Visualizing Environmental Science

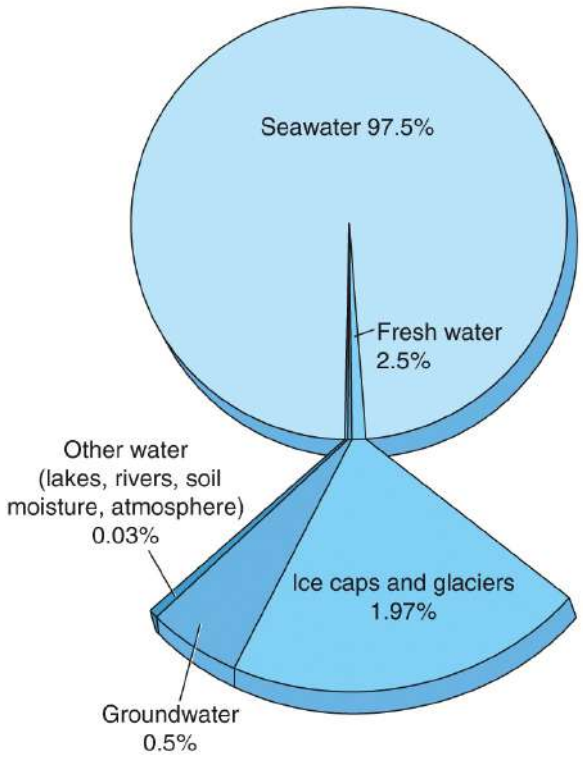
Freshwater Resources and Water Pollution

Chapter 10

Stuart Franklin/Magnum Photos

The Importance of Water

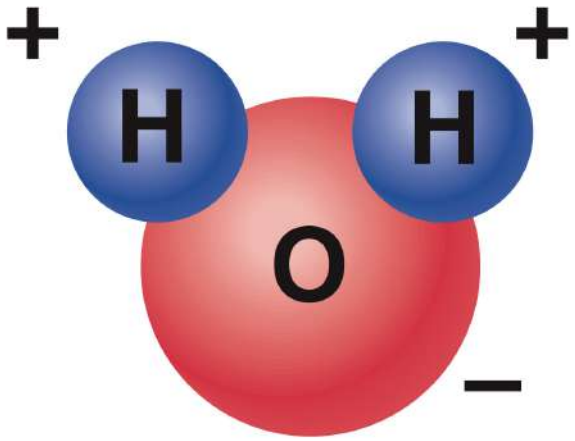
- Life on Earth would be impossible without water
  - All living organisms contain water
  - Humans are composed of approximately 70% water
- Less than 3% of Earth's water is consumable
  - 97% is salty
  - Uneven distribution - serious regional supply issues across the globe
  - By 2025, up to 2/3 of humans will live in areas subject to water-stressed conditions



Distribution of Earth's water

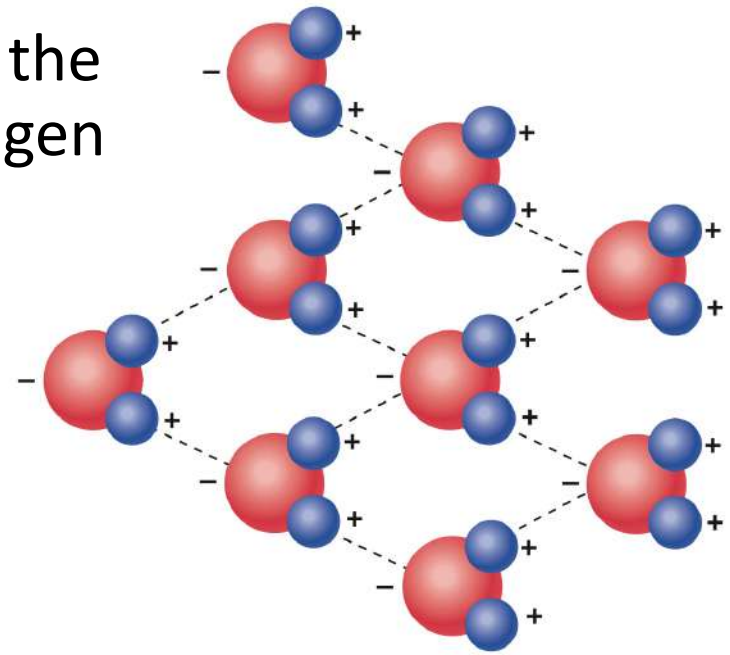
Properties of Water

- The chemical structure of water gives it unique physical properties
  - Each individual molecule of water (H_2O) contains one oxygen and two hydrogen atoms held together by strong covalent bonds
  - Water molecules are considered polar molecules (has 2 poles like a magnet)
    - The O end of the molecule has a negative charge
    - The H end of the molecule has a positive charge



