Soil Features

- **Soil**: a stew of geological ingredients (parent rocks and minerals), water, and billions of organisms

Soil Aggregates/Structure

- Physical features – particle size, aggregate structure that makes soils clump and crumble
- Provide sufficient movement of air, water and nutrient mobility

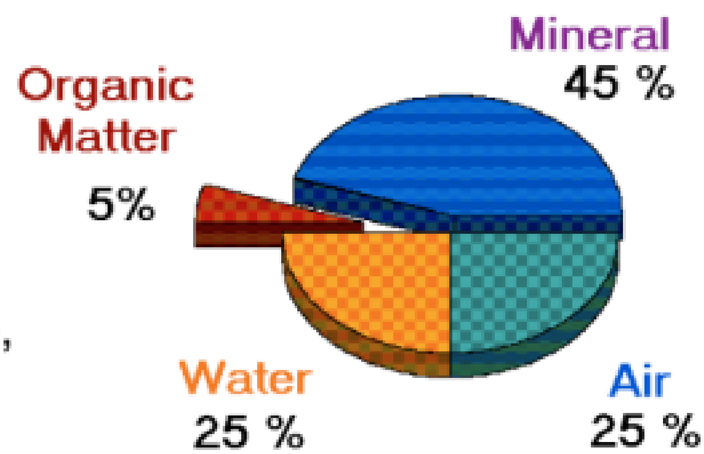
Soil Fertility - ability to grow crops long term

- need clump and crumble, not solely one
- Darker is better, implies organic matter
- Nutrients (N, P, K, and micronutrients) as well as organic matter from dead organisms, and pH

Soil Components

Soil Tilth

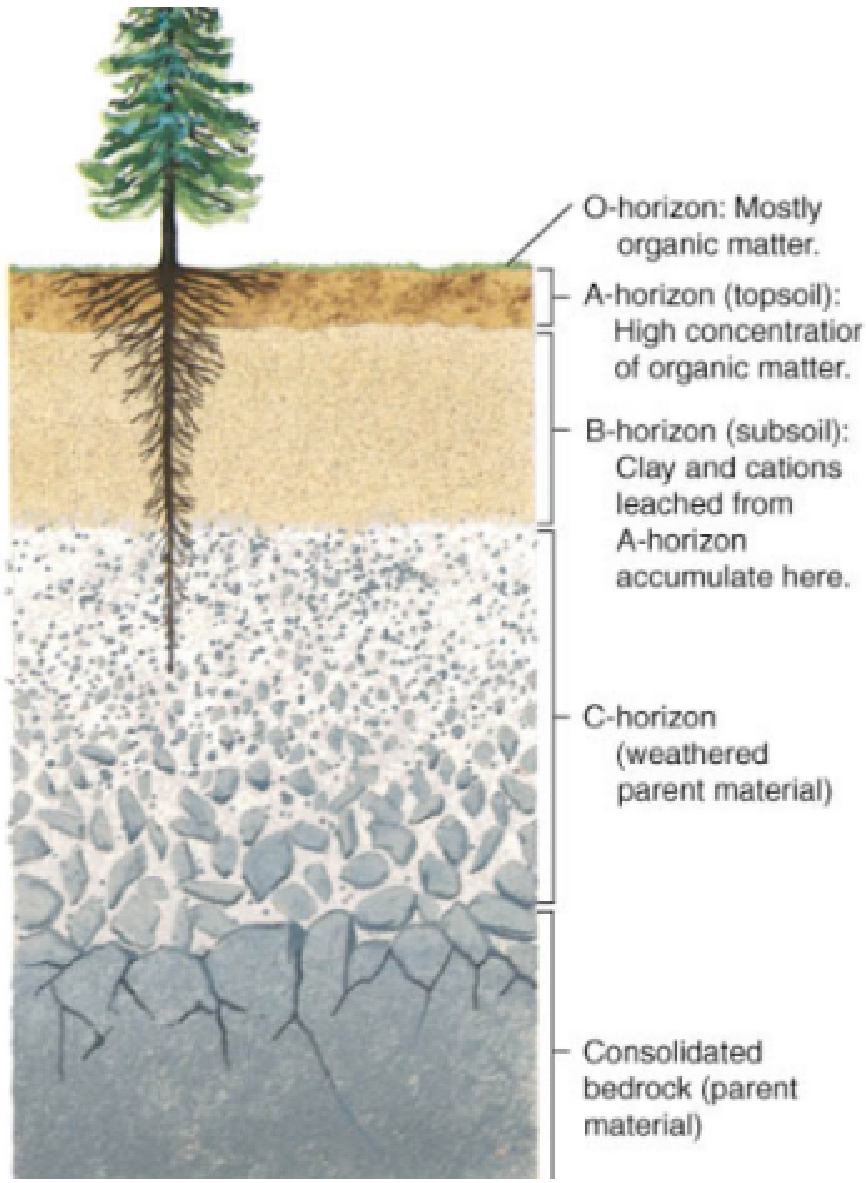
- balance between physical features
  - moisture and ability for water to infiltrate
  - degree of aeration that promote health root
- 4 major components:
  - Soil organic matter (SOM) - 5%
  - minerals - 45%
  - water - 25%
  - air - 25%



