Earth2Class Workshops for Teachers

GROUNDWATER

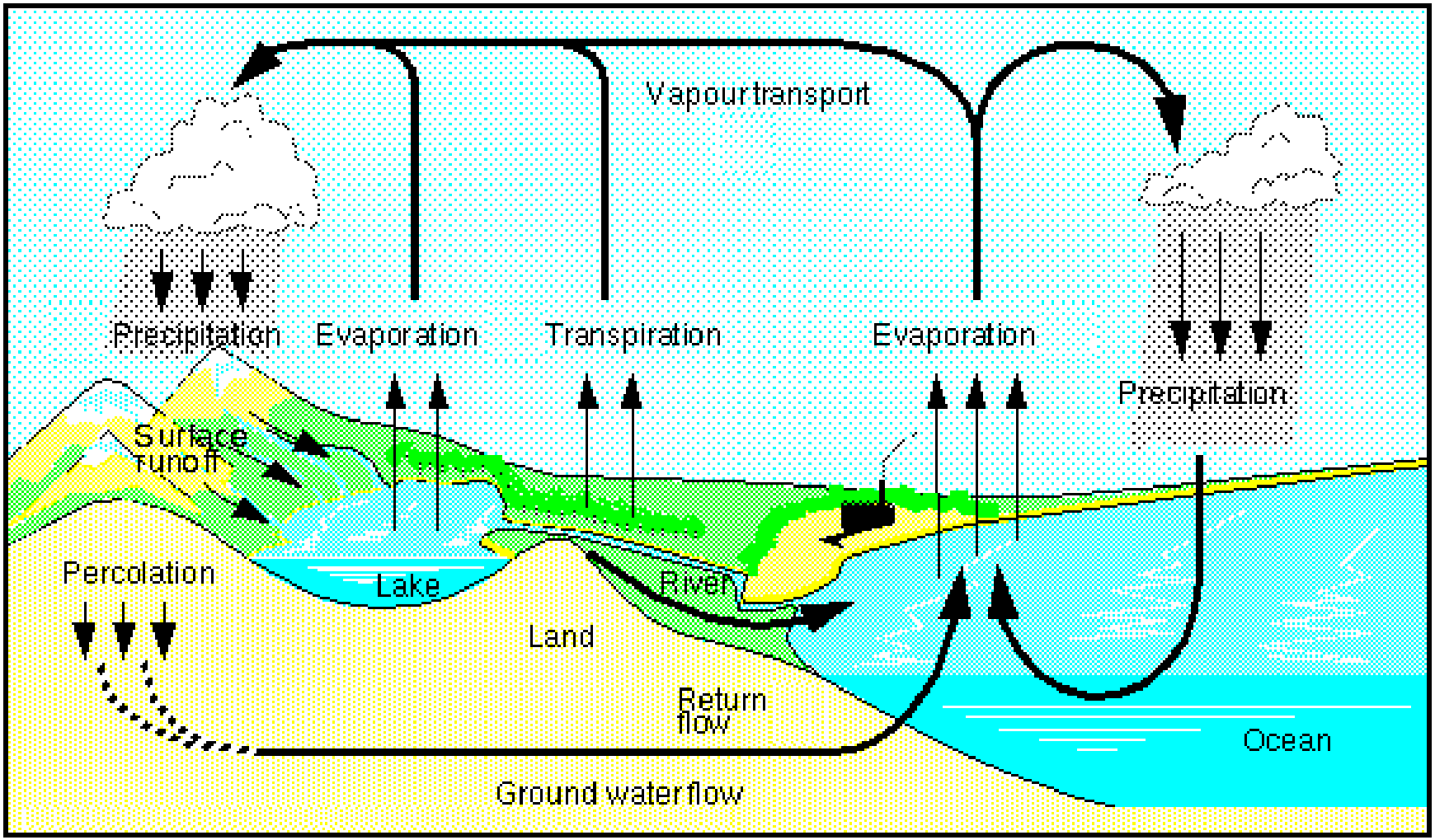
featuring

Dr. Alexander Van Geen:

Arsenic in the Groundwaters of Bengladesh

Originally presented 10 May 2003

Groundwater begins with the Water Cycle



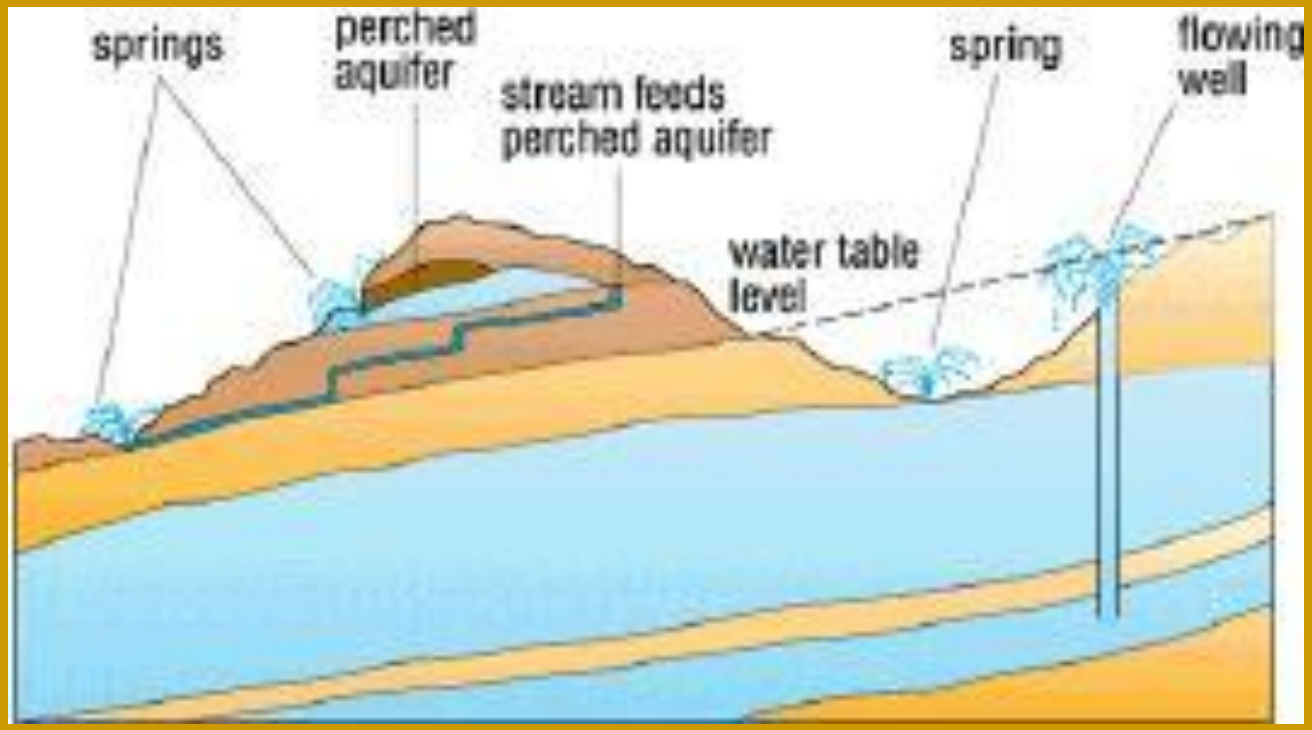
Courtesy Erich Roeckner, Max Planck Institute for Meteorology

http://www-k12.atmos.washington.edu/k12/pilot/water_cycle/grabber2.html

Some important groundwater terms

- Porosity
- Permeable/ impermeable
- Capillarity
- Infiltration
- Percolation
- Aquifer
- Recharge
- Water Table
- Zone of Saturation
- Zone of Aeration
- Well

Water Table Characteristics



http://www.tiscali.co.uk/reference/encyclopaedia/hutchinson/m0020647.html

SOIL

- “Residual”—formed by slow weathering of bedrock
- “Transported”—deposited after erosion

➢ “Glacial”—much of NY and northern NJ

➢ “Loess”—wind-blown, much of mid-West

➢ “Flood plain”—Mississippi Valley, Nile

http://soils.usda.gov/soil_survey/main.htm

Soil Horizons

In very generalized terms:

- “O” -- Organic
- “A” – Topsoil
- “B” – Subsoil
- “C” – weathered bedrock
- “D” – unweathered bedrock

Combined with groundwater zones, soils present some of the most complex ecosystems on our planet.

http://www.mo15.nrcs.usda.gov/Education/wissoil/sld005.htm

Soils, Zone of Aeration, and Zone of Saturation: “Porous Media”

Three-phase systems consisting of:

- Solid or mineral inorganic phase, often associated with organic matter
- Liquid or solution phase
- Gas phase (subsurface air)

Interact when system disturbed, then move toward equilibrium

Solid Phase

- Typically about 45 – 50% solids on a volume basis

  [Simple Mathematical Model of P-P-C]
- Si and O are most abundant, found in most soil minerals
- Weathering produces chemical changes (such as formation of clay) and range of particle size (texture)

  [Investigating Sediment Grain Sizes]

Selected aspects of soil chemistry

- Texture and structure affect movements of groundwater, pollutants, and soil micro-organisms
- Clay (mainly Al silicates) add surface area and electrical charge to soils
- Affects water retention capacity, flow through system—bacterial and pollutant

For more information, read ch. 4 in “Environmental Microbiology”.

Liquid Phase

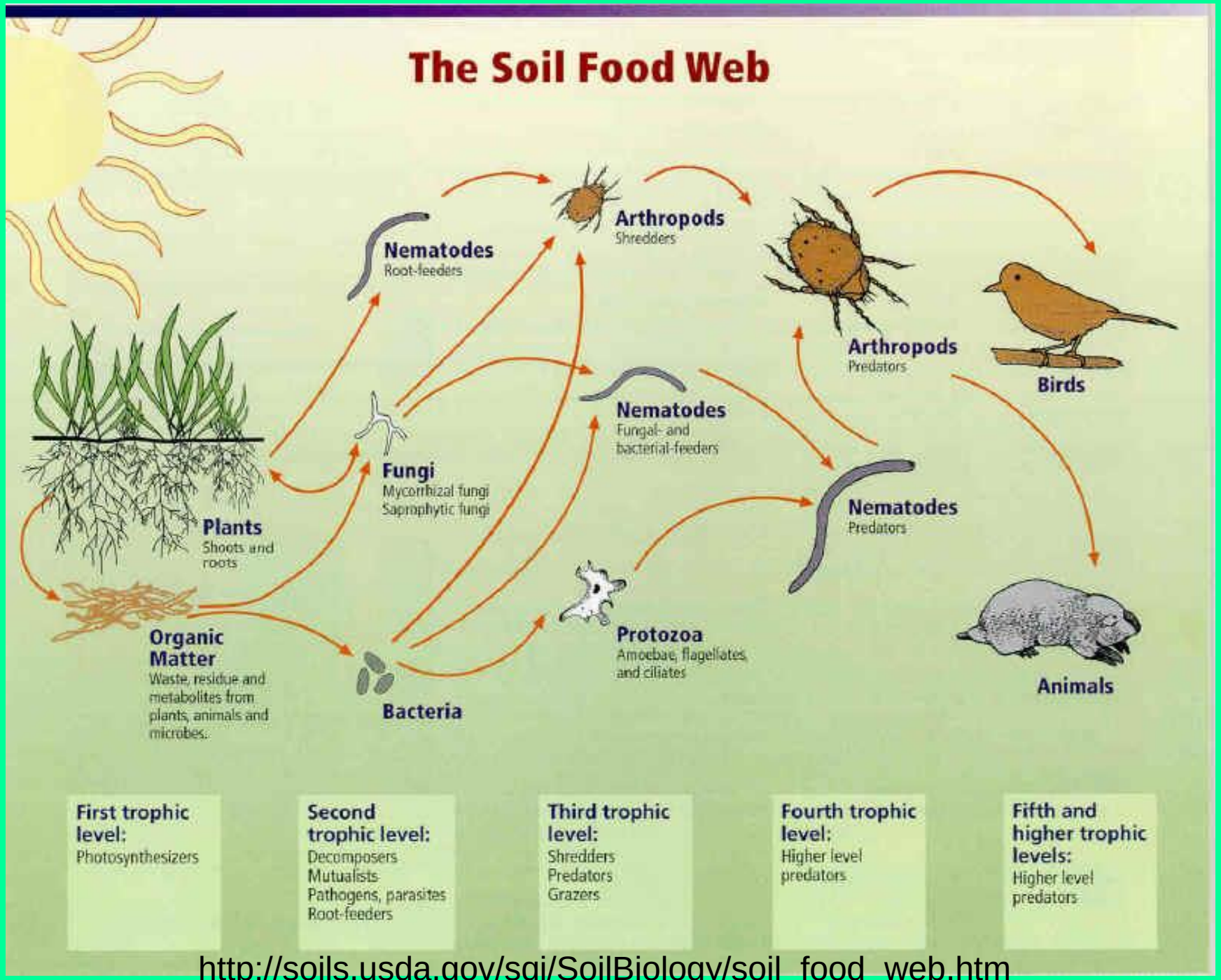
- Soil solution chemistry important for microorganisms, nutrient, and pollutant movement
- Soil pH and cations—may be acidic or alkaline
- Horizontal, vertical, and combined flow

