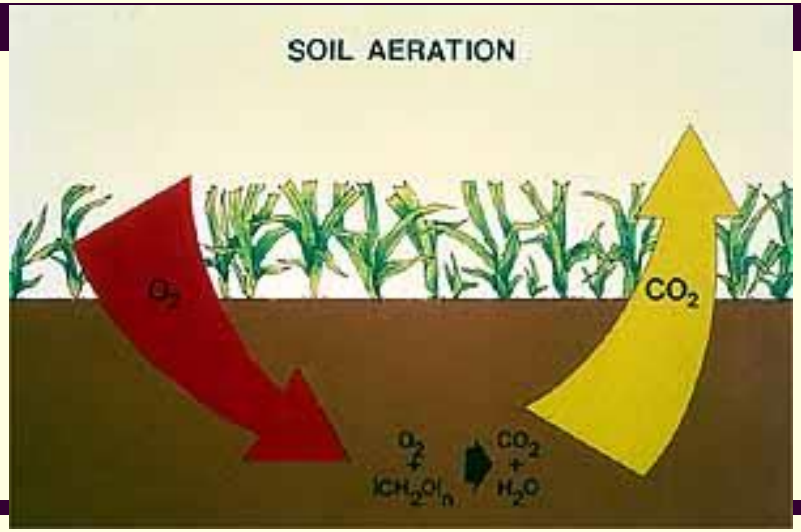
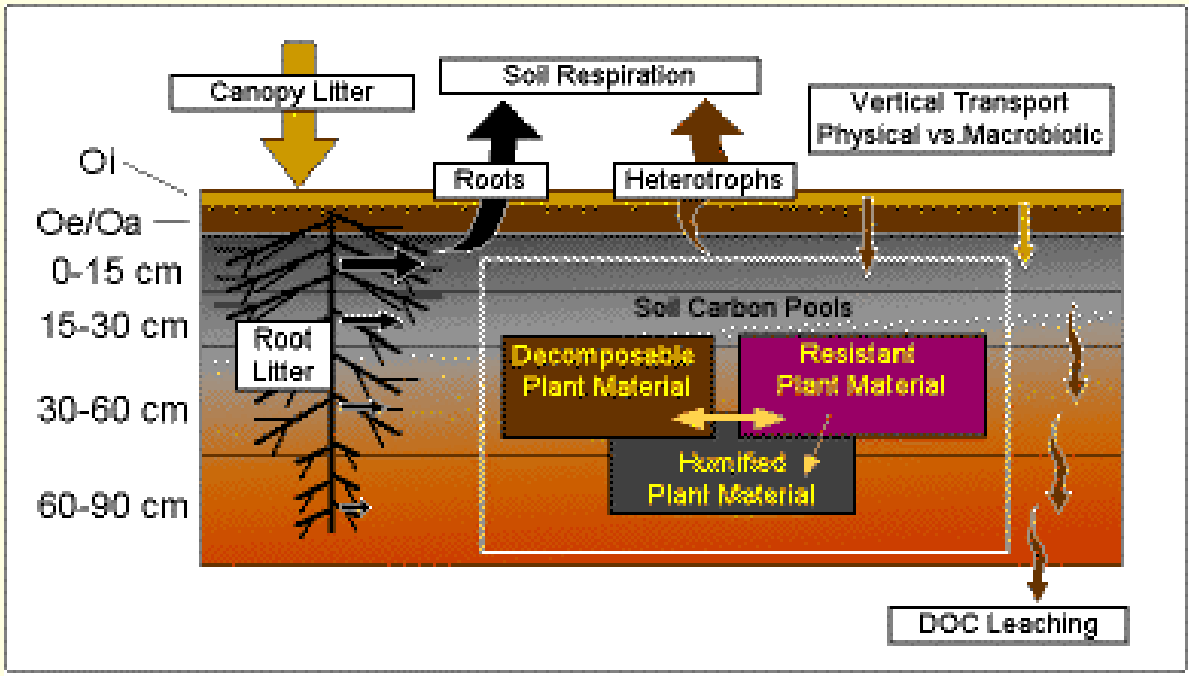
SOIL AERATION AND TEMPERATURE