- **SOM** is crucial for fertility, and has been decreasing
  - farming practices not recycling nutrients

Soils - Features and Formation

- **O horizon**
  - partially decomposed
  - mostly organic
- **A horizon**
  - a lot more decomposition (dark black, humus)
  - Leaching; rain brings nutrients deeper
- **B horizon**
  - zone of accumulations of material from layer A
  - grey-brown
  - sub soil
- **C horizon**
  - weathered rocks
  - groundwater
- Consolidated Bedrock



Soil Texture

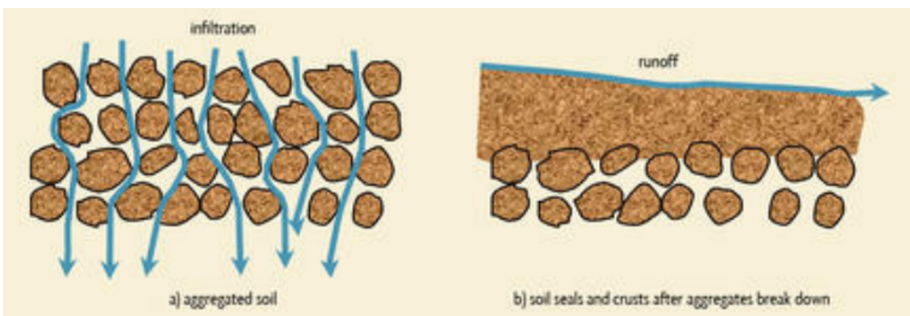
- Different particle sizes
  - **Sand** - high **porosity**; water and air moves through
  - **Silt** - in between
  - **Clay** - compact tight, no porosity, holds soils together
- Want 1/3 of each –> **loam**

Clod: soil so compacted that its unusable, like cement - clay more likely to from clods

Soil Structure - Physical Condition

Aggregate Stability

- How well mixed our soil is
- Want clump but also crumble
- If mix too much you will separate the particles
  - risk of **erosional processes** and **crusting**
    - limits water penetration
    - Runoff, fertilizer into rivers
- want sufficient pore space



Cation Exchange Capacity (CEC)

- **Negatively charged clay** and organic material "hold" minerals in the Soil (Mg, K, P . . .)
- Important to **slow flow of leaching**, so minerals don't go too deep
- Clay found in B horizon, holds nutrients for plants
- Acidic soils have H+, accelerate nutrient loss cuz have preferential binding to clay

Acid Rain = Deplete soils of nutrients

Soil Ecosystem - Soil Organic Matter (SOM)

- "When we are standing on the ground, we are really standing on the roof top of another world"
- Living in the soil are plant roots, viruses, bacteria, fungi, algae, protozoa, mites, nematodes, worms, ants, maggots and other insects and insect larvae (grubs), and larger animals.
- Crucial to fertility, stabilises soil aggregates, improving soil structure, and tilth

- Humus consists of chains of carbon molecules with a large surface area; these surfaces carry electrical charges, which attract and hold mineral particles

Symbiosis - Mutualism

Biotic Associations Found in Soils

- e.g., Symbiosis, **N2 Fixation**
- Roots colonised by fungi
- create internal network
- exchange sugars and nutrients
- fungi expand elsewhere, drawing in more nutrients
- 700x more area to assist with
- Mycorrhizal Fungi, symbiosis

Soil Food Web

- Begins with plants above ground
- things we do impact it all

Soil Ecosystem Services

- Increasing fertility through the build up of organic matter and symbiotic interactions
- Reduction in soil erosion and huge increase in water holding capacity
- Breakdown of toxins by decomposing community
- Enhanced carbon storage and long term storage (sequestration)
- Soil ecosystem dynamics heavily influenced by agricultural activities and climate
- How can temperature and precipitation determine soil organic matter?

