Self-Organizing Wetland Bioreactors (SOWBs) Application to Mining Reclamation: Direct and Indirect Bioremediation as a Design Tool for Mine Influenced Water (MIW) Benefaction

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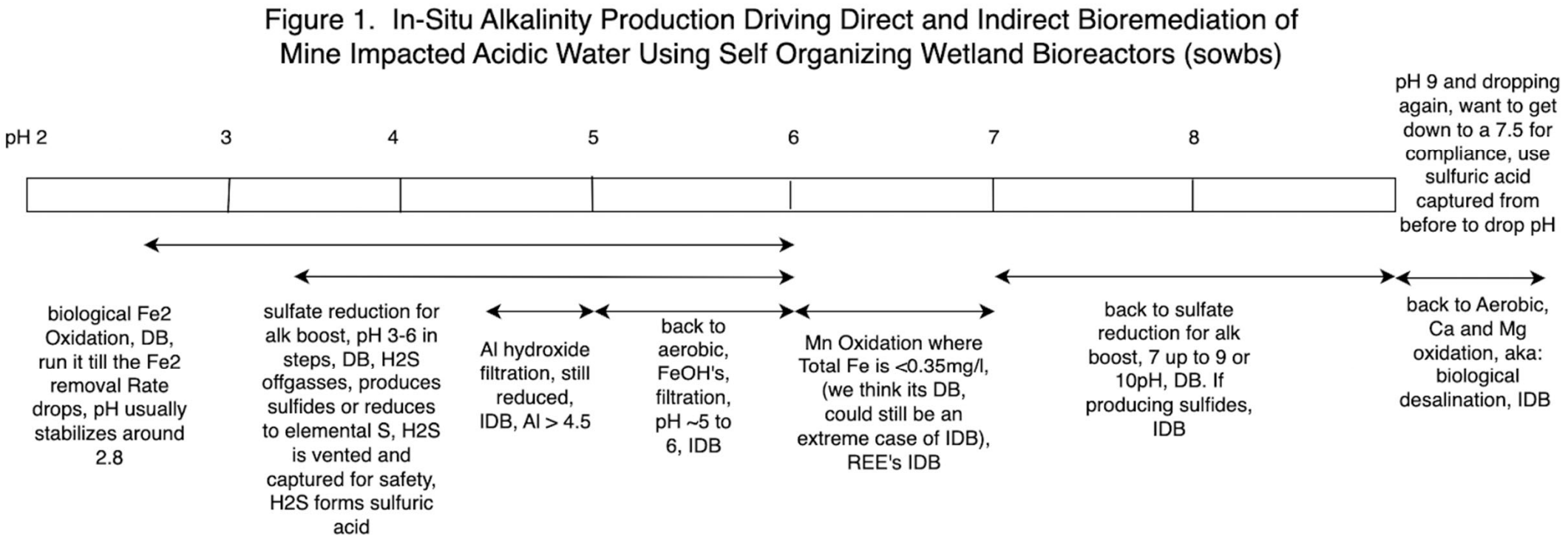
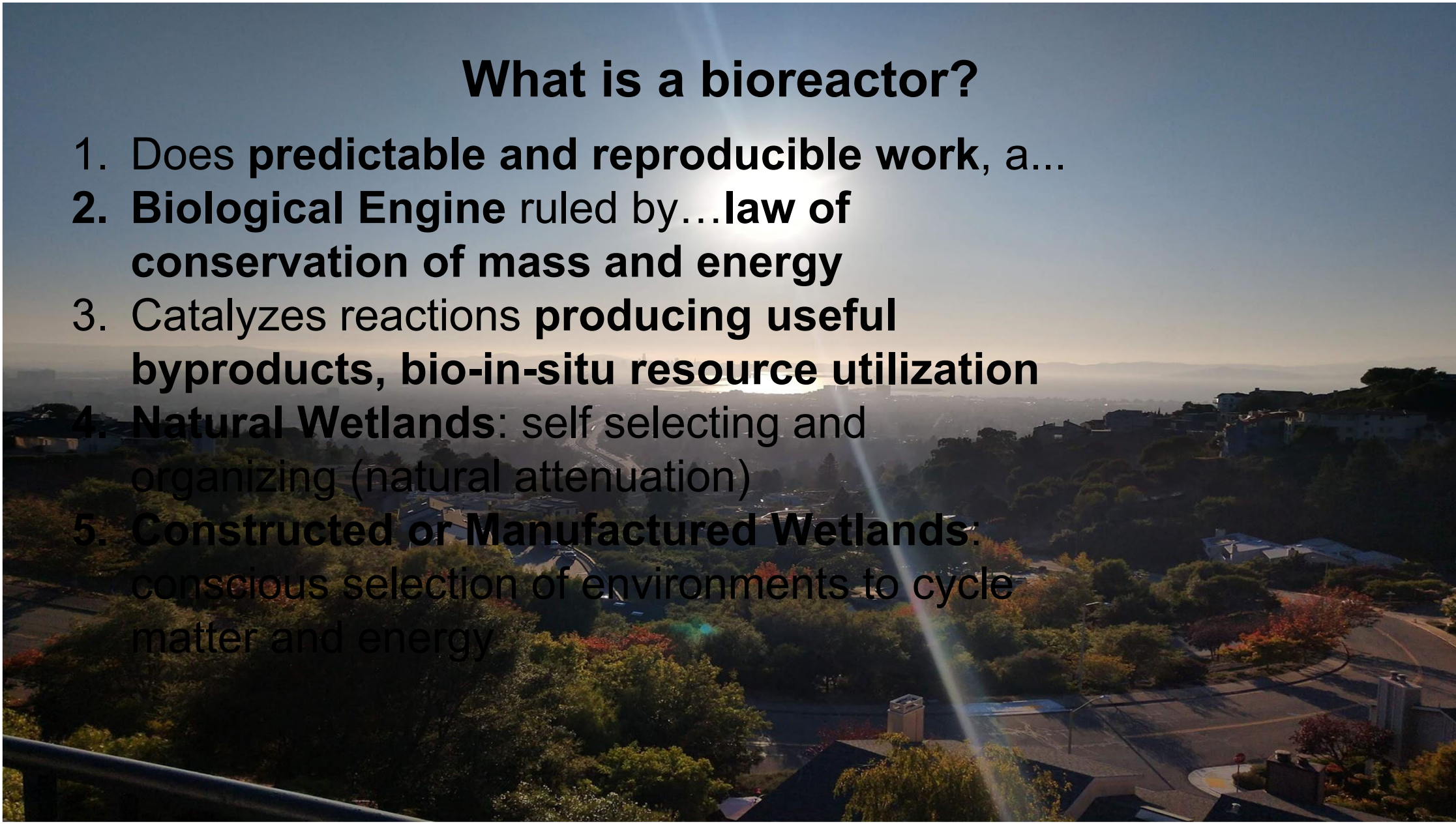
Figure 1, in your programs



