BUILDING A MICROBIAL FUEL CELL

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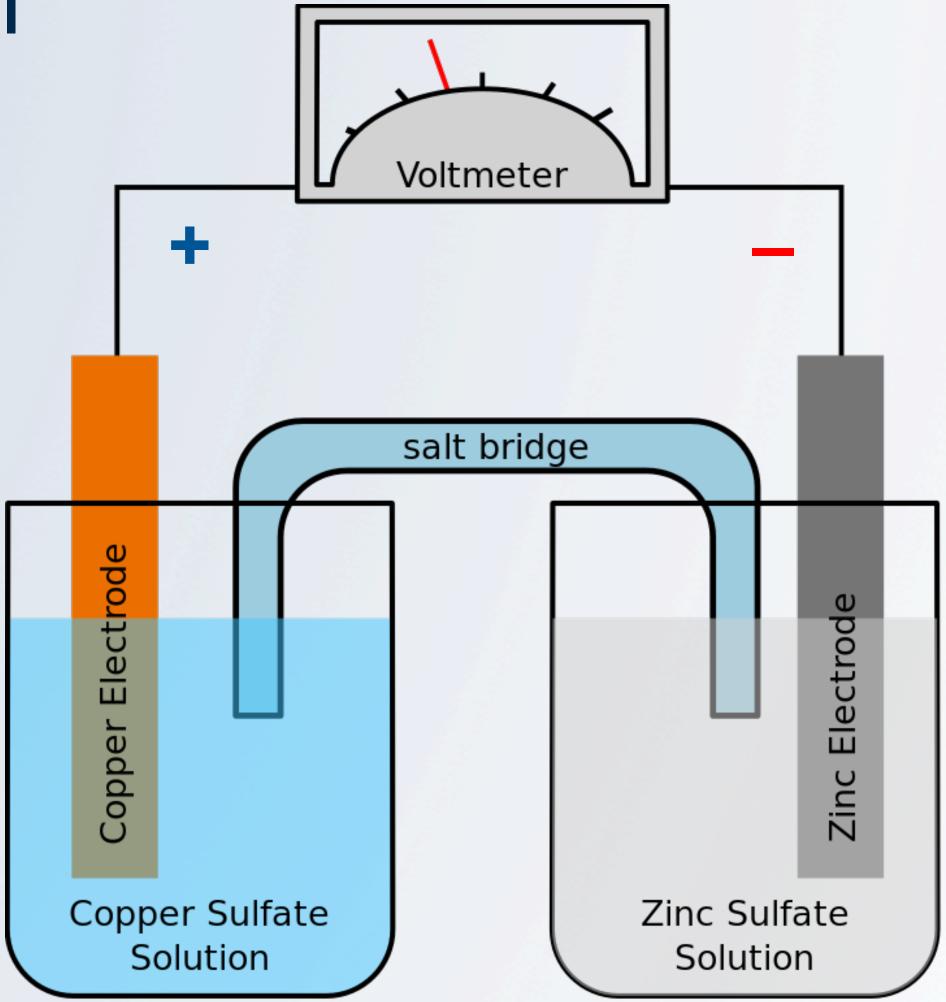
Galvanic or Voltaic Cell

- An electrochemical cell produces electrical energy from spontaneous oxidation-reduction (*redox*) reactions
- The cell consists of two different solid metals in the metal's salt solution connected by a salt bridge
- A redox reaction is a chemical reaction that transfers electrons between two species
- Reduction is the gain of electrons and Oxidation is the loss of electrons by a molecule, atom, or ion