Regeneration of our Lands video

Look for problems and solutions

- Loss of biodiversity –> destruction of soil
- top soil shrank in depth
- organic matter shrank
- rain can't infiltrate
  - resorting to tile drainage –> soil goes to watershed along with nutrients
- Lack of biodiversity, lower nutrient cycling
  - put in own, ruin everything
- Weeds from synthetic fertilizer
  - use herbicides, binds metal (nutrients), unavailable to plant, prone to disease, spray fungicides –> detrimental to soil biology, pests effect, spray pesticides –> decline predator insects and pollinators

- Current production model is all about killing
- Fewer children in schools, ruins health (lower nutrient densities in food), US spends tons on health care but still leads in diseases
- Natures way - Conventional Way
  - no mechanical disturbance
  - armour on surface
  - cycles water efficiently, infiltration perfect
  - living plant networks all throughout growing season
- 400 years ago tons of diversity
- 5 Principles
  - Least amount of mechanical disturbance
    - infiltration
  - Armour on soil surface - protect from wind and soil erosion
    - infiltration
  - Soil diversity -
    - more nutrients
  - Living roots in ground as long as possible
    - nutrients
  - Animal impact - out on pasture
    -
- 1700 beneficial insects for every pest
- More nutrient dense at lower cost
- infiltration depth increased

Windy Video

- field eroded, on hot sunny day, dust everywhere, goes into ditches or rivers

Tilled vs No Till Soils Video

- Tilled is lighter
- Till has little pore space
- Till has less nutrients and nutrient recycling
- Till has less organic matter
- untilled held by organisms
- Tilled is eroded in water
- tilled soil has runoff

Types of Agriculture

- **Subsistence**:
  - production small with goal to produce for family and local community
  - common in developing nations
- **Industrialized**:

  - large commercial farms, maximise profit
  - lots of mechanization
  - chemicals
  - species diversity not important
  - NA, China, Russia

Green Revolution

- 1940's-60's
- Enhanced crop production to Feed Population
  - new crop varieties, higher yields
  - chemical fertilizers
  - synthetic pesticides
  - lower production costs

Modern Agro-Ecosystems

- goal is monoculture/ low biodiversity
- planted in rows, lack spatial complexity
- tillage

Natural Landscape

- pests can't access easily, due to structural complexity

Next two sections are a recap from Ted Talk Video

Soil Decline with Conventional Farming

- Tillage activities (ploughing) can accelerate breakdown of organic matter/decomposition rates;
- Further loss of soil organic matter arises through burning and removal of crop residue
- Tillage impairs aggregate structure (no longer sticky and disintegrates)
- Bare and exposed soils encounter more erosion
- Poor nutrient cycling and less soil community
- Pesticides and synthetic fertilizers affect beneficial microorganisms
- Poor water infiltration and water storage when the aggregate mixture is disrupted and leads to greater dependency on irrigation and risks of pesticide/fertilizer runoff

Regenerative Strategies

- Lessen disturbance = review tillage practices
- cover crop – “armour” on the soil to minimize erosional processes with living roots in the ground as long as possible
- Improve nutrient cycling so that inorganic fertilizer application can be reduced
- Use biological processes to “feed the soils”
- diversity of plants leads to diversity in the soil community - improving SOM and infiltration
  - crop rotation; polyculture cropping
- domesticated animals mimic the natural disturbance of grazers historically and with healthier soils the stocking rate can be much greater
  - rotational grazing schedules

Legume –> nitrogen fixation

Slash and Burn Agriculture

- Forests cut and burned for ash to use as fertilizer
- productive soils only for short period
- Forest regrowth fails due to poor soil development
- Need to have canopy for shade, cover crop

Livestock in Africa

- livestock used in rotational grazing
- degraded regions restored, manure
- loss of grazers had the opposite effect

Anoxia: no oxygen

- can happen in water if too much decomposition
- opposite of photosynthesis reaction

