Previous Class

- What is bioremediation?
- Major pollutants in our environment and their sources
- Treatment environments and contamination zones
- Aerobic and anaerobic metabolism of biodegradation by microbes
- Stimulation of bioremediation (fertilizers, bacteria)
- Phytoremediation

Cleanup Sites and Strategies

- Which strategy is employed depends on many factors …
  - Chemicals pose a fire or explosive hazard?
  - Chemicals pose threat to human health (cleanup workers)?
  - Chemical released by single incident or long-term leakage?
  - Site of contamination?
  - Surface of soil? Below the ground? Water affected?
  - Size of contaminated area?

Soil Cleanup

– *In situ* bioremediation
  - Cleaning up the contaminated site **without excavation**.
  - most commonly used type of bioremediation because it is the **cheapest** and **most efficient**, so it's generally better to use
  - **Stimulating** microorganisms already present in the environment to biodegrade harmful contaminant

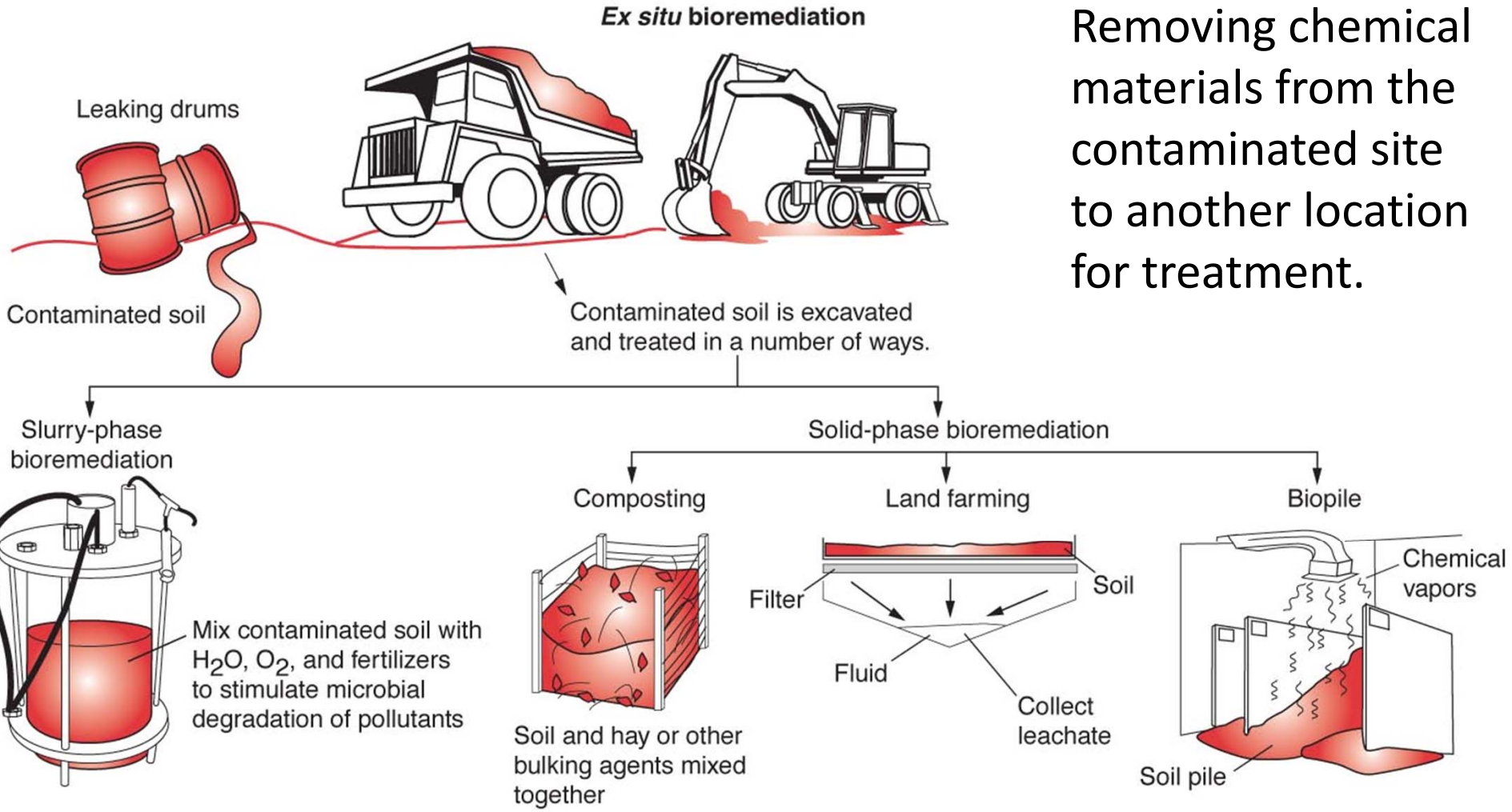
Bioventing

- most common *in situ* treatment
- involves **supplying air and nutrients** through wells to contaminated soil to stimulate the indigenous bacteria
- pumping either **air** or **hydrogen peroxide** into the contaminated soil for **aerobic degradation**
- H_2O_2 is easily degraded to water and oxygen
- **Fertilizers** may be added to stimulate growth and degrading activities of microbes

Limitations of in situ bioremediation

- Only useful in sandy soil (less compact so that microbes and fertilizers can spread rapidly)
- Can not be used readily for solid clay or dense rocky soil.

Ex situ Bioremediation



Removing chemical materials from the contaminated site to another location for treatment.

Slurry-phase bioremediation

- Contaminated soil is moved to another site
- Mixed with water, fertilizers, and oxygen in bioreactors
- Biodegradation is rapid
- Works well for small amounts of soil
- Composition of chemical pollutants should be well known

Solid-phase bioremediation

- Take more time and space
- But often best to degrade certain types of chemicals
- Three techniques are used
  - Composting
  - Land farming
  - Biopiles

Composting

- Degrade household wastes such as food scraps and grass clippings
- Can also degrade chemical pollutants
- Hay, straw and other material is added to contaminated soil
- These act as bacterial nutrients

Landfarming

- Spread contaminated soil on a pad
- Water and leachates can leak out
- Leachate is collected to avoid further pollution
- Thinner layer of soil spread over the pads allow chemicals to vaporize and aerates the soil
- Microbes can grow and better degrade pollutants

