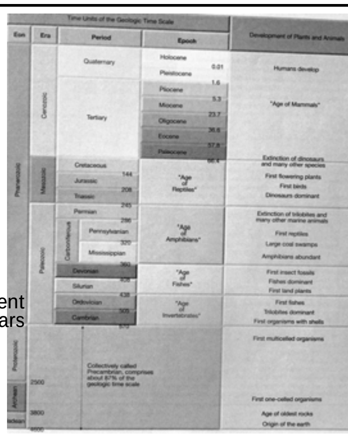
L0NG-TERM CLIMATE

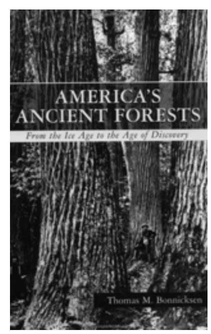
THE ICE AGES

EARTH
About 4.6 billion years old

- Earth began 4.6 billion years ago
- 1st multicelled animals 570 million years ago
- 1st flowering plants 208 million years ago
- Dinosaurs extinct 66.4 million years ago
- Pleistocene Epoch – 'Ice Age' began 1.6 million years ago
- Holocene Epoch –present age began 100,000 years ago



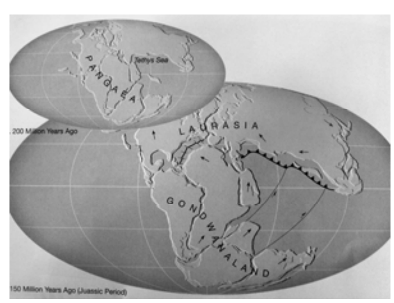
THE ICE AGES



In the beginning

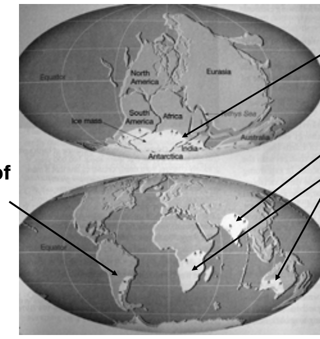
250 million years ago

Somewhat later



150 million years ago

250 million years ago Amphibians & first reptiles



Pleistocene Epoch 1.6 million years ago

- **Land based glacier evidence for 4 major glacial stages named for the Midwestern states in order of occurrence:**
  - Nebraskan
  - Kansan
  - Illinoian
  - Wisconsinan

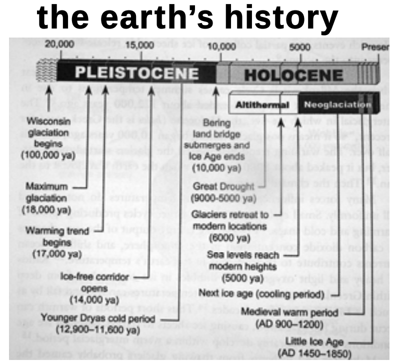
Wisconsin Glacier in Eastern United States

Pleistocene Epoch 1.6 million years ago

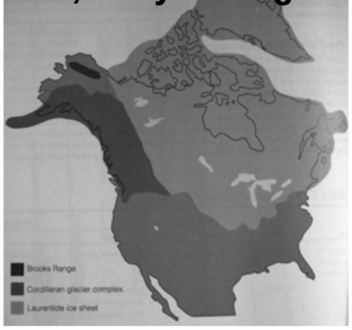
- **Seafloor sediment: glacial/interglacial cycles every 100,000 years**
- **20+ cycles of warming and cooling were identified in the "Ice Ages" beginning 2-3 million years ago**
- **Ice left its imprint on ~ 30% of the earth's land surface**
- **Antarctic ice sheet ~ 14 million years old**

Maximum extent of ice sheets in Northern Hemisphere

Events in the present period of the earth's history



Maximum Glaciation 18,000 years ago



Ice age North America 18,000 years ago

Bering land bridge: 56 miles long and 1000 miles wide

Beringia submerged 10,000 years ago

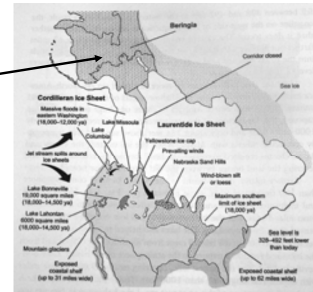
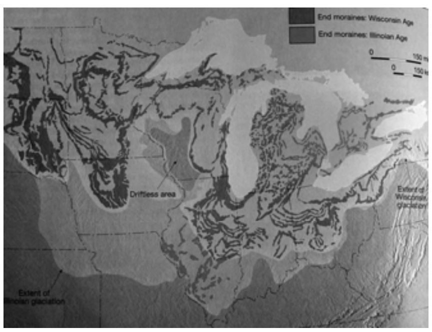


Fig. 1.3 Ice Age North America about 18,000 years ago.

Extent of Latest Glaciers



America's Ice Age Forests

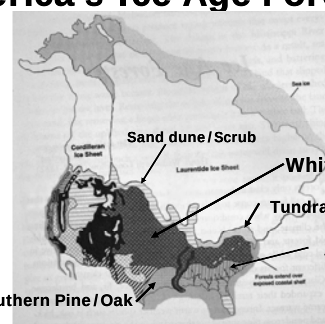
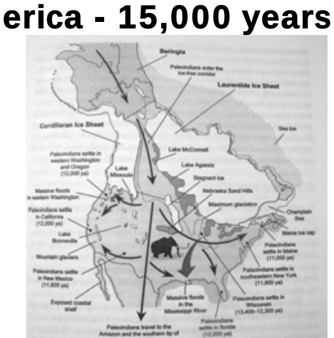


Fig. 2.1 America's Ice Age forests.

America's Ice Age Forests

Human Settlement of North America - 15,000 years ago



Paleoindians settle North and South America.

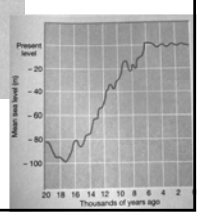
GLACIERS TODAY

- Glacier: a thick ice mass originating on land from the accumulation and compaction of snow
- Cover nearly 10% of land surface
- Part of the hydrologic cycle storing and releasing water
- ~ 2% of world's water tied up in glaciers
- Antarctic ice sheet = 80% of world's ice and 2/3 of world's <u>fresh</u> water; 1 ½ x size of United States

GLACIERS TODAY

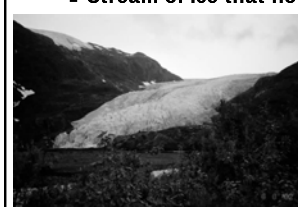
- Sea level would rise 60-70 meters if Antarctic ice sheet melted
- If it melted at a uniform rate could feed the Mississippi River for 50,000 years
- Present glaciers occupy one third the area they did in 'Ice Age'

GLACIERS TODAY



GLACIERS TODAY
Types of Glaciers

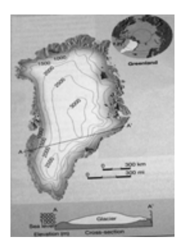
- <u>Valley (Alpine) Glaciers</u> – in high mountains, usually following valleys
  - Stream of ice that flows



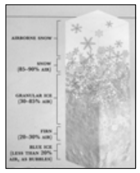
<u>Valley (Alpine) Glaciers</u>

GLACIERS TODAY
Types of Glaciers

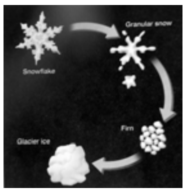
- <u>Continental Ice Sheets</u> – much larger; Two existing now, Greenland ice sheet and Antarctica



GLACIERS TODAY

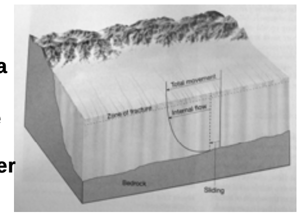


- Glaciers form from snow in areas where more snow falls than melts
- Snowflake breaks down to granular snow (__firn__) forcing air out; pressure on lower layers compacts to ice at 50 meters depth

