange



(Taken from Brix 1993)

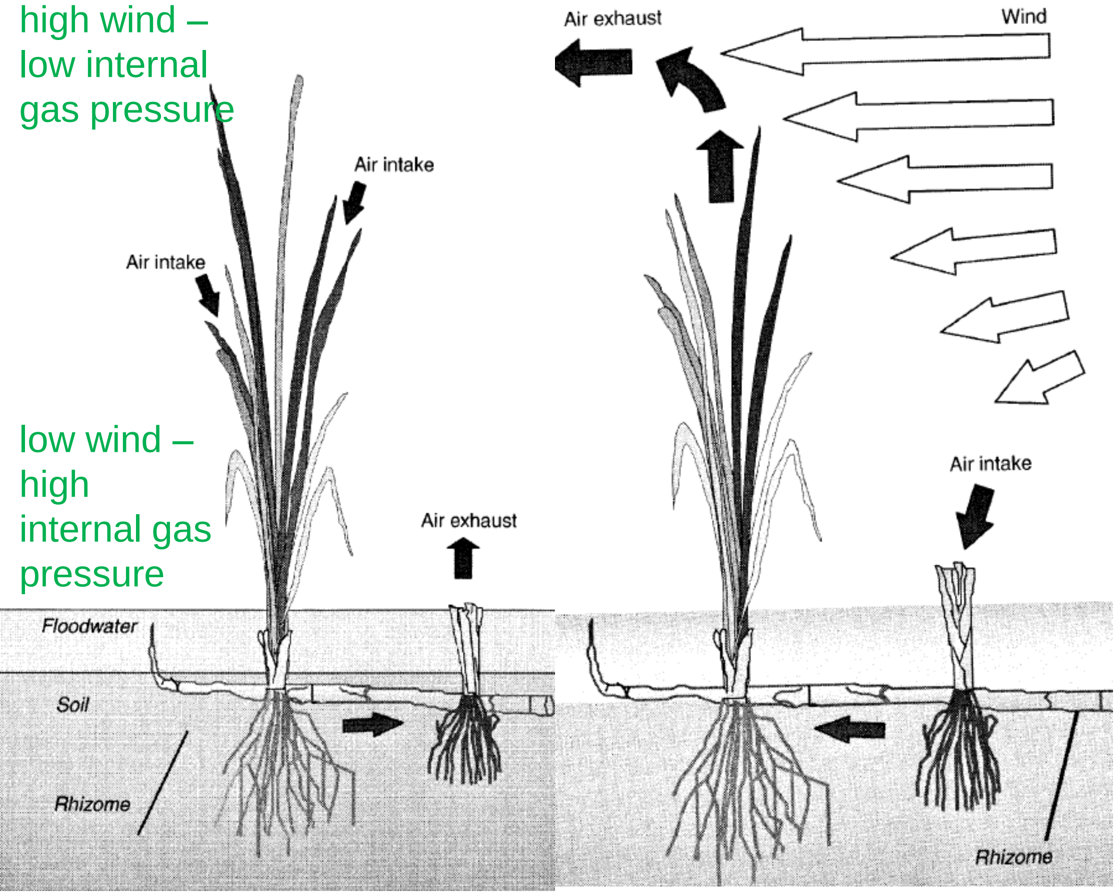
Adaptations to Anoxia (oxygen-poor conditions)

- Gas transport mechanisms
  - Ventri-induced convection: based on gradient in wind velocity; tall stems exposed to higher wind velocities and lower internal gas pressures as opposed to shorter stems where internal gas pressures are higher; air pulled into plant through short stems to rhizomes to higher stems
  - Could get rise of about 80% oxygen content