Properties of Water

- Hydrogen bonding
  - Each end of every water molecule is attracted to opposite charges on adjacent water molecules
  - These strong attractions between the molecules of H_2O are called hydrogen bonding
  - Responsible for many physical properties of water
    - High freezing/melting point
    - High boiling point
    - High heat capacity
    - Ability to act as a solvent

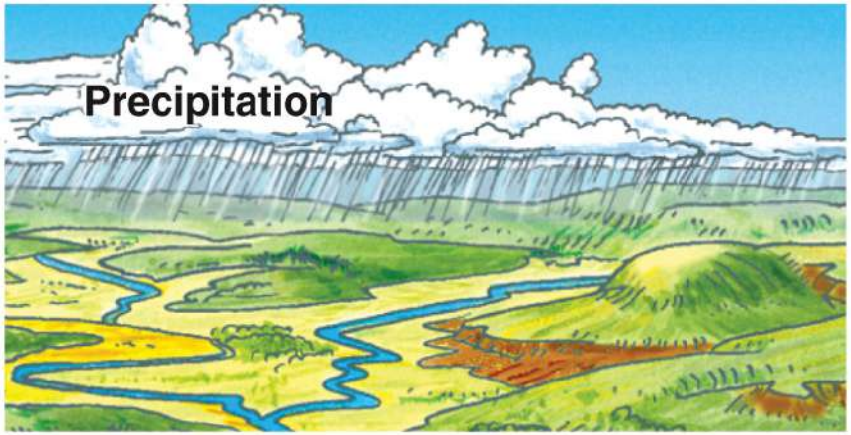


The Hydrologic Cycle and Our Supply of Fresh Water

- Water circulates in the environment
  - Provides balance of water in ocean, land, atmosphere
  - Renews supply of fresh water on land

Liquid and solid precipitation continuously falls from the atmosphere to the land and ocean.

a.



Evaporation continuously moves water vapor from the land and ocean into the atmosphere.

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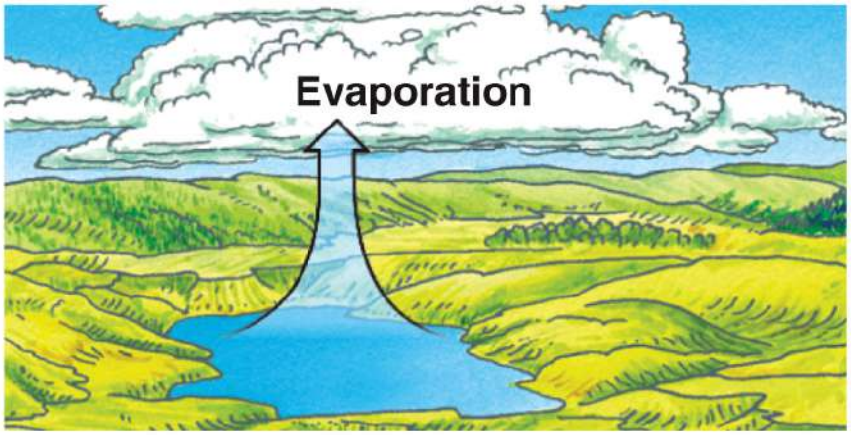


