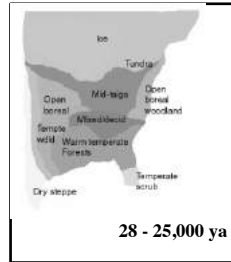


## Pleistocene Refugia ?

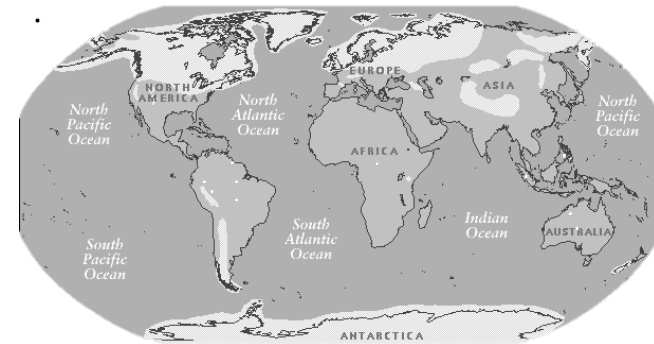


- Extensive boreal forest zone S to 33° N
- Mixed deciduous forest zone near Gulf
- 18,000 ya harshest conditions; zones were further north earlier



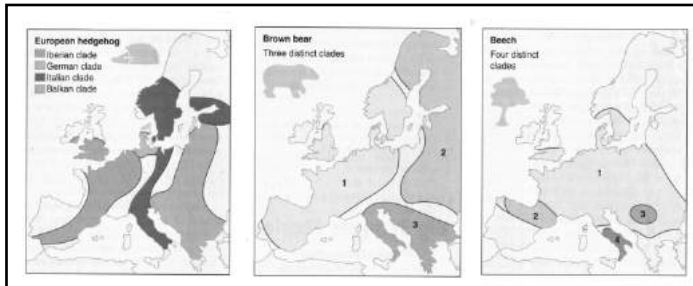
## Pleistocene Refugia ?

Presence of survival or refugia of these plants and animals *south* of the ice has been a major contention — are there consistent areas of refuge during the Pleistocene?



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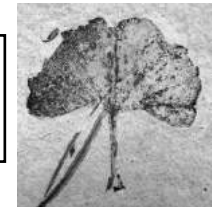
**Yes** - plant and animal phylogeographic studies provide congruent areas of centers of genetic diversity in Europe

## Pleistocene Refugia ?

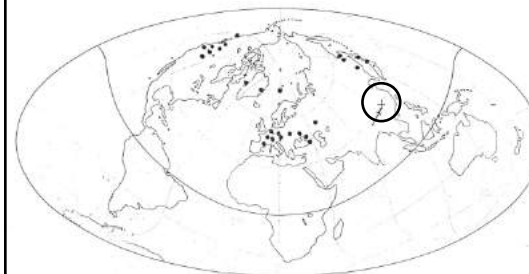
Phylogeography of a living fossil: Pleistocene glaciations forced *Ginkgo biloba* L. (Ginkgoaceae) into two refuge areas in China with limited subsequent postglacial expansion

Wei Gong<sup>1,2\*</sup>, Chuan Chen<sup>2,3</sup>, Christoph Dobeš<sup>4</sup>, Cheng-Xin Fu<sup>4,5,6\*</sup>, Marcus A. Koch<sup>1,2\*</sup>

2008 – Molecular Phylogenetics and Evolution

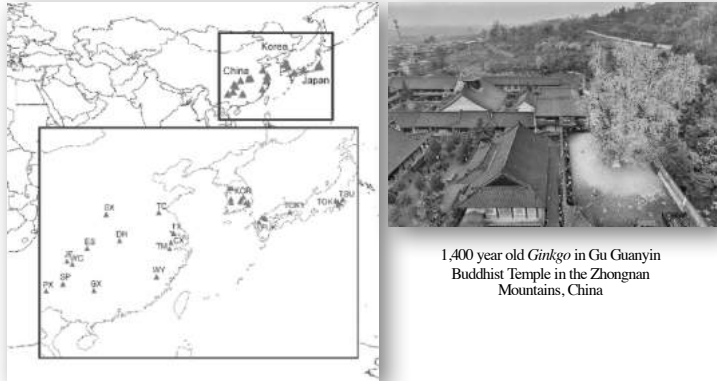


*Ginkgo* fossil from Washington, USA – 49 mya



*Ginkgo*, now confined to China, had a wide Holarctic distribution from the Paleocene into the Neogene as indicated by fossil localities (●)

## Pleistocene Refugia ?

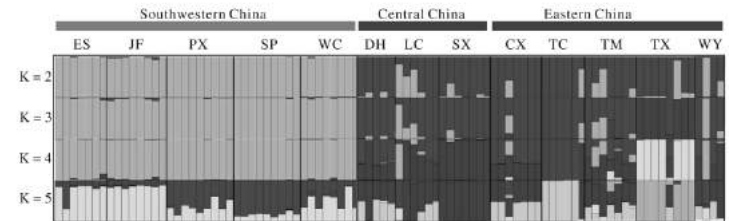


1,400 year old *Ginkgo* in Gu Guanyin Buddhist Temple in the Zhongnan Mountains, China