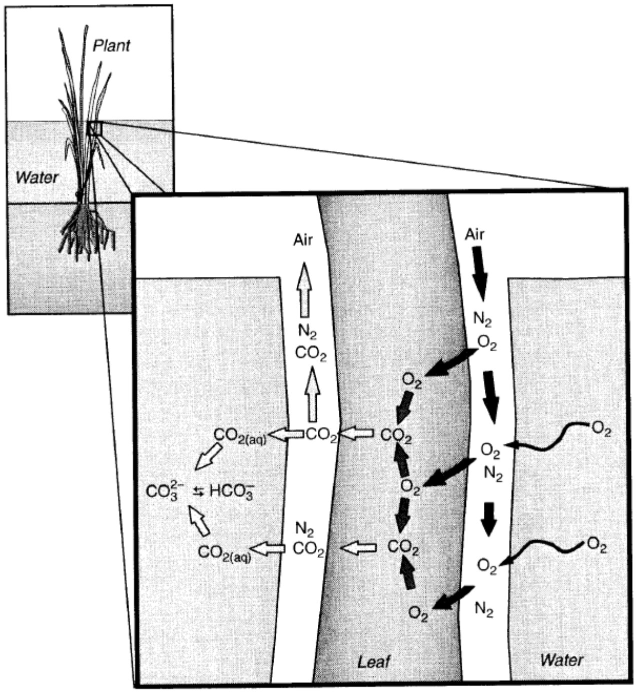
Ventri-induced convection

high wind – low internal gas pressure

low wind – high internal gas pressure



Gas exchange due to mass flow   Gas exchange due to convective flow

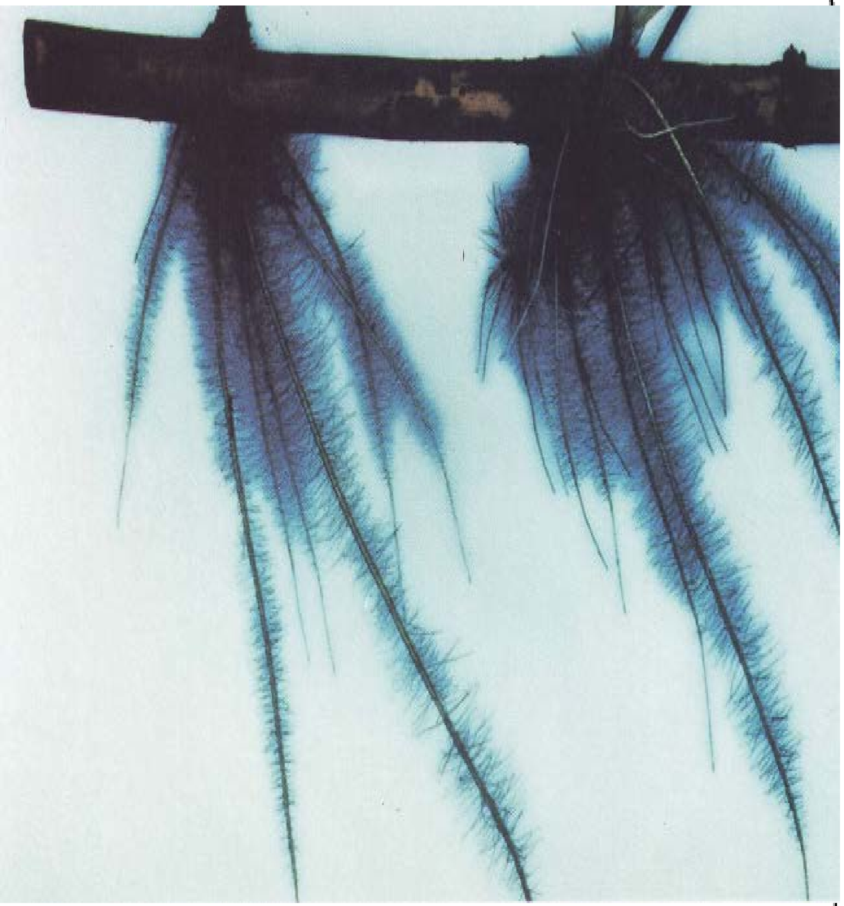


(From Reddy & DeLaune 2008)