But First, What is a wetland?

1. Holds water (most of the time),
2. Water moves through it,
3. High surface area (SA) to volume,
4. High biomass to volume bc of SA
5. Cycles matter and energy, lots of ways, biotic and abiotic
6. And, self-organizes by Gibbs free energy / prevailing atmos


Gibb Roll



What is a bioreactor?

1. Does **predictable and reproducible work**, a...
2. **Biological Engine** ruled by…**law of conservation of mass and energy**
3. Catalyzes reactions **producing useful byproducts, bio-in-situ resource utilization**
4. **Natural Wetlands**: self selecting and organizing (natural attenuation)
5. **Constructed or Manufactured Wetlands**: conscious selection of environments to cycle matter and energy

Mostly Aphotic Bioreactors, intentionally and by definition, a few cases

1. natural wetlands - flow through (FT)
2. methane digesters - batch
3. reclamation ponds - FT
4. fish tanks - lmtd FT
5. waste treatment plants - FT
6. wine and beer vats - batch

Oxidation/Reduction Potential (ORP) measured in millivolts (mV).

O2 to H2 is the "furthest" biotic voltage can be driven (that i've seen). Burning H2 and O2 produces similar exothermic energies.

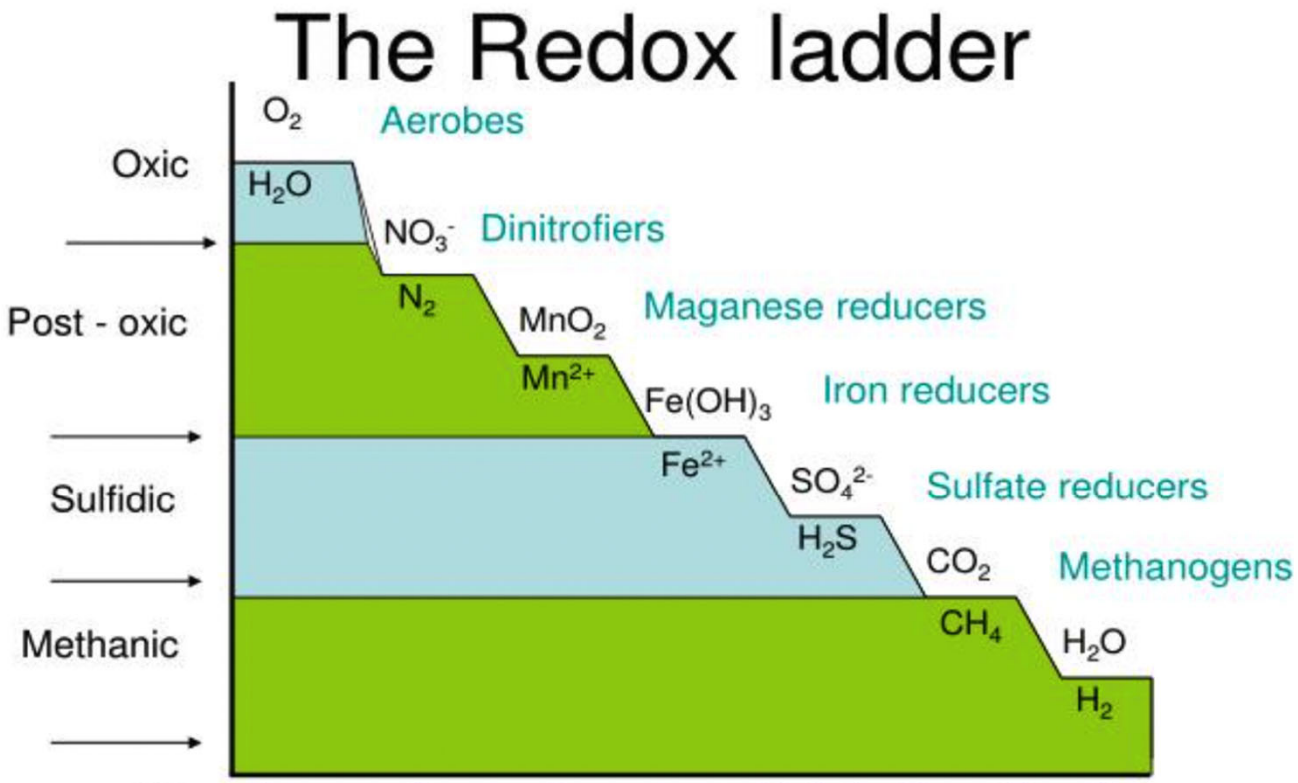
Can produce electrical current.

The most biology can squeeze out of biochemical bonds, broadly and generally.

+450 mV dc

= 0.9 mV dc

- 450 mV dc



The redox-couples are shown on each stair-step, where the most energy is gained at the top step and the least at the bottom step. (Gibb's free energy becomes more positive going down the steps)

