Peatlands (mires)
-all peat forming habitats either ombrotrophic (bogs, moors, muskegs) or minerotrophic (fens)
-extensively studied, especially in northern Europe

2 to 3% of the terrestrial land surface, BUT 1/3 of global C pool!!

- 90% in arctic, boreal, and temperate zones (Canada, Scandinavia, Russia, tropical Malaysia)

- Subalpine fen in the Tahoe Basin

- Tundra peatland

- Bog in the Tierra del Fuego

- Afro-alpine peatland
Pocosins – from Algonquin Indian word meaning “swamp-on-a-hill”

Type of peat deposit
- terrestrialization ("quaking bog")
- paludification ("blanket bog")

Terrestrialization

Paludification ("blanket bog")

Aerial view of blanket bogs in Scotland

British Islands
- for a long time paleoecologists thought that blanket mires were climatically induced
  BUT
- probably they have resulted from human activities ~ 3000 y BP cutting forest, reduced transpiration and interception
**Classification**
- according to water retention:
  - **Primary**: formed within water-filled depressions or basins
  - **Secondary**: grow upward beyond the confines of the basin while still remaining under the influence of ground or surface water
  - **Tertiary**: grow beyond the level of the groundwater source - perched above the accumulation of an impermeable peat

**Aapa mires**
patterned peatland subarctic and boreal - S of permafrost line
ladderlike arrangement of long ridges (strings) alternating with wet depressions (flarks) perpendicular to the slope
*dominant in N. Scandinavia, Labrador and Quebec*
the origin of strings and flarks is not very well understood
ice pushing up the ridges in the pools, peat sliding downslope

**Palsa mires**
zone of discontinuous permafrost on the southern edge of tundra
isolated mounds underlain by frozen peat and silt (permafrost). 5m tall, 150 m diam.
peat moved upward in a shallow pool that freezes in winter; insulated by lichens and mosses
core can melt, palsa collapses; tamarack; black spruce mosses, lichens, labrador tea, sedges

**Classification**
- according to pH, water source and vegetation:
  - ombrotrophic
  - transitional ("poor fens")
  - minerotrophic
  - pH: 3.7-4.2 4.2-5.7 >5.8
  - nutrient poor
  - nutrient rich
  - Sphagnum
  - mix
  - sedges
  - (Hochmoore Zwischenmoore Niedermoore)
Chemistry
pH, cation exchange capacity - absorption of positively charged ions, release of H+
low acidity due to dissociation of weak organic acids
galacturonic acid - bound to the cell walls of Sphagnum
- produced at the growing tips of Sphagnum
- source of CH4, depository for CO2

Nutrients
bogs very deficient, fens less deficient; K and P generally more limiting than N
N and P mineralization in fens and bogs:

<table>
<thead>
<tr>
<th></th>
<th>bogs</th>
<th>fens</th>
</tr>
</thead>
<tbody>
<tr>
<td>mineralization</td>
<td>fast</td>
<td>slow</td>
</tr>
<tr>
<td>cellulose decomp.</td>
<td>slow</td>
<td>fast</td>
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</tbody>
</table>

Sphagnum litter cells brake easily, release N & P; then refractory cell material very slow to decompose (lower microbial activity in bogs)
Low immobilization because of low microbial activity

Stress
- pH
- ice, (anoxia in ice encased for 10 months)
- low nutrients
- continuously rising moss surface
- atmospheric deposition
- human impact (peat mining)

Vegetation Structure
- mosses
- nitrogen fixing lichens
- sedges
- orchids
- carnivorous plants
- shrubs
- trees

Sphagnum "keystone species"
- 20 million years,
- 200 spp., 40 in NA and Europe
- extremely successful peat-inhabiting and peat-forming plant
- phenolic compounds including sphagnetoinhibit microbial activity
- “immortal” - grows upwards
- can “direct” succession - peatmoss layer in forest, acidification, suppression of tree seedlings, retention of mineral nutrients (cation exchange)
- accumulation of org. matter
- relocation of nutrients to living parts
- litter depleted in N & P
Hummocks and hollows - ups and downs - different rate of decomposition!!

S. fuscum - hummock lower pH; higher release of H+
S. cuspidatum - pool higher pH

Sphagnum - morphology and anatomy

Upright shoots with fascicles of branches
Cells with chlorophyll and empty water storing cells (hyaline cells)
capacity to retain cations and water
the adsorbing properties exceed clay
"moss-bags" - monitoring indicators for heavy metals

Other mosses
- brown mosses - succession changes due to acidification and eutrophication are changing moss composition

Low shrubs - tough leathery leaves, perennial, small
- Ericaceae (Kalmia, Ledum, Chamaedaphne, Vaccinium)
- Salix spp., Betula,

Orchids

Sedges

Carex spp.