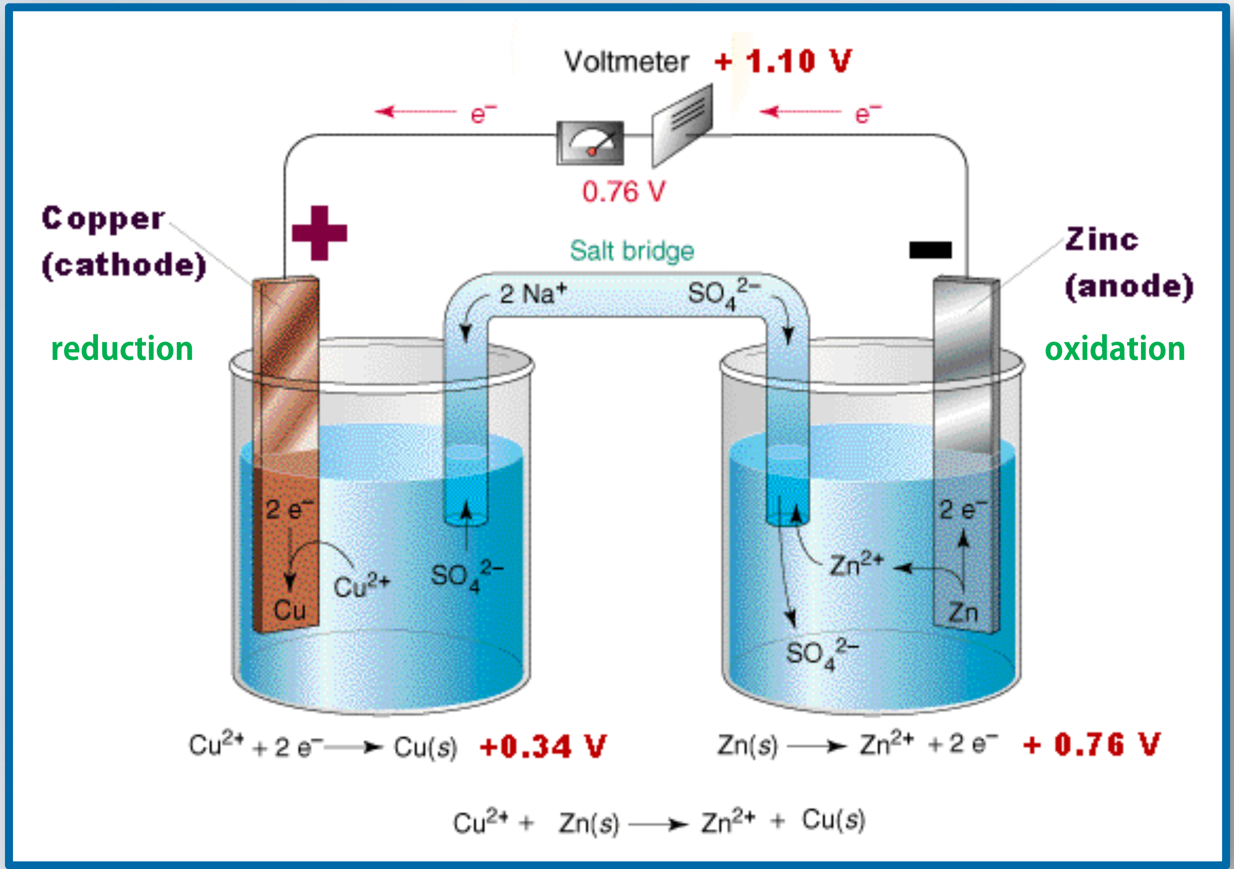


$Cu^{2+} + 2e^{-} \rightarrow Cu$

$Zn \rightarrow Zn^{2+} + 2e^{-}$

Galvanic Cells

- $Zn \rightarrow Zn^{2+} + 2e^{-}$ (Anode)
- $Cu^{2+} + 2e^{-} \rightarrow Cu$ (Cathode)
- One ½ cell reaction occurs in each container
- A salt bridge allows for charge neutrality in the solutions
- Current will not flow without the salt bridge to shuttle ions



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Build One – Materials

- 0.1 M $ZnCl_2$ solution
- 0.1 M $CuSO_4$ solution
- 0.1 M NaCl solution (for salt bridge)
- At least 3 dixie cups
- Copper wire (14G +)
- Galvanized (zinc-coated) nail
- Filter paper (for salt bridge)
- Voltmeter with alligator leads