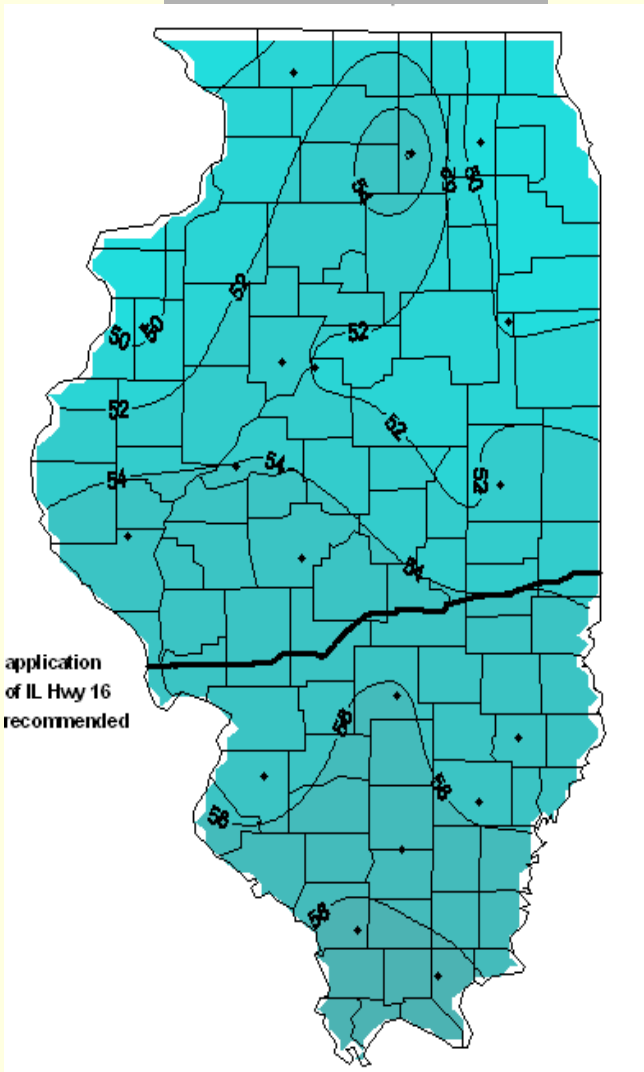
INTRODUCTION

- **Aeration** is directly impacted by soil:
  - Texture and structure
  - Porosity, water movement and retention
  - Microbes



INTRODUCTION

- **Soil temperature** affects:
  - Plant growth
  - Growth of microbes
  - Soil drying
  - Soil aeration
  - Physical and chemical properties



THE PROCESS OF SOIL AERATION

- **Aeration** involves:
  - Ventilation of the soil
  - Gas movement into and out of the soil
  - Determines the rate of gas exchange