Properties of Water

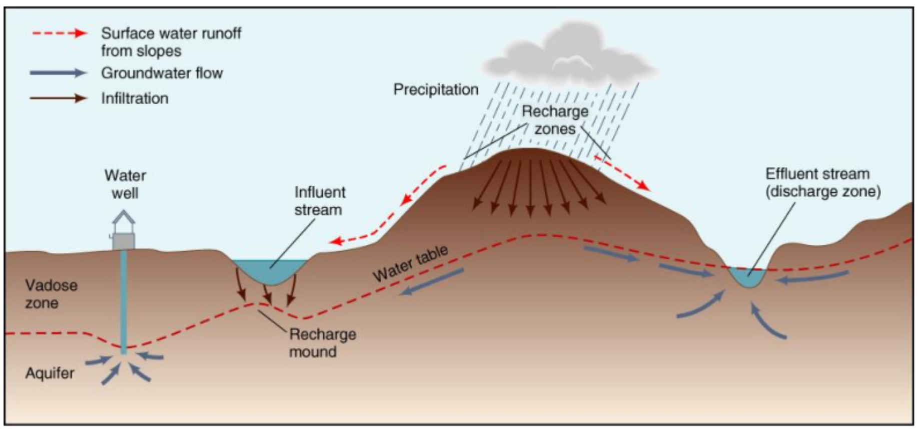
- High heat capacity - holds lots of energy
- Ice expand when freezes - floats on water
- Moderates climate
- Universal solvent - dissolve almost anything

Hydrological Cycle

- 3% of water is freshwater, 0.5% in groundwater, most in glaciers
- Cycle
  - Evaporation - fresh water to atmosphere, purifies water
  - Condensation
  - Precipitation
  - Transpiration - on plants

Groundwater Dynamics

- Water percolates into the ground, termed infiltration
  - depends on saturation and permeability (pore spaces vs clay)
- Water table: below saturated zone, above is unsaturated ground zone



- If take water from ground, water table decreases, wells may not reach water anymore
- Is ground water flow.
- **Influent Stream** - going into ground
  - gravity pushing water into unsaturated area
  - Gets recharge from runoff
- **Effluent Stream** - flowing out of ground
  - water table above stream, water leaves cuz pressure
  - Gets recharge from runoff and discharge from ground
- For groundwater, it *has* to rain
- Note: runoff is not freshwater

Surface Waters

Lake Winnipeg Watershed - Watershed, sink with a drain, Lake Winnipeg is the drain & watershed - runoff puts tons of contaminants into Lake Winnipeg

Water Quality

- The physical, chemical, and biological characteristics of water necessary to sustain desired water uses
- **Physical** - what's in water, who's in water
  - **Light** - need for photosynthesis for oxygen for life, need light
    - change light by erosional activities
      - dirt in water = less light
- **Chemical - nitrogen**, **phosphorus**, plant growth, too much, algae
  - Lake Winnipeg Algae
  - Sewage and manure - farming and toilets, profound effects
  - **dissolved oxygen (DO),** can have too little to support life
  - **Dead Stuff (Organic Carbon)** - energy
- **Biotic Responses - plants** like algae(influence oxygen), **fish** are good, **bacteria** (eat dead stuff, demand oxygen, suffocate fish)

Sources of Pollution

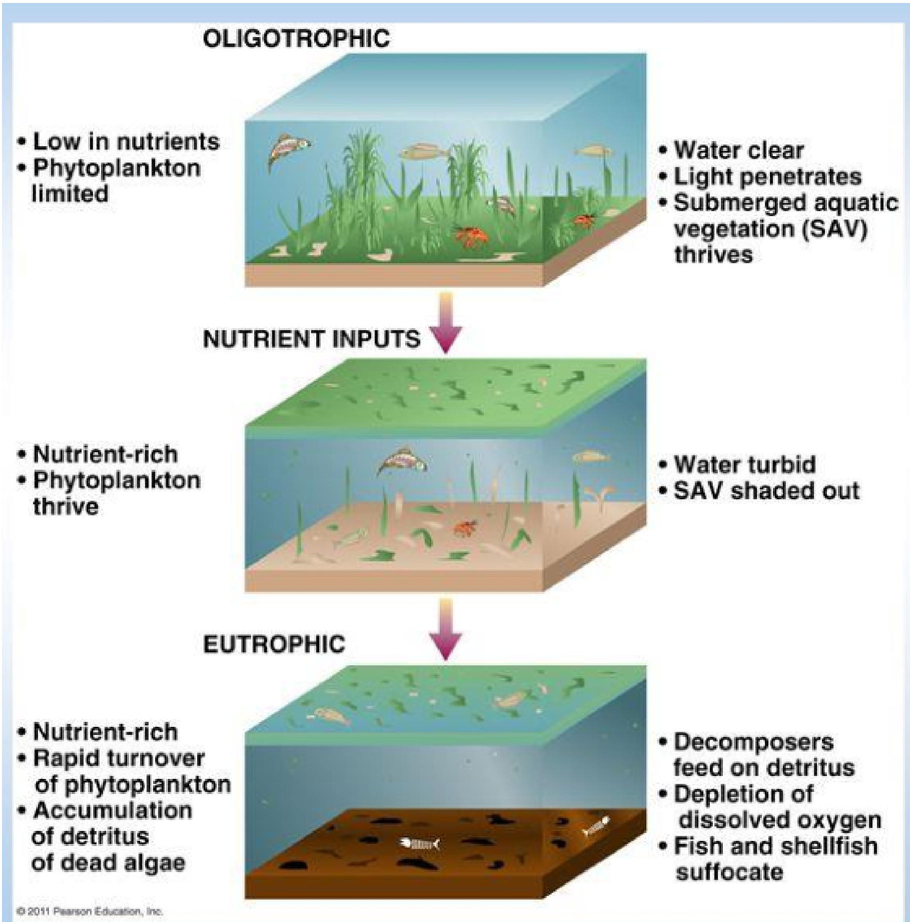
- **Point source pollution** – out of a pipe concentrated discharge such as sewage effluent. Know exactly where pollution is coming from
- **Non-point source** – over a large area within the watershed, diffuse and much more difficult to control and regulate. Cannot pinpoint where pollution is coming from

