What is the Environment?

In this course, Environment provides us with the **ecological goods and services** - We have a connection with it; **influence each other**

Forest example

- Goods: Tangible items, wood, shelter, house
- Services: trees naturally regenerate, oxygen production

Resources - Perpetual, Renewable and Non-renewable

![[Pasted image 20240110114730.png]] - Arrow goes both ways, continuum - Renewable resource shares perpetual and non-renewable features

Perpetual - Can't degenerate these resources; use forever into future

Non-renewable - Once run out its gone - Fossil fuels, take millions of years to convert - limited quantity or take longgggg time to be generated

Renewable - Regenerate through ecological service - Moving towards behaving like non-renewable - Need to manage correctly

Two Themes Explain Humanities Negative Impacts on the Environment

Theme 1: Over-Population

- 14000 BC, hunter-gatherer, productivity decreases, leave, environments regenerates
- 2024 AD, farming, productivity decreases, can't leave, ## 2 Things
- Excessive demand on resources
- forces us to stay put and not let environment recover

Industrialised vs Developing Nations

- industrialised countries have peaked in population
- Developing regions growing
-

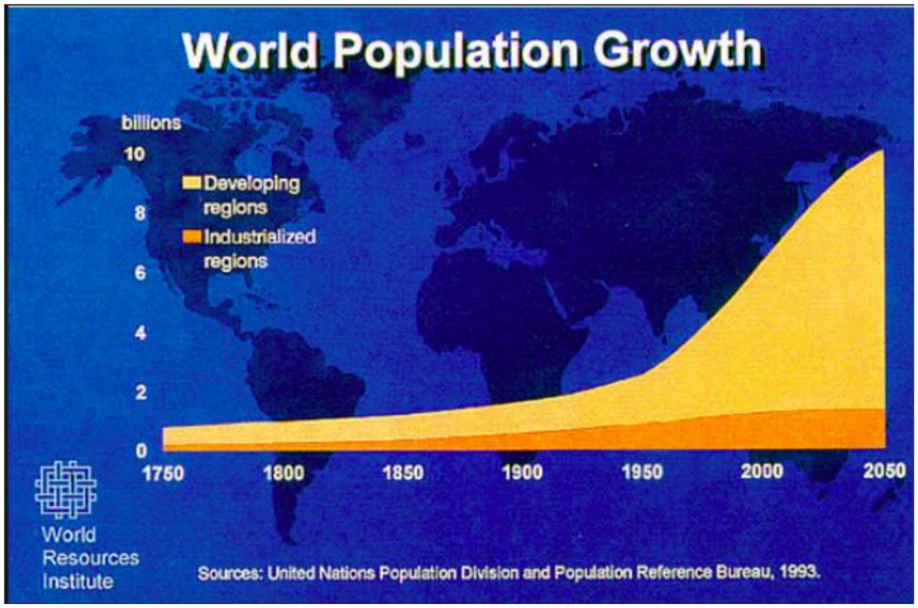


Figure 1: Pasted image 20240110120811

Theme 2: Over-Consumption of Natural Resources

- One person in an **industrialised nation** consumes far more than an individual from a **developing nation**
- **20%** of the worlds population consumes more than **50%** of the world's resources
- 1 person in Canada > 12 individuals in a developing nation!
- Related to how much money we have to spend

Why is footprint different between places

- Population: more mouths to feed = larger footprint
- Poverty = lower footprint, luxury = higher footprint
- 1.6 for whole world to sustain, Canada average is like 8
-
-