*Ginkgo* "native" distribution in China and "introduced" distribution in Japan

## Pleistocene Refugia ?

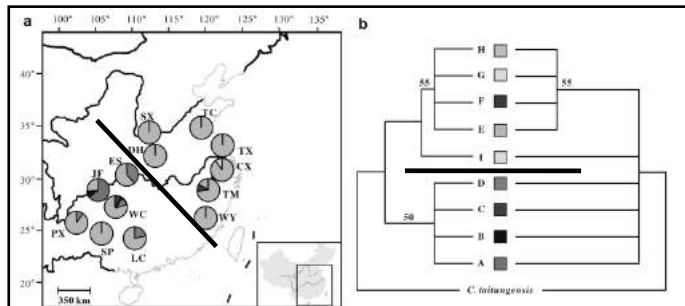
Is there genetic evidence of a Pleistocene refugium?



AFLP variation indicates two strongly differentiated set of populations – southwestern China and east-central China

## Pleistocene Refugia ?

Is there genetic evidence of a Pleistocene refugium?

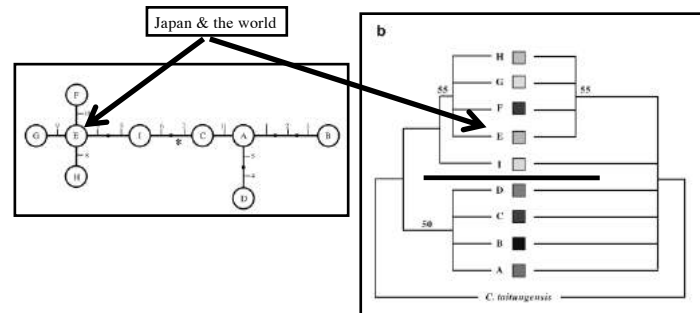


AFLP and cpDNA haplotypes indicate two refugia – southwestern China and east-central China

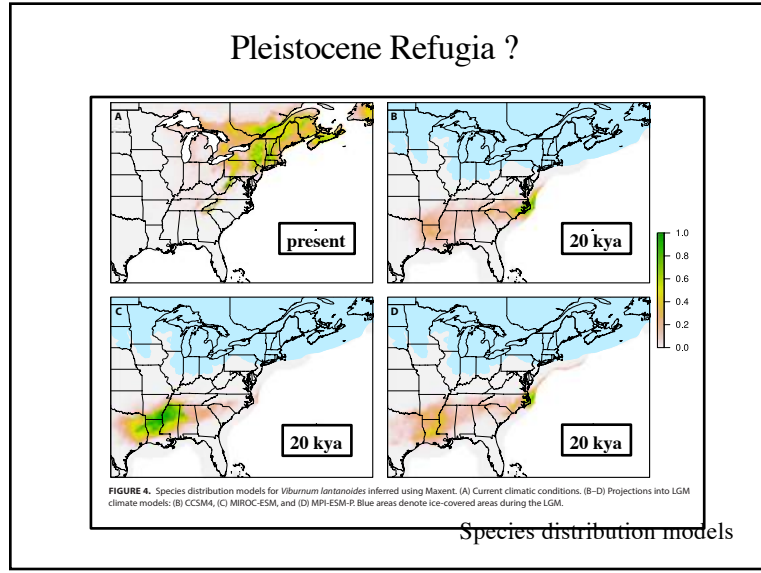
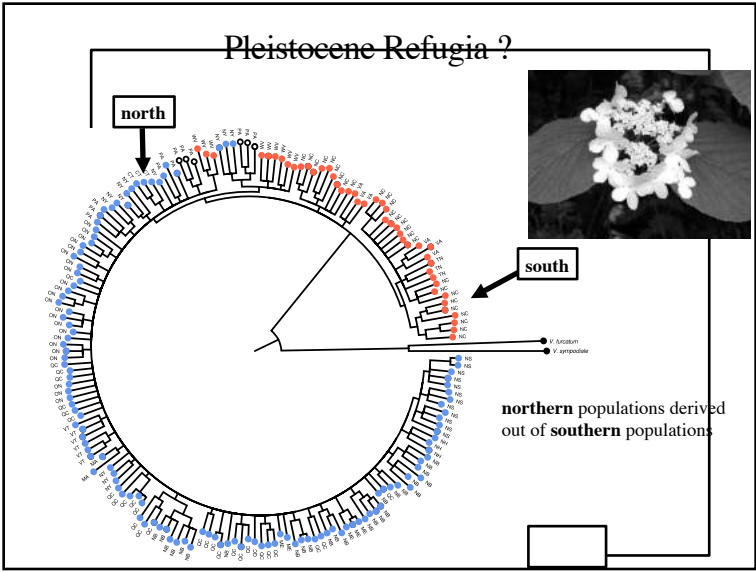
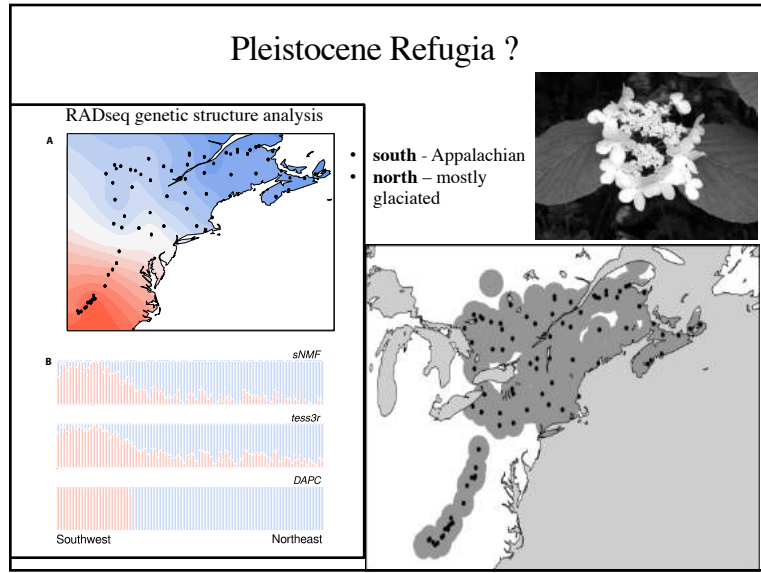
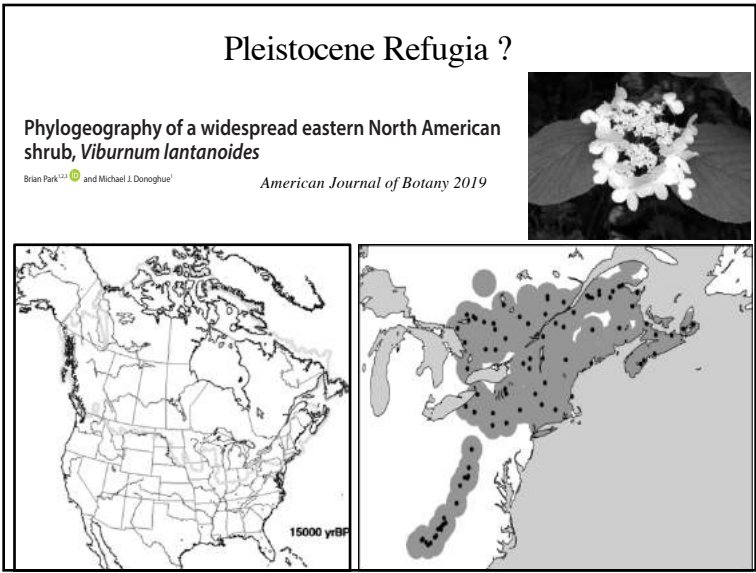
## Pleistocene Refugia ?