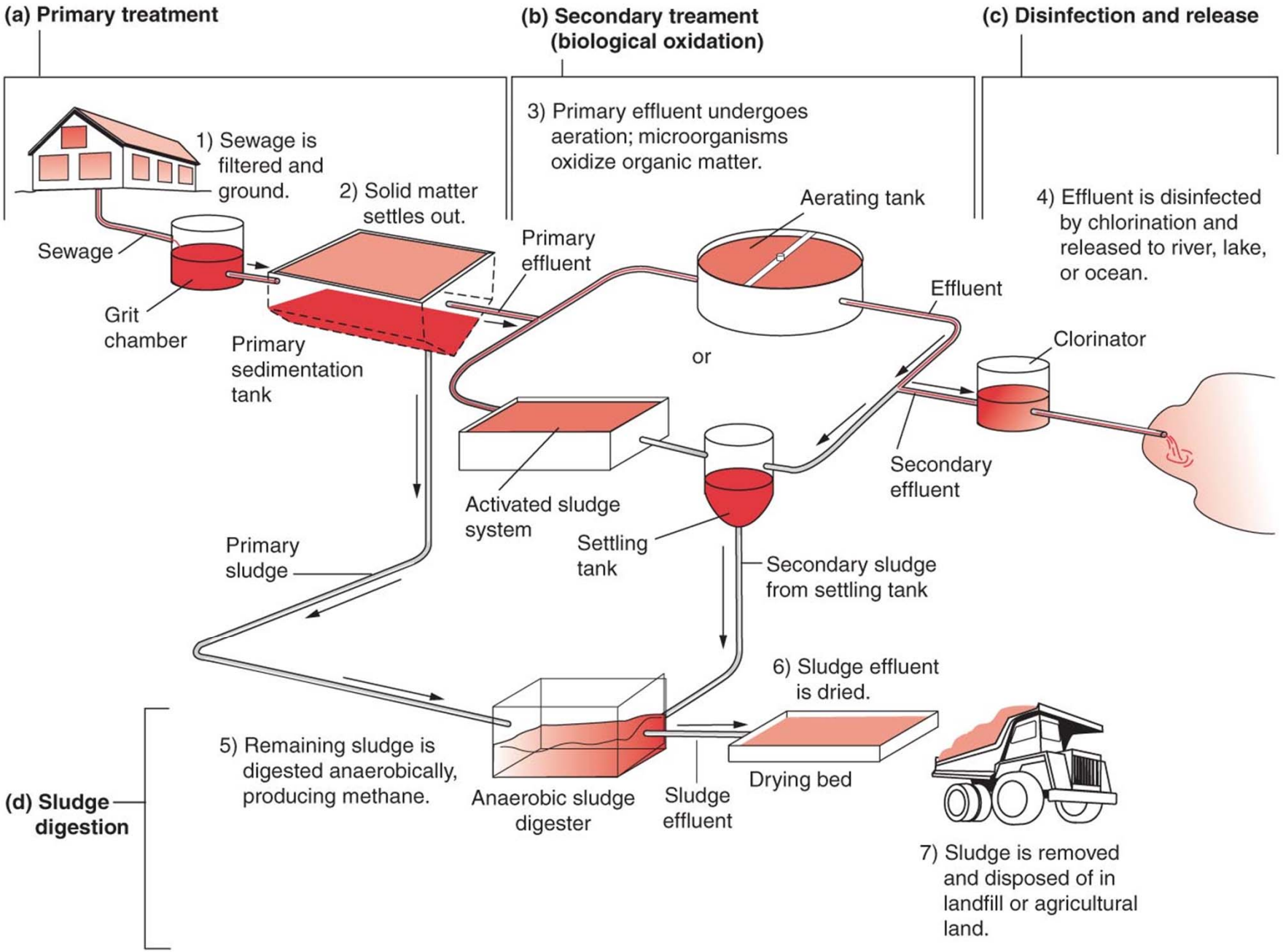
Soil Biopiles

- Used when chemicals in soil can evaporate easily and microbes in soil pile can rapidly degrade the pollutants
- Biopiles differ from composts as few bulking agents are added and fans and pipes are used to pump air into or over the pile
- As chemical evaporates, vacuum airflow pulls the chemical vapors away from the pile
- Chemicals are either released in atmosphere or trapped in filters for disposal