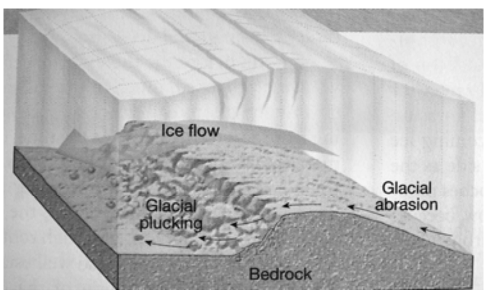


GLACIERS TODAY
Glacial Flow

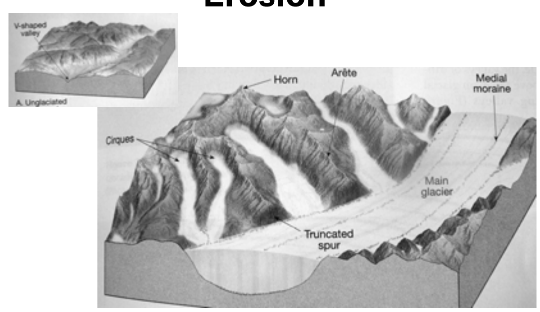
- __Plastic flow__ – move within the ice; at depth > 50 meters (165 ft.) behaves as a plastic material
- __Basal slip__ – entire ice mass slipping along the ground; meltwater 'oils' the flow (melting point decreases with increased pressure)



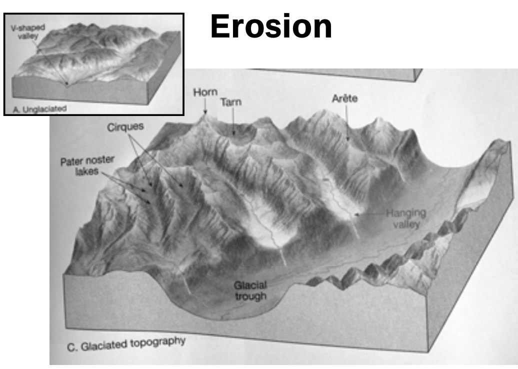
GLACIERS TODAY
Glacial Flow



Glacial Effects on Land
Erosion



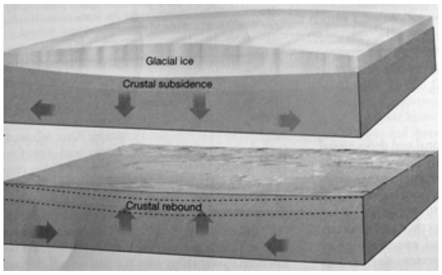
Glacial Effects on Land
Erosion



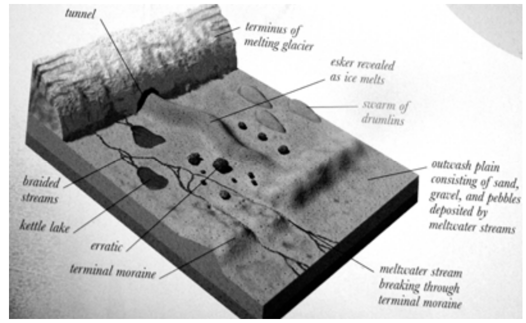
Glacial Effects on Land

- Erode by __plucking and abrasion__
- "Rock Flour" – pulverized rock carried by glacier
- Striations – linear scratches and grooves cut in rocks carried by glaciers
- Till – unsorted sediment deposited by a glacier
- Stratified drift –sediments laid down by glacial meltwater
- Fiords – drowned glacial troughs
- Compaction

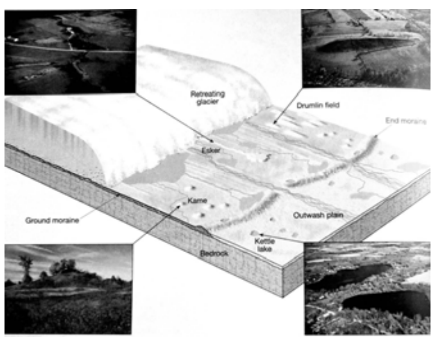
Glacial Effects on Land Compaction/Rebound



GLACIAL LAND FEATURES

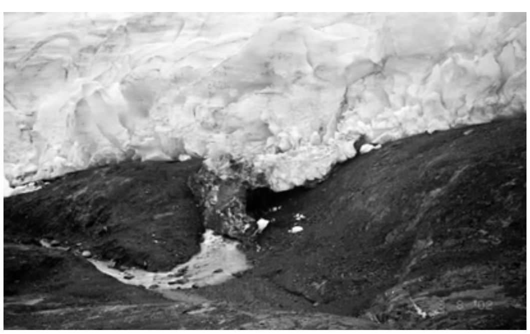


GLACIAL LAND FEATURES

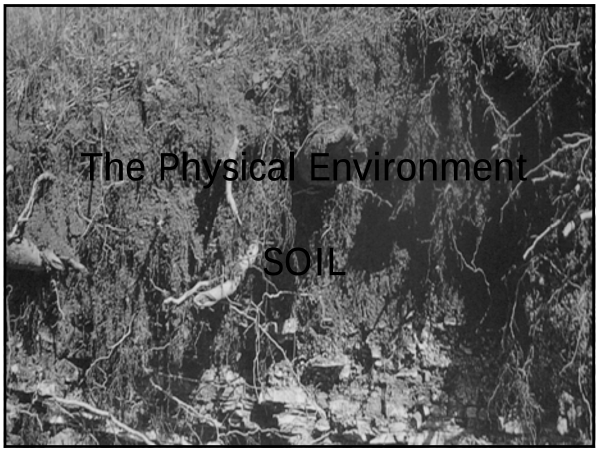


GLACIAL OUTFLOW Braided River

GLACIAL OUTFLOW



GLACIAL OUTFLOW Meltwater Cave



The Physical Environment

SOIL

SOIL

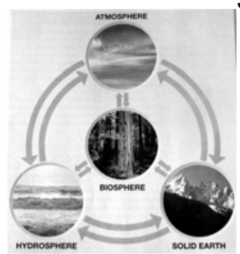
- **“Science, in recent years, has focused more and more on the Earth as a planet, one that for all we know is unique – where a thin blanket of air, a thinner film of water and the thinnest veneer of soil combine to support a web of life of wondrous diversity in continuous change.”**

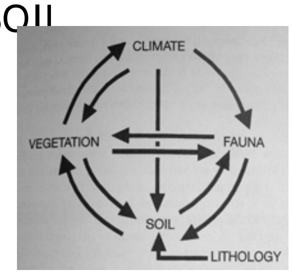
Jack Eddy, “A fragile Seam of Dark Blue Light”, *Proceedings of the Global Change Research Forum.* USGS, 1993, p15

SOIL

- **Soil: an <u>interface</u> – the bridge between life and the inanimate world**
- **Soil: the foundation of terrestrial communities**
- **Soil: a natural product formed from weathered rock by the action of climate and living organisms**
- **Soil: a collection of natural bodies of Earth that is composed of mineral and organic matter and is capable of supporting plant growth**

SOIL





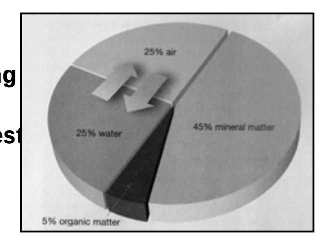
Soil is a material that develops in response to complex environmental interactions among different parts of the earth system

SOIL

Soils vary based upon:
Local climate
Landforms
Plant life growing on and with them

SOIL

- **Soil: porous medium consisting of:**
  - **Minerals –largest portion**
  - **Organic matter (humus)**
  - **Water**
  - **Gases**

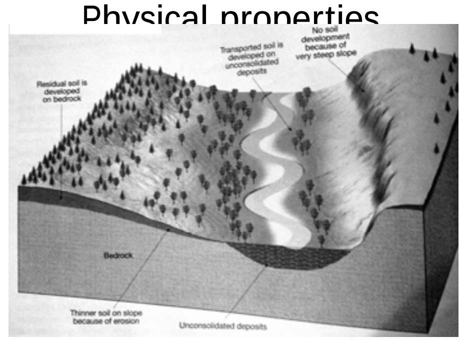


SOIL
Parent Material

Parent Material - Unweathered geologic material

- **Consolidated (residual): igneous, sedimentary, metamorphic rock;**
  - **Unglaciated**
  - **No moving water or oceanic uplift**
- **Unconsolidated (transported): mineral particles transported by water, ice or wind**
  - **EX: Wisconsinan Glaciation (14,000 yrs BP) deposited till, outwash, etc.**
  - **Loess - wind blown dust, silt - as Great Plains**