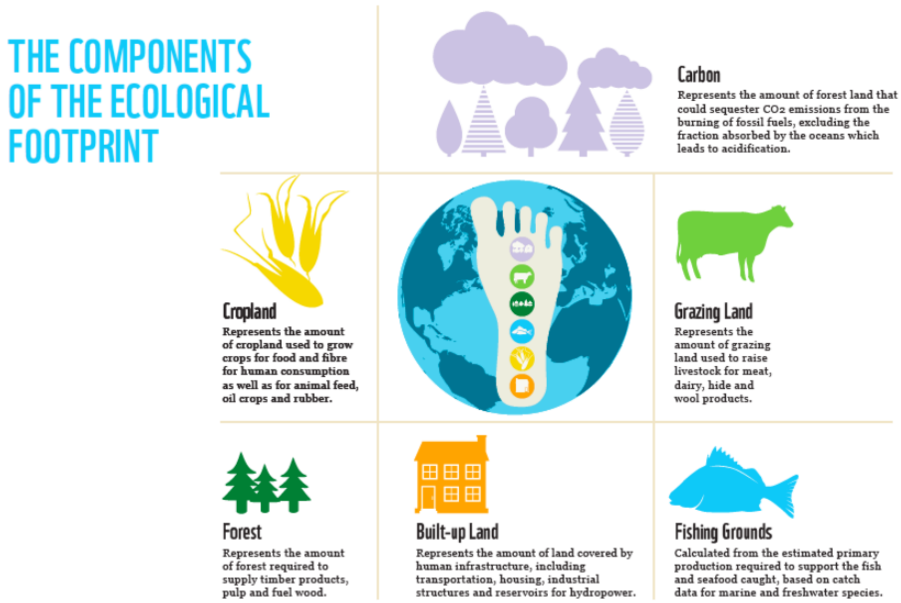


Figure 2: Pasted image 20240112120543

From Online Map

- Green was supply > demand, good
- Red was supply < demand, bad

Think about bank account

- if just take out interest, will get same interest in future
- if take out more, then will have less interest for next withdrawal (capital shrinks)

1983 - Emergence of Sustainable Development (SD)

- Control overpopulation, eradicate poverty and reduce consumption to promote environmental sustainability.

Sustainable Development:

Meet the needs of the present without compromising the ability of future generations to meet their own needs - Decision-making encompassing needs of society and human well-being; economic prosperity and all within the context of environmental limitations and constraints. - *"How can we all live well within the limitations of one planet"*

Principles of Sustainable Development – 3 Pillars

![[Pasted image 20240112121516.png]] # Environment, Social, Economic **NEEDS equal balance** between three Pillars (cannot prioritise one) - 1/3 **Environment** Pillar - 1/3 **Social** Pillar - -1/3 **Economic** Pillar

The "Science" in Environmental Science

Why do we use a foundation of scientific study to examine environmental issues? - We can devise experiments - We can study cause and effect relationships; building complexity in our understanding of how the environment "behaves". - Theories and laws about the way our natural world operates flow from scientific research - Knowledge gained through scientific research contributes to political decisions made by our governments

Example

You are walking along a riverbank and observe a pipe discharging something into the river. You continue walking and notice a change in the appearance of the water. There is a thick green mat of something floating on the top of the water column.

The Scientific Method - Example continued

![[Pasted image 20240115113930.png]]

A famous study discovered phosphorus was causing this (plant fertilisers).

Ecological Principles

- Ecology is described as the study of one's house
- Interactions of living and non-living components
- Focus attention to the processes and activities in the 4 spheres:
  - **Atmosphere**: Air and gases
  - **Lithosphere**: Rock layer
  - **Hydrosphere**: Water
  - **Biosphere**: Organisms

The focus in ecology is restricted to the superficial layer of the Earth where life exists. . . . .like the skin of an apple.

Biotic Features in the Environment

Levels of Organization found in an Ecosystem

- **Species: individuals** that share common genetic characteristics and able to breed and produce viable offspring
- **Population: members of a species** interacting in groups that live together in a particular place or habitat. Population is ONE species.
- **Community:** consists of **populations of different species** living and interacting in an area (**living**)
- **Ecosystem:** is a community (**living**) interacting with its physical and chemical environment (**non-living**). All 4 spheres.
- **Landscapes:** connections linking several ecosystems in a particular region.

Systems are "Wired" with Feedback Loops

- All component parts are interacting (ex: bodies are a system)
- Defined: The output of the system feeds back into the system as an input and leads to changes in that system.

Two types of feedback loops

- Negative Feedback Loop
- Positive Feedback Loop

Negative Feedback Loop

- Input and output essentially cancel out, stabilising the system
- Wolf and rabbit example (no significant change)

Positive Feedback Loops

- The output feeds back into the system and drives it further in one direction toward an extreme
- Population increases, no predators, keeps increasing.
- Snowball effect.

