BIOMES OF WISCONSIN
Ecology 460: Stanley Dodson

CLIMATE EFFECTS
MACROCLIMATE
MICROCLIMATE
PRAIRIES
DECIDUOUS FORESTS (DRY OAK AND MOIST SUGAR MAPLE)
EVERGREEN FORESTS (BOREAL, TAIGA)
* *

BIOMES: The world's major communities, classified according to the predominant vegetation and characterized by **adaptations of organisms to a particular environment**. The distribution of the biome depends on climatic boundaries.

In Wisconsin ecologists recognize three major biomes and two transitions:
PRAIRIE
SAVANNA
DECIDUOUS FOREST
MIXED FOREST
BOREAL FOREST

BIOME DISTRIBUTION IN WISCONSIN: The Mixed and Boreal forests are found above the tension zone, and the other biomes south of the tension zone. The tension zone runs diagonally across Wisconsin, from the northwest (about St. Croix Falls) to the southwest (Milwaukee).

These biomes are generally discussed as they occurred in about 1850, when Europeans were just moving into Wisconsin (see the map entitled "Original Vegetation of Wisconsin). Since then, there have been massive changes in the patterns of distribution. However, even before the European invasion, Native Americans had modified the landscape, especially in prairie and floodplain areas.

Curtis (1959: p. 461) writes:

> "There are five main ways by which the Indians, both prehistoric and modern, influenced the nature of the vegetation in which they lived. These are mostly related to their methods for obtaining food. The hunting tribes could affect the plant communities directly through the use of fire and indirectly through their influence on populations of large mammals. The food-gathering activities usually associated with hunting cultures could have been of direct importance in influencing populations of some of the species harvested. The agricultural tribes exerted a direct destructive effect on the vegetation of the areas used as fields or gardens. The fifth influence was that of plant introduction, both intentional and accidental." [Only circumstantial evidence exists for the latter influence, for Canada plum, white gentian, wild leek, sweet flag, groundnut, Kentucky coffee tree, red mulberry, giant mallow, lotus, and a variety of cultivated and domesticated crop plants, such as maize.]

A careful study of human effects on the landscape in a floodplain region of Tennessee (on the Little Tennessee River, now flooded by the Tellico Dam: Chapman, Delcourt, and Delcourt 1989. Strawberry fields, almost forever. Natural History. September 50-59) shows changes in the vegetation starting about 4,400 years ago. If the data existed, a similar pattern would probably be found for well-settled areas in southern Wisconsin, such as the Aztalan area, as in Tennessee. (see Appendix)

Great changes in plant distributions and abundances have occurred since 1850. For example, prairies were in patches south of the tension zone and concentrated in a band from the south western part of the state to Lake Winnebago. Prairies are now restricted to a few small preserves (UW Arboretum, Chiwaukee Prairie), railroad right-of-ways (especially those that are burnt regularly, not those cleared by herbicides), and odd corners (Leopold's essay: "Great Possessions").

2. CLIMATE EFFECTS

MACROCLIMATE: The extent of the major biomes is largely a function of temperature and mean annual precipitation. Other factors, such as fire frequency, soil type, snow cover and perhaps grazing also have an effect.

MICROCLIMATE: The climate due to local geography, such as the climates on the north and south sides of a hill: insolation and temperature are higher on the south side, wind tends to come from the west, evaporation rate is higher on the south side, so soil is dryer and tends to have less organic content on the south side.

Local climate is also affected by soil character, which is affected by the bedrock, glacial activity, and the plants growing on the soil.

Many of the soils in Wisconsin are developed on Glacial deposits of coarse sediments: sand or gravel. These porous soils, especially when on an incline, tend to be well drained, and to be dryer than soils on loess (fine-grained wind-blown glacial silt) or on stream deposits of small-sized particles (clay and mud). Thin soils on nearly-exposed bed rock also tend to be very dry. Loess, flood plain soils and thick soils on limestone bed rock or limestone glacial rubble (till) tend to be the richest in inorganic nutrients. Soils on metamorphic rocks, such as the Baraboo quartzite, tend to be poor in inorganic nutrients.