SOIL
Physical properties

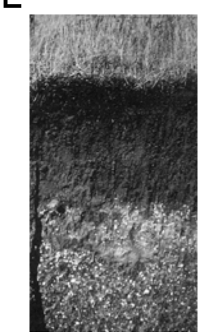


SOIL

- **Weathering – Combination of**
  - **Physical abrasion**
  - **Chemical dissolution**
  - **Living organisms**
- **Pedon: soil body large enough to study properties and all horizons**

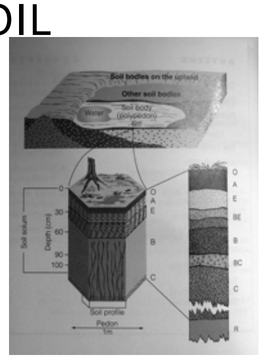
SOIL

- **Soil Profile (make up of a pedon) depends upon:**
  - **Climate**
  - **Parent Material**
  - **Biota**
  - **Physiography**



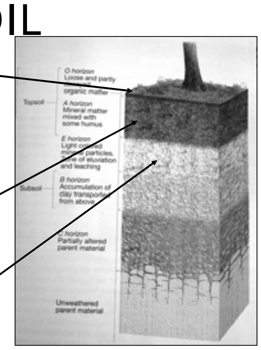
SOIL

- **Soil Profile: Parent material weathers and is occupied by organisms & differentiates into horizontal layers**
- **Horizons: each horizon distinct as to thickness, color, texture, chemistry …**



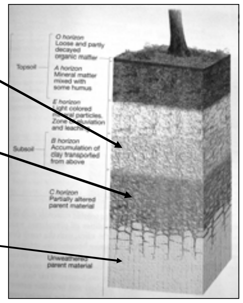
SOIL

- **HORIZONS:**
  - **O Horizon: surface layer – organic (absent in cultivated soils) Maximum biologic activity**
  - **A Horizon: upper layer of mineral soil; accumulation of organic matter**
  - **E Horizon: zone of maximum leaching (*eluviation*)**



SOIL

- **HORIZONS:**
  - **<u>B Horizon</u>: Zone of *illuviation*, collection of leached material (Subsoil)**
  - **<u>C Horizon</u>: weathered material; like or unlike parent material**
  - **<u>R Horizon</u>:**



SOIL

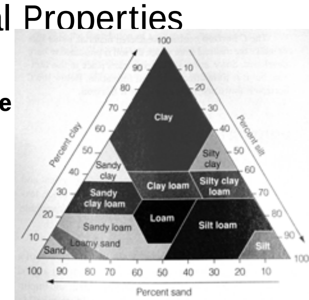
- **Topsoil = Horizons O & A**
- **Subsoil = Horizon B**
- **Solum (true soil)= Horizons O,A,E,B**
- **'Mature soil' indicates stable conditions over prolonged time**
- **'Immature soil' building over a**

SOIL
Physical Properties

- **COLOR – little direct influence on the function of a soil**
  - **<u>Brown/black:</u> usually high organic content**
  - **<u>Red/yellow:</u> from iron oxides or red parent material; more common going south**
  - **<u>Grayish:</u> permanently saturated soils with iron in ferrous form**
  - **<u>Mottled</u>: imperfectly or poorly drained**

SOIL
Physical Properties

- **TEXTURE – Determined by the proportion of particle sizes**
  - **Clay = <0.002mm**
  - **Silt = 0.002-0.05mm**
  - **Sand = 0.05-2.0mm**

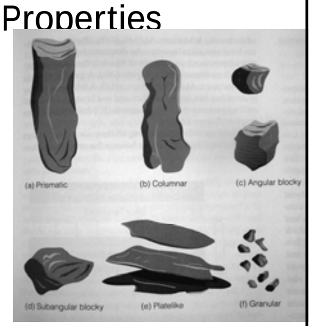


SOIL
Physical Properties

- **TEXTURE relates to pore space in the soil**
  - **<u>Coarse-textured soils</u> (sand) have large pore spaces; favor water filtration, rapid drainage**
  - **<u>Finer the texture</u>, (silt or clay) the smaller the pores, more active surface for water adherence and chemical activity**
  - **<u>Very fine texture</u> (heavy clay) easily**

SOIL
Physical Properties

- **SOIL STRUCTURE:**
  - **Particles are held together in clusters called <u>aggregates</u> or <u>peds</u>**
  - **Influenced by texture, plants, soil organisms, chemical status**



SOIL
Physical Properties

- **DEPTH: Varies based on slope, weathering, parent material and vegetation**
  - **Grasslands: soils usually deep**
  - **Forests: Relatively shallow**
    - **A Horizon ~15 cm**
    - **B Horizon ~ 60 cm**
  - **Slopes: Shallow at top with bedrock near;**

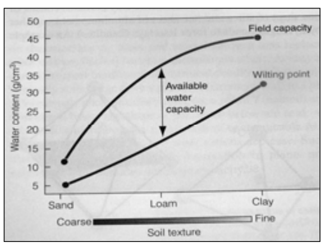
    Deep at bottom

SOIL
Physical Properties

MOISTURE – Amount of water/unit volume important characteristic – most influenced by texture

- **<u>Field Capacity (FC)</u>: Maximum water a soil can retain**
- **<u>Wilting Point (WP)</u>: inability of plants to extract water from the soil**
  - **The ability to extract water as the content declines varies by species**
- **<u>Available Water Capacity (AWC)</u>: Amount of water retained between FC and WP; highest in intermediate clay loam soils**

SOIL
Physical Properties



- **Variations in Field Capacity and Wilting Point as a function of soil texture**

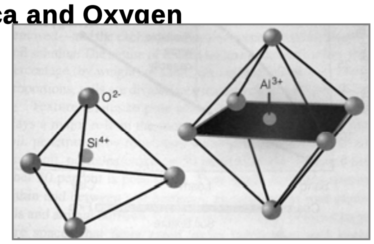
Soil drainage class	Characteristics
1. Very excessively drained	**Plant roots restricted to upper soil layer – water deficiency**
2. Excessively drained	
3. Well-drained	**Roots to 90 cm**
4. Moderately well - drained	**Roots to 50 cm**
5. Somewhat poorly drained	**Roots to 36 cm**
6. Poorly drained	**Wet most of the time; alders, willows**
7. Very poorly drained	**Standing water**

SOIL
Chemical Properties

- **Chemical elements in the soil:**
  - **Are influenced by parent material, vegetation, moisture, clay, etc.**
  - **Are dissolved in solution**
  - **A constituent of organic matter**
  - **Adsorbed on soil particles**

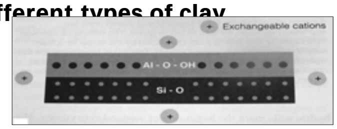
SOIL
Chemical Properties

- **Clay controls many important properties of soil –contains Aluminum, Silica and Oxygen**



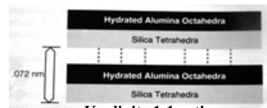
SOIL
Chemical Properties

- **Micelles – plate-like particles**
  - **Silica sheets bond to aluminum sheets; variety of arrangements result in different types of clay**

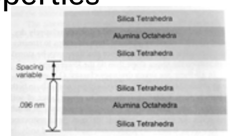


  - **One element on surface of micelle can exchange with another without changing the structure**

SOIL
Chemical Properties



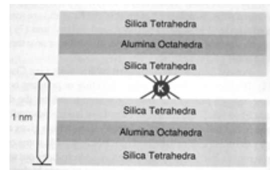
Kaolinite 1:1 ratio



2:1 clay Montmorillonite

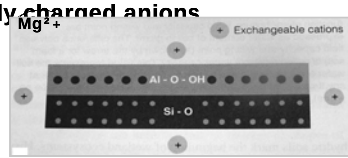
Illite 2:1

K as a bridge



SOIL
Chemical Properties

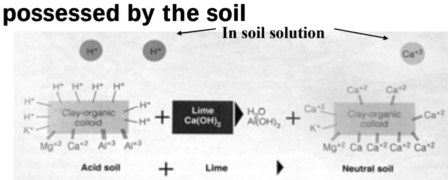
- **Substitution results in negative charges that must be balanced by positive charges**
- **Negatively charged edges and sides act as highly charged anions**



SOIL
Chemical Properties

- **<u>Cation Exchange Capacity (CEC):</u> represents the net negative charges possessed by the soil**

In soil solution



•Exchange sites occupied by positively charged Ca^{2+}, Mg^{2+}, K^+, Na^+ and H^+