Winogradsky Columns, biological distillation in the classroom

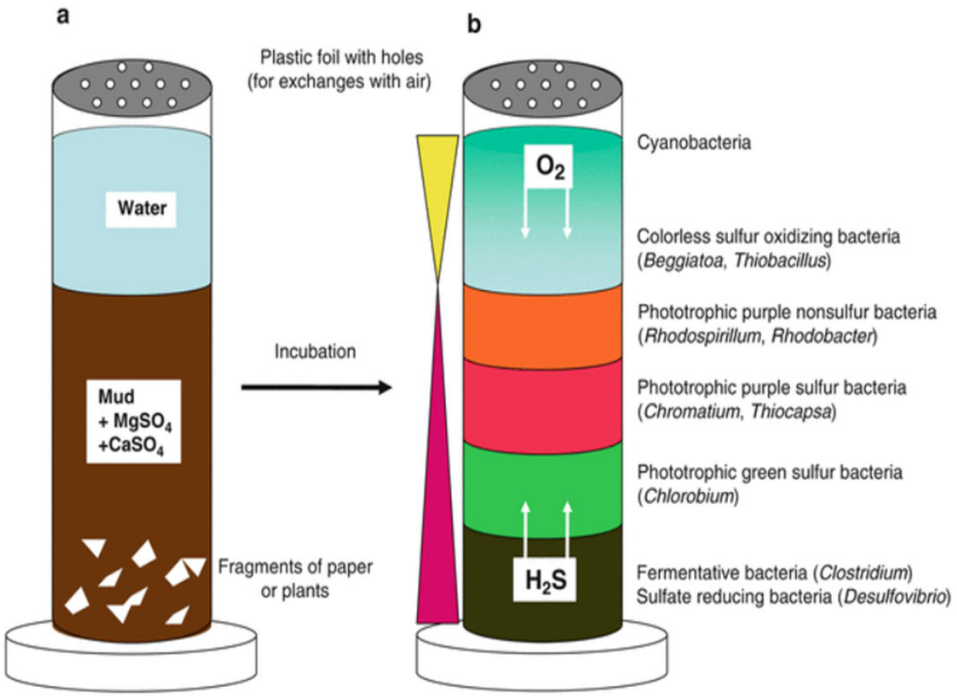
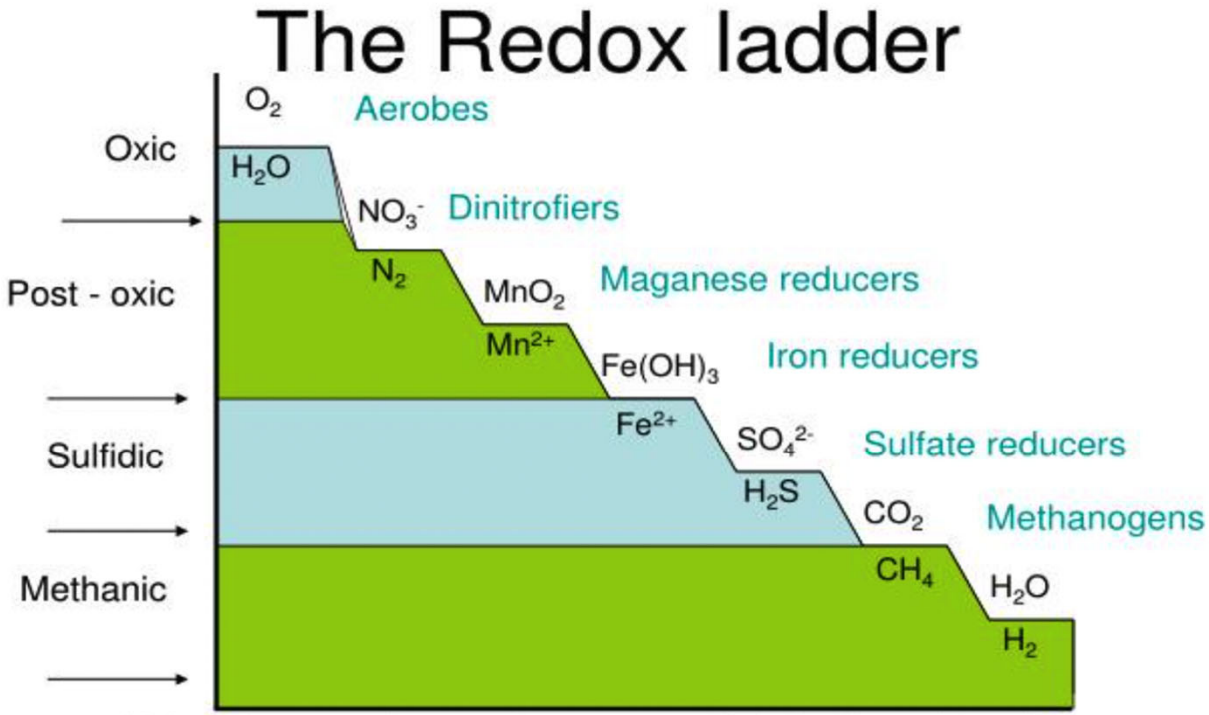