Energy Flows in Ecosystems

![[Pasted image 20240115121227.png]] - Arrows flow in one direction ; Energy flows in one direction. - Most energy is lost to the environment

Energy: Capacity or ability to do work - Organisms require energy to grow, move, reproduce, etc. - **Flows** through ecosystems in one direction as it travels in all directions from the Sun - Two forms of energy to consider: potential and kinetic ![[Pasted image 20240117113040.png]] - Sugars(glucose) are the stored energies in our bodies # First Law of Thermodynamics - Energy cannot be created but can be transformed: ### Examples - Solar energy transformed into thermal/heat energy - Solar energy transformed into sugars by plants through a process of photosynthesis

Need plants to have an ecosystem

Second Law of Thermodynamics

Energy transformations are very inefficient - As transformed there is tremendous loss that is not useful - Lots lost as heat that is unusable biologically - Heat released into air and dissipates into space.

Only about 10% is transferred each time (ex: plant -> herbivore -> carnivore), so can only have 4-5 trophic levels

A. Producers (Autotrophs) are the Solar Energy transformers

- Plants trap solar energy and transforms it into chemical/potential energy in the form of sugars
- Energy is trapped in the bonds between C and H and O
- Process is called **photosynthesis**. ![[Pasted image 20240117114738.png]] ***Carbon dioxide + Water + Solar Energy -> Glucose/Sugar + Oxygen*** Note: Glucose has Carbon.

Converted to ***kinetic energy*** by all living organisms, includes work, heat, light Process is called **respiration**. Opposite of photosynthesis ![[Pasted image 20240117115120.png]] Note that **combustion** and **decomposition** are other reactions that also result in the release of stored potential energy.

B. Consumers – Heterotrophs

- Feed on others to obtain potential energy
  - Herbivores - 2nd trophic level | Primary consumer
  - Carnivores
  - Omnivores

C. Decomposers

- Break down remains and waste products as a part of the cycling of materials
- They **DO NOT** recycle energy

Examples: Fungi, Bacteria

Flow of Energy – Food Chains and Webs

![[Pasted image 20240117115511.png]] **Note:**
- Second Trophic Level is the primary consumer, - Third Trophic Level is the secondary consumer

Food Web Example

![[Pasted image 20240117120215.png]] - Keep in mind: Relative to food chains. - Ex: Omnivore is always in at least 2 chains, and always at 2nd trophic level in at least one chain. - Better for organism to have multiple sources of food. -> Food Web Worksheet on UM Learn. # Pyramid of Energy - Big number at start of food chain, small number at top (more vulnerable to extinction). ![[Pasted image 20240117120633.png]] - Explained by second law

Sugar is potential energy, made by plants using photosynthesis plants and trees are fundamental/ultimate transformers Few trophic levels, energy lost as heat, 2nd law Autotroph -> Makes own food, self-feeder (plants) Heterotroph -> consume others

Biological Production

- A method to quantify the energy trapped by (plants)
- Measured as changes in **biomass** (weight/unit area) over time or between locations ![[Pasted image 20240117120909.png|300]]
- Used extensively to assess changes over time, between locations etc. Documents changes in desertification, deforestation, deforestation for example.

Sometimes we want a lot of energy trapped (farms), sometimes we do not (algae)

Biomass is weight per unit area

Productivity is a difference in biomass

- Assessing state of environment
- Not always good, algae example.

Why is this Useful?

![[Pasted image 20240119114607.png]] - Using satellites to determine productivity - Deep green = forest = high productivity - Oceans: Red high (heavy pollution), purple low.

Material Cycling - Bio- geo- chemical Cycles

- Materials move from one place (source) to another (sink) by way of a pathway (arrow). Call these reservoirs
- Typically involves atmosphere, hydrosphere, lithosphere, biosphere
- organisms on earth have greatly altered the cycling of chemicals because the chemicals are the nutrients to support life

Bio - organisms Geo - physical chemical - reactions

Chemicals are the Nutrients for Organisms

Macronutrients (SPONCH)

- required in large amounts as cell "building blocks"
- Carbon (C), Hydrogen (H), Oxygen (O), Nitrogen (N), Phosphorus (P), Sulphur (S)
- May also include Calcium, sodium, potassium, magnesium and chloride ions in the list given the demand ### Micronutrients
- Elements required in small amounts or moderate amounts by only some forms of life (vitamins, coenzymes) ### Availability of these chemicals influences what species will be present in the environment and how many individuals can be supported in that environment
- Size of a population; how quickly the population can reproduce
- Which species will be favoured in the ecosystem

Carbon Cycle

- Organic carbon is the stuff in organisms (associated with life/biosphere)
- Glucose is an organic carbon
- inorganic is other
- Geological and Biological Cycles for Carbon