SOIL
Chemical Properties

- **<u>Percent Base Saturation:</u> % of sites occupied by basic cations: Ca^{2+}, Mg^{2+}, Na^+, & K^+;**
  - **Represents the ability of soil to buffer the input of Hydrogen ions**
- **<u>Percent Base Saturation</u>**
  - **Low in acidic soils; high number of exchangeable hydrogen ions**
  - **High in neutral to alkaline soils**

SOIL
Chemical Properties

- **Soils with High CEC are potentially fertile**
- **Soils with High CEC and base saturation fertile unless they are saline or contain toxic heavy metals**
- **Cations and anions dissolved in soil solution and occupy clay/humus particles**
- **Availability of most nutrients greatest at neutral pH (~7.0)**

SOIL
Chemical Properties

- **Soil's ability to relinquish base cations to weathering can be exhausted**
  - **pH declines until soil reaction is dominated by Al.**
- **Forest soils range from pH 4.0 to pH 6.5**
- **Conifer forests decrease pH to a greater degree than do hardwood forests**
- **Individual species influence pH**
  - ***Liriodendron tulipifera* average pH 4.7**
  - ***Tsuga Canadensis* average pH 4.0**

SOIL
Chemical Properties
<u>Sources of Hydrogen Ion</u>

- **Respiration of plant roots and soil microbes**
  - **CO^2 dissolves to form carbonic acid**
- **Decomposition of plant material**
- **Plant roots – organic acids**
- **Industrial activities**
  - **Oxides of nitrogen and sulfur from fossil fuels**

SOIL
Organic Matter

- **Soil organic matter**
  - **Contributes to aggregate formation**
  - **Storehouse of nutrients**
  - **Influences water availability**
- **Sources**
  - **Above ground – trees and plants**
  - **Below ground – roots (fine and coarse)**

SOIL
Organic Matter

- **Plant litter digested and metabolized by soil organisms producing carbon dioxide, water, energy and humus**
- **<u>Humus</u> major component of A Horizon**
  - **Provides dark color to soil**
  - **Resistant to further degradation**
  - **Surface can have a net negative charge**
    - **CEC can exceed that of some clays**

SOIL
Organic Matter

- **Humus – Types**
  - **<u>MOR</u> – characteristic of dry or moist <u>acid</u> habitats**
    - **Heathland, coniferous forests**
    - **Well defined, matted or compacted**
    - **Sharp break between O and A Horizons**
    - **Unmixed with mineral soil**
    - **Decomposed by fungi**

SOIL
Organic Matter

- **Humus Types:**
  - **<u>MULL</u> – characteristic of mixed and hardwood forests; on fresh and moist soils with adequate calcium**
    - **Thin scattering of litter on surface**
    - **Mineral soil high in organic material**
    - **Less acid**
    - **O and A horizon blend**
    - **Bacteria chief decomposers; diverse soil organisms**

SOIL
Organic Matter

- **Humus types:**
  - **<u>MODER</u> – highly modified by soil animals**
    - **Form a loose, netlike structure**
    - **Moder has higher organic content than Mull**
    - **Restricted nitrification**
    - **Characteristic of hardwood forests**

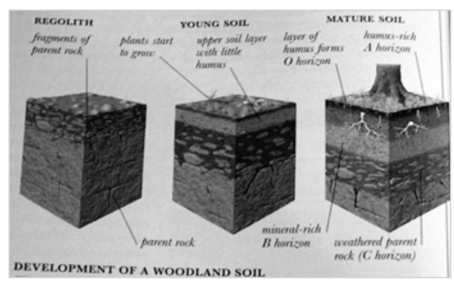
SOIL FORMATION

- **Parent material:**
  - **Transported material is often more fertile due to the diversity of materials**
- **Climate:**
  - **Radiant energy – constant heating and cooling**
  - **Water – involved in all biogeochemical reaction**
- **Topography:**
  - **Major factor influencing radiant energy intensity and amount of water**
- **Time:**
  - **Production of well-developed soil takes 1000's of years**

SOIL FORMATION

- **Biota -**
  - **Vegetation – provides organic material**
  - **Animals – consume material and return in droppings**
    - churn soil upper and lower layers of soil material
  - **Bacteria & Fungi – further reduce material into nutrient components**

SOIL FORMATION



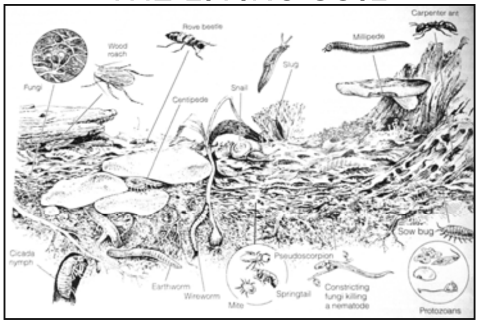
SOIL FORMATION

- **Soil formation results from four processes**
  1. **<u>Additions</u>: organic or inorganic material added**
  2. **<u>Losses</u>: Material lost through erosion or leaching**
  3. **<u>Translocation</u>: Material moved vertically and laterally**
  4. **<u>Transformation</u>: Mineral and organic substances changed**

SOIL FORMATION

- **Subprocesses within this framework**
  - **Melanization – grasslands; darkening of upper layers from mixing of organic matter**
  - **Calcification – semiarid areas; calcium carbonate accumulates**
  - **<u>Podzolization –</u> forest regions; leaching of Ca, Mg, Fe, Al, and organic matter from the upper horizon with the retention of silica**

THE LIVING SOIL



THE LIVING SOIL

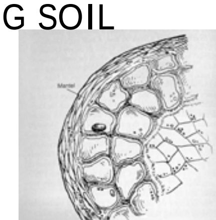
- **MICROSCOPIC ORGANISMS:**
  - **<u>Bacteria</u>, unicellular algae, <u>protozoa</u>, rotifers and <u>nematodes</u>**
- **MACROSCOPIC ORGANISMS:**
  - **Millipedes, centipedes, earthworms, insect larvae, slugs, beetles, ants, etc.**
- **FUNGI:**
  - **Wood decaying fungi**
  - **Mycorrhizal fungi**

THE LIVING SOIL

- **MYCORRHIZAL FUNGI – <u>An Obligate Symbiotic Mutualism</u>**
  - **Hyphae attach to roots and extend into soil**
  - **Increase capacity of roots to absorb nutrients and water from the soil**
  - **Assist the plant in uptake of nutrients from soil**
  - **Plant provides the fungi with energy source**

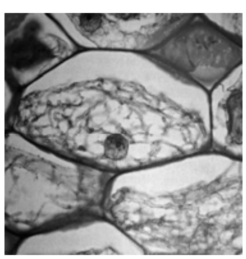
THE LIVING SOIL

- **ECTOMYCORRHIZAE**
  - **Fungal sheath around the root**
  - **Connected to inside of root by a network of hyphae (Hartig's net)**
  - **Outside hyphae resemble coral and function as extended root hairs**



THE LIVING SOIL

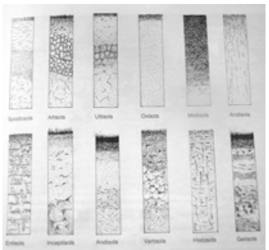
- **ENDOMYCORRHIZAE**
  - **Also known as vesicular arbuscular mycorrhizae (VAM)**
  - **Hyphae penetrate cells of host**
  - **Form an <u>arbuscle</u> (fine network of hyphae)**
  - **Arbuscle is site of nutrient exchange**



SOIL CLASSIFICATION
SOIL TAXONOMY

- **Developed by USDA Soil Conservation Service (NRCS) in 1975**
- **Based on measurable morphological characteristics present within a particular soil profile**
- **Not based on soil forming process**

SOIL CLASSIFICATION SOIL TAXONOMY



- **Categories range from <u>Orders</u> (largest grouping) to <u>Series (narrow grouping)</u>**
- ***Soil Taxonomy* recognizes 12 Orders**
- **Worldwide distribution determined by climate and vegetation**

SOIL CLASSIFICATION SOIL TAXONOMY

- **Soil Orders supporting forests in North America:**
  - **Entisols – recent soils**
  - **Inceptisols – more weathered; weakly developed B Horizon**
  - **Spodosols – cold and temperate climates, leaching**
  - **Alfisols – (Al & Fe) cool to hot humid areas**
  - **Histosols – High organic content; poorly drained landscape**
  - **Ultisols – common on old land in warm, humid climates; Southeastern Unites States**