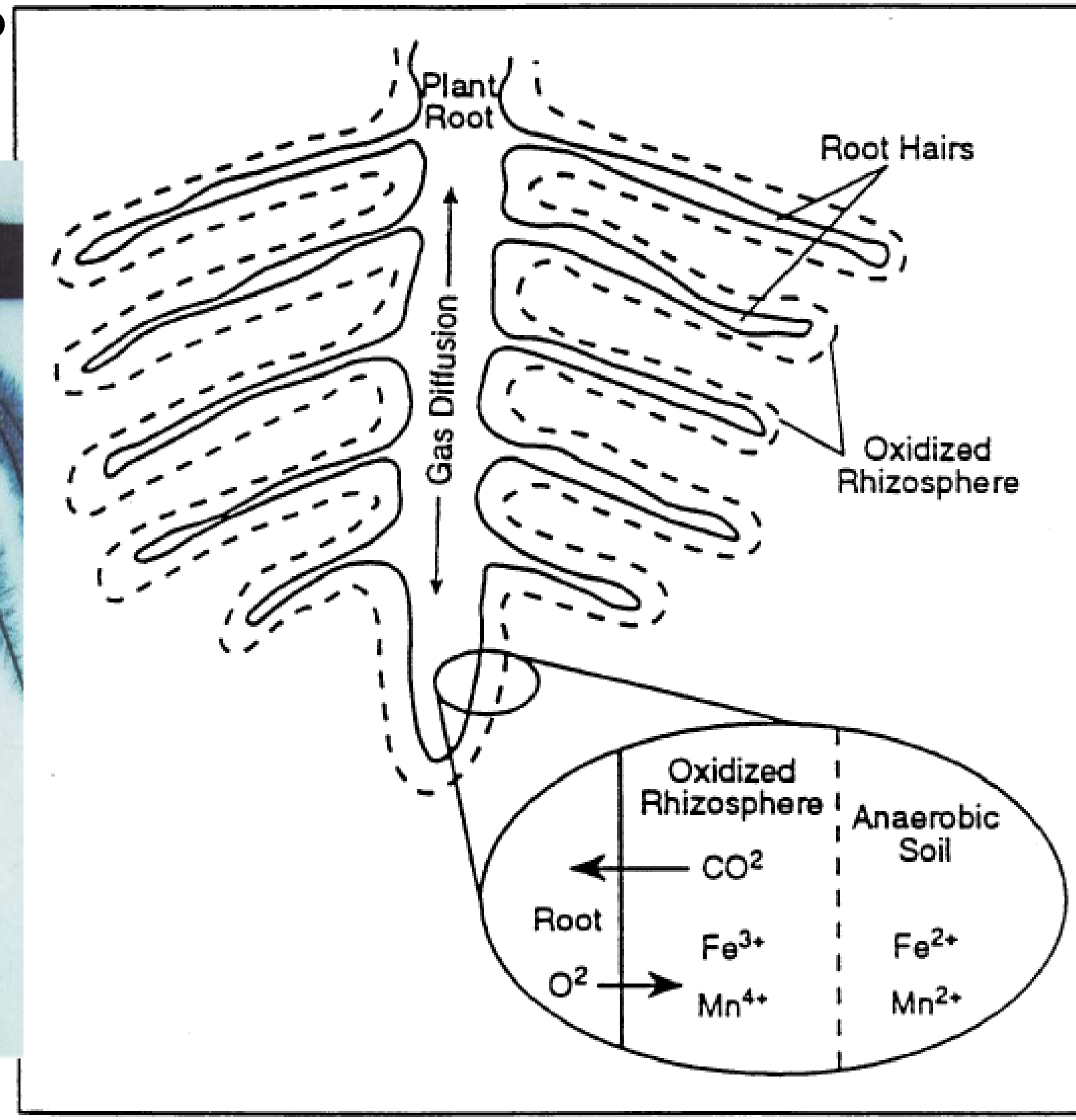
Adaptations to Anoxia (oxygen-poor conditions)

- Radial Oxygen Loss
  - O_2 transported through aerenchyma is used by root/rhizome respiration and radial oxygen loss
  - Radial oxygen loss results in oxygenation of area immediately adjacent to plant roots = rhizosphere
  - Driven by diffusion and concentration of O_2
  - Differs among plant species; different morphology
  - Beneficial because it may oxidize toxic substances in soil/water; e.g. supply O_2 to nitrifying bacteria to transform ammonia to nitrate; reduce iron uptake by oxidizing it as plaques