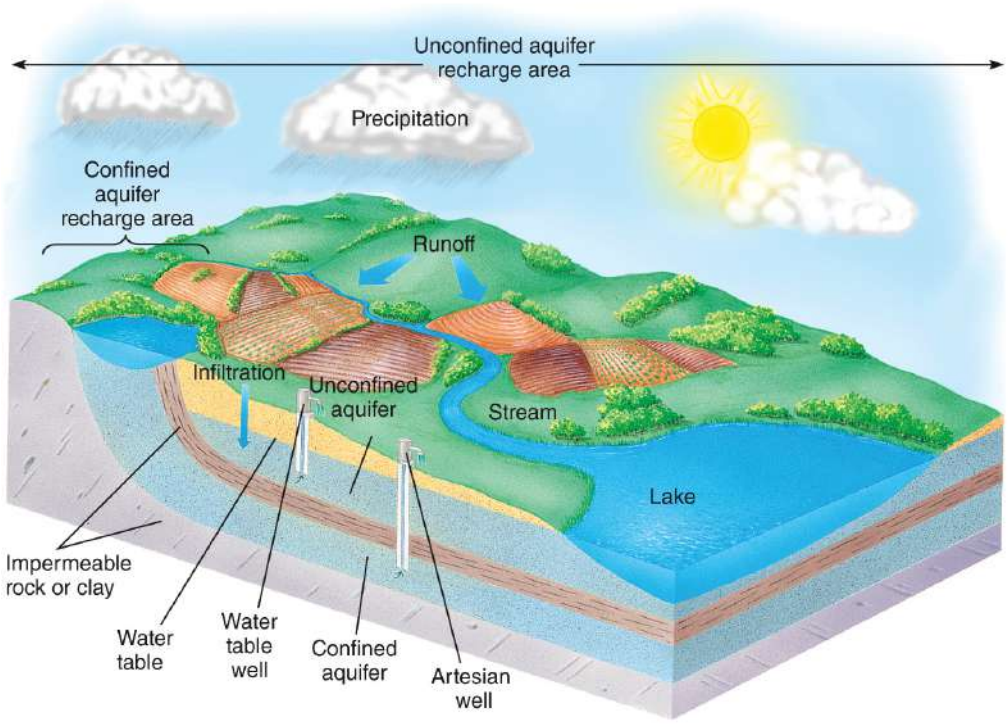
Adapted from Figure 2.8 on p. 28 in Strahler, A. and A. Strahler. *Physical Geography: Science and Systems of the Human Environment.* Copyright 2002. This material reproduced with permission of John Wiley & Sons, Inc.

The Hydrologic Cycle and Our Supply of Fresh Water

- Surface water
  - Precipitation that remains on the surface of the land and does not seep down through the soil
- Runoff
  - The movement of fresh water from precipitation and snowmelt to rivers, lakes, wetlands, and the ocean.
- Drainage basin/watershed
  - The area of land drained by a single river or stream
- Groundwater
  - The supply of fresh water that is stored in underground aquifers (underground reservoirs)

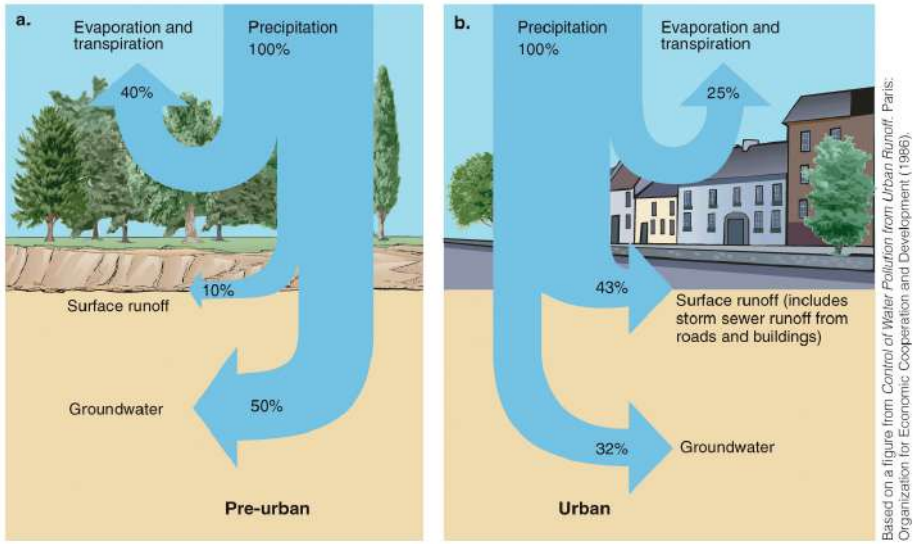
Water Resource Problems

- Three categories
  - Too much water
  - Too little water
  - Poor-quality water



Water Resource Problems

- Too much water
  - Flooding
    - Occurs when a river's discharge cannot be contained within its normal channel
    - Humans remove water-absorbing plant cover and construct buildings on floodplains



Water Resource Problems

- Too little water
  - Arid lands
    - Desert
    - Plant growth is limited by lack of precipitation
  - Farmers use irrigation to increase agricultural productivity of arid and semi-arid lands
    - Amount of irrigated land has tripled globally since 1955
    - Population growth in arid and semiarid areas intensifies water shortage