SOIL CLASSIFICATION SOIL TAXONOMY

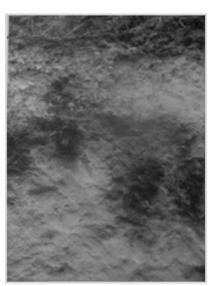
- **ENTISOL**
  - **Mineral soil**
  - **Very poor horizon development**
  - **Bedrock close to surface**
  - **20% of global land area**
  - **Soil forming processes have been interrupted**
  - **Occurs in areas susceptible to erosion, deltas, flood plains**

SOIL CLASSIFICATION SOIL TAXONOMY

- **INCEPTISOL**
  - **Mineral soils rich in weatherable materials**
  - **Some subsoil development**
  - **More weathered than Entisols**
  - **Steeply sloping mountain lands**
  - **Common forest soils in Pac NW, Rockies and Eastern US**

SOIL CLASSIFICATION SOIL TAXONOMY

- **SPODOSOL**
  - **Highly acidic**
  - **Dark B horizon (oxides of iron) under gray to white E Horizon**
  - **Common to boreal coniferous forests**
  - **Boreal forests, NE and Lake State, Pac. NW**
  - **Can form in warm humid climates**



SOIL CLASSIFICATION SOIL TAXONOMY

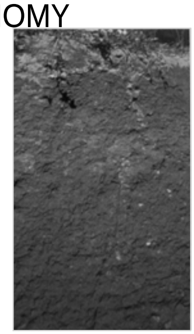
- **ALFISOLS**
  - **Occupy 13% of global land area**
  - **Associated with humid temperate mixed forests**
  - **Named from chemical abbr. for Al & Fe**
  - **B Horizon accumulates clay**
  - **Little organic material on surface**

SOIL CLASSIFICATION
SOIL TAXONOMY

- **HISTOSOLS**
  - **Wide spread globally**
  - **Form in poorly drained areas**
  - **High organic matter content (>20%)**
  - **Bogs, swamps and peat land**
  - **Aeration causes loss of organic matter**

SOIL CLASSIFICATION
SOIL TAXONOMY

- **ULTISOL**
  - **Warm, humid climates**
  - **Acidic and intensely weathered**
  - **Red or strongly yellow due to iron oxides**
  - **Intense leaching with clay in B Horizon**
  - **Can be productive if fertilized**

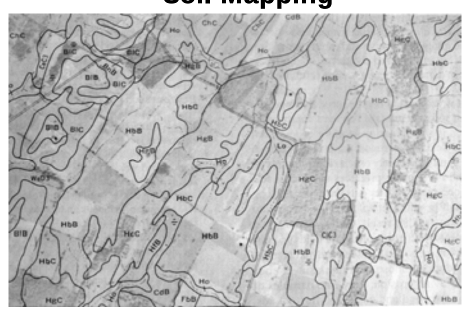


SOIL CLASSIFICATION
SOIL TAXONOMY

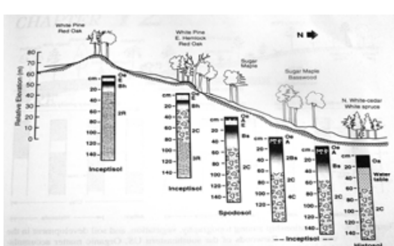
- **LOWER SOIL CATEGORIES**
  - **Further divided into**
    - **Suborders – reflect environment**
    - **Great groups – presence or absence of diagnostic horizons**
    - **Families – physical and mineral properties**
    - **Series – soils formed from a particular parent material and alike except for A Horizon**

SOIL CLASSIFICATION
SOIL TAXONOMY

Soil Mapping

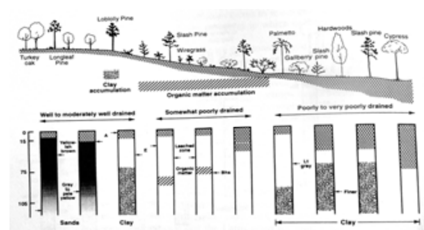


SOIL CLASSIFICATION
SOIL TAXONOMY
Landscape Relationships



UPPER MICHIGAN

SOIL CLASSIFICATION
SOIL TAXONOMY
Landscape Relationships



COASTAL PLAIN SE UNITED STATES

SUMMARY

- Soil - the foundation of terrestrial ecosystems
- Weathered outer layer of earth's crust
- Pedon –smallest unit of study
- Soil profile contains 5 horizons and bedrock
  - O Horizon = organic material / litter
  - A Horizon = organic material
  - E Horizon = zone of leaching
  - B Horizon = zone of accumulation

SUMMARY

- Physical properties of soil
  - Texture: proportion of particle sizes
    - Sand, silt and clay
  - Structure:
  - Color:
- Texture important in movement and retention of water

SUMMARY

- Cation Exchange Capacity (CEC):
  - Attribute of soil particles
  - Key to nutrient availability
  - # of negatively charged anions that can attract cations
  - Soils with high CEC are potentially fertile
  - Related to percent base saturation

SUMMARY

- Soil is a living system
- Larger organisms live in pore spaces
- Microorganisms live in water film on roots and soil particles
- Fungi
  - Decomposers
  - Mycorrhizal fungi – ecto- and endo-

SUMMARY

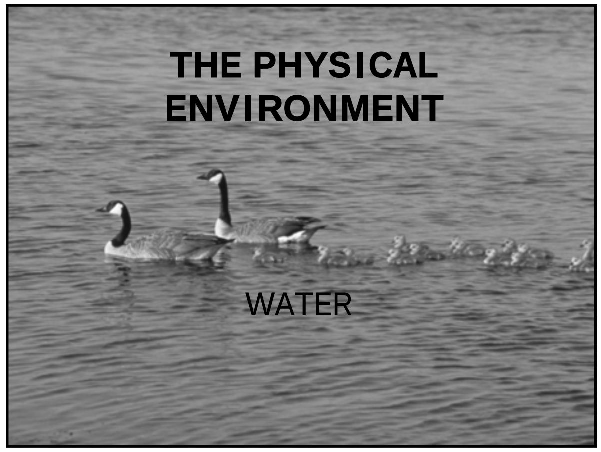
- Soil Formation – interaction climate, water, topography and parent material
- Physical weathering – mechanical breakdown of parent material
- Chemical weathering – transformation of primary minerals into secondary material and translocation and leaching of those materials
- Organic matter –Humus (mor, mull, moder)

SUMMARY
Soil development processes

- Additions to soil body
- Losses from soil body
- Translocation within the soil body
- Transformation of materials within the soil body

SUMMARY

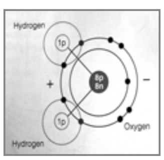
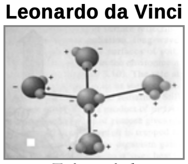
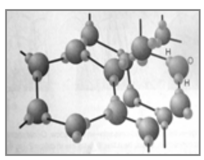
- **Soil Classification**
  - **Entisols – poorly developed horizons**
  - **Inceptisols – slightly more developed**
  - **Spodosols – highly acidic, boreal forest**
  - **Alfisols – humid temperate mixed forests**
  - **Histosols – High organic content, wetlands**
  - **Ultisols – warm, humid climates, acidic, red/yellow**



WATER

- "**Water is the driver of nature**"

Leonardo da Vinci

Gas Liquid Solid

WATER
Properties of water

- **Specific heat = 1**
  - **High heat of fusion and of evaporation**
- **Cohesion: due to polarity and Hydrogen bonding, water molecules hold together**
- **Adhesion: holding together of unlike substance**
- **Capillarity: ability to move through pores and conducting tissues in**

WATER
Properties of water

- **Surface Tension: water molecules under the surface attract each other equally; on the surface air is small attractive force and water molecules contract.**
- **Viscosity: resistance to flow; high in water (i.e.: laminar flow in streams)**

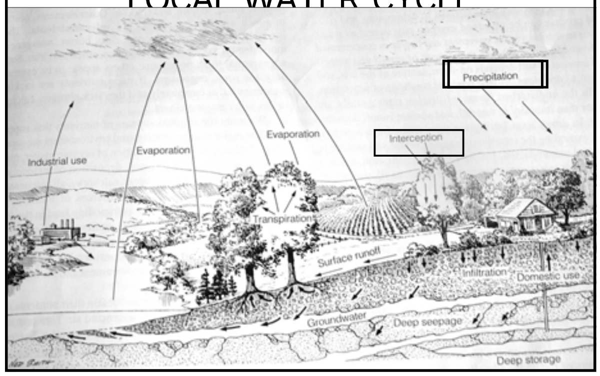
WATER
Functions of water in plants

- **Principle constituent of living organisms: makes up ~ 90% (wt) of cytoplasm; ~ 50% of woody tissue**
  - **Structural integrity best when fully hydrated:**
  - **Physiologic processes most efficient at maximum turgor**