Is there genetic evidence of a Pleistocene refugium?

Is there genetic evidence of human movement to Japan and later the world?

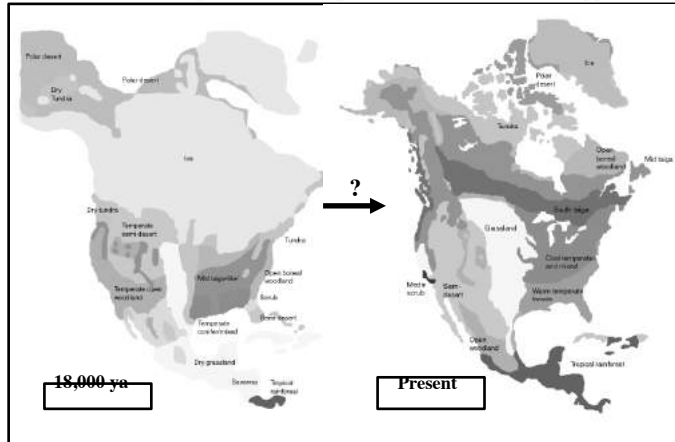


Haplotype E is the only Chinese haplotype found in Japan and the rest of the world – derived originally from east-central China



## Assembly of Great Lakes Flora

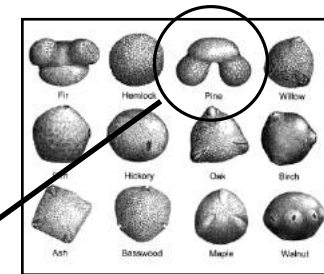
How did the assembly of flora and vegetation in the Great Lakes happen?



## Assembly of Great Lakes Flora

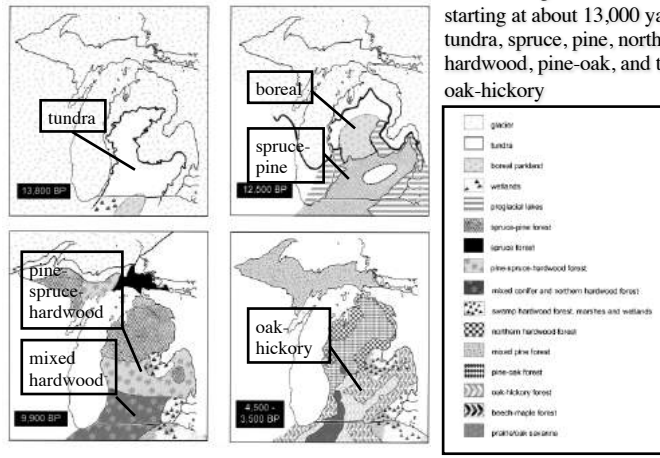


Yearly deposits accumulate in lake bottoms to be covered by silt in layers, or in bog peat strata