Sediment Pollution

- soil particles from erosion
- accumulate at bottom, takes away habitat
- Problems:
  - **Turbidity** - reduces light penetration
  - **Siltation** that destroys fish habitat
  - Adhered pollutants

Eutrophication (Nutrient Pollution)**

- nitrogen and phosphorus that encourage growth
- **Cultural Eutrophication**: Humans accelerate natural processes that normally take thousands of years into 10 years
- increases carrying capacities of algae
- Large mats of plants reduce health of ecosystem, take light
- From sewage, fertiliser, shampoos
- Lower nutrients = more biodiversity



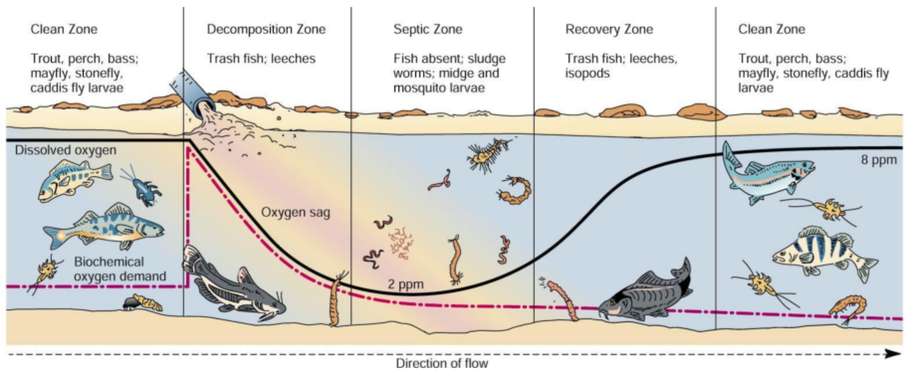
- after all dead, decomposers take all the oxygen for their decomposition reaction, anoxia, no oxygen, eutrophication kills fish, **

Decomposition and Oxygen Sag

- uses DO, dissolved oxygen
- Org-C + DO → CO2 + H2O
- More food (Org-C) for decomposers = higher decomposition rate
- Sources of Org-C
  - Natural Sources - leaf litter, fish, trees, branches, animal
  - Human Sources - sewage, manure
  - Eutrophied Water - Generates org-C because excessive plant growth

Organic Pollution: DO Sag and Biodiversity Loss

- Oxygen Sag - dissolved oxygen declines in concentration in polluted area, cant regenerate fast enough
  - oxygen demand spikes at pipe pollution, then decreases



- High BOD lead to fish having nowhere to live - **Winter Fish Kill** - no oxygen
  - algae die from cold, ice on top doesn't let oxygen in, bacteria eats algae that dies, take all oxygen, fish all die

Measure Bacterial Demand for Dissolved Oxygen in Decomposition

- **Biochemical Oxygen Demand (BOD)**
  - Determine rates of decomposition through an assessment of the DO consumed by bacterial community
  - The amount of oxygen that is used by decomposers over a period of time to break down organic matter present in a given water sample.
  - Seal off bottle (no oxygen in), put in dark (no photosynthesis), measure DO before and after, determines BOD

BOD Level in mg/liter	Water Quality
1 - 2	**Very Good:** There will not be much organic matter present in the water supply.
3 - 5	**Fair:** Moderately Clean
6 - 9	**Poor:** Somewhat Polluted - Usually indicates that organic matter present and microorganisms are decomposing that waste.
100 or more	**Very Poor:** Very Polluted - Contains organic matter.