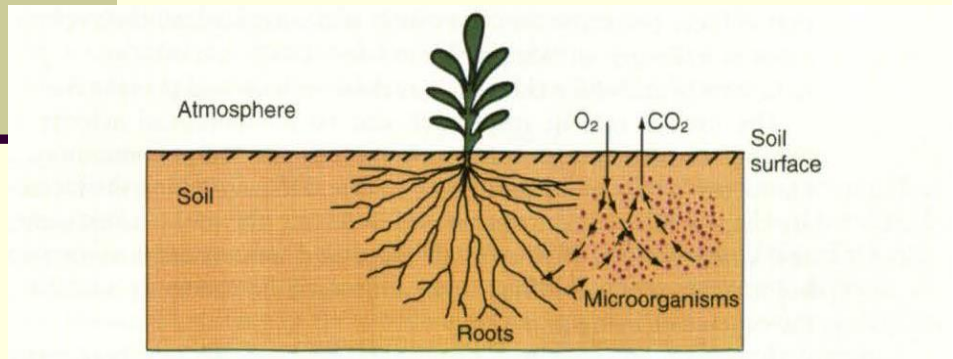
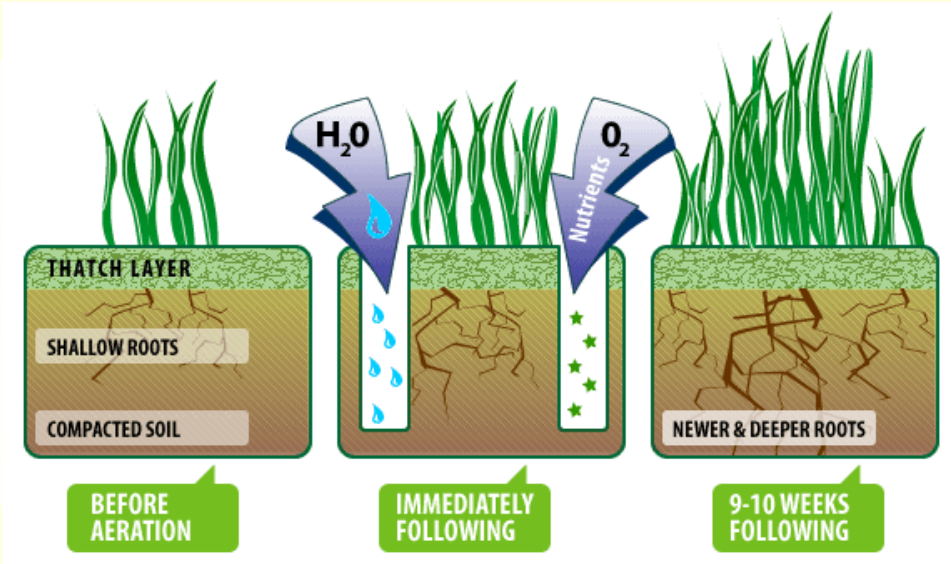
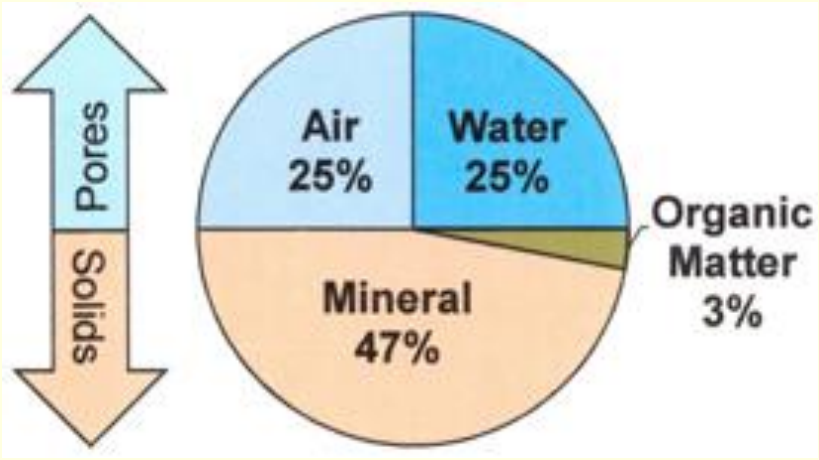


Fig. 5.14. Soil aeration is primarily a process of O_2 and CO_2 exchange between the air phase of the soil and the external atmosphere.



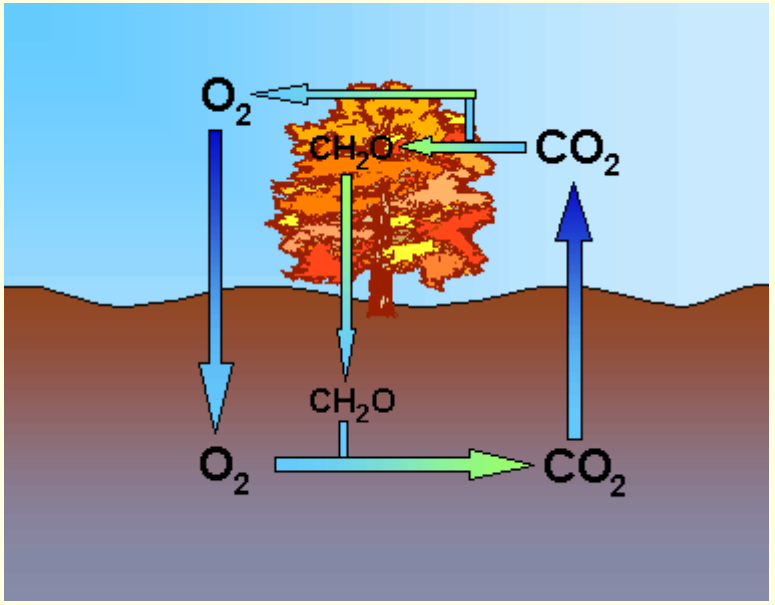
AERATION INVOLVES

- Proportion of pore spaces filled with air
- Composition of soil air
- Oxidation/reduction potential