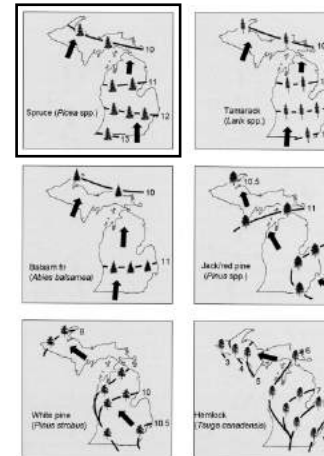
## Assembly of Great Lakes Flora

Shifts of vegetation belts starting at about 13,000 ya with tundra, spruce, pine, northern hardwood, pine-oak, and then oak-hickory

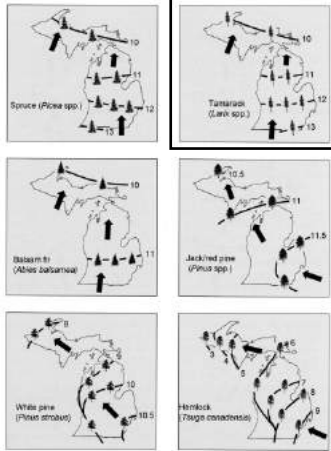


## Assembly of Great Lakes Flora

Coniferous species migrated into the Great Lakes region in waves:  
Boreal species like spruce, tamarack, and balsam fir arrived first



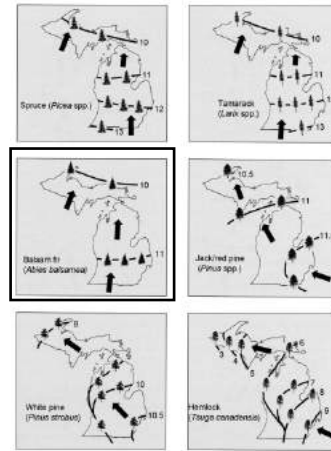
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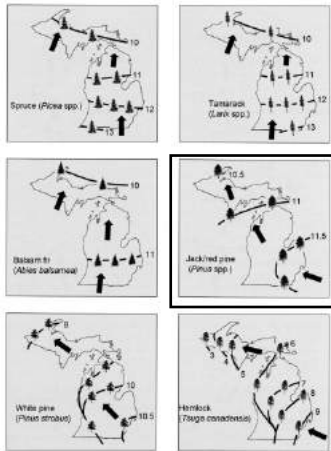
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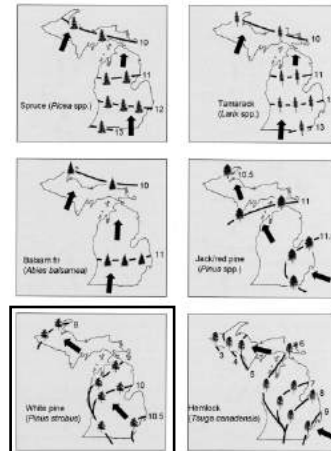
### Assembly of Great Lakes Flora



Coniferous species migrated into the Great Lakes region in waves:  
Xeric pine species like jack pine and red pine arrived next



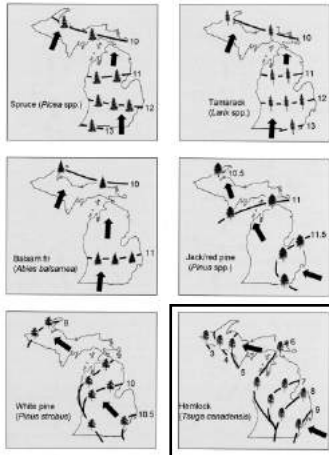
### Assembly of Great Lakes Flora



Coniferous species migrated into the Great Lakes region in waves:  
... followed by more mesic white pine



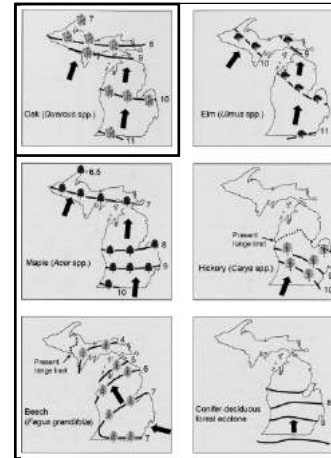
### Assembly of Great Lakes Flora



Coniferous species migrated into the Great Lakes region in waves:  
Hemlock, characteristic of mesic Northern Hardwood forests, arrived last



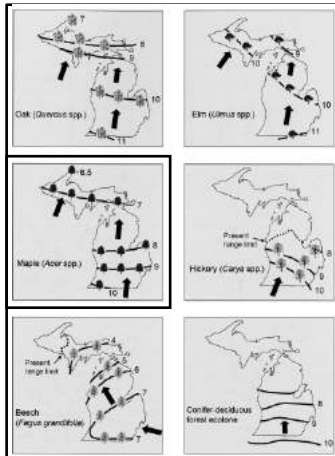
### Assembly of Great Lakes Flora



Angiosperm trees migrated into the Great Lakes region in waves towards the end of conifer migration:  
Oaks, hickories and elms arrived first - 11,000 ybp