Bioremediation of Water

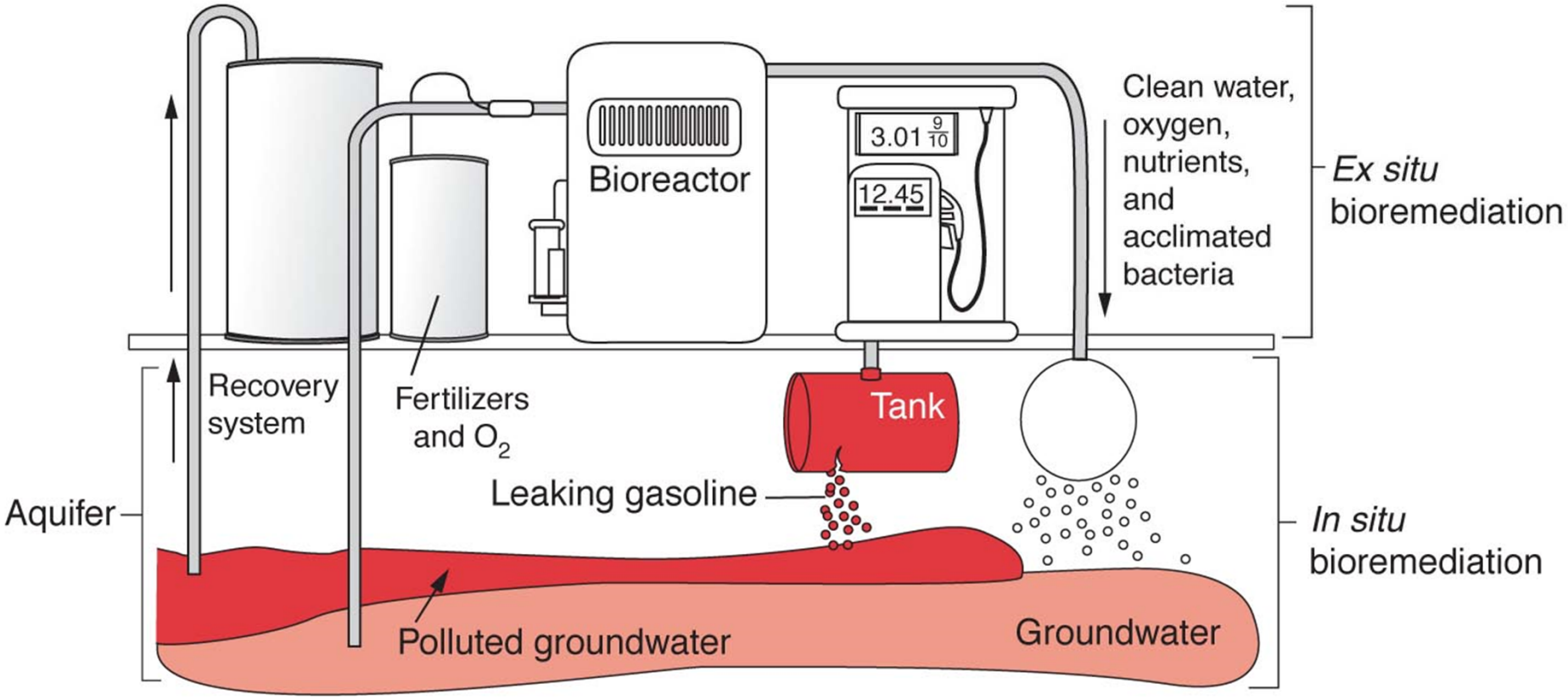
- Wastewater treatment
  - Remove human sewage (fecal material and paper wastes)
  - Soaps, detergents, household chemicals
  - **Septic system**
    - human sewage moves to underground septic tanks
    - Solid material (feces and paper waste) settle to bottom and degraded by microbes
    - Liquid flow out to septic bed (area of soil and gravel)
    - Indigenous microbes degrade waste
    - Anti clogging agents are added to septic tanks. These contain freeze-dried bacteria rich in enzymes (lipases, proteases, amylases, and cellulases to degrade fats, proteins, sugars, and cellulose in paper and vegetable matter, respectively) - bioaugmentation

Wastewater (sewage) treatment



- Ammonium (major waste in urine) degradation is important before releasing water into environment
- High amounts of ammonium cause algal blooms and diminish oxygen concentration in waterways
- Aerobic bacteria is used to oxidize ammonium