Figure 10.5. Winogradsky sulphuretum. Columns are assembled using mud and water as sources of inocula, supplemented with sulphate as a terminal electron acceptor, and organic material. Exposure to light provides energy for the phototrophs, but beyond the gas exchange at the surface, the columns will develop with distinct communities based on the local physicochemical conditions. [Credit: Bertrand et al., 2015. Copyright Springer Science+Business Media Dordrecht 2015, all rights reserved]

https://ecampusontario.pressbooks.pub/microbio/chapter/10-x-characterizing-the-uncultivated/



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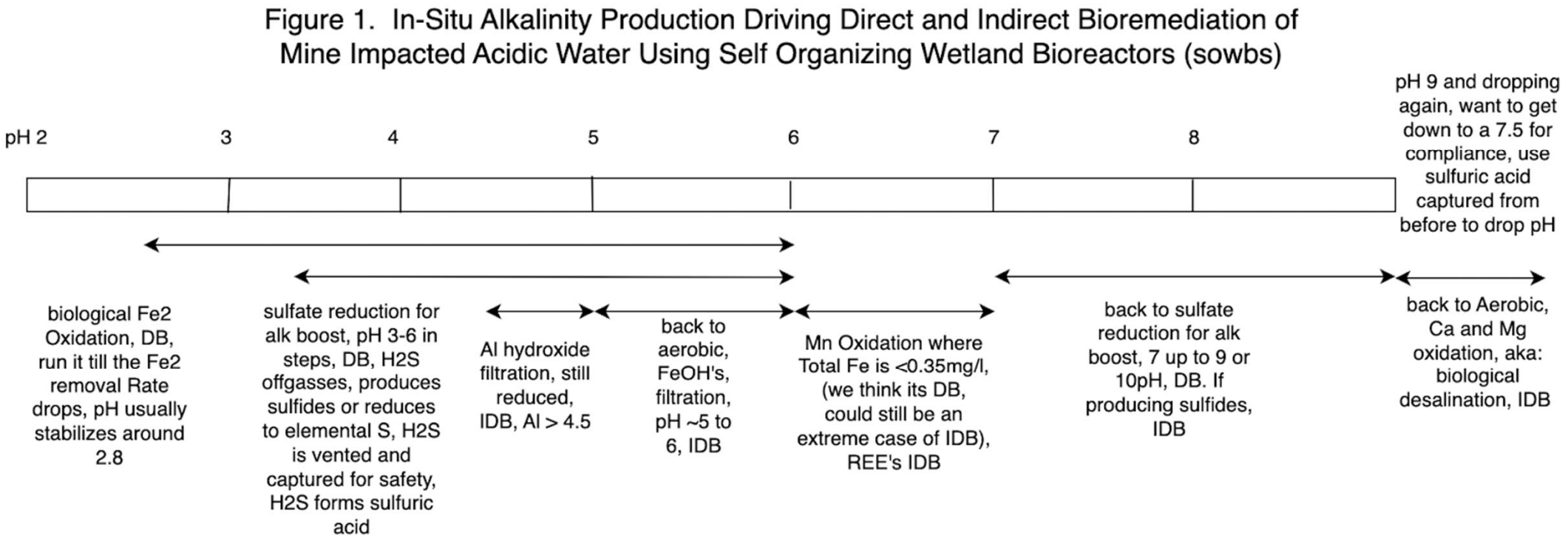
For the chemists and engineers:

In this context and application, sowbs are multi-fuel and multi-oxidant biological engines that self organize to use each reductant and oxidizer sequentially, based on the energy released and availability of the metabolic pathways.

Metabolites can be skipped over if the genetics aren’t present.