THE PROCESS OF SOIL AERATION

- **Aeration** requires:
  - Supply oxygen
  - Removal of CO_2



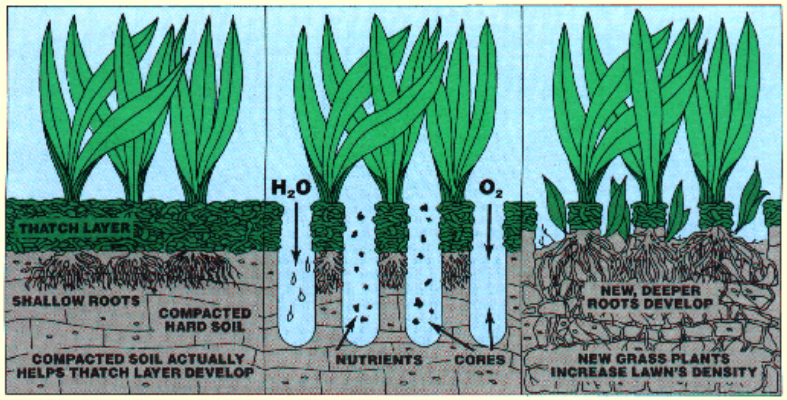
- **Balance between O_2 and CO_2 in well-aerated soils**

AERATION REQUIREMENTS FO UPLAND PLANTS

- Upland plants require O_2 in soil air = 0.1L/L
- O_2 levels in atmosphere = 0.2L/L
- Methane and ethylene must not build up

REGULATION OF AVAILABLE OXYGEN

- **Soil macro-porosity**
  - Affected by texture and structure
- **Soil water content**
  - Affected by proportion of porosity filled with air
- **O_2 consumption** by respiring organisms



SOIL AERATION IN THE FIELD

- ***Poor soil aeration refers to a condition in which the availability of O_2 in the root zone is insufficient to support optimal growth of plants and microorganisms***

SOIL AERATION IN THE FIELD

- Problem when 80-90% of pore space is filled with water

- Provides little pore space for air

EXCESS MOISTURE HAMPERS SOIL AERATION

- Block pathways for gas exchange with atmosphere

- Compaction has the same effect, even if soil is not wet

EXCESS MOISTURE

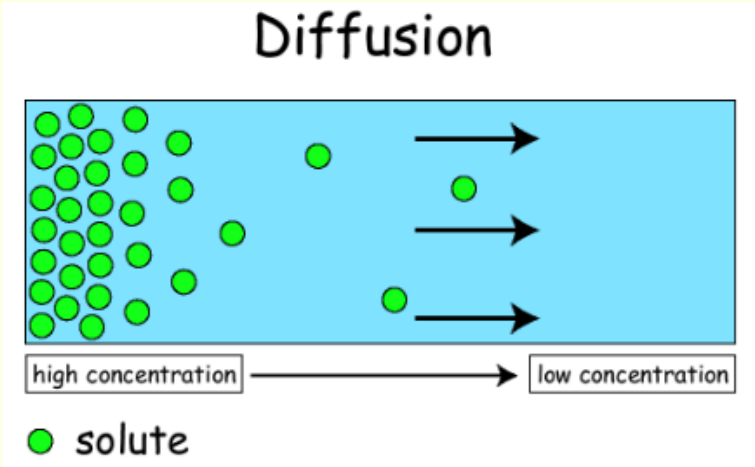
- **Water saturated or waterlogged** – nearly all soil pores are filled with water
  - Wetlands
  - Depressions
  - Flat areas on upland sites
  - Well-drained areas with excessive water

HYDROPHYTIC PLANTS

- Plants adapted to live in waterlogged soils
  - Rice
  - Eastern gamma grass
  - Marsh grass
  - Bald cypress
  - Mangroves

GASEOUS INTERCHANGE

- **Mass flow** – movement of air
  - Enhanced by fluctuations in soil moisture Changes in barometric pressure
  - Not as important as diffusion
- **Diffusion** – movement of atoms in a gaseous mixture due to random motion
  - Gases move in direction based on its partial pressure