Build One – Procedure

- Pour ~ 20ml of $ZnCl_2$ solution in a dixie cup and add the galvanized nail so its head sticks out of the cup
- Pour ~ 20ml of $CuSO_4$ solution in a dixie cup and add the copper wire so its end sticks out of the cup
- Clip one voltmeter lead to the nail and the other lead to the wire – Is there a voltage?
- Soak filter paper in NaCl solution and then roll the soaked paper into a tube shape
- Place one end of the NaCl soaked filter paper tube in the $ZnCl_2$ solution and the other end in the $CuSO_4$ solution – Is there a voltage?

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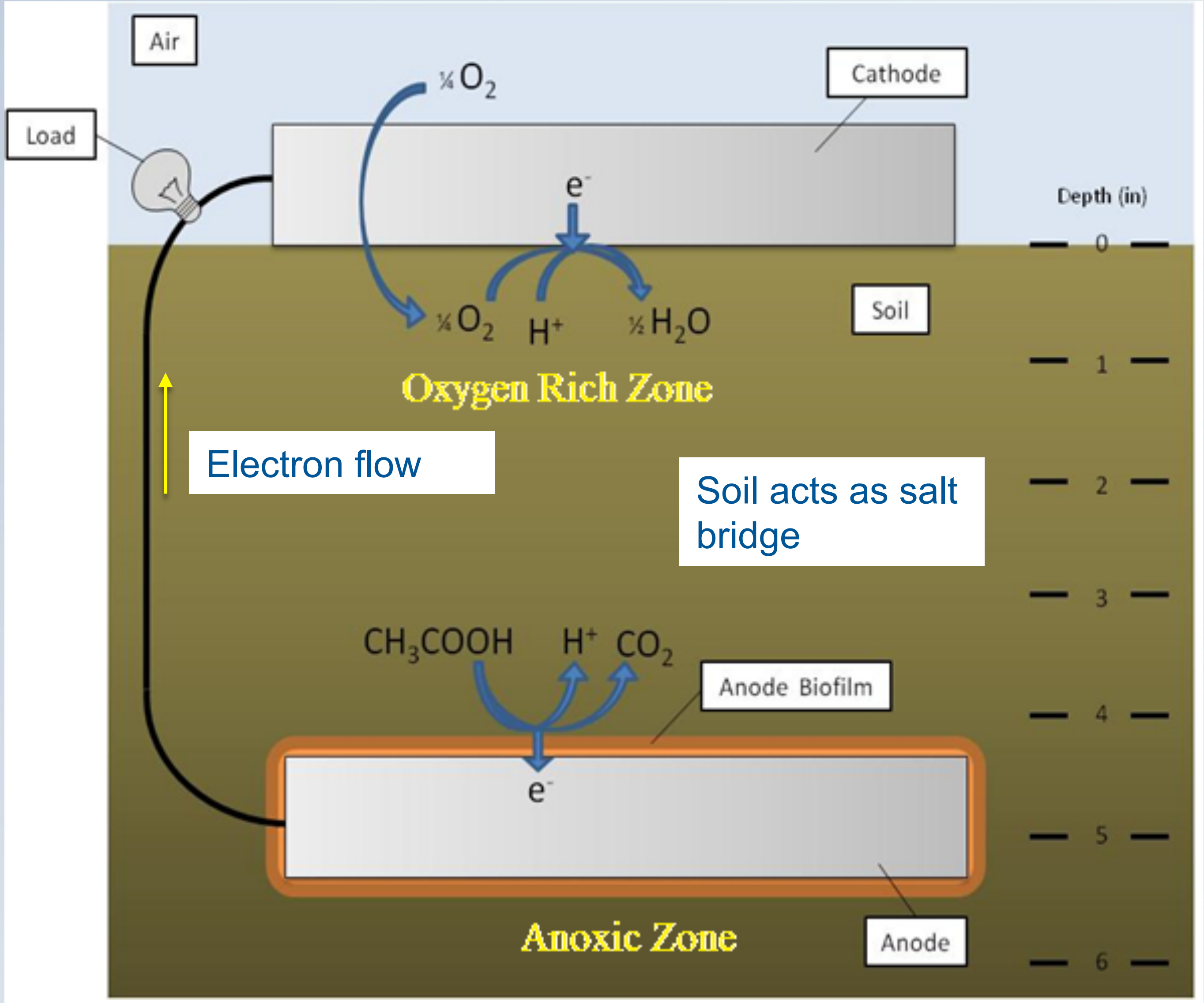
Summary