TENSION ZONE: Defined by plant distributions: The tension zone is a narrow band running diagonally across Wisconsin, representing the northernmost boundary of many southern plants and the southernmost boundary of many northern plants.

Plant distributions in Wisconsin depend largely on degree of snow persistence in the winter (and therefore the degree to which the soil freezes).

The tension zone is not determined by soil, total precipitation, geographic or average primary productivity phenomena, but seems to reflect winter snow cover. In the winter, the soil tends to be exposed and frozen below the tension zone, but snow-covered and frost-free above the tension zone. In the summer, the weather tends to be warmer and drier to the south, because of prevailing weather patterns.

COMPARISON OF THE PRAIRIE AND THE DECIDUOUS FOREST BIOMES

For Each Biome, a regular set of questions will be addressed concerning:

A.) Dominant Plants
B.) Plant adaptations to soil, light, and water
C.) Role of Disturbance
D.) Dominant Animals and their adaptations

PRAIRIE

A.) DOMINANT PLANTS:

Grasses: Growing points at ground level. Long linear leaves. Roots matted and relatively shallow. Flowers wind pollinated.

Sunflowers: Growing points at tips of plants, but the plants have a strong ability to resprout from storage roots, which can be large and relatively long (up to about 3 meters). Large plate-like hairy leaves. Bright yellow, orange, red flowers (often butterfly flowers).

Legumes: Growing points at tips of plants, often somewhat woody, strong ability to resprout from base. Delicate compound leaves. Roots intermediate between grasses and sunflowers, often with symbiotic nitrogen-fixing bacteria. Flowers blue or pastel colors, bee pollinated.

B.) PLANT ADAPTATIONS TO SOIL, LIGHT, AND WATER:

SOIL Character: pH 6.5-8, high organic content. It is often said that 2/3 of Prairie under ground, as roots and tubers. The soils are made up of loess from glacial erosion and accumulated decaying organic material. The black color is due to decomposition of FIBROUS ROOTS in place. Some Prairie soils are meters deep, although "high lime" prairies have very thin soils.

Earth worms are scarce or absent here. Ants are very important for the soil. They shred organic matter and aerate the soil.

Prairie soils can be dry for at least part of the summer. Many prairie plants have TAP ROOTS meters long, to reach moisture.

NITROGEN may be limiting, because it can be lost as gaseous oxides when the prairie burns. This gives nitrogen-fixing plants (LEGUMES) an advantage. The symbiotic nitrogen-fixing bacteria associated with legume roots replenish the soil nitrogen.

LIGHT CONDITIONS: Intense sunlight penetrates to nearly ground level.

WATER CONDITIONS: the whole gamut exists in prairies, from wetlands to desert-like conditions in the soil. Because of the intense insolation and penetration of the sun's heat to nearly the soil level, EVAPORATION is high and the foliage tends to dry quickly.

LEAF STRUCTURE: Leaf Structures of Prairie plants: LEAVES are often linear, dissected, tough, few stomata, parallel to light path, and more or less perpendicular to the ground. The form (high surface to volume ratio, thick cuticle, and few stomata) allows the primarily C4 plants to take advantage of the high insolation levels while not loosing too much water, and storing as little heat as possible.

C.) ROLE OF DISTURBANCE: The prairies in Wisconsin depend on dry conditions, but also on regular burning. There would probably be no prairies in Wisconsin without fires: the extension of prairies from the great plains to the moister areas to the east in the midwest, such as Wisconsin, is called the "PRAIRIE PENINSULA". The fires were natural and set by Indians. Bur Oaks and grasses are particularly adapted to this form of disturbance. Fires favor GRASSES and SUNFLOWERS by removing light-competitors, such as trees and woody shrubs, remove toxic mulches, and allow the soil to warm quickly in the spring, giving the plants a longer growing season.