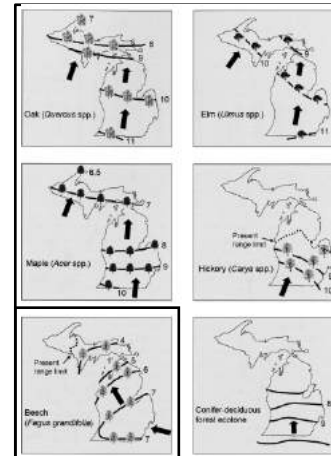
### Assembly of Great Lakes Flora



Angiosperm trees migrated into the Great Lakes region in waves towards the end of conifer migration:  
Followed by mesic-loving maples



### Assembly of Great Lakes Flora

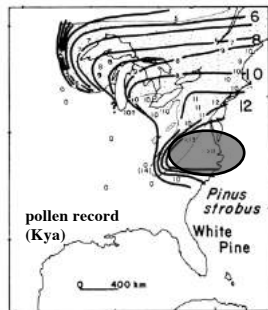


Angiosperm trees migrated into the Great Lakes region in waves towards the end of conifer migration:  
And finally American beech last



## Pleistocene Refugia ?

Importantly, the different species of trees (and herbs) entering the Great Lakes region after the glaciers retreated entered via different routes - that is, they came from different refugia or survived *south* of the ice

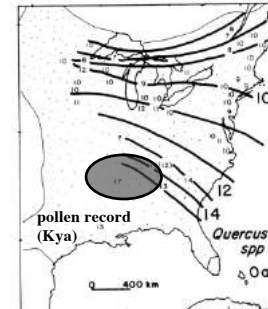


White pine from the Alleghenian refugium and present distribution



## Pleistocene Refugia ?

Importantly, the different species of trees (and herbs) entering the Great Lakes region after the glaciers retreated entered via different routes - that is, they came from different refugia or survived *south* of the ice



Oaks from either the Alleghenian (white oak) or Ozarkian (bur oak) refugia and present overlapping distributions

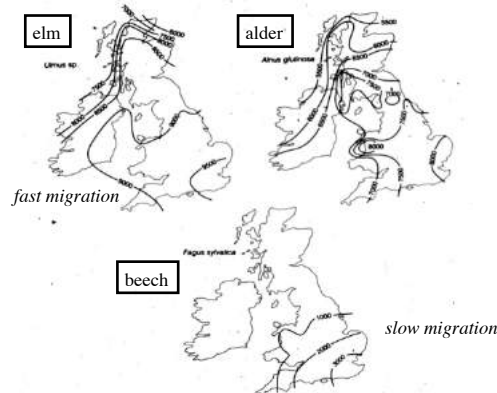


Ozarkian

Alleghenian

## Pleistocene Refugia ?

The assembly of Holocene flora in northern Europe, especially Great Britain, shows a similar pattern to that in eastern North America

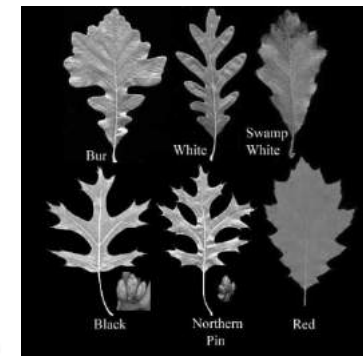


## Assembly of Great Lakes Flora

The flora of the Great Lakes can be divided into a number of elements, each of which shares a common geographical origin.

Closely related species (such as oaks) can often be part of different floristic elements.

This is due to both different ecological preferences (such as hydric vs. mesic vs. xeric) and to geographical origin.



Quercus - the oaks



## Assembly of Great Lakes Flora

The flora of the Great Lakes can be divided into a number of elements, each of which shares a common geographical origin.

1. Alleghenian: group of species with ranges centered from Cumberland and Great Smoky mountains; dominant in deciduous forests; e.g. white pine, hemlock and basswood; ancient element extending back to the Tertiary



*Pinus strobus* - white pine



*Tsuga canadense* - hemlock

## Assembly of Great Lakes Flora

1. Alleghenian:



*Fagus grandifolia* - American beech



*Acer saccharum* - sugar maple



*Tilia americana* - basswood

*Quercus alba* - white oak

## Assembly of Great Lakes Flora

Jeff Rose's pictures  
from field trip

1. Alleghenian:



*Erythronium albidum* - trout lily



*Dicentra cucullaria* - Dutchman's breeches



*Claytonia virginiana* - spring beauty

## Assembly of Great Lakes Flora

The flora of the Great Lakes can be divided into a number of elements, each of which shares a common geographical origin.

2. Ozarkian: species grouped around the Ozark Mts. of Arkansas and Missouri; more adapted to xeric or dry conditions, but similar to Alleghenian (many genera, but not species overlapping between the two elements); e.g. bur oak and black oak, hickory



*Quercus macrocarpa*  
Bur oak



*Carya ovata*  
Shagbark hickory

## Assembly of Great Lakes Flora

2. Ozarkian:



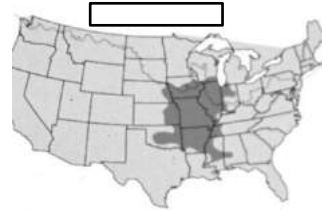
*Phlox divaricata*  
Blue phlox

*Anemella thalictroides*  
Rue anemone

## Assembly of Great Lakes Flora

The flora of the Great Lakes can be divided into a number of elements, each of which shares a common geographical origin.