Aquifer Depletion

- Aquifer depletion
  - Results from removal of groundwater faster than it can be recharged by precipitation or melting snow
  - Lowers the water table
    - The upper surface of the saturated zone of groundwater
  - Causes subsidence (sinking of the land)
    - In areas with porous sediments
  - Saltwater intrusion can occur in coastal areas
    - Movement of seawater into depleted freshwater aquifers

Overdrawing of Surface Waters

- Growing human populations place demands on water sources that are not sustainable
  - Wetlands dry up
  - Estuaries become saltier
    - Estuaries serve as breeding grounds for many species
  - Water shortages have great economic and ecological ramifications

Salinization of Irrigated Soil

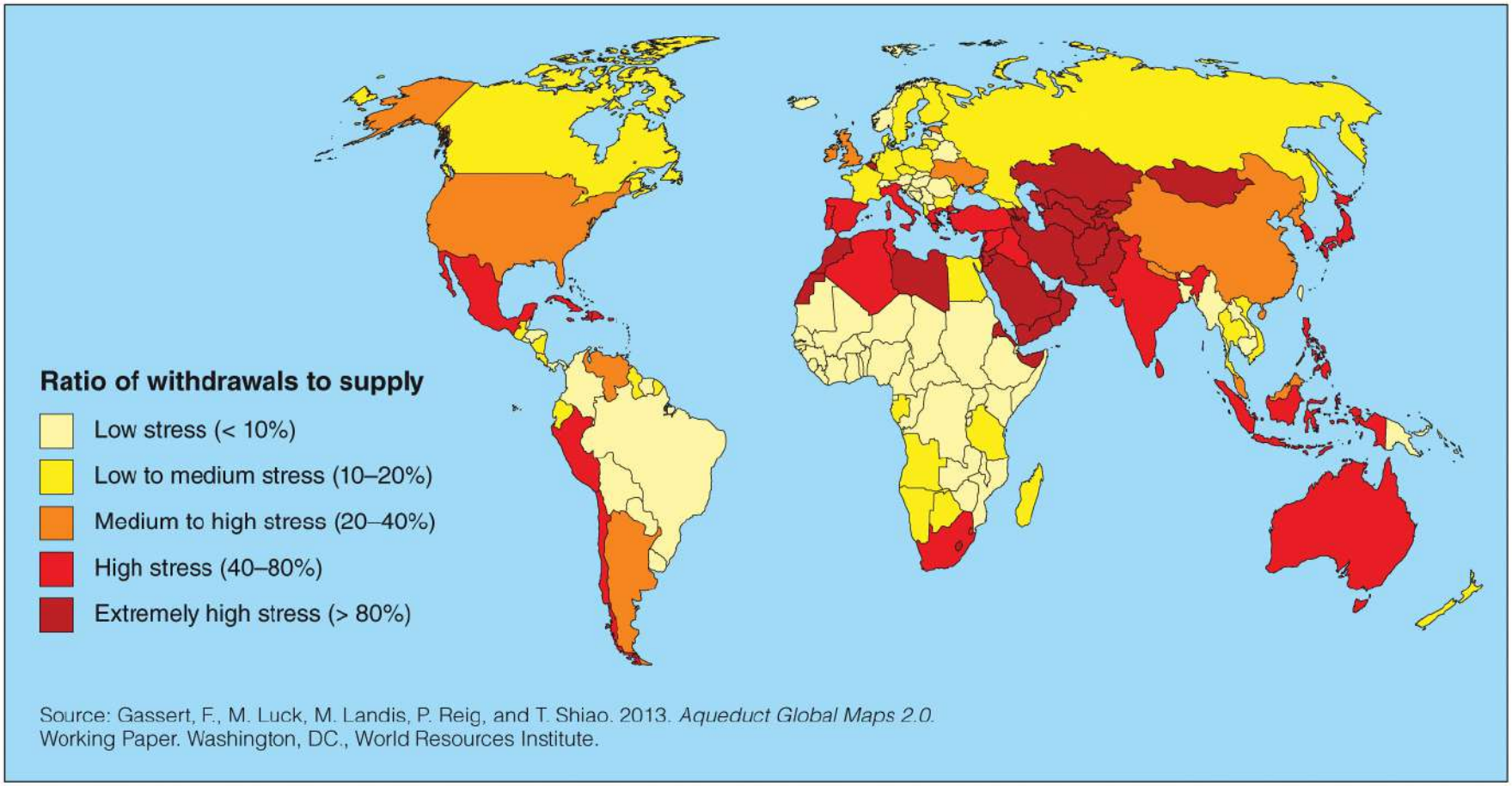
- Irrigation water contains small amounts of dissolved salts
  - Salinization of soil can be caused by the gradual accumulation of salt in soil due to use of this irrigation water
  - Normally, precipitation runoff would carry salts away, but in arid and semiarid areas there is little precipitation, so the salts remain in the soil
  - Salt accumulation becomes poisonous for plants, and over time this salinization may render soil unfit for crop production