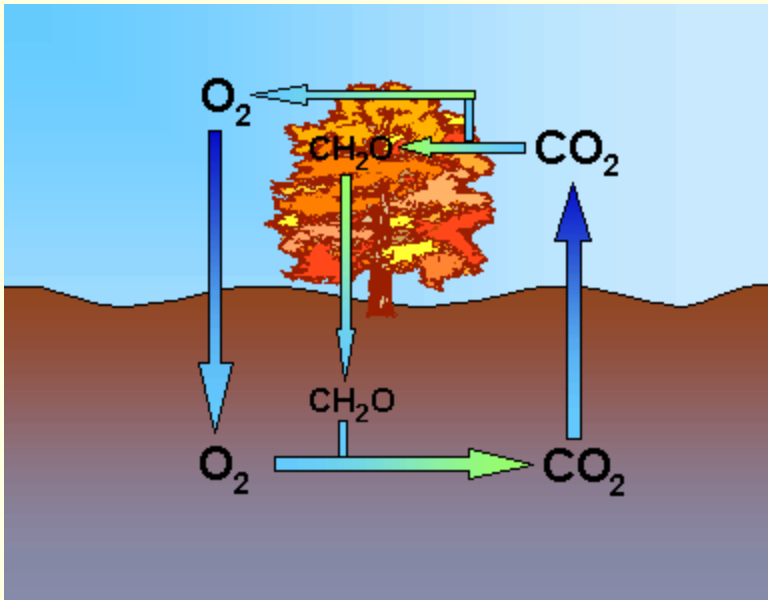
PARTIAL PRESSURE OF A GAS

- The pressure a gas would exert if it alone were present in the volume occupied by the mixture

- **Example:**
  - **If** pressure of air = 1 atmosphere
  - **And** O_2 makes up 21% of air by volume
  - **Then** the partial pressure of O_2 = 21kPa

GASEOUS INTERCHANGE

- **Oxygen** will move from atmosphere to soil
- **Carbon dioxide** and **water vapor** move from soil to atmosphere

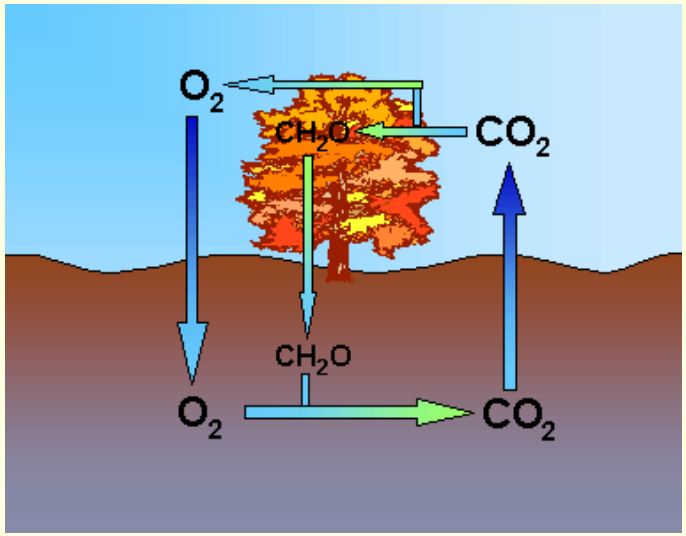


GASEOUS COMPOSITION OF SOIL AIR

- **Oxygen**
  - **Atmosphere:** 21% O_2; 0.035% CO_2; 78% N_2
  - **Soil air:** < 21%O_2; > 0.035% CO_2; 78% N_2
- **Anaerobic** – lack of oxygen in soil environment

GASEOUS COMPOSITION OF SOIL AIR

- **Carbon dioxide**
  - **Atmosphere:** 0.035% CO_2
  - **Soil air:** 0.35%CO_2
- **When CO_2 levels reach 10%, it may be toxic to plants**



GASEOUS COMPOSITION OF SOIL AIR

- **Soil water vapor is higher in the soil** than atmosphere
- **Methane** and **hydrogen sulfide** higher in waterlogged soils
- **Ethylene** can be toxic to plant roots

AIR-FILLED POROSITY

- **Microbial activity and plant growth are severely inhibited when:**
  - Air-filled porosity < 20% of pore space or 10% of total soil volume
- ***Oxygen diffuses 10,000 times faster through air-filled pores than water-filled pores***