3. Prairie: species whose ranges includes all or part of existing prairies  
e.g. needle grass, side oats



*Silphium integrifolium* - silphium



## Assembly of Great Lakes Flora

3. Prairie:



*Andropogon gerardii*  
big bluestem

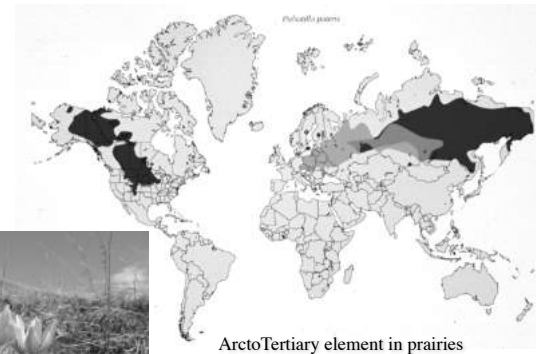


*Amorpha canadense* - leadplant



## Assembly of Great Lakes Flora

3. Prairie:



ArctoTertiary element in prairies



*Anemone patens*  
Pasque flower  
(photo: John Zabusky - Apr 27, 13)

## Assembly of Great Lakes Flora

The flora of the Great Lakes can be divided into a number of elements, each of which shares a common geographical origin.

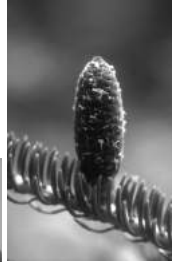
4. Boreal: species w/ranges from Alaska to Upper Great Lakes, many species circumboreal (with ranges in Eurasia) e.g. tamarack, white spruce, and balsam fir



*Picea glauca*  
White spruce



*Larix laricina*  
Larch, tamarack



*Abies balsamea*  
Balsam fir

## Assembly of Great Lakes Flora

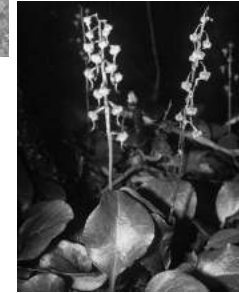
4. Boreal:



*Pyrola rotundifolia*  
Round-leaved shinleaf



*Iris lacustris*  
Dwarf-lake iris



*Linnaea borealis* - twinflower

## Assembly of Great Lakes Flora

The flora of the Great Lakes can be divided into a number of elements, each of which shares a common geographical origin.

5. Coastal Plain: species with distributions originating from the coastal plain region of SE United States . . .



*Gledistia tricanthos*  
Honey locust



*Betula nigra*  
River birch

## Assembly of Great Lakes Flora

*Chamaesyce polygonifolia*  
Seaside spurge

5. Coastal Plain: . . . and including species inhabiting water edges of the Great Lakes and maritime regions of the Coastal Plain



## Assembly of Great Lakes Flora

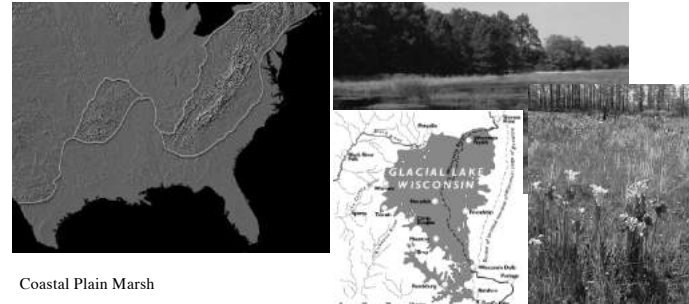
*Lathyrus japonicus*  
Beach pea



5. Coastal Plain: . . . and including species inhabiting water edges of the Great Lakes and maritime regions of the Coastal Plain



*Cakile edulenta*  
Sea rocket



Coastal Plain Marsh

Sandy to peaty-mucky lakeshores, pondshores, depressions, and ditches in and around the bed of extinct glacial Lake Wisconsin may harbor assemblages of wetland species including some which are significantly disjunct from their main ranges on the Atlantic Coastal Plain. There is often a well-developed concentric zonation of vegetation. Frequent members of this community are sedges in the genera *Cyperus*, *Eleocharis*, *Fimbristylis*, *Hemicarpha*, *Rhynchospora* and *Scirpus*; rushes (*Juncus* spp.); milkworts (*Polygala cruciata* and *P. sanguinea*), toothcup (*Rotala ramosior*), meadow-beauty (*Rhexia virginica*), grass-leaved goldenrod (*Euthamia graminifolia*), hardhack (*Spiraea tomentosa*), lance-leaved violet (*Viola lanceolata*), and yellow-eyed grass (*Xyris torta*).

## Assembly of Great Lakes Flora

The flora of the Great Lakes can be divided into a number of elements, each of which shares a common geographical origin.