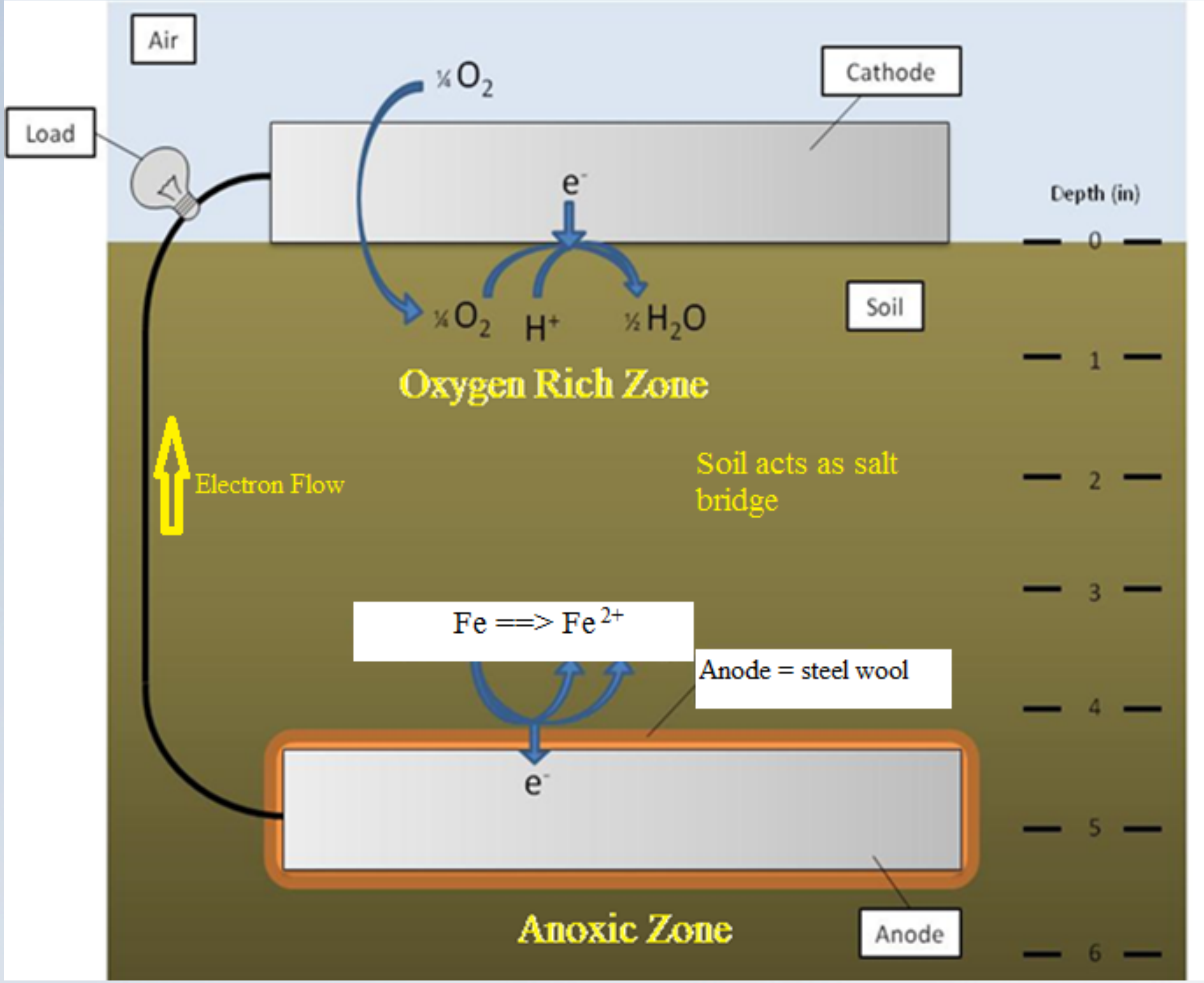
- The theoretical voltage generated by the Zn/Cu galvanic cell is +1.1V under standard conditions, i.e.
  - T = 25°C and P = 1 bar for gases,
  - Solids and liquids are pure, and
  - Solutions are 1 M in all species.
- Real voltage will vary
  - Has equilibrium been reached & maintained
  - Concentrations change over time
  - Temperature dependence