Geological Cycle

- no life, carbon moving by physical processes, no life

Biological

- Life using it. ![[Pasted image 20240119120845.png]] # The Carbon Cycle - Geological Pathways and Reservoirs ![[Pasted image 20240119115928.png]]

![[Unit 2 - Ecology and Ecosystem Dynamics 2024-01-19 11.59.30.excalidraw]]

Label the Boxes and Arrows – Carbon Cycle

![[Pasted image 20240119120746.png]]

The Carbon Cycle

![[Unit 2 - Ecology and Ecosystem Dynamics 2024-01-22 11.36.22.excalidraw]] # Positive Feedback - More forest fires - More decomposition # Negative Feedback - put into oceans, oceans give back - photosynthesis

ON TEST

- tell me about what moves carbon around
  - different spheres, talk about processes
- Look at responses to use putting carbon in atmosphere
  - positive and negative feedback
  - positive is bad, negative good
- organic compounds create potential energy

![[Unit 2 - Ecology and Ecosystem Dynamics 2024-01-22 12.10.04.excalidraw]]

The Nitrogen Cycle

- Nitrogen sueless to most plants
- bacteria controls everything
- Atmosphere –> Lithosphere (Bacteria)

![[Unit 2 - Ecology and Ecosystem Dynamics 2024-01-24 11.36.33.excalidraw]] # Nitrogen Fixation (STEP 1) - nitrogen gas into ammonia - Rhizobium ad cyanobacteria ## Industrial Fertilizer production Humans can produce ammonia manuals

Nitrogen Cycle

1. Nitrogen Fixation
2. Nitrification
3. Denitrification
4. Ammonia and Nitrate Uptake
5. Ammonification *Memorise steps.*

Nitrogen Fixation and Ammonification are distinct (different sources on nitrogen)

![[Pasted image 20240124115000.png]]

![[Pasted image 20240124115012.png]]

Phosphorus (P) Cycle

- **No significant amount** of phosphorus gas (big difference with other cycles)
  - Exists in the form of P combined with O and other molecules – orthophosphate
- **ESSENTIAL** for biosphere, controls a lot.
- **Major reservoirs** include rock and soils; plants and animals; very little dissolved in water (unless polluted); sediments of lakes and oceans
- P liberated from rock through the slow process of weathering and erosion (or agricultural activities)
  - Slow release
  - Patchy distribution around the world
  - Guano (bird droppings) represent rich deposits from sea birds
- Phosphorus crucial element in building DNA, energy, and healthy bones.

Phosphorus out of rocks is same as carbon (hit by rain, slow) When becomes available it is rapidly taken by biosphere **IF** *gets in to water, a plant their will take it*

Phosphorus in two places - rocks - biosphere ![[Unit 2 - Ecology and Ecosystem Dynamics 2024-01-24 11.56.38.excalidraw]]

![[Pasted image 20240124115434.png]]

Human Mine for Phosphorus

Our demand for phosphorus in agricultural and domestic activities creates water pollution: - mining sources for cleaning products (shampoos, detergents) - municipalities add P to drinking water; treated effluent often has high levels of P; - a key component of fertilizers; - Improper land application contributes to runoff in water bodies and algal growth as a results (details of this to follow)

Phosphorus

- No atmosphere –> leads to patchy distribution
- Farmers need it, so they take and bring too much, then goes into hydrosphere (bad)
- Hungry plants and trees take it all before getting to hydrosphere

Carbon and phosphorus most similar Know cycles in and out Fertilizers and shampoos/detergents are forms of phosphorus

Biodiversity

- Variety of life in all its forms, levels, and combinations within an area

- Diversity is generally defined on four fronts: **(LEGS)**
    - **L**andscapes
    - **E**cosystems/habitats
    - **G**ene pool
    - **S**pecies and *three components(evenness, richness, and dominance)*
- Biodiversity is linked to the goods and services we rely on to fulfil our requirements

forests have the most biodiversity, ground, tree, etc. Chop it down, it is gone we rely on the diversity of species in our world, future

`![Why are Wildlife Important?](https://www.youtube.com/watch?v=7tgNamjTRkk)`

What are the five reasons biodiversity is important to us? (Will be on test)