- we want low Org-C in our waters

Pathogens and Water Quality

- Fecal coliforms are pathogens originating from fecal materials from sewage, manure, water treatment failure
  - One example is E. coli
- 3 Types:
  - bacteria
  - viruses
  - protozoa
- **Bacterial Counts** found by growing a population on a petri plate
- in a 100ml sample
  - Must be 0 colonies in drinking water
  - less than 200 coliform colonies to swim

Cyanobacterial Dominance

- Lake Winnipeg dominated by them
- Cyanobacteria:
  - outcompete organisms for oxygen and nutrients
  - blue/green algae
  - fix nitrogen gas to form ammonia **(nitrogen fixation)**
- Should be 16 N : 1 P –> N to P ratio
  - Lake Winnipeg is 16 N : 4 P, so too much phosphorus
    - nitrogen not a problem, cant just add nitrogen to fix ratio because it is toxic to fish
    - Good algae take nitrogen, then some phosphorus when needed
    - Cyanobacteria take nitrogen gas from atmosphere and then take phosphorus, as much as they want

Maintaining Water Quality

- Point Source **Sewage Treatment**
- Non-point source treatment
  - **Storm Water** runoff in cities
  - **Agricultural Run-off**

Sewage Treatment City of Winnipeg

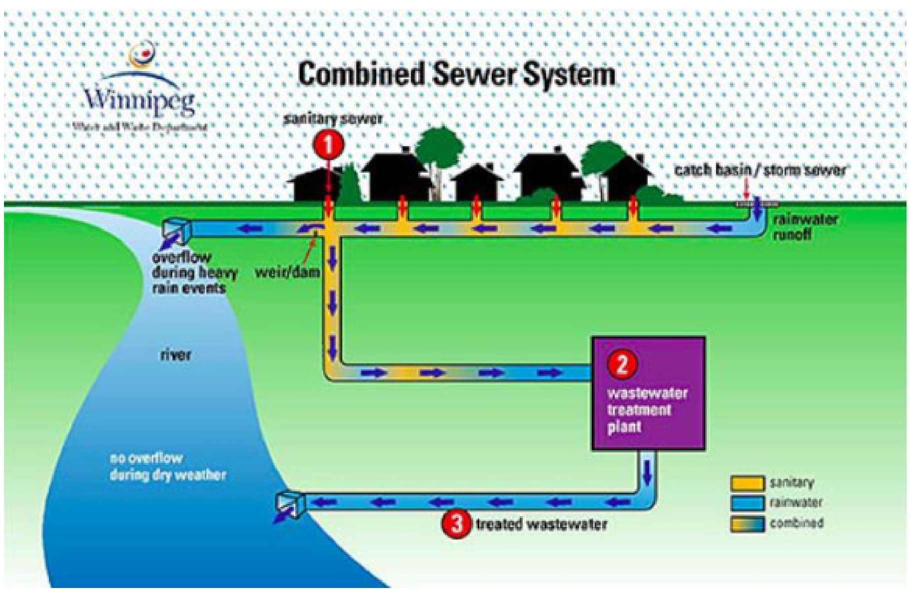
Municipal Sewage Treatment

- 3 Steps
  - **Primary**
    - separating solids and liquids
    - at best remove sediment pollution

- **Secondary**
  - add oxygen and sludge(bacteria) to remove organic material
    - jacking up rates of decomposition so no food for bacteria once in river
    - digest dead stuff / organic carbon
  - disinfection, killing pathogens
- **Tertiary**
  - removing nutrients, nitrogen and phosphorus

Non-Point Source Pollution Issues in Surface Water Quality - Urban Centres

- Runoff brings tons of pollutants to rivers, cities must deal with it
- **Combined Sewers**
  - Rain water combined with sewage
  - if get too much, it overflow the weir/dam and goes into rivers
  - the non-overflow gets treated before deposition into river
  - horrible way to handle runoff