Badger, gopher and ant mounds and bison wallows provide occasional refuges for early SUCCESSIONAL PLANT (opportunistic) species: susans, evening primroses, daisy fleabane, coneflower, and ragweed.

When the Europeans invaded NA, the practice of FIRE SUPPRESSION, fencing, plowing, and grazing led to a quick appearance of forests from fire-suppressed tress such as bur oak and hickories. Trees disappeared from the river bottoms as the rich, flat soil was turned into farmland, and rapidly appeared on the ridge tops as grubs grew into trees.

Curtis (1959) has moving descriptions of prairie fires seen in the early 1800s.

D.) DOMINANT ANIMALS:

GRASS EATERS: The large grass eaters were the Bison and other large herbivores, an especially diverse group before the Pleistocene extinctions. Smaller mammalian herbivores include the jack rabbit, prairie dog, ground squirrel, and gopher.

The small grass eaters are large tough crunchy insects, such as the grasshoppers and locusts. These animals were roughly as important consumers as the large herbivores. They have large bodies (small surface to volume ratio) with thick exoskeletons as the optimal adaption to the dry and hot conditions.

Herbivory selects for the presence of grasses. Grasses have their growing points at or below ground level, so herbivores tend to do more damage to other plants. There is some evidence of an indirect effect: the more herbivores the more grasses, which sustain herbivores.

Endophyte mutualism provides some protection to plants, especially grasses, from herbivores (Don Strong, 1988 Ecology 69:1). Endophytes are ascomycete fungi that grow inside leaves and stems of higher plants. Endophytes may be as common and as important as mycorrhizae are to the biology of higher plants. Many endophytes produce mycotoxins that may deter or harm herbivores: "ryegrass staggers" and poisonous darnel are caused by fungi that have long been considered agricultural pests, but are better understood as mutualists (with the host grass. Many grasses have "constitutive mutualists" that live within the seed of the host plant, and the fungi make up a significant portion of the plant biomass. Tall fescue is a good example (Clay 1989. Natural History. September 8-14). The fungus cannot reproduce except vegetatively, it lives between the cells of the grass tissues, uses organic compounds from the grass for energy, and produces toxins. Each grass plant is inhabited (possessed?) by a single fungus individual. The fungus grows into developing seeds, and is thus passed on to the next grass generation. Livestock will not eat the infected grass if they have a choice. If the grass is eaten, it produces weight and milk production loss, excessive salivation, and even death in extreme cases. Infected grass in pastures is often untouched by livestock, so it appears more vigorous than uninfected grass. It was for this reason that seeds from a luxuriant stand in Kentucky were turned into a commercial variety (Kentucky-31) which was distributed widely in the US in the 1930s.

The "**Paradox of the Prairie**" is the presence of a large mass of vegetation at ground level, in easy reach of all herbivores. What keeps the herbivores from becoming so common as to eat all the vegetation? This paradox is probably resolved by the observation that much of the prairie vegetation in of low food value, requiring specialized digestion, fast growing, and some (the grasses) are protected mechanically by inclusions of glass particles: silica dioxide, which makes the grasses wear down teeth rapidly: only specialized herbivores can eat prairie vegetation. The large herbivores tend to have large complex guts with symbiotic gut fauna, and constantly growing teeth. Small mammals, especially the rabbits, have complex guts, but also produce two kinds of feces: the first passage of food through the gut produces soft feces which are eaten, and the second time through the gut, the digestion is completed, increasing protein content by harvesting the bacteria the second time through. The smaller mammals cannot have complex enough guts to process the low quality food: a result of surface-to-volume considerations. The insect herbivores tend to be restricted in time to the period of growth of the vegetation, and are relative ineffective during most of the photosynthetic season.

SEED EATERS: A variety of insects, rodents, and birds eat seeds. Ants and rodents tend to hoard seeds, which has an effect on distribution and germination success of seeds.