WATER
Functions of water in plants

- **<u>Chemical reagent:</u> A primary chemical in photosynthesis**
- **<u>Universal solvent:</u>**
  - **Nutrients move in solution**
  - **Biochemical reactions occur in solution**
  - **Transfer of chemicals in and out**

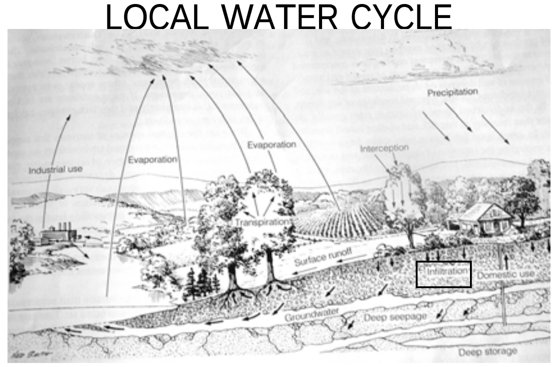
LOCAL WATER CYCLE



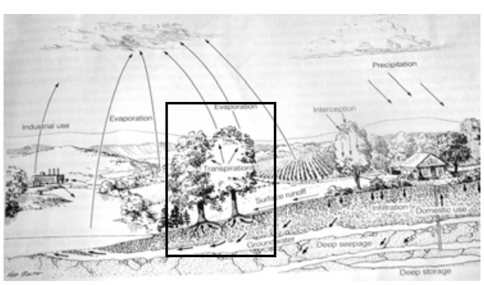
LOCAL WATER CYCLE

- **Precipitation: driving force of water cycle**
- **Interception: precipitation caught by vegetation**
- **Throughfall (or stem flow): Water exceeding the storage capacity of the canopy**

LOCAL WATER CYCLE



LOCAL WATER CYCLE
Transpiration



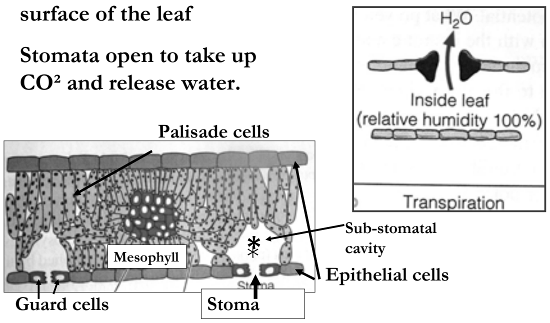
TREES
AND THE
WATER CYCLE

- **<u>EVAPOTRANSPIRATION</u>: Total flux of evaporating water from surfaces of ground and vegetation**
- **<u>TRANSPIRATION</u>: Plants take in water from the soil *via* their roots and lose it through their leaves and other organs**

ANATOMY OF TRANSPIRATION

Stomata: openings on the surface of the leaf

Stomata open to take up CO^2 and release water.



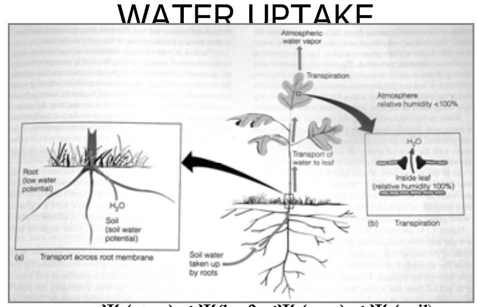
TRANSPIRATION

- **Purpose:**
  - **Carbon Dioxide intake: CO^2 essential for photosynthesis**
  - **Dissipation of heat (water):**
- **Problem: Maintenance of turgor and high photosynthetic rates when water supply declines**

WATER UPTAKE

- **Leaf loses water via transpiration**
- **Turgor of the leaf cells drops**
- **Pressure gradient exists from the leaf to the root-soil surface**
- **Water moves from soil into root and through the conductive tissue to the leaf**

WATER UPTAKE



Ψ (atm.) < Ψ(leaf) <Ψ (root) < Ψ (soil)
[Ψ (psi) = water potential]

TRANSPIRATION
Conditions favoring

- **Abundant soil moisture**
- **Low Relative Humidity**
- **High temperature**
- **Solar radiation**
- **Moderate wind – laminar flow**

TRANSPIRATION

- **Photosynthesis requires stomal opening to obtain Carbon Dioxide**
- **Transpiration dissipates heat**
- **With good turgor stoma guard cells hold stoma open; with loss of turgor guard cells collapse**

OSMOSIS

- **Movement of water molecules across a differentially permeable membrane in response to a concentration or pressure gradient**

OSMOTIC POTENTIAL

- **As plants lose water the concentration of intracellular water molecules decreases**
- **<u>Osmotic Potential</u>: tendency of solutes in a solution to cause water to move from area of high to low concentration**
- **The higher the concentration of solutes; the greater the osmotic potential; the greater the tendency**

MATRIC POTENTIAL

- **The tendency for water to adhere to surfaces**
- **As water content of soil declines remaining water clings more tightly to soil particles**
- **Soil with finer particles have higher surface area; maintain a more negative matric potential**
- **<u>Gravitational Potential</u> - Water must overcome gravity to move up the**

PLANTS AND WATER

- **Xerophytes: plants growing in very dry areas (xeric)**
- **Mesophytes: Plants growing in areas that are well drained with moderate moisture (mesic)**
- **Hydrophytes: plants growing in very wet areas (hydric)**

PLANTS AND WATER
Water Stress - Short term

- **Stomatal closure reduces water loss**
- **Solar radiation continues and leaf internal temperature rises**
- **Some plants respond with leaf curl or wilt**

PLANTS AND WATER
Water Stress

- **Curling and wilting reduce the surface area exposed to solar radiation**
- **Prolonged deficit inhibits chlorophyll production**
- **Water deficit may cause yellowing (early fall coloration) and premature shedding**

PLANTS AND WATER
Water Stress

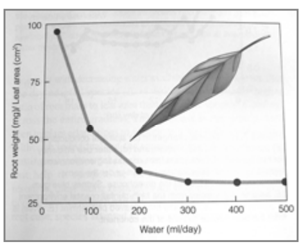
- **WINTER DROUGHT:**
  - **Conifers and other evergreens can experience winter drought in temperate areas**
  - **Warm temperatures thaw ice in vessels of woody plants stimulating transpiration**
  - **Soil water is frozen and unavailable to the tree**
    - **Browning and dieback result**

PLANTS AND WATER
Long term moisture variations

- **Changes in total leaf area – size and shape of leaves/needles**
- **Plants growing with low water availability have thicker and smaller leaves**
  - **More layers of mesophylls/ surface area**
  - **Increased photosynthetic capacity**
  - **Reduces surface area absorbing radiation and losing water**

PLANTS AND WATER
Long term moisture variations

- **Rooting habits – depth and fiber content** **(generally within 18" of the surface)**
  - **Reduced allocation to production of leaves accompanied by increased allocation of carbon to root production**



WATER DEFICIT & TREE GROWTH

- **Tree growth responds more to water stress than any other factor in the forest site**
- **Soil water deficits during the middle of the growing season affects vertical growth in the current and succeeding season**
- **Water stress important in radial growth, affecting the size of the annual ring**

PLANTS AND WATER
Avoidance mechanisms

- **Ability of roots to extract large amounts of water from the soil**
- **High root to shoot ratio**
- **Reduced leaf surface area**
- **Stomatal control to reduce transpiration**
- **Thick cuticle to protect from solar radiation**
- **High proportion of water conducting**

PLANTS AND FLOODING

- **Symptoms of excess water similar to drought**
  - **Stoma closure**
  - **Yellowing and premature loss of leaves**
  - **Wilting**
  - **Rapid reduction in photosynthesis**

PLANTS AND FLOODING

- Excess water around roots reduces oxygen levels
- Results in death of root tips (Most permeable area for water uptake)
- Root death can clog the xylem further reducing water uptake
- New roots grow horizontally along oxygenated zone