Figure 1, in your programs



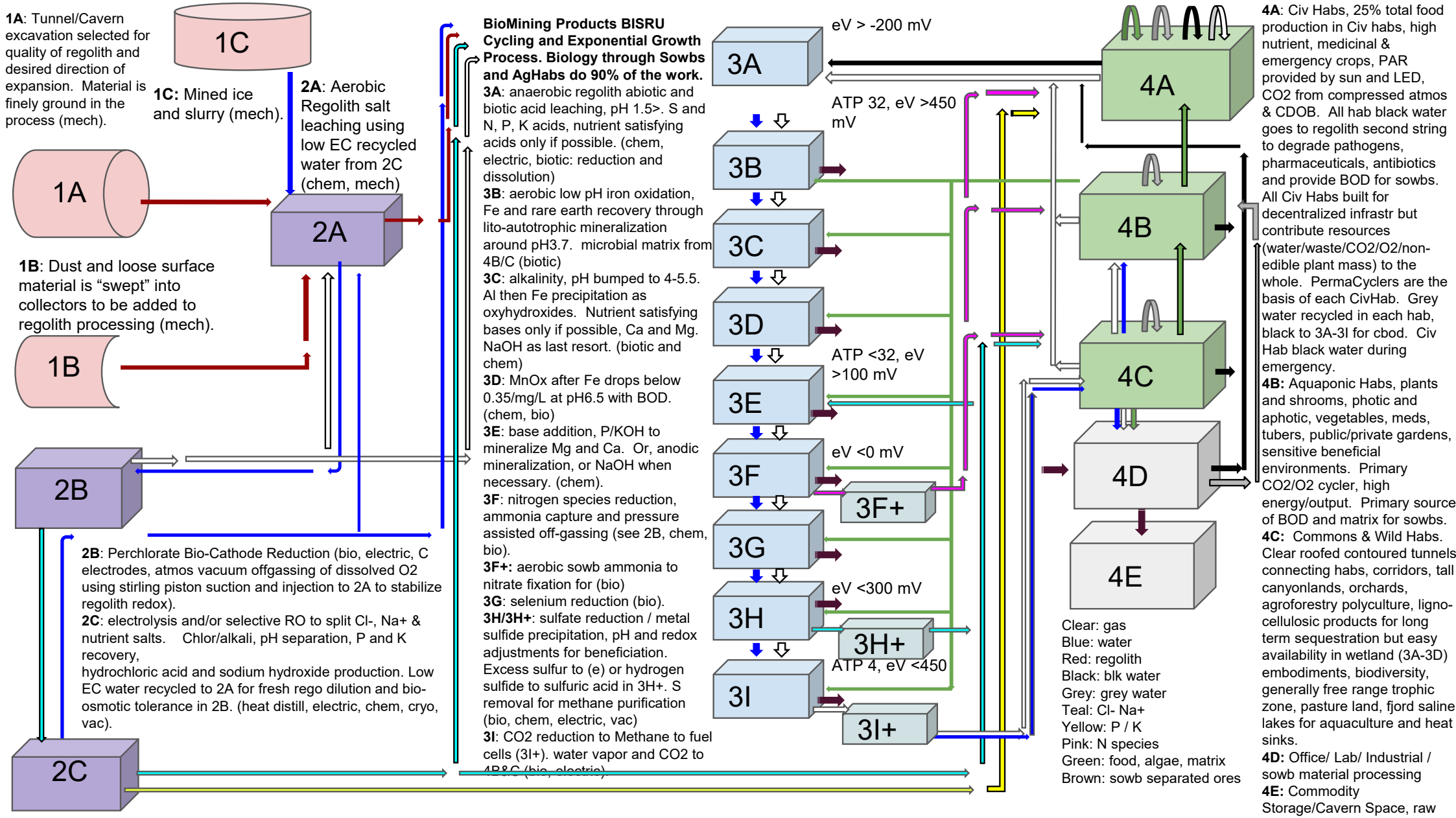
Brisbin, PA, 2022 and March 2024

MnOx, 85% purity, birnessite, grown from solution.

Other Applications: Ubiquity across Influences. Wetlands cycle matter and energy in a number of ways, by...