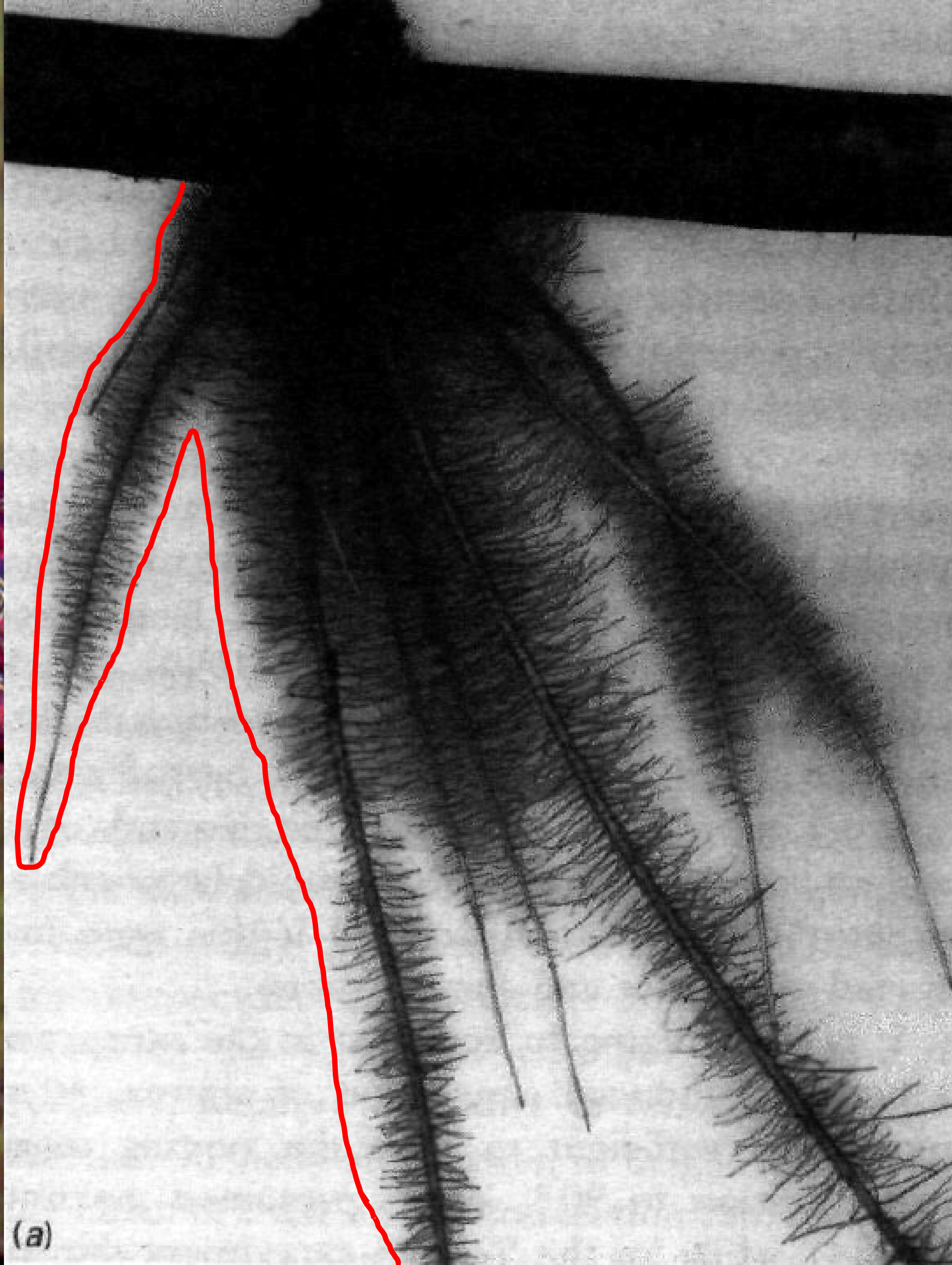
Radial oxygen loss



(from Cooper et al. 1996)



(from Kadlec 1988)


(a)

Adaptations to Anoxia (oxygen-poor conditions)

- Carbohydrate storage structures:
  - Flood intolerant plants can withstand anoxia for up to 3 days; flood tolerant plants can withstand anoxia for 4-90 days
  - Plants require great supplies of glucose under anaerobic than under aerobic respiration; usually stored in rhizomes as carbohydrate which is fermented to glucose
  - Rhizome and season determines when plants can survive prolonged flooding; i.e. *Glyceria*: 7-14 days in spring and < 7 days in mid-summer