SOIL AERATION

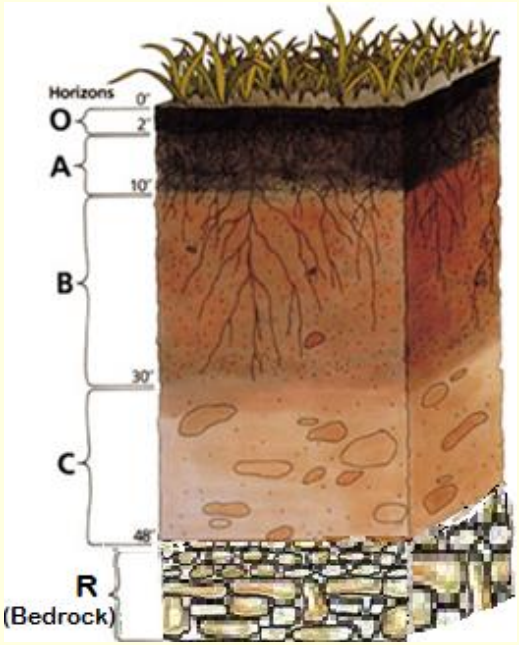
- ***"Soil aeration helps determine the specific chemical species present and, in turn, the availability, mobility, and possible toxicity of various soil elements"***

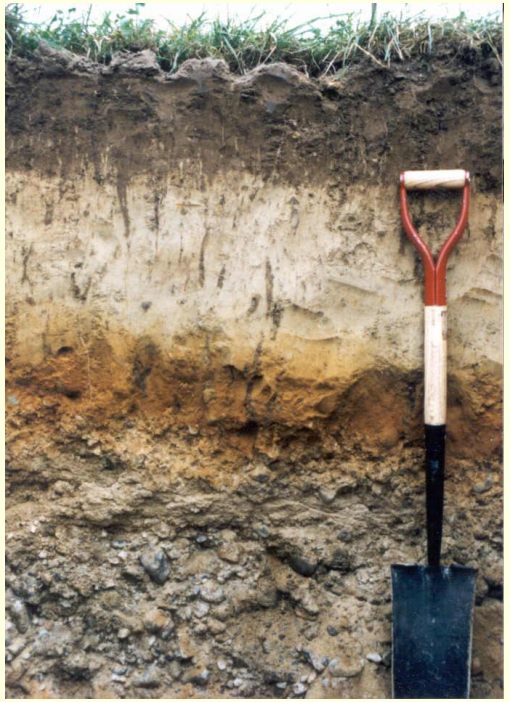
RATES OF RESPIRATION

- Oxygen and carbon dioxide levels are dependent on microbial activity
- Incorporation of organic matter affects respiration rates
- Plant root respiration
- Respiration rates increase with temperature

SOIL HETEROGENEITY

- Subsoils more oxygen deficient than topsoils
- Total pore space is lower in deeper horizons





SOIL HETEROGENEITY

- **Profile**
  - Oxygen decreases and carbon dioxide increases as you move down the profile
- **Tillage**
  - Short term may increase aeration
  - Long term my reduce macro-porosity

SEASONAL DIFFERENCES

- **Oxygen exchange is low in spring**
  - Soils are wetter and cooler
- **Gas exchange is higher in summer**
  - Soils are dryer and warmer