1. Satisfying CBOD, chemical and biological oxygen demand (when aerobic)
2. Capturing TSS, total suspended solids
3. Predation upon F. Coliform et al (indicator species), ecological, secondary and tertiary productivity
4. sequestration and use of cooking oils as TED's

Phillips Mushroom Farm, Kennett Square, PA. Refit 2016 Mk307's, ~40 gpm / 150 lpm, Sept 2022


1A: Tunnel/Cavern excavation selected for quality of regolith and desired direction of expansion. Material is finely ground in the process (mech).
1C
1C: Mined ice and slurry (mech).
2A: Aerobic Regolith salt leaching using low EC recycled water from 2C (chem, mech)
1A
2A
1B: Dust and loose surface material is "swept" into collectors to be added to regolith processing (mech).
1B
2B
2C
2B: Perchlorate Bio-Cathode Reduction (bio, electric, C electrodes, atmos vacuum offgassing of dissolved O2 using stirling piston suction and injection to 2A to stabilize regolith redox).
2C: electrolysis and/or selective RO to split Cl-, Na+ & nutrient salts. Chlor/alkali, pH separation, P and K recovery,
hydrochloric acid and sodium hydroxide production. Low EC water recycled to 2A for fresh rego dilution and bio-osmotic tolerance in 2B. (heat distill, electric, chem, cryo, vac).
BioMining Products BISRU Cycling and Exponential Growth Process. Biology through Sowbs and AgHabs do 90% of the work.
3A: anaerobic regolith abiotic and biotic acid leaching, pH 1.5>. S and N, P, K acids, nutrient satisfying acids only if possible. (chem, electric, biotic: reduction and dissolution)
3B: aerobic low pH iron oxidation, Fe and rare earth recovery through lito-autotrophic mineralization around pH3.7. microbial matrix from 4B/C (biotic)
3C: alkalinity, pH bumped to 4-5.5. Al then Fe precipitation as oxyhydroxides. Nutrient satisfying bases only if possible, Ca and Mg. NaOH as last resort. (biotic and chem)
3D: MnOx after Fe drops below 0.35/mg/L at pH6.5 with BOD. (chem, bio)
3E: base addition, P/KOH to mineralize Mg and Ca. Or, anodic mineralization, or NaOH when necessary. (chem).
3F: nitrogen species reduction, ammonia capture and pressure assisted off-gassing (see 2B, chem, bio).
3F+: aerobic sowb ammonia to nitrate fixation for (bio)
3G: selenium reduction (bio).
3H/3H+: sulfate reduction / metal sulfide precipitation, pH and redox adjustments for beneficiation. Excess sulfur to (e) or hydrogen sulfide to sulfuric acid in 3H+. S removal for methane purification (bio, chem, electric, vac)
3I: CO2 reduction to Methane to fuel cells (3I+). water vapor and CO2 to 4B&C (bio, electric)
3A
3B
3C
3D
3E
3F
3G
3H
3I
3F+
3H+
3I+
eV > -200 mV
ATP 32, eV >450 mV
ATP <32, eV >100 mV
eV <0 mV
eV <300 mV
ATP 4, eV <450
4A
4B
4C
4D
4E
Clear: gas
Blue: water
Red: regolith
Black: blk water
Grey: grey water
Teal: Cl- Na+
Yellow: P / K
Pink: N species
Green: food, algae, matrix
Brown: sowb separated ores
4A: Civ Habs, 25% total food production in Civ habs, high nutrient, medicinal & emergency crops, PAR provided by sun and LED, CO2 from compressed atmos & CDOB. All hab black water goes to regolith second string to degrade pathogens, pharmaceuticals, antibiotics and provide BOD for sowbs. All Civ Habs built for decentralized infrastr but contribute resources (water/waste/CO2/O2/non-edible plant mass) to the whole. PermaCyclers are the basis of each CivHab. Grey water recycled in each hab, black to 3A-3I for cbod. Civ Hab black water during emergency.
4B: Aquaponic Habs, plants and shrooms, photic and aphotic, vegetables, meds, tubers, public/private gardens, sensitive beneficial environments. Primary CO2/O2 cycler, high energy/output. Primary source of BOD and matrix for sowbs.
4C: Commons & Wild Habs. Clear roofed contoured tunnels connecting habs, corridors, tall canyonlands, orchards, agroforestry polyculture, ligno-cellulosic products for long term sequestration but easy availability in wetland (3A-3D) embodiments, biodiversity, generally free range trophic zone, pasture land, fjord saline lakes for aquaculture and heat sinks.
4D: Office/ Lab/ Industrial / sowb material processing
4E: Commodity Storage/Cavern Space, raw

Thank you!

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Slava Ukraini!