Global Water Issues

- Water resources and human populations are often not located in the same areas
- Severe climate events can disrupt nations' abilities to provide stable water supplies
- Increased population pressure and land development reduces natural replenishment of freshwater sources
- Pollution from increasing industrial and agricultural activities contaminate surface and groundwater, further reducing water availability for drinking and irrigation

Global Water Issues

Global water stress



Source: Gassert, F., M. Luck, M. Landis, P. Reig, and T. Shiao. 2013. *Aqueduct Global Maps 2.0.* Working Paper. Washington, DC., World Resources Institute.

Water Pollution

- A physical or chemical change in water that adversely affects the health of humans and other organisms
  - Water pollution is a global problem that varies in magnitude and types of pollutants from one region to another
    - In many locations, particularly in developing countries, the main water pollution issue is providing individuals with disease-free drinking water

Types of Water Pollution

- Sewage
- Disease-causing agents
- Sediment pollution
- Inorganic plant and algal nutrients
- Organic compounds
- Inorganic chemicals
- Radioactive substances
- Thermal pollution

Types of Water Pollution

Types of water pollution • Table 10.3

Type of pollution	Source	Examples	Effects
Sewage 	Wastewater from drains or sewers	Human wastes, soaps, detergents	Threatens public health; causes enrichment and high biochemical oxygen demand (BOD)
Disease-causing agents 	Wastes of infected individuals	Bacteria, viruses, protozoa, parasitic worms	Spread infectious diseases, including cholera, dysentery, typhoid, infectious hepatitis, and poliomyelitis
Sediment pollution 	Erosion of agricultural lands, forest soils exposed by logging, degraded stream banks, overgrazed rangelands, strip mines, construction	Clay, silt, sand, and gravel, suspended in water and eventually settling out	Reduces light penetration, limiting photosynthesis and disrupting food chain; clogs gills and feeding structures of aquatic animals; carries and deposits disease-causing agents and toxic chemicals
Inorganic plant and algal nutrients 	Human and animal wastes, plant residues, atmospheric deposition, fertilizer runoff from agricultural and residential land	Nitrogen and phosphorus	Stimulate growth of excess plants and algae, which disrupt natural balance between producers and consumers and cause enrichment, bad odors, and high BOD; suspected of causing red tides, explosive blooms of toxic pigmented algae that threaten the health of humans and aquatic animals in coastal areas

Types of Water Pollution

Types of water pollution • Table 10.3

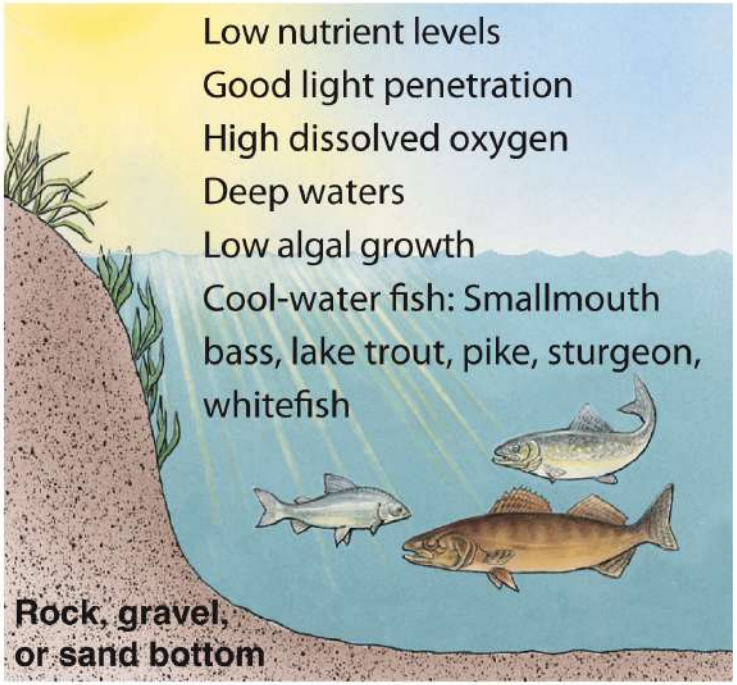
Type of pollution	Source	Examples	Effects
Organic compounds 	Landfills, agricultural runoff, industrial wastes	Synthetic chemicals: pesticides, cleaning solvents, industrial chemicals, plastics	Contaminate groundwater and surface water; threaten drinking water supply; found in some bottled water; some are suspected endocrine disrupters
Inorganic chemicals 	Industries, mines, irrigation runoff, oil drilling, urban runoff from storm sewers, deposition from industrial emissions, especially coal burning	Acids, salts, heavy metals such as lead, mercury, and arsenic	Contaminate groundwater and surface water; threaten drinking water supply; found in some bottled water; don't easily degrade or break down
Radioactive substances 	Nuclear power plants, nuclear weapons industry, medical and scientific research facilities	Unstable isotopes of radioactive minerals such as uranium and thorium	Contaminate groundwater and surface water; threaten drinking water supply
Thermal pollution 	Industrial runoff	Heated water produced during industrial processes, then released into waterways	Depletes water of oxygen and reduces amount of oxygen that water can hold; reduced oxygen threatens fishes