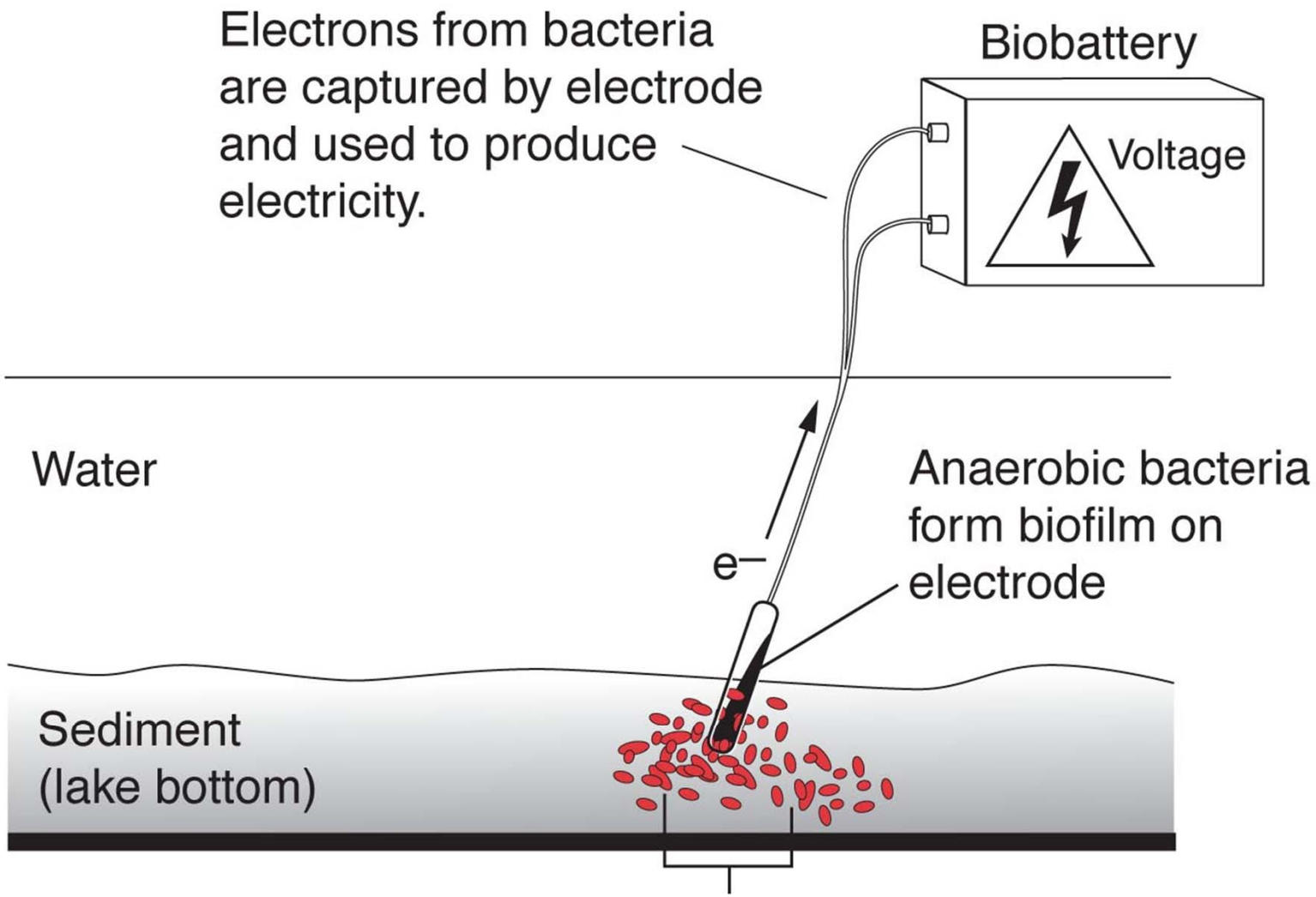
Groundwater cleanup



Turning Wastes into Energy

- Anaerobic bacteria in bioreactors can convert food waste and other trash into
  - **Methane gas –** used to produce electricity
  - **Soil nutrients –** can be sold commercially as fertilizers
- Sediment is rich in organic matter
- Anaerobes in sediment use organic molecules to generate energy
  - **Electrigens** – electricity-generating microbes
  - Oxidize organic compounds to carbon dioxide and transfer electrons to electrodes
  - Electrigens can cluster and interconnect to form nanowires that conduct electrons.

Microbial Fuel Cell



Applying Genetically Engineered Strains to Clean Up the Environment

- Many indigenous microbes can not degrade certain types of chemicals (very toxic compounds)
  - Manufacturing of plastic and resins
  - Radioactive compounds
- Petroleum-Eating Bacteria
  - Created in 1970s by Ananda Chakrabarty
  - Isolated strains of *pseudomonas* from contaminated soils
  - Contained plasmids that encoded genes for breaking down the pollutants

Applying Genetically Engineered Strains to Clean Up the Environment

- *E. coli* to clean up heavy metals
  - Copper, lead, cadmium, chromium, and mercury
  - Naturally occurring metal-binding proteins in plants and other organisms – metallothioneins and phytochelatins
  - For rapid uptake of metals *E. coli* is engineered to express transport proteins

Applying Genetically Engineered Strains to Clean Up the Environment

- **Biosensors** – bacteria capable of detecting a variety of environmental pollutants
  - Genetically engineered *P. fluorescens* can degrade polycyclic aromatic hydrocarbons (PAHs)
  - Bacterial genes metabolozing these contaminants are spliced with *lux* genes for bioluminescence
  - As PAHs are degraded, bacteria release light and biodegradation rates can be monitored
  - Biosensors are used for assessment of heavy metals

Applying Genetically Engineered Strains to Clean Up the Environment

- Genetically Modified Plants and Phytoremediation
  - Plants that can remove RDX and TNT

- Bulking agents, such as wood chips, sawdust or straw, can also be added to the pile to facilitate the movement of air through the pile