Lotus rhizomes

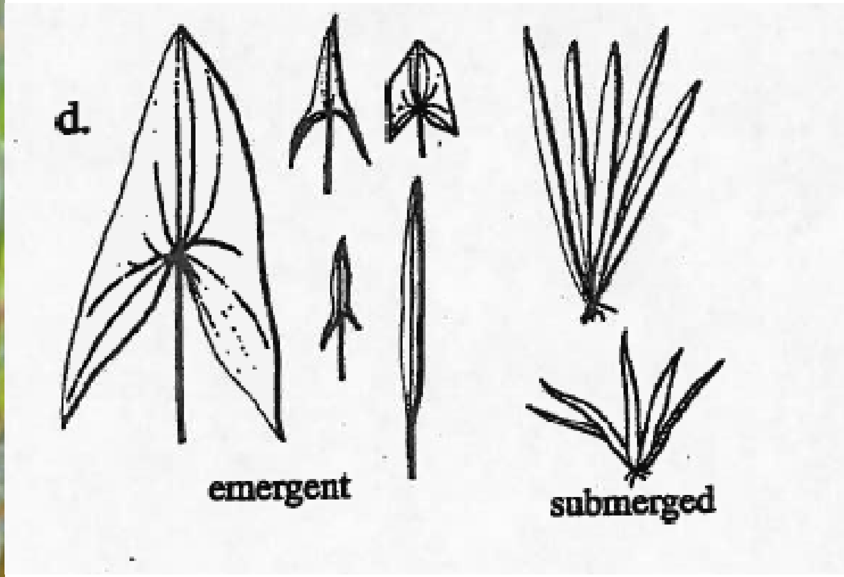
(From: http://delightfultastebuds.wordpress.com/2011/03/27/lotus-root-soup/)

Nuphar advena – Bullhead lily

(From: http://roadsidebouquets.blogspot.ca/2012/04/collecting-texas-wildflowers.html)

Adaptations to Submergence

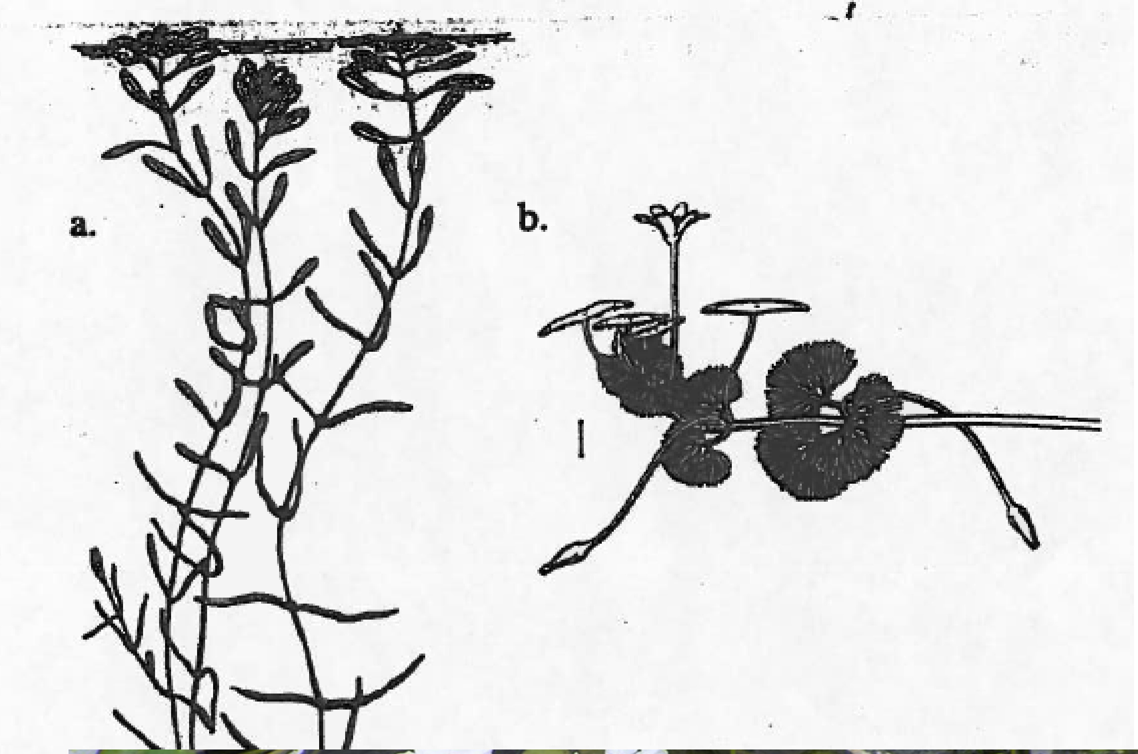
- Adaptations to limited light
  - Ribbon-like leaves; higher surface to volume ratio which facilitates light and diffusion of gases
  - Chlorophyll concentration may be greater
- Adaptations to limited CO_2
  - Greater aerenchyma which increases buoyancy
  - May use bicarbonate ions (HCO_3) for carbon source for photosynthesis
- Adaptations to Fluctuating Water Levels
  - Heterophylly: allows plants to survive dry and wet conditions