Wetlands / Riparian Zones

- incredible water purification, must have ton of vegetation on water edge, like cattails, suck up nutrients
- water into storm drain goes to wetland, holds water and sediments go down. Bacteria in soils break down organics. Vegetations sucks of nutrients. Then

is released via gate into river, diluting nitrogen and phosphorus (good)
- soils have ton of bacteria, take nutrients from farmland runoff, converting to CO2

Ecosystem Services of Riparian Zones

- Trap sediments
- filter water of pollutants and pathogens
- Stabilise stream banks
- store floodwater and energy
- Recharge groundwater
- Enhance biodiversity
- Increase plant production –> sustainable harvesting

Toxicology - study of poisons/toxins and their effect on organisms

toxins can be synthetic or natural

Environmental (Eco)Toxicology

- toxicology and investigation of environmental factors influencing exposure dynamics
- How does the substance behave in the environment?
- Does the substance undergo transformations that affect how poisonous it is?
- What are the indirect influences on the various biotic interaction in an ecosystem

Toxins and Pest Management

- toxins used in pesticides (an antibiotic)
- **What is a pest?**
  - an undesirable competitor, parasite, or predator that interferes in some way with human welfare or activities. It could still have an important connection within the ecosystem

Factors that Affect Toxicity of Substances in the Environment

- **Persistence** - how long a chemical takes to break down in the environment
  - long persistence is bad, interacts more with ecosystem
- **Solubility** - Ability of a chemical to dissolve in liquid
  - **Water-soluble** can be excreted from your body
    * However, water soluble chemicals may easily enter and accumulate in aquatic ecosystems

- **Fat-soluble** chemicals are absorbed into fatty tissues and there is potential of build up in bodies, can't rid it
    - **organic is fat-soluble**, like organic mercury, or carbon

Factors that Affect Toxicity

- **Bioaccumulation**
  - Build-up of persistent fat-soluble chemical in body over time
- **Biomagnification of the toxin in the food-web**
  - Leads to concentration in each trophic level
  - animals higher on food chain accumulate more toxins

Factors that Affect Toxicity

- **Acute Exposure**
  - Symptoms develop fast
  - includes exposure to large amounts of a chemical
- **Chronic Exposure**
  - takes place over long period of time of prolonged exposure
  - often low level pollutants

Antagonistic Effect - these are chemicals that interact to cancel out or lessen the toxicity effect

Synergistic Effect - combining these toxins results in a pronounced effect and much greater response than would be expected

Mobility of Toxicants

- Toxicants go to unintended places... duh
- **Broadcast Spraying** - Via planes
  - low % reaches target
  - 98% ends up in air surface water, groundwater, bottom sediments

Long Range Transport of Pollutants

- thousands of km
- tend to go to Arctic - **"Grasshopper Effect"**
  - leap to poles with **convective currents**
    - also means that pollutants descend in Canada from elsewhere (US)
- Transported by wind/convection, water/ocean

Indirect Ecotoxicological Stresses

- quality of habitat, food
- kill predators –> rapid pests

Genetic Resistance/Tolerance

- Mutant individuals become resistant over repeated exposure, evolution
- Over time they become majority of population
  - Rebound: after pesticide, mutants multiply/reproduce
- New or more pesticides required

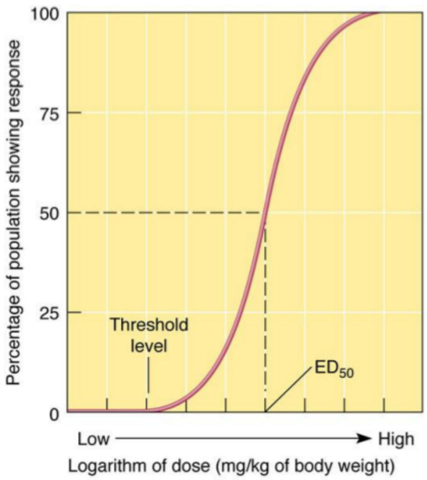
How Do We Manage Toxins?