Types of Water Pollution

- Sewage
  - Wastewater from drains or sewers; includes human wastes, soaps, and detergents
    - May carry disease-causing agents
  - Sewage causes enrichment of bodies of water
    - Fertilization of a body of water due to high levels of nutrients
      - Overenrichment of a body of water can cause high biochemical oxygen demand (BOD) which causes organisms to die because there is not enough oxygen dissolved in the water

Eutrophication: An Enrichment Problem

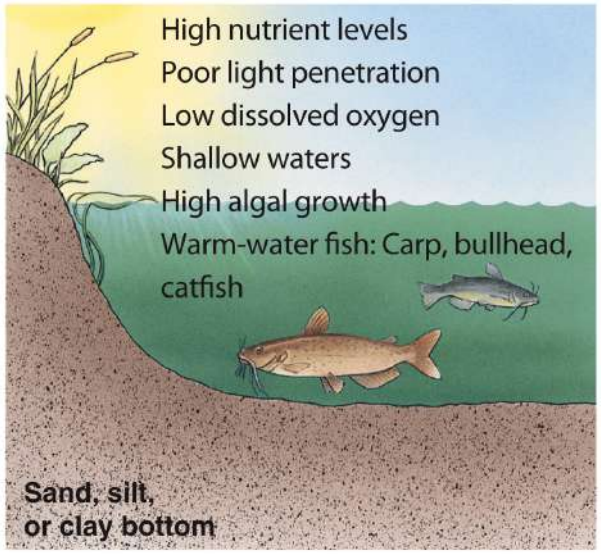
- Oligotrophic lakes
  - Unenriched, clear water, support small populations of aquatic organisms



Age fotostock/SuperStock

Eutrophication: An Enrichment Problem

- Eutrophic lakes
  - Cloudy water due to large numbers of algae and cyanobacteria
  - Water is enriched with inorganic nutrients such as nitrogen and phosphorous




Michael P. Gadomski / Science Source

Sources of Water Pollution

- Water pollutants come from both natural and human activities and they reach waterways from either *point* or *nonpoint sources*
  - Point source pollution
    - Water pollution that can be traced to a specific point of entry into a waterway (e.g. pipes, sewers, ditches)
  - Nonpoint source pollution
    - Pollution that enter a body of water over large areas rather than a specific, single point of entry
      - For example: Precipitation washes pollutants out of soil and causes polluted runoff to enter local rivers over a wide area as the runoff drains from land to the waterway