INSECT EATERS: Rodents, reptiles (small snakes and lizards), and birds. The birds that eat the large insects of the prairie tend to have large and strong beaks (meadowlarks, kestrels). Thus, the physiological constraints on one guild (herbivorous insects) shows up as a factor affecting the structure of another (insectivorous birds).

SMALL MAMMAL EATERS: The smaller herbivores and predators are eaten by larger mammals (badgers, coyote), soaring birds (possible in prairie, but not the forest), and large snakes (bull snake, rattle snake). Timber wolves were present in all biomes at the time of settlement, but are now restricted to a few animals in northern Wisconsin.

LARGE MAMMAL EATERS: Remember that the largest predators (several species of lions and wolves) are missing since the Pleistocene, grizzly bears were removed by European invaders. The savannas of Africa may serve as a model of what we have lost.

DECIDUOUS FORESTS

A.) Dominant species depend on soil, water and disturbance:

oaks, hickories: poor dry sandy soil, with fires
maples, ashes, oaks: rich moist soil, no fire

B.) Adaptations to light, water, and soil conditions

LIGHT: The CANOPY and UNDERSTORY are well lit in dry oak forests, dark in maple forests, which leads to SHRUBS in oak forests and SPRING EPHEMERALS in the maple forests.

WATER: oaks use deep TAP roots to reach water in dry areas.
maples have shallow roots (also flood plain adaptations).

SOIL:
oaks make the upper soil worse with ACID & nutrient poor leaves.
sugar maples use MYCORRHIZAE, do not withdraw nutrients from leaves.
Worms and ants are abundant in the soil.

C.) Role of disturbance: Succession leads to sugar maple (most shade tolerant) if there are no fires, and if the forest is on rich, moist soil. If fire occurs occasionally, even once in a century, the forest will be diverse, probably dominated by oaks.

D.) Dominant Animals and their adaptations: rodents, birds, insects all tend to be in the canopy during the summer. The forest habitat is quite different from that of a prairie, because in a forest, food (leaves or herbivores) is high up off ground. This means most animals will be small, able to climb and stay in trees. For example, snakes tend to be small and slender.

LEAF EATERS: Mostly insects in Wisconsin forests. Higher humidity under the canopy allows small soft insects to prosper. Small insects tend to out-compete large insects, because small size allows for faster reproduction and quicker response to temporary food sources, and grants the ability to mature on small amounts of food.

SEED EATERS: Nuts in dry oak forest are an especially important food source for rodents, which are diverse and abundant when the nuts are abundant.

INSECT EATERS: The abundance of small insects favors small insect-eating birds with small thin beaks.

SMALL MAMMAL EATERS: Include small slender snakes, perching hawks and owls, and mustellids (weasels).

LARGE MAMMAL EATERS: Large predators were probably never very common in these forests, because most of the prey are small animals high in the trees.

BOREAL FOREST (EVERGREEN, TAIGA)

A.) Dominant species: white spruce, balsam fir, white pine, white birch, white cedar; black spruce and tamarack dominate in wet conditions.

B.) Adaptations to light, water, and soil conditions

CANOPY is thick (trees are close together) and UNDERSTORY is very dark and often moist. Deep snow in the winter protects a GROUND COVER of evergreen plants.

WATER tends to be available in the winter (the ground does not freeze), and sometimes scarce in the summer (because of the thin poor soil).

EVERGREEN leaves are an adaptation for low productivity (low temperature, poor soil). The leaves must have water in winter, so evergreens do poorly in places where the soil freezes (for example, below the tension zone).

SOIL is made acidic and nutrient poor by decaying evergreen leaves. The soil is often very thin, sandy, nutrient poor, covered with needles.

MYCORRHIZAE (symbiotic association of plant roots and fungi) are present, along with a lot of other fungi living on slowly decaying evergreen leaves.