PLANTS AND FLOODING

- **Response of trees to flooding depends upon**
  - **Duration – more than half the growing season usually results in death**
  - **Movement of water – standing in stagnant water more injurious than in flowing water**
  - **Species of tree**

PLANTS AND FLOODING

- Growing plants need both adequate water and rapid gas exchange
- When soil pores are water filled no gas exchange can occur
- Plants are asphyxiated and in effect drown
- Metabolism is shifted from aerobic to anaerobic.
- Ethylene gas (a growth hormone) accumulates

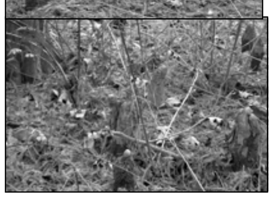
PLANTS AND FLOODING

- **Ethylene in high amounts stimulates adjacent cells in the root to lyse and form gas pockets.**
- **These <u>Aerenchyma</u> allow some gas exchange and are typical of hydrophyllic species**
- **Wetland species lose less oxygen**

PLANTS AND FLOODING

•Trees growing on permanently flooded areas develop <u>pneumatophores</u> (erect respiratory root)

Taxodium distichum



SUMMARY

- **Water molecule has polarity allowing hydrogen bonding between molecules**
- **Physical properties of water: specific heat, cohesion, adhesion, capillarity, surface tension and viscosity**
- **Understand the local water cycle**
- **Terrestrial plants take up CO^2 *via* leaf openings called stomata**

SUMMARY

- **Stomata opening also results in water loss and dissipation of heat**
- **Plants maintain a stable water balance by affecting osmotic potential and turgor pressure (water potential)**
- **Water potential decreases from soil to leaf pulling up water**

SUMMARY

- **Plant responses to moisture deficit**
  - **Close stomata to stop transpiration**
  - **Decrease rate of photosynthesis – can kill the plant if drought is severe**
- **Plant allocates more carbon to root growth; less to leaf growth**
- **Smaller, thicker leaves reduce surface area for solar radiation and increase photosynthetic capability due to increase in mesophylls**

SUMMARY

- **Excess water leads to asphyxiation, accumulation of toxic substance, adventitious root growth at soil surface**
- **Some plant species adapt to excess water by forming "knees" or pneumatophores to provide above water access to oxygen**

NUTRIENTS
&
NUTRIENT CYCLING

NUTRIENTS

- **Direct factors necessary for autotrophs**
  ('autotrophs' = plants that create their own food source)

√ **HEAT**	**OXYGEN**
√ **LIGHT**	**CARBON DIOXIDE**
√ **WATER**	**MINERAL NUTRIENTS**

NUTRIENTS

- **Nutrient: a substance required by organisms for normal growth and activity**
- **Organisms require nutrients in inorganic/mineral form**
- **Macronutrients: Elements needed in large amounts**
- **Micronutrients: Elements needed in much smaller amounts**

NUTRIENTS

- **MACRONUTRIENTS:**
  - **Carbon, Oxygen, Hydrogen – basic constituents of all organic matter – derived from CO_2 and water**
  - **Nitrogen (N)– Utilized in fixed form, basis of proteins**
  - **Calcium (Ca) – essential to root growth, with pectin gives rigidity to cell walls**
  - **Phosphorus (P)– energy transfer ADP to ATP, component of nuclear material**

NUTRIENTS

- **MACRONUTRIENTS:**
  - **Magnesium (Mg) – integral part of chlorophyll**
  - **Potassium (K)- Formation of sugars and starches**
  - **Sulfur (S) – basic component of protein**
- **Above six elements exist in soil**

NUTRIENTS

- **MICRONUTRIENTS:**
  - **Include – Copper, Zinc, Iodine, Silica, Selenium, Iron and others**
- **Micronutrient deficiency causes organism failure as surely as does macronutrient lack**

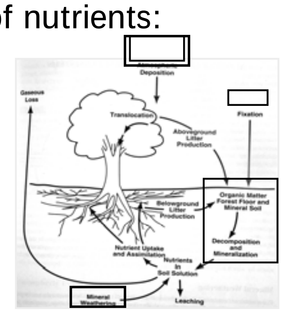
NUTRIENTS

- **The maintenance of inorganic nutrients involves recycling of nutrients between the abiotic environment and living organisms – <u>Nutrient cycling</u> or <u>biogeochemical processes</u>**
- **Nutrient cycles:**
  - **Gaseous: oxygen, carbon, nitrogen**
  - **Sedimentary: sulfur, phosphorus**

NUTRIENTS

Sources of nutrients:

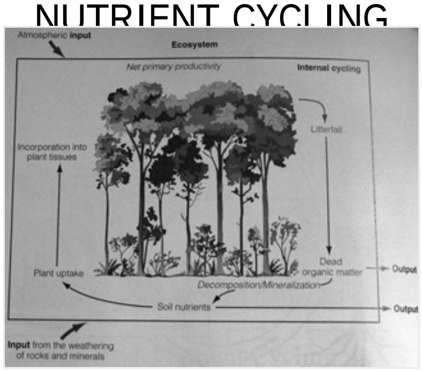
- **Weathering of mineral soil**
- **Nitrogen fixation**
- **Atmospheric gases**
- **Precipitation with deposition of atmospheric particles**
- **Decomposition of organic matter**



NUTRIENTS

- **NUTRIENT CYCLING: The movement of nutrients from soil to plant and back to the soil after decomposition**
- **Nutrient cycles involve the chemical exchanges of elements among air, soil, water and living organisms**

NUTRIENT CYCLING



DECOMPOSITION

- **All heterotrophs are decomposers**
- **Digestion breaks down organic matter, alters its structure and releases it as waste**
- **Decomposers: organisms that feed on dead organic material (Microflora)**
  - **Bacteria**
  - **Fungi**
  - **Certain insects (detritivores)**

DECOMPOSITION

- **Bacteria: principal decomposers of animal matter**
- **Fungi: major decomposers of plant material**
- **Both organisms secrete enzymes into tissues to break down the complex organic compounds.**
- **Organic matter may be decomposed by successive groups of microflora**
- **This continues until the original matter is reduced to inorganic nutrients**

DECOMPOSITION

- **Detritivores: invertebrates that fragment dead plant and animal matter includes**
  - **Protozoa, nematodes, mites, springtails, millipedes, worms, etc.**
- **Microbivores: feed on the bacterial and fungal decomposers**
  - **Control abundance and distribution of fungi**

DECOMPOSITION

R = Dead material

F =fragmentation

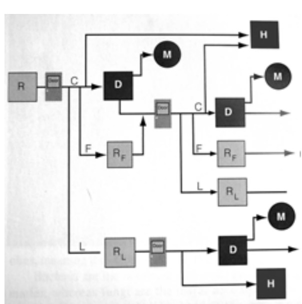
L = leaching

C = breakdown complex to smaller compounds

H = humus

D = resynthesized

M = mineralized

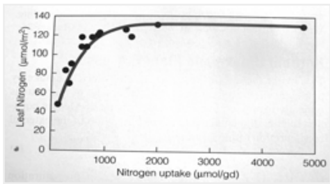


NUTRIENT UPTAKE

- **Factors influencing rate of nutrient uptake**
  - **Demand**
  - **Availability**
- **Rate of uptake most important variable controlling the nutrient content of plants**
- **Rate of uptake is a function of the external concentration of the nutrient**

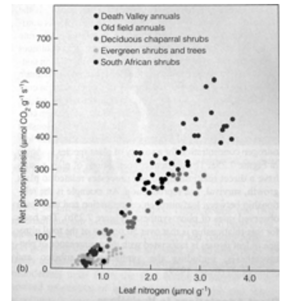
NUTRIENT UPTAKE

- **As nutrient concentration rises uptake rises until reaching a maximum uptake rate**



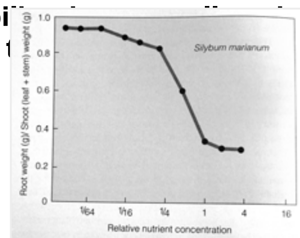
NUTRIENT UPTAKE

- **Nutrient concentrations of plant tissues have direct relationship to key plant processes**
- **Over 50% of total leaf N is associated with photosynthesis**