Sources of Water Pollution

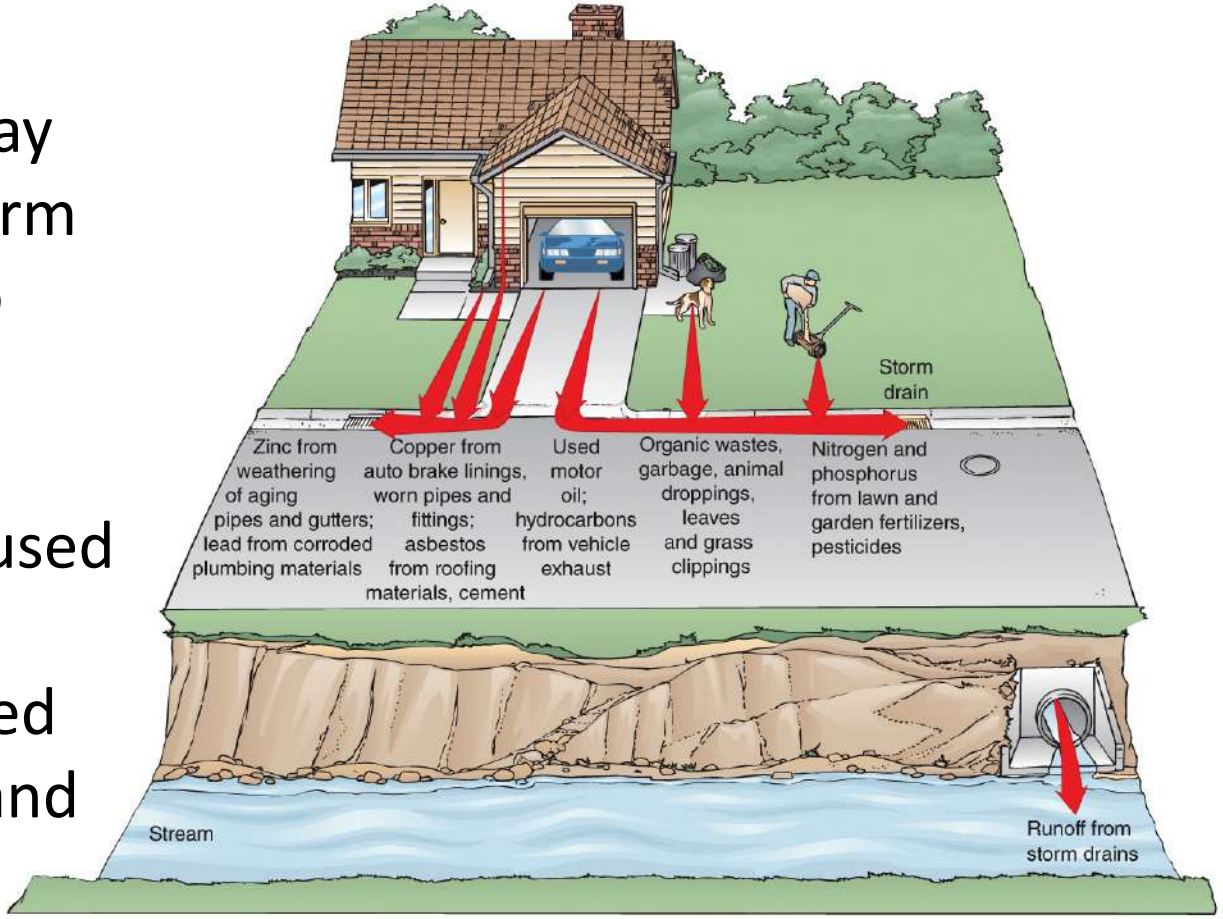
- Agriculture is the leading source of surface water quality impairment in the U.S.
  - Responsible for 72% of river water pollution
    - Fertilizer runoff causes water enrichment
    - Chemical pesticides can leach into soil and then waterways
    - Soil erosion causes sediment pollution in waterways
    - USDA has developed guidelines for livestock farmers to prevent manure from becoming polluted runoff

Sources of Water Pollution

- In urban areas, in addition to point source pollution from many sources, urban runoff is a significant source of non-point pollution
  - Urban runoff is water that has traveled off of buildings and across roadways, and carries a variety of wastes as a result. Salt, construction debris, animal wastes, garbage, oil and other hydrocarbons, chemicals, and other pollutants all end up dissolved in rainwater, which then drains to waterways, causing significant pollution over a wide area