Mycorrhizae are crucial to the physiology of many plants, especially trees. However, these fungi (some of which produce edible mushrooms) are disappearing from the temperate forests: perhaps due to a combination of human exploitation and air pollution (Science 254:1458)

C. Role of disturbance: Boreal forests tend to be dominated by even-aged stands of trees. Large tracts of forest can be destroyed by cataclysms such as fire, disease, wind storms. When the mature trees are gone, light reaches the soil, and a new cohort of trees begins growth. These trees cannot grow in the shade of their parents.

D. Dominant Animals and their adaptations:

The primary grazers are probably small insects. As in the deciduous forest, the insects tend to be small and delicate.

Blood sucking insects are common in these forests: they can live in the high humidity beneath thick canopies; they require blood (protein) because their larvae live in low-productivity habitats (shaded pools, clear water).

Seeds of the evergreen trees provide a food source for some birds (cross bills) and rodents.

Large Pleistocene animals, like mastodons may have been important in the ecology of these forests, but have been exterminated by humans.

Boreal forests have a fairly intact food web (with some large predators), because of the relative absence of humans from the extremely inhospitable environment (long winters, deep snow, low productivity for agriculture, and insect-infested summers).

APPENDIX

The "natural" biomes of Wisconsin are generally discussed as they were in about 1850, when Europeans were just moving into Wisconsin (e.g., JT Curtis. 1959. Vegetation of Wisconsin). Since then, there have been massive changes in the patterns of plant and animal distribution. However, even before the European invasion, Americans had modified the landscape, especially in prairie and floodplain areas.

A careful study of human effects on the landscape in a floodplain region of Tennessee (on the Little Tennessee River, now flooded by the Tellico Dam: Chapman, Delcourt, and Delcourt 1989. Strawberry fields, almost forever. Natural History. September 50-59) shows changes in the vegetation starting about 4,400 years ago. If the data existed, a similar pattern would probably be found for well-settled areas in southern Wisconsin, such as the Aztalan area or the Door Co area (V. Dirst. 1993. People of the Dunes. Wisconsin Natural Resources 17(3) 12-16), as in Tennessee:

12,000 BP	First human inhabitants of the valley of the Little Tennessee River (LTR); hunters of the Pleistocene fauna. Valley was completely forested, conifer and hardwood.
10,000 BP	First evidence of permanent villages along the LTR. Food was native plants and animals.
4,400 BP	Introduction of maygrass to LTR, a wild grass with edible seeds
4,000 BP	Charcoal from hearths from villages along LTR shows a change in wood burned toward more red cedar and Virginia pine, trees characteristic of new growth, indicating the beginning of clearing and opening up the floodplain forest.
2,800 BP	Evidence of extensive gardening of native plants: sunflower, amaranth, goosefoot, marsh elder and maygrass.
1,775 BP	Introduction of maize as a food crop to LTR. (At about 2000 BP people - North Bay People - first occupied Door County, Wisconsin, leaving pottery remains and chert chips: Dirst 1993).
1,500 BP	Ragweed becomes common along LTR, a weed characteristic of a high level land disturbance associated with agriculture. Also evidence of increasing occurrence of vegetation fires and increasing rate of erosion. The fires may have been set to clear land; in Wisconsin, such fires would increase the extent of prairie vegetation. (At about this time, the late Woodland "Heins Creek" people first occupied Door County; these people are currently known as the Menomini: Dirst 1993)
600 BP	The LTR floodplains intensely cultivated and towns of several hundred people. (At about this time, Door Co. was first occupied by the late Woodland "Oneota" people, who are now known as the Winnebago [Ho Chunk]: Dirst 1993)
450 BP	1540 De Soto brings European diseases that killed many of the native inhabitants of Tennessee and resulted in recolonization of the area by Cherokee survivors from the adjacent region.
1700-1838	Cherokee learn to read and write, engage in trade with Europeans, and are nearly annihilated and evicted from the LTR area, the remnants moved by cruel force to Oklahoma. Land use in their homeland shifts to a European style of agriculture and animal husbandry.