1. **Economic value**
    - fish, timber

- **Ecological life support**
    - Services it provides, water purification, oxygen
- **Cultural value**
    - Indigenous paintings, historic culture, kangaroo, bison
- **Recreational Value**
    - Leisure, walk in parks, swim in lakes, go to beaches
- **Scientific Value**
    - Pursuit of knowledge, cancer care, NASA

Negative value: Diseases, killed by crocodiles

We Must:

- address biodiversity decline
- understand complexity
- inform resource use discussions ### Ecosystem Management
- Community involvement
-

    ### Public involved

    ## How Many Species Are There?

- Estimates of total number range from 3.6 to 100 million species, around 10 mil

    - Canada has 160,000 species, because weather

Four factors contribute to variations in species diversity: (GLAS)

- **Geographic isolation** reduces biodiversity by limiting gene dispersal
    - Cut forest, roads, city
- **Latitudinal Gradient** - Biodiversity is greatest at the equator and declines with latitude and is associated with climatic stability in temperature and precipitation
    - Moderate temperatures towards equator. Higher latitude = lower biodiversity
- **Age of the ecosystem** - tropical regions are "older" because they did not undergo glaciation and this has promoted the evolution of new species
    - Ice age kill diversity. Older = more biodiversity
- **Structural complexity of the ecosystem** – forests offer more ecological niches than grasslands
    - Squirrel in forest vs. in grassland

Age from ice ages, not higher latitudes being colder

How Do Scientists Evaluate Biodiversity within Ecosystems?

Require Three Measurements:

- **Species Richness:** # of species
- **Species Evenness**: # individuals per species
- **Dominance**: is there more of any one species ![[Pasted image 20240129114713.png]]![[Pasted image 20240129114723.png]]
- Richness: same
- Evenness: different
- Dominance: bottom ecosystem is dominant **Conclusion:** Top has more biodiversity

Ecological Niche

Ecological Niche represents a multi-dimensional view of **everything** an organism does: - Adaptations to live in water, fly or run on the savannah - Use of resources - Interactions with other organisms - Lifestyle

Organisms cannot live in complete isolation and will be influenced by others. The individuals whether in the same or different species must compete for their resources.

If they have exactly the same needs, one species will outcompete and lead to the exclusion of others

*To minimize this competition species will alter aspects of their ecological niche. This is called **resource partitioning** ![[Pasted image 20240129115750.png]] Fundamental Niche: Where species could theoretically use resources Realised Niche: Where they must use resources because of competition

Specialist ALWAYS vulnerable to extinction, like Panda Generalist: wide range (lives everywhere, does what it wants, eats whatever)

Symbiosis - Mutualism

- Sharing benefit *Bee feeds on nectar to acquire food and in so doing it is covered by pollen that can be transported to the next flower and contribute to pollination*

Symbiosis - Commensalism

- One species benefits, other not affected *Barnacles on whales*

Symbiosis - Parasitism

- Parasite benefits, host is "harmed" *Ticks*

Predation

- Consumption of one species by another
- Elaborate predator-prey strategies develop
  - Nocturnal behaviour
  - Live in social groups
  - Mechanical and chemical defences
  - Camouflage

The Importance of Species to Ecosystems

Keystone Species

- Impact on ecosystem is massive (nutrients, physical), more than expected
- If removed, there is an expected substantial change to the ecosystem
- Analogy to stone piece (keystone)
- Can be any type of organism (anywhere on food chain) ![[Pasted image 20240131115044.png]]

Example - Prairie Dogs are a Keystone Species

- Burrow in ground
  - Brings up nutrients and seeds buried in ground
  - Productivity increase, diversity increases
  - Burrow dens become home for other species
- Herbivore
  - eat plants to spread seeds and nutrients
- Food for Carnivores
  - Needed to be eaten

Wolves of Yellowstone National Park - In-class video

How influence biosphere, physical processes (erosion, flow rates)

Watch the video and find examples of the over-arching influence of the wolves of Yellowstone National Park on: - Populations and Communities - Nutrient cycling ### Notes - tree height, - birds came - beavers built dams - otter, fish etc. - less coyotes, number of rabbit, more eagle, bears, more berries - Bears kill some wolf cubs - changes river, meander less, more pools, - forests stabilises banks, less erosion, less deer and more vegetation mean soil erosion *Keystone because we could tell from before an after affect, typically we only realise when a species is remove. We know prairie dogs are a keystone species because we removed them for agriculture and then realised degradation*

Measuring Species through Population Dynamics

- **A population is ONE species**
- Dense population, waste, then disease
- Take all of their food source, geese destroy soil

Factors Affecting Population – Size and Growth Rate

Population Growth Rate

- The percentage increase in a population over a period of time
- birth rate, immigration ; deaths, emigration ![[Pasted image 20240202113240.png]] ### Doubling Time
- The ***time*** needed for a population to double its size assuming the growth rate remains the same.
- 5% takes 14 years to double population. That's high.