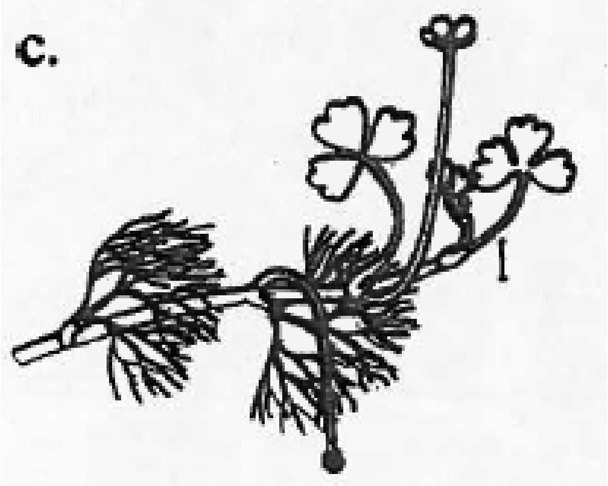


Sagittaria rigida - Arrowhead

(From: http://calphotos.berkeley.edu/cgi/img_query?enlarge=0000+0000+0107+1796)

(From: http://www.umces.edu/al/project/vallisneria-genetics-project-effects-genetic-diversity-restoration-success)





(From: http://www.botanicalgarden.ubc.ca/potd/2008/11/ranunculus_aquatilis.php)

Adaptations to Saltwater - Halophytes

- Salt avoidance
  - **Exclusion**: special structures in roots (i.e. Casparian bands) keep salt from entering
  - **Secretion**: salt glands on leaves
  - **Shedding**: loose salt by shedding plant parts (i.e. leaves); carried away in tides
  - **Succulence**: increase water content/unit area of leaf; dilutes the internal salt concentration and lessens salt effects; can close stomata to conserve water when water becomes limited

Adaptations to Limited Nutrients

- Mychorrhizal associations
  - Symbiotic fungi associated with plant roots; assists plants to capture water, P and other nutrients; fungi use carbohydrates from plant
- Nitrogen fixation
  - Gaseous form of N_2 is made available to plants,usually in N-fixing bacteria in nodules; e.g. alder, sweet gale, and pine
- Carnivory
  - Trap, kill, digest zooplankton to insects; frogs and birds for nutrients; mostly in sub-tropics
- Evergreen leaves
  - Allows plants to maintain foliar nutrients longer than single season


Utricularia vulgaris

(From: http://www.imagejuicy.com/images/plants/t/trientalis/1

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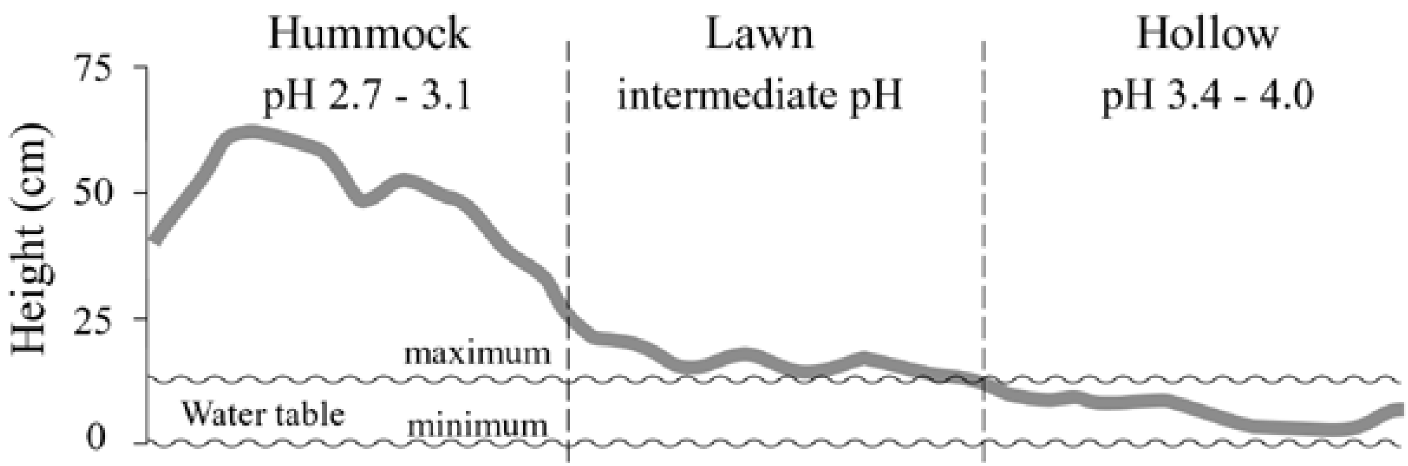
Wetland Vegetation - Peatlands