Microbial Fuel Cell



Taken from "Advanced Intro to MFC's", keegotech.com (2011)

Microbial Fuel Cell—Alternate Anode



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Theoretical Voltages

Double-Biofilm Cell

Anode:	$CH_3COOH + 2H_2O \rightarrow 2CO_2 + 8H^+ + 8e^-$	$E^o = -0.097$ V
Cathode:	$2O_2 + 8H^+ + 8e^- \rightarrow 4H_2O$	$E^o = +1.33$
NET:	$CH_3COOH + 2O_2 + \rightarrow 2CO_2 + 2H_2O$	**$E^o = +1.23$ V**

Steel Wool at Anode

Anode:	$Fe \rightarrow Fe^{2+} + 2e^-$	$E^o = -0.44$ V
Cathode:	$2O_2 + 8H^+ + 8e^- \rightarrow 4H_2O$	$E^o = +1.33$
NET:	$CH_3COOH + 2O_2 + \rightarrow 2CO_2 + 2H_2O$	**$E^o = +1.77$ V**

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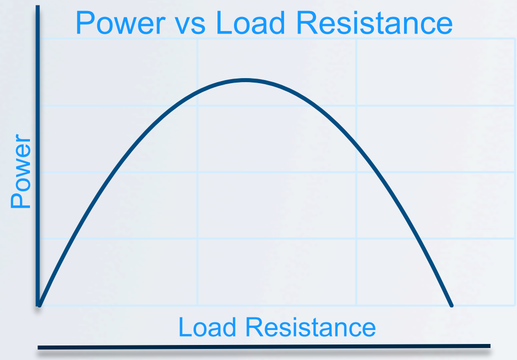
Potential MFC Construction Pitfalls

- Moisture content of soil
  - Maintain moisture with lid
- Electrical circuit considerations
  - Ensure top cathode contact with soil
  - Avoid short circuits between electrodes
  - Optimal load resistance
- Soil/microbial nutrients and additives
  - Sugary foods drinks can increase voltage, but beware of noxious-smelling byproducts
- Maintaining anoxic and oxygen-rich zones
  - Avoid air pockets during assembly
  - Iron (steel wool/nails) is good oxygen scavenger



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History

- In 1780, Luigi Galvani contracts frog leg muscles with two different metals
- In 1799, Alessandro Volta invents a non-biological cell similar to the galvanic cell
- Later, Carlo Matteucci constructs a battery entirely out of biological material
- These discoveries paved the way for electrical batteries and Volta's cell is an IEEE Milestone (1999)

Practical Applications of MFC's

- UN Sustainable Development Goals

Wastewater Treatment

- MFC’s used in wastewater treatment can
  - effectively remove organic waste
  - generate electrical power
- 1.5% of electricity produced in US is used for wastewater treatment (15 GW)
- Successful pilot programs treated municipal wastewater in
  - Bottrop, Germany
  - Harbin, China

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Recharging portable devices in the developing world

- MFC's built with local materials costing 10 to 20 US dollars have the demonstrated ability to
- Power LED lamps
- Recharge cell phones