ECOLOGICAL EFFECTS OF SOIL AERATION

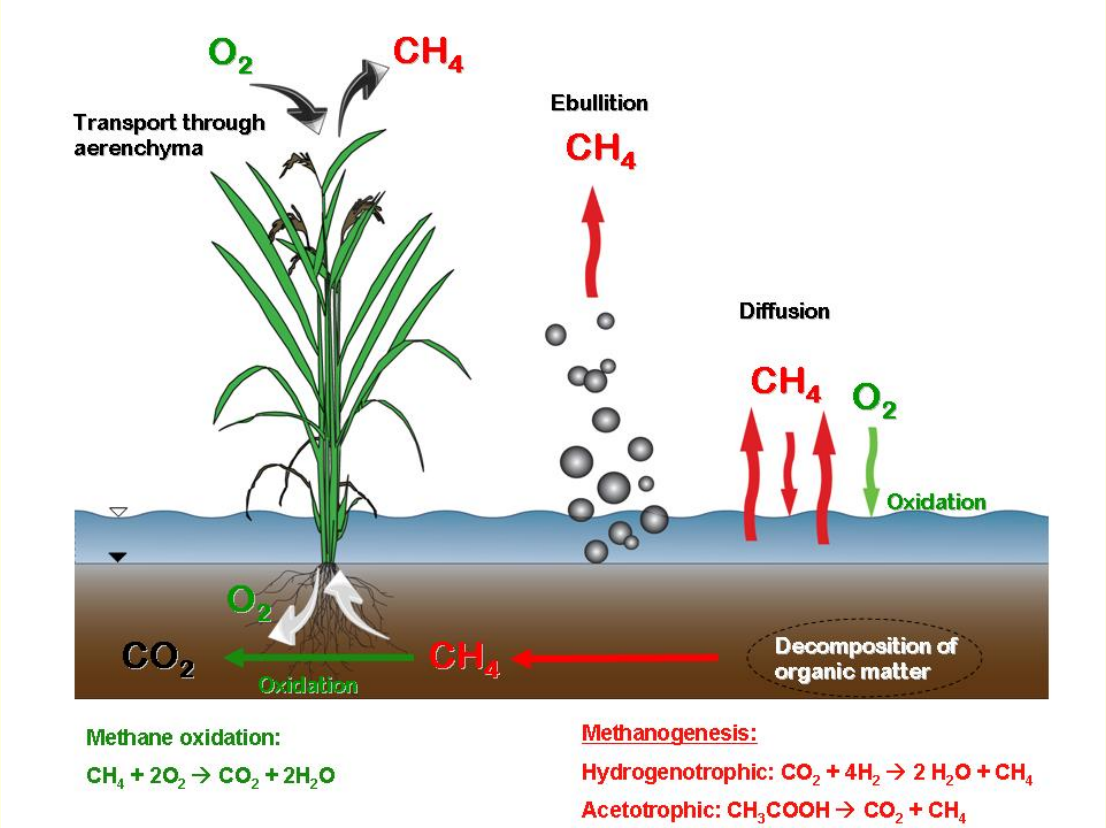
- **Rate of breakdown of organic matter**
  - Slower in poorly drained soils
  - Build up of gases which can be toxic to plants

ECOLOGICAL EFFECTS OF SOIL AERATION

- **Soil colors**
  - Well-oxidized soils are red, yellow, and reddish brown
  - Streaked soils indicate lack of uniform drainage

METHANE PRODUCTION IN SOILS

- Produced by a reduction of CO_2
- Common in wetlands and rice paddies



AERATION AND SOIL AND PLANT MANAGEMENT

- Container grown plants suffer from overwatering
  - Mineral soil makes up about 1/3 of potting mixes
- Young trees and newly transplanted trees must be protected from **water-logging**

AERATION AND SOIL AND PLANT MANAGEMENT

- Adding fill to mature tree root zones can result in suffocation
- Compacted areas due to foot traffic may need to be core aerified

SOIL TEMPERATURES

PROCESSES AFFECTED BY SOIL TEMPERATURE

PROCESSES AFFECTED BY SOIL TEMPERATURE

- Physical, biological, and chemical processes
- **Most plants have a narrow range of soil temperatures that are optimum and affects:**
  - Yield
  - Plant growth
  - Plant life cycles
  - Seed germination
- **Vernalization** – period of cold temperature to stimulate germination or breaking of dormancy

PROCESSES AFFECTED BY SOIL TEMPERATURE

- **Root functions**
  - Nutrient and moisture uptake are slowed in cool soils

  - **Winter burn or physiological drought**

PROCESSES AFFECTED BY SOIL TEMPERATURE

- **Microbial processes**
  - **Biological Zero:** Temperature at which activity ceases (below 40^{o}F)
  - Respiration doubles for each 10^{o}C rise
  - Optimum range is 80 - 100^{o}F

PROCESSES AFFECTED BY SOIL TEMPERATURE

- **Freezing and thawing**
  - Alters physical structure of the soil

- **Frost heaving** – forcing of objects upward in soil due to freezing and thawing
  - Silts and sands are more susceptible
  - Clay soils are less susceptible

ABSORPTION AND LOSS OF SOLAR ENERGY

- **Solar radiation reaching earth is primary source to heat soils**
  - **Cloudy humid regions** = 35-40% of solar radiation
  - **Cloud-free arid areas** = About 75% of solar radiation
  - **Globally** = About 50% of solar radiation
- **Absorbed solar radiation is about 10%**

ABSORPTION AND LOSS OF SOLAR ENERGY

- **Albedo** – fraction of incident radiation reflected by land surface
  - 0.1 – 0.2 for rough, dark colored surfaces
  - > 0.5 for smooth, light colored surfaces
  - Darkest soils are usually the wettest and slower to warm up
- **Aspect** – direction of slope
  - Rays hitting perpendicular to earth's surface will heat the soil faster

