What is Necessary for Plant Growth?

- pH (~5 to 8);
- water
- structural support
- minerals and nutrients
  Macronutrients (C HOPKNS CaFe Mg)
  (Nutrients must be in a chemical form that plants can use.)
- Cation exchange capacity
**THEREFOR...**

- All plants rely on soil microbes to remineralize nutrients;

- Microbes need an electron accepter;

- In the absence of $O_2$, bacteria use other oxidized elemental forms as terminal electron acceptors;
The Redox “Hierarchy”

<table>
<thead>
<tr>
<th>Element</th>
<th>Oxidized Form</th>
<th>Reduced Form</th>
<th>Eh (mV)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Oxygen</td>
<td>O₂</td>
<td>H₂O</td>
<td>400 to 600</td>
</tr>
<tr>
<td>Nitrogen</td>
<td>NO₃⁻ (nitrate)</td>
<td>N₂O, N₂, NH₄⁺ (nitrous oxide, nitrogen gas, and ammonium)</td>
<td>250</td>
</tr>
<tr>
<td>Manganese</td>
<td>Mn⁴⁺ (manganic)</td>
<td>Mn²⁺ (manganous)</td>
<td>225</td>
</tr>
<tr>
<td>Iron</td>
<td>Fe³⁺ (ferric)</td>
<td>Fe²⁺ (ferrous)</td>
<td>120</td>
</tr>
<tr>
<td>Sulfur</td>
<td>SO₄⁻² (sulfate)</td>
<td>S⁻² (sulfide)</td>
<td>-75 to -150</td>
</tr>
<tr>
<td>Carbon</td>
<td>CO₂ (carbon dioxide)</td>
<td>CH₄ (methane)</td>
<td>-250 to -350</td>
</tr>
</tbody>
</table>
Reducing $\text{Fe}^{3+} = \text{Fe}^{2+}$

$\text{Fe}^{3+}$ (ferric) is not water soluble, reflects red light.

$\text{Fe}^{2+}$ (ferrous) is not water soluble, neutral color (absorbs most light).

$\text{Fe}^{3+}$ is used in plant metabolism.

$\text{Fe}^{2+}$, on the other hand, is toxic to plants.
How can you use soil color to indicate a wetland soil?

Wetland (hydric) soil:
...saturation, flooding, or ponding...during the growing season...anaerobic conditions in the upper part

Soil Color: upland soils are yellow-brown-red, wetland soils are usually gray or black.
Coating of Fe$_2$O$_3$

Mineral grain (gray)

Remove Fe if reduced

Upland Soil

Red Soil Coatings

Wetland Soil

Gray Soil
Wetland Plants and Stress
Biotic Response to Salt

Osmoconformers: the capacity of a plant (or animal) to survive and grow even though subjected to an unfavorable environment: i.e. it can sustain the effects of stress without dying or suffering irreparable damage. Plants will reach a thermodynamic equilibrium (acclimation).

Sporobolus alterniflorus: stores organic compounds and excess salts in cells that allows diffusion gradient where water moves into plant. Also has hollow stems for oxygen diffusion to roots.
Biotic Response to Stress

Osmoregulator: plant does not come to thermodynamic equilibrium with the stress or can exclude the stress by means of a physical or metabolic barrier.

Sporobolus pumila: under salt conditions (and water stress) *S. patens* rolls leaves (involute margins) to cover stomata. Moisture regime in rolled leaf moist. Can only be sustained for short period of time.
There are adaptations for both types of strategies.

(a) **Conformer**
- Value of variable in internal environment vs. value of variable in external environment.
- Line of conformity: Internal = external.
- Examples: starfish (salinity), annelid worms (oxygen).

(b) **Regulator**
- Zone of stability where homeostasis is maintained.
- Internal ≠ external.
- Examples: crustations (oxygen), mammals (temperature, etc.).
Summary:

Osmoconformers must find way to reach isostasis (hyper- or isohaline conditions) using inorganic or organic salts.

Osmoregulators must leave area or find way to avoid stress.

In both cases Homeostasis is the goal!
What Effect does Salt have on Plants?

- High amounts of salt can result in a drought-like environment for plants.

- Plants will exhibit drought or root damage injuries.
**SALT STRESS**

*Cell Level: Osmotic Homeostasis*

Most plants live in an “isotonic” environment where \([\text{salt}] = \text{cell [salt]}\) (isostatic osmotic potential).
SALT STRESS
Cell Level: Osmotic Shock

Salt: Plants that grow with root systems in soil of high salt content have low osmotic potentials as a result an increased [] of solutes and are salt tolerant. High salt [] can cause both osmotic stress and toxicity.