- **Vegetation**: plants considered collectively, especially in a particular area or habitat
- **Flora**: specific plant species in a particular habit; e.g. shrub flora or moss flora
- **Vegetation zone or community**: Vegetation changes and changes in floristic composition in peatlands are controlled by habitat conditions; mostly hydrology and water chemistry

SNR	A Very Poor	B Poor	C Medium	D Rich	E Very Rich	F Hyper
Available nutrients	very low	low	average	plentiful	abundant	excess alkali or salt accumulation
Water pH	<5.0	4.5 – 6.0	5.0 – 6.5	6.0 – 7.4	6.5 – 8.0	8.0+
vonPost of surface tier	1 – 3	3 – 6	4 – 7	7 – 10	8 – 10	
Ground - water flow through site	stagnant					
				seasonal seepage		
					continuous seepage	
C:N ratio	High					
			Medium			
					Low	
Surface tier material		Fibrimor		Saprimoder		
			Mesimor			Marl
				Mineral		
Water colour		tea colored; yellowish-deep brown and turbid				blue-green and very clear (alkaline)
			green-brown and clear			
				green-brown and turbid		
Colour of surface peat		pale				
				dark		
Surface tier saturation		always saturated				
				seasonal exposure of substrate		
				diurnal exposure of substrate		

Taken from: Mackenzie and Moran 2004



	Hummock	Lawn	Hollow
Mosses:	*Sphagnum fuscum*	*Sphagnum magellanicum*	*Sphagnum cuspidatum*
	Sphagnum capillifolium	*Sphagnum capillifolium*	*Sphagnum majus*
	Polytrichum strictum	*Sphagnum angustifolium*	*Sphagnum fallax*
	Aulacomnium palustre	*Sphagnum rubellum*	*Sphagnum angustifolium*
	Pleurozium schreberi	*Sphagnum papillosum*	*Sphagnum pulchrum*
	Dicranum undulatum		*Warnstorfia fluitans* var *fluitans*
	Pohlia nutans		*Cladopodiella fluitans*
Vascular plants:	*Rubus chamaemorus*	*Carex oligosperma*	*Carex limosa*
	Kalmia angustifolia	*Eriophorum angustifolium*	*Carex oligosperma*
	Ledum groenlandicum	*Eriophorum virginicum*	*Eriophorum virginicum*
		Scirpus cespitosus	*Rhynchospora alba*
		Andromeda glaucophylla	*Utricularia cornuta*
			Andromeda glaucophylla

Table 5. Floristic composition of the tall-shrub thickets and black spruce bog forests.

This is a summary of vegetation from bogs in northeastern US and Canada (from Damman and French 1979)