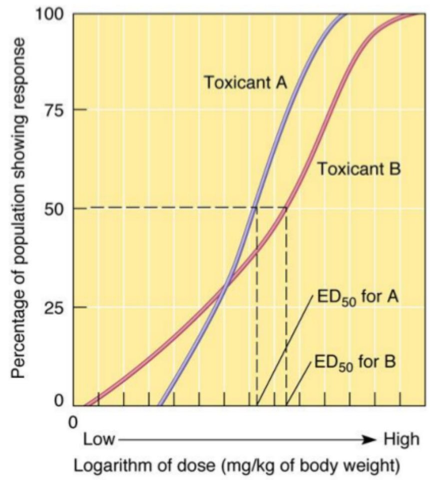
- Conduct Risk Assessments
  - 1. Hazard Identification - not too important
  - 2. Dose-response assessment
    - in lab
  - 3. Exposure assessment
    - in environment
    - Persistence, solubility, mobility, interaction, exposure
  - 4. Risk characterisation
    - bring steps 2 and 3 together - get Hazard Quotient
- **Risk:** probability that an activity or exposure to a substance will be harmful

Dose Response - Step 2

- **Dose**: amount that enters body
- **Response:** type and amount of damage
- **Lethal Dose:** causes death - **LD50** lethal to 50% of population
- **Sub-lethal Dose:** has measurable effect
  - **Effective Dose:** want **ED50** - cause 50% population to exhibit specific response

Dose Response Curve





- choose dose where ED50 - Effective Dose
- notice low slope of no response at start until Threshold Level
  - Can use up to Threshold Level to not affect certain organism
    - Ex: Kill pest but not fish.
  - Not all chemicals have this.
- Start with high doses and work way down to LD50 and ED50
- Quantify the **threshold level**: Max dose with NOEL, no observable effect

Risk Characterisation - Step 4 - Hazard Quotient (HQ)

$$HQ = \frac{\text{Exposure concentration (EEC)}}{\text{Effect concentration (TBC)}}$$

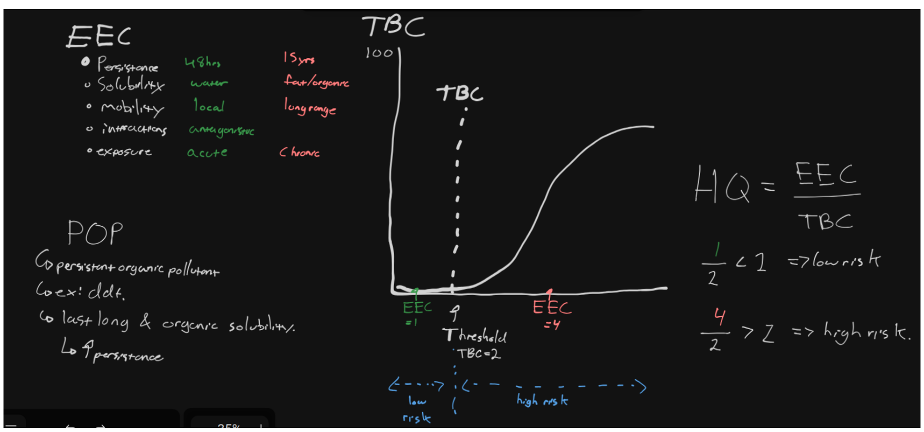
- **EEC**: expected environmental concentration - from step 3
  -
- **TBC**: toxicological benchmark concentration - from step 2
  - usually the threshold on the graph, or ED50
- HQ > 1 –> BAD
- HQ < 1 –> GOOD

Stockholm Convention

- trying to remove harmful chemicals such as POPs
  - now PCBs are a concern, spilled everywhere, never again

Example

- DDT
  - last 15 years, is bad, it kills
  - **persistent organic pollutant (POP)**, bioaccumulates and magnifies
  - concentrates over time and in food web
  - Mobility - threat of concentrating in an area
  - Exposure - chronic
  - **High EEC** - in range far right on graph, bad
- Green chemical - good
  - Persistence - 48 hours
  - Water soluble, excretes from kidneys
  - Mobility - local drift
  - Exposure - don't have to worry - acute
  - Interactions - antagonistic: cancels out, need much higher dose before response
  - **Low EEC** - in range left of threshold, good



Mercury Toxicity

- naturally occurring, can't control
- 2 Forms:
  - inorganic: liquid silverly metal
    - highly toxic, but not deadly
  - Methylmercury - organic/fat soluble

    * deadly, acquire from eating sea animals
    * humans release through industrial activities
        - then accumulate at sea floor
        - bacteria in mud transform it to methylmercury
    * **Minamata disease** - mercury poisoning, first in Japan

Mercury in Arctic

- Mercury deposited in Arctic through convection and ocean.
- Takes protein from the ocean.
- Effects worsened through biomagnification