Sources of Water Pollution

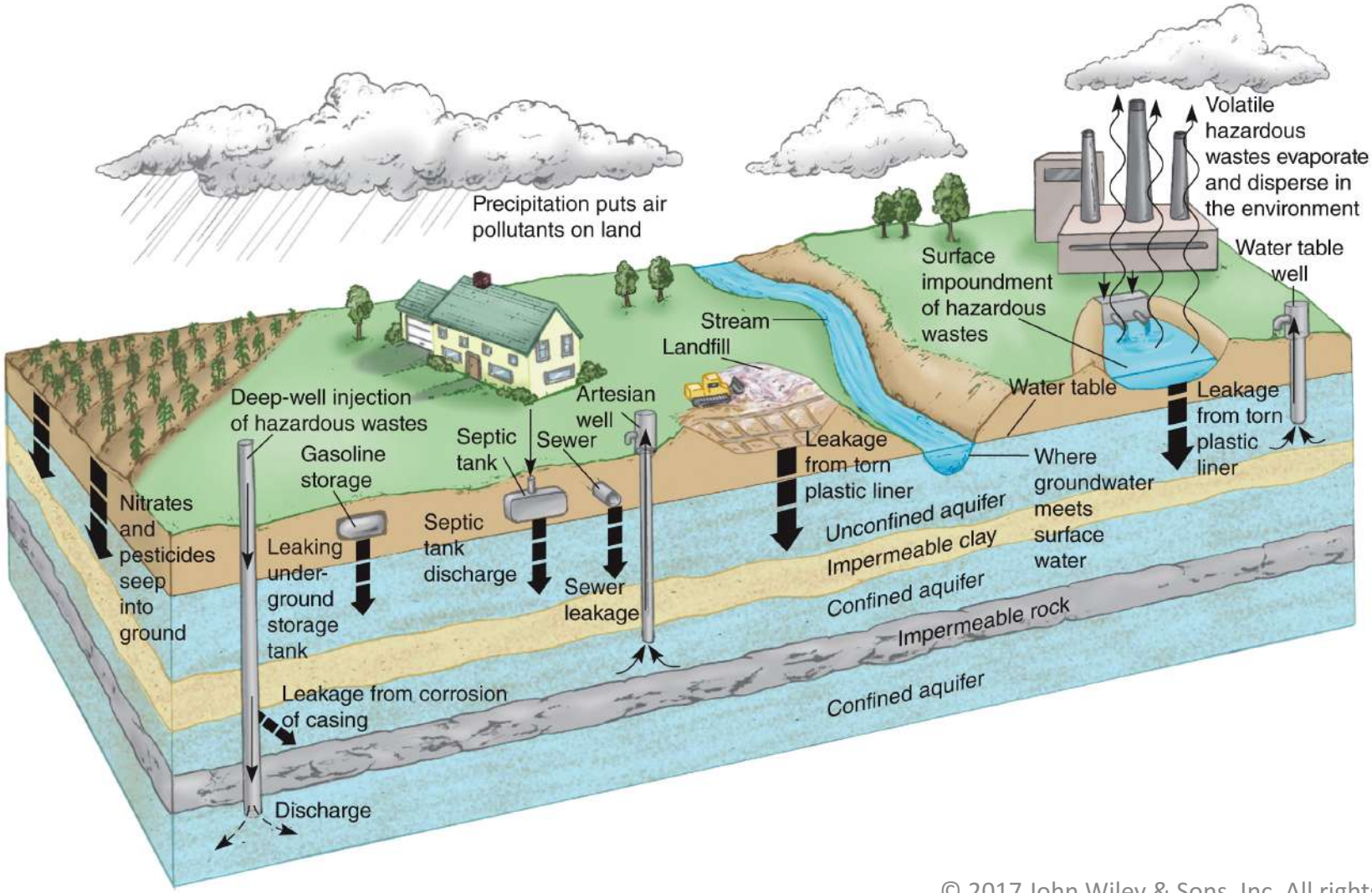
- Urban runoff
  - Many pollutants may be carried from storm drains on streets to streams and rivers.
  - Other everyday pollutants include used motor oil, which is often illegally poured into storm drains, and heavy metals.



Groundwater Pollution

- Groundwater pollution
  - Half of the people in the U.S. obtain their drinking water from groundwater sources
    - Quality is a concern
      - Pesticides, fertilizers, organic compounds, can seep into groundwater from landfills, storage tanks, backyards, golf courses, agricultural lands, etc.
    - Cleanup of contaminated groundwater is not always technically feasible
      - Very costly if it is even possible to accomplish

Sources of Groundwater Contamination



Case Study: China's Three Gorges Dam

- The Three Gorges Dam on the Yangtze river in China is the largest dam in the world, on the world's longest river
- Completed in 2008, it had multiple goals:
  - Flood control in rainy season, water reserves during dry season
  - Electricity generation
- Along with the positive effects of the dam, there are many negatives:
  - Relocation of 2 million people due to reservoir placement
  - Habitat fragmentation
  - Decline in fish species, and rare freshwater mammals endangered
  - Silt buildup behind dam
  - River bank destabilization and erosion, increasing landslide probability
  - Massive water pollution issues due to increased industry and shipping