ABSORPTION AND LOSS OF SOLAR ENERGY

- **Soil cover**
  - Bare soils warm more quickly and cool more rapidly than covered soils
  - Frost penetration is greater in bare soils compared to covered soils

MAXIMUM SOIL TEMPERATURES FOR FOUR TYPES OF SURFACES

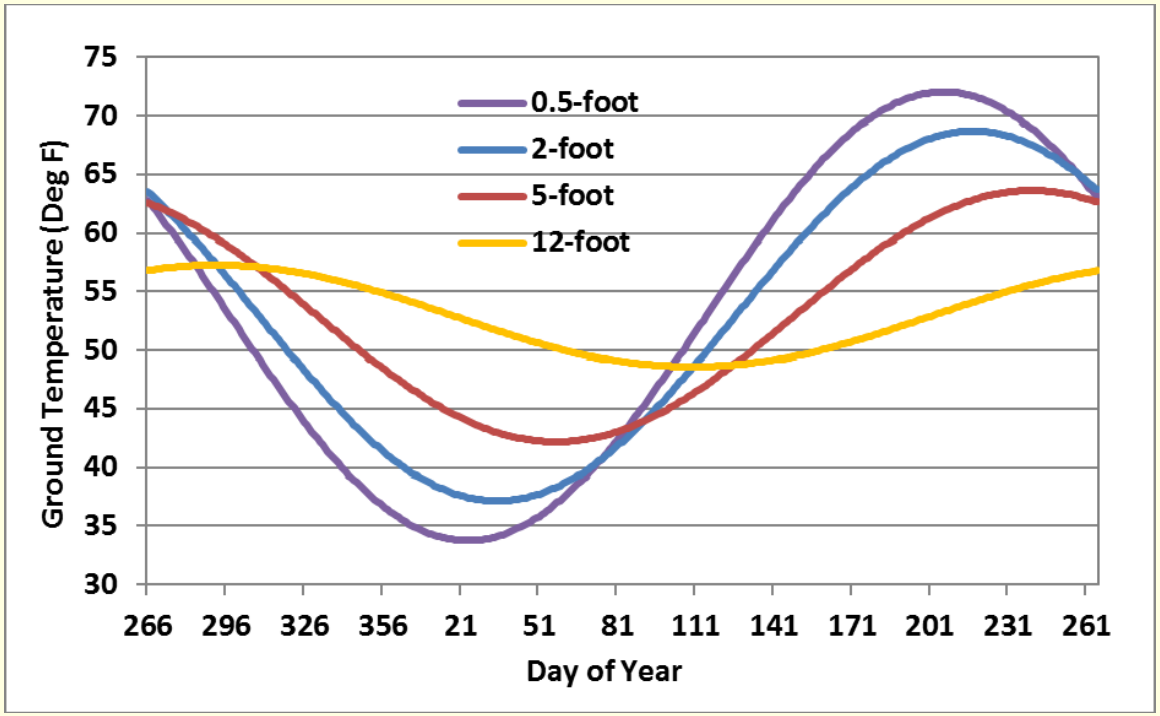
SURFACE	MAX.TEMP.	MAX. TEMP.
	Day (ºC)	**Night (ºC)**
Turf	31 (88ºF)	24 (75ºF)
Dry, bare soil	39 (102)	26 (79)
Brown grass	52 (126)	27 (80)
Synthetic turf	70 (160)	29 (84)

THERMAL PROPERTIES OF SOILS

- Dry soils heat up more easily than wet soils
- **Specific heat (heat capacity)** – heat capacity per unit mass
  - Pure water = 1.00 cal/g
  - Dry soil = 0.2 cal/g
- **Heat of vaporization** – heat required to evaporate water from a soil surface
  - 540 kilocalories/kg
- **Low temperature of wet soils in spring is due to evaporation and high specific heat**

DAILY VARIATIONS

- Surface soil temperatures lag behind air temperature maximums
- Temperature change is less at greater soil depths
- Lower subsoils show very little daily and/or weekly fluctuations



FACTORS AFFECTING SOIL TEMPERATURE CONTROL

- Cover crops or mulch on the soil

- Practices that reduce soil moisture

FACTORS AFFECTING SOIL TEMPERATURE CONTROL

- **Organic mulches and plant residue** management
  - Mulches buffer extremes in soil temperatures

- **Plastic mulches**
  - Used in vegetable production to increase soil temperature

END OF PRESENTATION