COMMUNITY		1 Highbush Blueberry Thicket	2 Cinnamon Fern—Highbush Blueberry Thicket	3 Mountain Holly—Black Spruce Thicket	4 *Sphagnum magellanicum*—Black Spruce Forest	5 *Carex trisperma*—Black Spruce Forest
TREE LAYER	Height (m)	6-12	10-16	6-12	8-12	10-15
	Cover (%)	<5	2-20	15-40	>50	>60
Acer rubrum (Red Maple)		—	—	- - -	- - -	
Larix laricina (Larch)		- - -	- - -	—	—	- - -
Picea mariana (Black Spruce)		- - -	- - -	—	▨	▨
Pinus strobus (White Pine)		- - -	- - -	- - -	- - -	
Pinus rigida (Pitch Pine) S[a]		- - -	- - -			
Abies balsamea (Balsam Fir) N				- - -		—
SHRUB LAYER (2-3 m)	Cover (%)	80-100	80-100	<50	<10	<10
Vaccinium corymbosum (Highbush Blueberry)		■	■		- - -	
Rhododendron viscosum (Swamp Honeysuckle)		▨	▨			
Rhododendron nudiflorum (Purple Honeysuckle)		- - -	- - -			
Lyonia ligustrina (Maleberry)		- - -	- - -			
Pyrus arbutifolia (Red Chokeberry)		- - -	- - -			
Clethra alnifolia (Sweet Pepperbush)			- - -			
Rhus vernix (Poison Sumac)			- - -			
Alnus serrulata (Smooth Alder)			- - -			
Alnus rugosa (Speckled Alder)			- - -			- - -
Ilex verticillata (Common Winterberry)			▨	- - -		- - -
Viburnum cassinoides (Wild-Raisin)			- - -	—	- - -	—
Nemopanthus mucronata (Mountain-Holly)			- - -	▨	—	—
HERB LAYER[b]	Cover (%)	<20	40-80	<50	30-50	40-60
Chamaedaphne calyculata		—	- - -	—	—	- - -
Kalmia angustifolia		- - -	- - -	▨	—	—
Kalmia polifolia				—	- - -	- - -
Ledum groenlandicum N				▨	—	—
Rhododendron canadense N				▨	- - -	- - -
Gaylussacia baccata		- - -	- - -	—		
Gaylussacia frondosa S		- - -	- - -			
Vaccinium angustifolium				—	- - -	—
Vaccinium oxycoccos				—	—	
Drosera rotundifolia				—	—	- - -
Sarracenia purpurea			- - -	- - -	- - -	- - -
Carex trisperma var. *billingsii*		- - -	- - -	- - -	—	
Carex trisperma			—		—	▨
Osmunda cinnamomea			▨		- - -	—
Smilacina trifolia N						—
Carex paupercula N				- - -	- - -	- - -
Carex pauciflora N				—		
Cornus canadensis				—	- - -	—
Maianthemum canadense			- - -	- - -	- - -	—
Coptis groenlandica			- - -	- - -	- - -	—
Trientalis borealis			- - -	—	—	—
Linnaea borealis N				- - -	- - -	—
Gaultheria hispidula N				—	- - -	—
Pyrola secunda				- - -		—
Clintonia borealis			- - -	- - -		—
Aralia nudicaulis			- - -			- - -
Calla palustris			—			- - -
Dulichium arundinaceum			- - -			
Iris versicolor			- - -			- - -
Carex crinita			- - -			- - -
Carex folliculata			- - -			- - -
Carex stricta			- - -			
Dryopteris thelypteris			- - -			—
Symplocarpus foetidus			- - -			

COMMUNITY		1	2	3	4	5
MOSS LAYER	Cover (%)	<60	60-80	80-100	90-100	80-100
Sphagnum magellanicum		—	▨	▨	■	—
Sphagnum nemoreum		—	—	▨	—	—
Sphagnum angustifolium		- - -	- - -	▨	—	—
Sphagnum fallax		▨	▨	—	- - -	▨
Sphagnum russowii			- - -		—	—
Sphagnum fuscum N				- - -	- - -	
Sphagnum palustre			- - -			
Sphagnum fimbriatum		- - -	—			- - -
Sphagnum teres			- - -			- - -
Sphagnum centrale			▨			- - -
Sphagnum girgensohnii			- - -			▨
Sphagnum papillosum		- - -	- - -			
Sphagnum imbricatum			- - -			
Sphagnum riparium N						- - -
Dicranum scoparium		- - -	- - -	—	- - -	—
Polytrichum commune		- - -	- - -			
Aulacomnium palustre		- - -	—	- - -		—
Pleurozium schreberi			- - -	—	- - -	—
Bazzania trilobata			- - -	—	—	—
Dicranum polysetum			- - -	—	- - -	—
Hylocomium splendens			- - -	—		—
Hypnum crista-castrensis				—		- - -
Ptilidium ciliare				—	- - -	

■ Dominant; cover over 40%
▨ Sometimes dominant
— Usually or always present; variable cover
- - - Occasionally to frequently present
"Blank" Absent or rare

Plant Indicators

Indicator Category	Symbol	Occurrence in Wetlands
obligate wetland	Obl	> 99%
facultative wetland	FacW	67-99%
facultative	Fac	34-66%
facultative upland	FacU	1-33%
upland	UPL	< 1%

** In US, classified plant species in each indicator category; varies according to region
In Ontario, classified as wetland/non-wetland species; occupies bog, fen, swamp, marsh, open water