6. Western North America: species with a primary western North America distribution and disjunct occurrence in the Great Lakes region

Essentially a variety or subspecies of the western *A. columbianum*



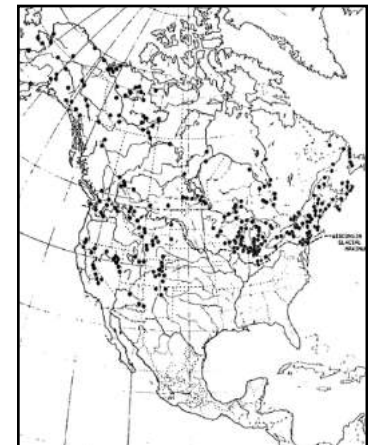
*Aconitum noveboracense*  
Northern monk's hood

## Assembly of Great Lakes Flora

6. Western North America:



*Dasiphora fruticosa*  
Shrubby cinquefoil

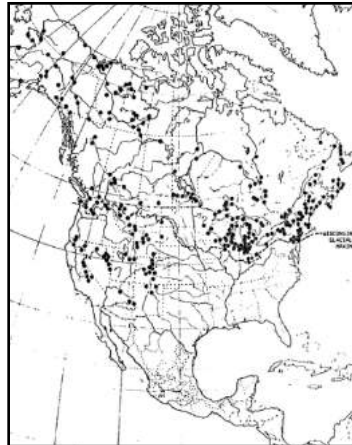


## Assembly of Great Lakes Flora

6. Western North America:

- **western** distribution spans both glaciated and unglaciated regions
- **eastern** distribution confined to glaciated regions

*Dasiphora fruticosa*  
Shrubby cinquefoil



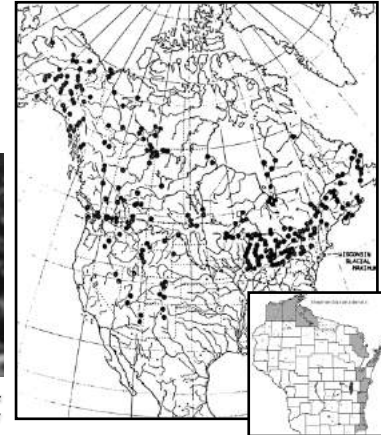
## Assembly of Great Lakes Flora

6. Western North America:

Note that the distribution in the east is north of glacial maximum



*Shepherdia canadensis*  
Buffalo-berry



## Assembly of Great Lakes Flora

6. Western North America:

Note that the distribution in the east is north of glacial maximum



*Actaea rubra*  
Red baneberry



## Assembly of Great Lakes Flora

6. Western North America:

Note that a close eastern relative is not confined to glacial regions



*Actaea pachypoda*  
White baneberry



## Assembly of Great Lakes Flora

### 6. Western North America:

Basically confined to glacial regions despite available sites in Driftless Region



*Besseyia bullii*  
Kitten's-tail  
(Muralt Bluff Prairie)



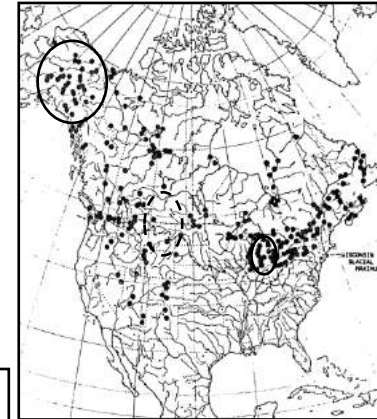
## Assembly of Great Lakes Flora

### 6. Western North America:

A number of western elements are completely disjunct between Alaska (unglaciated areas) and sandy areas of the Great Lakes (beaches, sand outwash)

or with sporadic occurrence in Dakotas, Wyoming, Alberta

Typical western North America — Great Lakes pattern



## Assembly of Great Lakes Flora

### 6. Western North America:

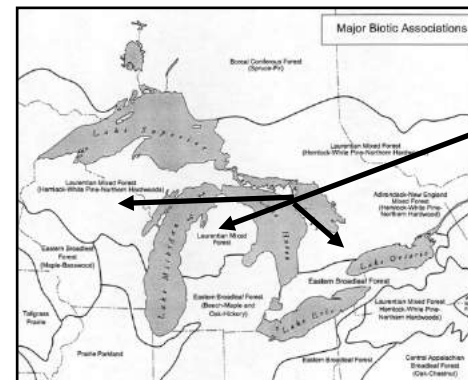
Species restricted to beaches of Great Lakes and into Maritime region of eastern Canada. Hulten considered it as a subspecies of the Alaskan and Pacific Northwestern species *T. bipinnatum*.

*Tanacetum huronense*  
Lake Huron Tansy



## Assembly of Great Lakes Flora

Species migrating into the Great Lakes region not only came from different places and at different rates, but also ended up in specific regions and associated with specific groups.