Soil Atmosphere

- Basically similar to air in well-aerated soil
- In fine clay, more N, less O, more CO2
- Soil microorganisms and plants will greatly affect relative proportions, especially when not well-aerated
- Mainly moved by diffusion, but can also move with porous medium by mass flow due to pressure differences (more water)

Soil Microorganisms

- Viruses
- Bacteria
- Fungi
- Algae
- Protozoa
- Annelids, insects, other animals
- Plants



http://soils.usda.gov/sqi/SoilBiology/soil_food_web.htm

Bacteria: Key to Healthy Soils

A ton of soil bacteria may be in an acre of soil (below)

Bacteria on fungi hyphae (above)

http://soils.usda.gov/sqi/SoilBiology/bacteria.htm

BIOGEOCHEMICAL CYCLES

- Carbon Cycle

  Carbon Dioxide—Oxygen cycle of photosynthesis and respiration
- Nitrogen Cycle
- Sulfur Cycle
- “Reservoirs”—sources and sinks

Selected other soil and groundwater quality parameters often measured

- BOD “Biological Oxygen Demand” Biochemical Oxygen Demand (BOD) refers to the amount of oxygen that would be consumed if all the organics in one liter of water were oxidized by bacteria and protozoa (ReVelle and ReVelle, 1988).
  [http://hermes.ecn.purdue.edu/http_dir/ced/ccw/crc/agen521/agen521/epadir/wetlands/oxygen_demand.html]
- Coliform bacteria
- Heavy metals (such as Fe, Mn, Pb)
- Hardness
- Sulfates and Hydrogen Sulphide
- Organics

“Redox” in Soils

- Reduction and Oxidation important in soil chemistry
- May be result of physical processes (such as leaching) or biological (microbes)
- Very important in understanding and responding to pollution, especially of toxic metals

Examples of Redox in Soils

"LEO says GER"