<table>
<thead>
<tr>
<th>Permeable membrane</th>
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<tbody>
<tr>
<td>Salt Water</td>
</tr>
<tr>
<td>+</td>
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<tr>
<td>+</td>
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</table>

<table>
<thead>
<tr>
<th>Plant cell</th>
</tr>
</thead>
<tbody>
<tr>
<td>+</td>
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<td>+</td>
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<td>+</td>
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Salt Water: Plants that grow with root systems in soil of high salt content have low osmotic potentials as a result an increased [] of solutes and are salt tolerant. High salt [] can cause both osmotic stress and toxicity.
SALT STRESS

Cell Level: Osmotic Shock

Salt: Plants that grow with root systems in soil of high salt content have low osmotic potentials as a result an increased [] of solutes and are salt tolerant. High salt [] can cause both osmotic stress and toxicity.
Cell Level: Coping with Salt

Single cell organisms increase internal salinity

Increase inorganic molecules
  Specifically $K^+$ (actually decrease $Na^+$)

WHY?

Increase organic molecules
  (e.g. Glycerol and/or arabinol)

These do NOT interfere w/ enzyme activity
Higher Plants

1) Increase inorganic molecules and organic compounds (K+, arabitol, glycol, glycerol);

2) Structural complexity
   a. Barriers (endodermis)
   b. Excrete salts (Spartina alterniflora)

Salinity within intercellular space of leaves of black mangrove is 50-70% NaCl, rest is organic composition

Other species (Bidens) had only 10%NaCl and 90% organic.
**Anoxia**

Anoxia in a wetland is defined as the point where all the available oxygen in the soil and pore water has been depleted, usually through respiration of micro-organisms.

Anaerobic respiration: plants respond by increasing the rate of glycolysis (break down of glucose to pyruvate and lactic acids) and fermentation.
Roots do not photosynthesize

- Use $O_2$ in pore space of soil to metabolize (they “respire”);

- Water drives $O_2$ out, what little $O_2$ remains is quickly used up by microbes;

- Now roots must find alternate source of $O_2$. 
Two types of metabolic respiration:

• Use $\text{O}_2$ in pore space of soil to metabolize (glycolysis);

• Use alternate electron source to metabolize (fermentation);

• Fermentation produces toxic byproducts. Thus, roots would be better off finding an alternate source of $\text{O}_2$. 
**Anaerobic Respiration**

Uses an endogenous electron acceptor, which is usually an organic compound.

Glucose → Fermentation → ADP, ATP

Pyruvate → (Malate) (Fatty Acids) → decarboxilation

Acetaldehyde (toxic) → NAD_{ox} → NAD_{red} (toxic)

Ethanol (toxic)
Anaerobic Respiration

All byproducts of aerobic respiration are non-toxic!

\[ \text{H}_2\text{O}, \text{ATP}, \text{NAD}^{\text{ox}} \]

Most byproducts of anaerobic respiration are toxic!

Acetaldehyde, Ethanol,
\[ \text{NAD}^{\text{red}} \]
Morphological (structural) Adaptations

Aerenchyma

Buttressed tree trunks

Shallow roots

Pneumatophores

Adventitious roots

Hypertrophied lenticels

Pressurized gas flow
Aerenchyma
Aerenchyma
Aerenchyma
Alligator weed, *Alternanthera philoxeroides*; stem cross-sections show progressively larger aerenchyma formations from the drier site (upper left) to the wettest site sample (lower right).

Corps of Engineers

Aerenchyma
Aerenchyma & Passive Diffusion
Increased Air

Old Stems

Rhizome

New Stems
Pressurized ventilation (mass flow, bulk flow, or convective through flow)
Buttressed Trunks
Pneumatophores
Black Mangrove (*Avecinia germinans*)
Gaseous Exchange

Air

CO₂

CO₂

Gaseous Exchange
Adventitious roots
Red Mangrove (*Rhizophora mangle*)
Reproductive Strategies

Delayed or accelerated flowering

Buoyant seeds

Vivipary

Large persistent seed banks

Production of tubers, roots, and seeds that can survive long periods of submergence
Temperature/Irradiation
High Light Intensity

1) Chlorophyll content is reduced. This reduces the rate of light absorption and the rate of photosynthesis;

2) Increase in temperature of leaves which in turn induces rapid transpiration and water loss;

3) High leaf temperature inactivates the enzyme system that changes sugars to starch.

From Edmond et al. (1978)
C4 v. C3 Plants

C4 plants have a competitive advantage over plants possessing the more common C3 carbon fixation pathway under conditions of drought, high temperatures and nitrogen or carbon dioxide limitation.
Increase in Temperature of Leaves

1) Induces rapid transpiration and water loss;

2) The guard cells lose turgor, the stomates partially or completely close, and the rate of diffusion of carbon dioxide into the leaves slows down;

3) Rate of photosynthesis decreases while respiration continues, resulting to low availability of carbohydrates for growth and development.
Granular (stacked chlorophyll-found in leaf blade of all plants)

Agranular (only found surrounding bundle sheath of veins of C4 plants)
Atriplex patula (C4) v. C3 A. rosea (C3)
That’s not all, Folks!