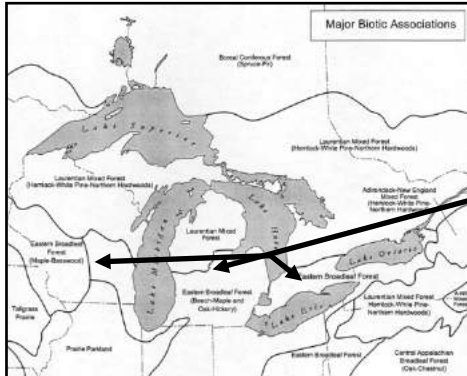


Two major biotic associations exist in the Great Lakes region:

1. northern hardwood-conifer forest

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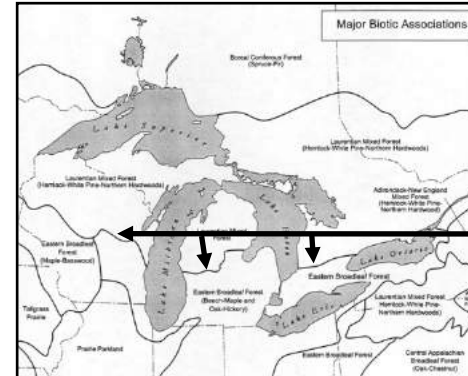


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1. northern hardwood-conifer forest
2. eastern deciduous forest

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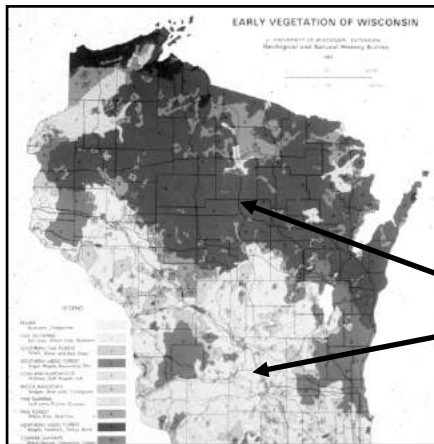


Two major biotic associations exist in the Great Lakes region:

1. northern hardwood-conifer forest
2. eastern deciduous forest

These two associations are separated by a fairly sharp tension line or zone

## Assembly of Great Lakes Flora



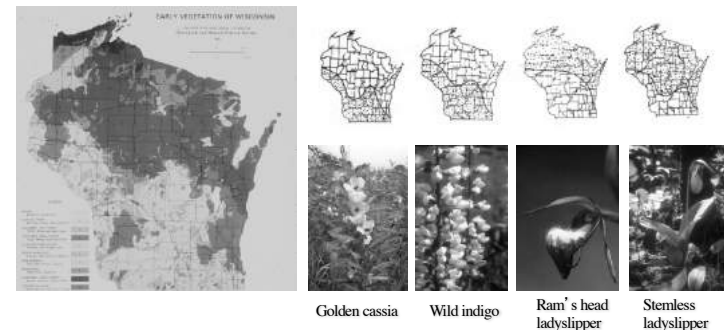
The tension zone is quite obvious just by looking at a pre-settlement vegetation map of Wisconsin

In Wisconsin the two areas are often referred to as two floristic provinces:

- Northern Hardwoods
- Prairie-Forest

## Assembly of Great Lakes Flora

The tension zone separating the two provinces is based on the upper and lower distributional limits of the southern and northern species, respectively.



Golden cassia    Wild indigo    Ram's head ladyslipper    Stemless ladyslipper

## Assembly of Great Lakes Flora

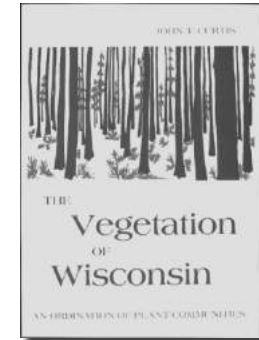


A compilation of the range limits (northern or southern) of 182 species in Wisconsin shows species range limits per county

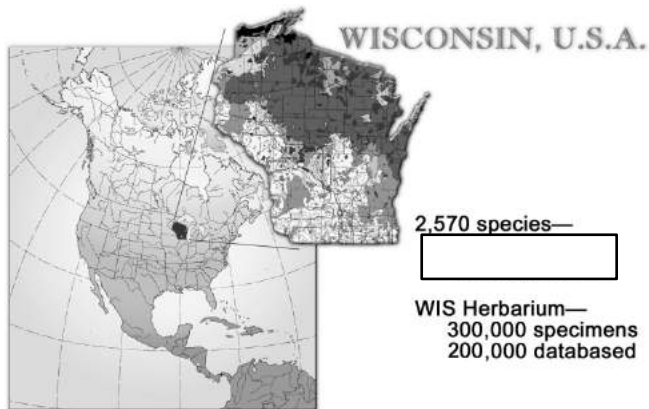
Tension zone

## Assembly of Great Lakes Flora

Within each province, there are ecological (not floristic) assemblages of species called plant communities. John Curtis in the *Vegetation of Wisconsin*, described about 35 communities (the subject of Botany 455).



## Vascular Flora of Wisconsin . . . after the assembly . . .



## Vascular Flora of Wisconsin . . . after the assembly . . .

Information source: Wisconsin State Herbarium  
[www.botany.wisc.edu/herbarium/](http://www.botany.wisc.edu/herbarium/)



*Arethusa bulbosa*  
Dragon's mouth  
Native species = 1889



*Alliaria petiolata*  
Garlic mustard  
Introduced species = 681

158 families 758 genera 2570 species