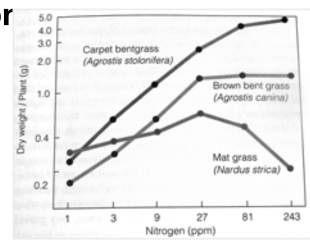
NUTRIENT UPTAKE

- **Adaptation for low nutrient availabil n of carbon t**



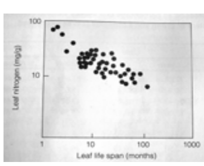
NUTRIENT UPTAKE

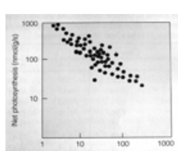
- **Plants adapt to nutrient availability by altering growth respor**



NUTRIENT UPTAKE

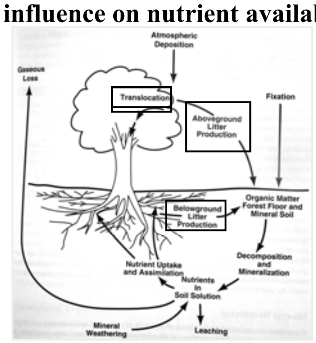
- **Plants adapt to nutrient availability by altering leaf longevity:**





NUTRIENT UPTAKE

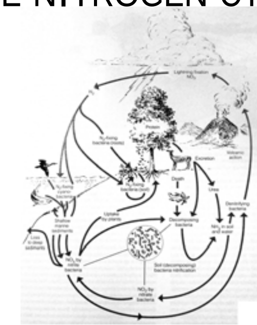
Plant influence on nutrient availability



THE NITROGEN CYCLE

- N_2 in the atmosphere can not be used by plants; four processes required for complete nitrogen cycle
- <u>Fixation</u>
- <u>Mineralization/ ammonification</u>
- <u>Nitrification</u>
- <u>Denitrification</u>

THE NITROGEN CYCLE



NITROGEN FIXATION

- Fixation done by specific groups of bacteria/fungi (90 % of fixed N)
  - Rhizobium bacteria grow in and on the roots of certain terrestrial plant species (legumes and root-nodulated non-legumes)
  - Live on carbon from the plant and return nitrogen
  - Mycorrhizal fungi
- Lightning produces nitrates (high-energy fixation)

NITROGEN FIXATION

- Biological fixation produces ammonia (NH_3)
  - N_2 split to 2N
  - $2N + 3H_2 = 2\ NH_3$
- High energy fixation produces nitrates
- Once available by either form of fixation N is available to plants
- Death returns organic compounds to soil
- N in these compounds unavailable to plants

MINERALIZATION

- Proteins are broken down by decomposers into amino acids
- Amino acids oxidized to CO_2, H_2O, NH_3 and energy
- Ammonium absorbed directly by roots and incorporated into protein
- Some ammonium dissolved and bound in the soil

NITRIFICATION

- Ammonia oxidized to nitrates and nitrites yielding energy
  - $NH_3 + 1\ ½\ O_2 \longrightarrow HNO_2 + H_2 + 165$ kcal
  - $NO_2^- + 1\ ½\ O_2 \quad NO_3^-$
  - Biological process (bacterial)
- Nitrates leach more easily than ammonium
- DENITRIFICATION: nitrates are reduced by certain bacteria to gaseous N to obtain oxygen

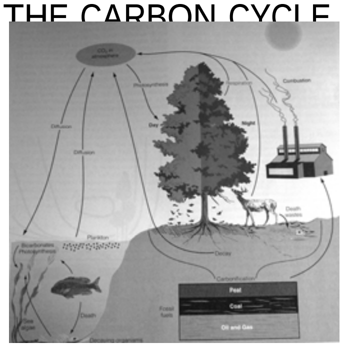
DECOMPOSITION

- **Decomposition is breakdown of chemical bonds formed during the development of plant and animal tissue**
- **Decomposition involves respiration - the release of energy originally fixed by photosynthesis**
- **Rate of decomposition dependent upon temperature, moisture and**

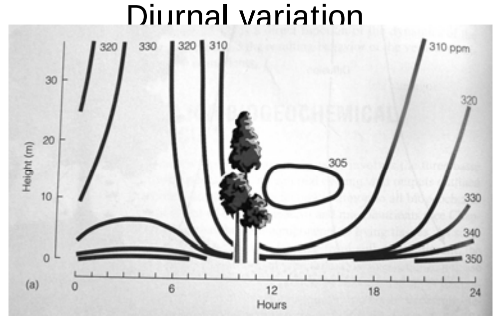
THE CARBON CYCLE

- **Carbon: basic constituent of all organic compounds**
- **Major element in fixation of energy by photosynthesis**
- **Productivity often measured as grams of carbon fixed/unit area/year**
- **Source of all fixed carbon is carbon dioxide**
  - **$6CO_2 + 12\ H_2O \rightarrow C_6H_{12}O_6 + 6H_2O +$**

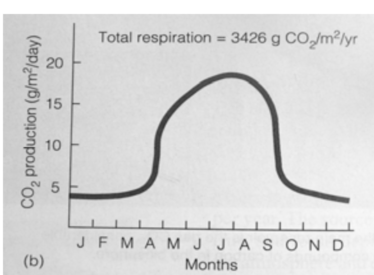
THE CARBON CYCLE



THE CARBON CYCLE
Diurnal variation



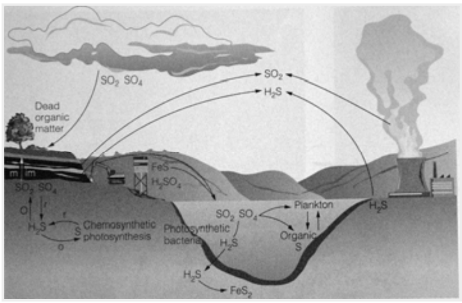
THE CARBON CYCLE
Seasonal variation



THE SULFUR CYCLE

- **Sulfur (S) contained in;**
  - **organic material - coal, oil and peat**
  - **inorganic form - pyrite rocks and sulfur deposits**
- **Released by:**
  - **Weathering**
  - **Erosion**
  - **Decomposition**
  - **Industrial production**

THE SULFUR CYCLE



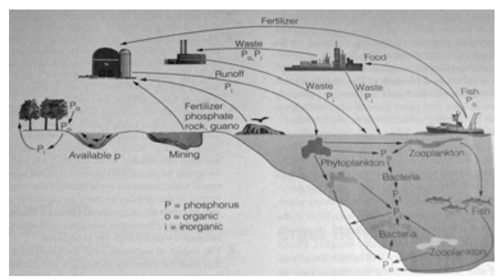
THE SULFUR CYCLE

- **Sulfur in soluble form incorporated into sulfur bearing amino acids**
- **Sulfur utilized as an O_2 receptor in the reduction of carbon dioxide**
- **In the presence of iron and anaerobic conditions will precipitate as FeS_2 – a highly insoluble compound**

THE PHOSPHORUS CYCLE

- **Occurs in minute amounts in the atmosphere and total available amount is small**
- **Source in soil is apatite a phosphate of calcium ($Ca_5(PO_4)_3(F,Cl,OH)$)**
- **Principal sources: rock and natural phosphate deposits**

THE PHOSPHORUS CYCLE



THE PHOSPHORUS CYCLE

- **Essential in energy transfer and component of nuclear material**
- **Phosphorus – low availability**
- **Most limiting factor on infertile soils such as the Utisol**
- **Forests on infertile soil cycle P more efficiently than those on moderately fertile soils**

BIOGEOCHEMICAL CYCLES

- **Major cycles are all linked to each other**
- **All are components of living organisms**
- **Proportions of nutrients involved in various processes are fixed**
- **Limitation of one nutrient can affect the cycling of all others**

SUMMARY

- **Organisms obtain chemical elements essential to growth and development from their environment**
- **Macronutrients: needed in large amounts**
- **Micronutrients: needed in smaller amounts**
- **Nutrients flow from living to nonliving components of the**

SUMMARY

- **Types of nutrient cycles:**
  - **Gaseous - atmosphere**
  - **Sedimentary – earth's crust**
- **Availability of essential nutrients depends on nature of the soil**
- **Plant uptake of nutrients incorporated into living tissue**

SUMMARY

- Decomposition returns dead organic material to usable mineral form
- Rate determined by environmental factors
- Carbon cycle tied to energy flow
  - Diurnal and seasonal variation
- Nitrogen cycle – fixation of atmospheric N and decomposition of organic matter to make N available

SUMMARY

- **Phosphorus cycle: wholly sedimentary**
- **Sulfur cycle both gaseous and sedimentary**
  - **Released by weathering and decomposition**
- **All major biogeochemical systems are linked**