Eriophorum spp (cotton grass)
**Trees**
Thuja occidentalis - northern red cedar,
Picea spp. - spruce
Fraxinus spp. - ash,
Larix - tamarack,
Alnus - alder

**Carnivorous plants**
- Sarracenia - pitcher plant - hollow leaves
  Drosera - sun dew; Utricularia - bladderwort

**Nitrogen fixing lichens**
- symbiosis with cyanobacteria

**Plants growing in association with Sphagnum**
- adaptation to low pH
- waterlogging
- low nutrients
- extreme temperatures
- adaptation to continuously rising surface
all vascular plants growing in Sphagnum have the ability to continuously move their growing points upward to "keep up" adventitious roots on old buried stems

**Hummock**
dwarf shrubs  |  creeping sedges
---|---|---
HUMMOCK | LAWN | HOLLOW
New Zealand – restiad raised bogs; family Restionaceae (see Poaceae)

Empodisma minus
Sporodanthus ferrugineus

Sedges
Empodisma
Sporodanthus (15,000 y old)
Wetlands 24: 133, 2004

Succession:
Recently: willow and Ulex invasions; drainage; fire;

Functions
- low primary production
- peat production - results of growth and decomposition; 20 - 80 (200) cm per 1000 y
- higher PP of sedges in fens
- the contemporary rate of exploitation 90 mil. tons/year - many times greater than replacement

Global climate change
- greatest warming expected in boreal and subarctic regions
- carbon budget: CO₂ x CH₄ x DOC
- DOC input into boreal lakes and rivers => impact on downstream aquatic ecosystems (PP, microbial activities, UV attenuation)
- when more DOC retained => increase in CH₄ and CO₂ emissions

Methanogenic bacteria inhibited by sulfates

Regions with high sulfur deposition:
- competition of sulfate reducing and methanogenic bacteria for organic substrate, acetate
- inhibition of methanogens by sulfate reduction products
- if too much SO₄, redox does not drop enough

Use of peat
- horticulture
- fuel; building material
- dressing for wounds; oil spillage;
- historical archives

Vile et al. 2003: Use of peat
Cloudberries, Rubus sp. (F Inland)

Vaccinium macrocarpa (N. Am.)

Peat mining operations
- block-cutting
- vacuum mining

Acrotelm 10-40 cm deep

Catotelm (anoxic)

Draining

Conservation
- Project Telma - IUCN
- International Peatland Society

Finland 90% destroyed; Netherlands about 2% left; Poland 65% destroyed;

Inventory program - Quebec: regional maps of peat deposits, use of remote sensing

“Restoration” of mined peatlands as shallow lake wetlands - the Netherlands
Restoration projects
- "biodiversity" (goal: a reasonable approximation of original conditions)
- "production" (goal: repeated peat harvesting, food, forest products, raw materials)
- "regulation" (goal: flood mitigation, storage of nutrients, water quality improvement)

Important: to initiate restoration process ASAP after peat harvesting to minimize peat degradation (oxidation) and losses through wind/water erosion

Hydrology:
- water table - 30 +/- 14 cm
- soil moisture >50%

Water source (!) Tree removal: provide seeds; prevent invasive species

Restoration projects - cont.
- immitation of the successional process, e.g., establish a sedge community with some minerotrophic Sphagnum species
- importance of paleoecological data (!)
- reestablishment of acrotelm/catotelm dynamics
- productivity, decomposition and nutrient cycles
- other trophic levels
- time frame: 3-5 y for key species
  about 10 y for stable water table
  about 30 y for functional ecosystem

Effects of nutrient enrichment may require mowing regimes to keep tall macrophytes under control

Restoration - spontaneous regeneration
Eastern Quebec
Capability of some species to naturally colonize
Depends on:
- Soil acidity
- Water table (< -40 cm); blocking the drainage canals
- Nutrients
- Frost
- Wind erosion
- Propagules


Vascular plants and Sphagnum have different nutrient pools; VP rely on mineralization for their supply of N & P; Sphagnum from atmospherically deposited N; supply of water to Sphagnum by capillary rise along stems up to 40 cm
+ nitrogen => increased growth of vascular shrubs => negative impact on Sphagnum