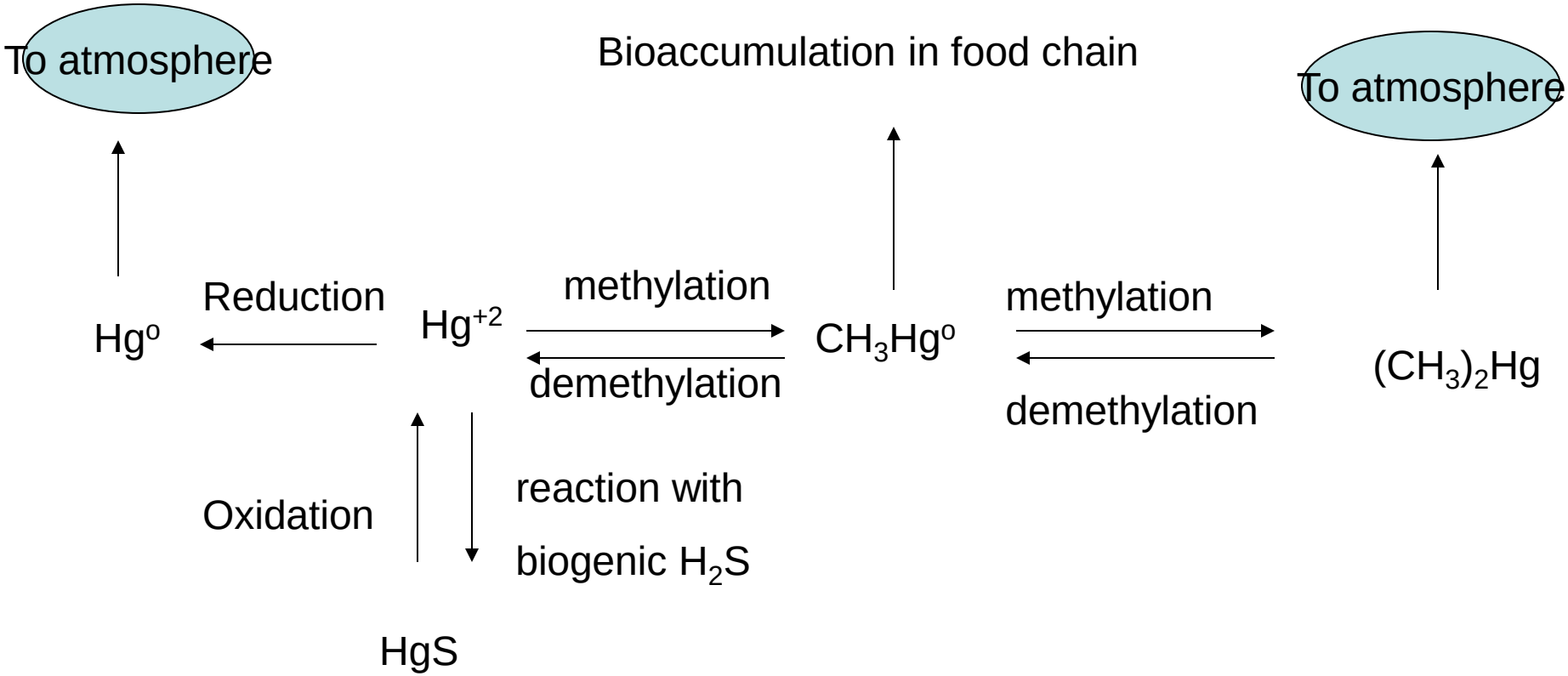
"Lose electrons—oxidized

Gain electrons—reduced"

$Cu_2S + 2Fe_2(SO_4)_3 \rightarrow$

$2CuSO_4 + 4FeSO_4 + S^o$

Microbially-mediated mercury reactions in the environment



Source: Environmental Microbiology, p. 353.

Arsenic – Segue to Lex Van Geen's Presentation

Arsenic is a metalloid that, like Hg, can be methylated.

Some fungi can methylate As into mono-, di-, and trimethylarsenates (highly toxic)

Poisonings have occurred when fungi growing on damp wallpaper converted and volatilized As use as coloring in the paper.

Dr. Van Geen discussed more about groundwater characteristics and soil chemistry in his presentation.

During the Workshop, we visited Dr. Van Geen's lab facilities in the New Core Lab building for examples of how heavy metals and other variables are identified.

Here is a link to a recent news story about his work: http://www.columbia.edu/cu/news/01/11/vanGeen.html

Selected Resources

- Maier, R., et al., 1999, *Environmental Microbiology*. Academic Press.
- http://www.columbia.edu/cu/news/01/11/vanGeen.html
- http://www.earthinstitute.columbia.edu/news/story4_3.html
- http://superfund.ciesin.columbia.edu/home.html
- http://soils.usda.gov/soil_survey/main.htm
- http://www.mos.org/oceans/planet/watercycle.html
- http://www-k12.atmos.washington.edu/k12/pilot/water_cycle/grabber2.html
- http://soils.usda.gov/sqi/SoilBiology/bacteria.htm
- http://soils.usda.gov/sqi/SoilBiology/soil_biology_primer.htm
- http://wilkes.edu/~eqc/schoolprojects.htm