Growth Patterns in Populations

Exponential Growth - Increases by a fixed percentage (rate of growth) over time (hours; years)

- Takes on J-shaped in which it is slow at the start (lag) and then a small change in time results in a dramatic increase in population size
  - Think couple getting comfortable in new home first then later breed in the ideal conditions
- Characteristic of small rapidly growing species such as bacteria and fungi
- Requires ideal environmental conditions to promote the rapid growth

Logistic Growth Pattern

- Population first grows at exponential rate but then slows as one or several environmental factors become limiting
- Population no long increases in size.
- The number of individuals remains relatively constant after this point (carrying capacity) ![[Unit 3 - Biodiversity and Management 2024-02-02 11.35.54.excalidraw]]

Carrying capacity

- Maximum number of individuals that can live in an environment
- Healthy environment = high carrying capacity
- doesn't stay the same.
- If population below capacity = stability.

Consequences of Unregulated Population Growth – Snow Geese Population Predictions

![[Pasted image 20240202115207.png]]

Case Study: Snow Geese Population Explosion

`![](https://www.youtube.com/watch?v=u1Wgt-OsZM)`

Answer the Following

- What are the habitat and ecosystem requirements for the snow geese and how do these influence population dynamics?
- What is/are the limiting factor(s) to snow geese populations?
  - food, predators
- Why does the population continue to grow exponentially regardless of the limiting factor?

    - humans, farms, remove predators
- What are the consequences of unrestricted population growth?
    - Decreased carrying capacity
    - Indigenous have less food
- What does the population growth curve appear as? Can you identify the carrying capacity, population overshoot and die back?
- What evidence is there that the population has exceeded its carrying capacity?
    - Mudflats
    - Different vegetation ![[Unit 3 - Biodiversity and Management 2024-02-02 11.54.43.excalidraw]]

Says to review this [[Climate Change Fact Sheet (by Environment Canada).pdf]]

Component Parts of Earth's Climate Change

- 4 Spheres and the sun
- Sun is main driver
- Water is crucial in all stages
- 70% of earth's surface is ocean
- atmosphere is protective blanket, ozone protects radiation
- forest converts energy, change climate

Incoming Radiation - The Electromagnetic Spectrum

![[Pasted image 20240209113909.png]] - Role of atmosphere is to screen out shortwave radiation like ultraviolet - Infrared radiation is heat, not harmful, long wave, leaves earth(outgoing) - visible light (incoming) used for photosynthesis - plant leaves green because chlorophyl, uses reds and blues, but not green - Green light is reflected back at use, plant doesn't use green - but absorbs others –> absorbs heat - Black T-shirt absorbs, white reflects (cooling) - Planet doesn't absorb the infrared, it absorbs visible light, colour depicts how much colour is absorbed

The atmosphere has distinct layers and provides numerous services essential to life

- **Thermosphere**: aurora borealis, gamma rays and x-rays absorbed (heated)
- **Mesosphere**: temperature dropping
- **Stratosphere**: ozone layer (absorbs UV radiation, generates heat), pollution(CFC)

- **Troposphere**: life ![[Pasted image 20240209115532.png]] Pause: boundary, no change in temperature

Earth's Energy Budget

![[Pasted image 20240209115715.png]] - 70% energy is absorbed, 30% reflected - atmosphere is 20% absorbed, 20% reflected - 6% land surface contributes to reflection - Greenhouse gases play their role on the outgoing side of the relationship where they absorb heat - 47% absorbed by land and ocean - land is 6-10% reflected, 50% absorbed # Not All Surfaces Are Equal in Energy Absorption/Reflection - Albedo **Albedo** is a measure of the **reflectivity** of the Earth's surfaces - Light coloured surfaces have highest albedo because they reflect more energy than they absorb; dark coloured surfaces, vegetation and oceans have low albedo because they absorb more than they reflect ![[Pasted image 20240209120145.png]] - oceans: 5% reflected - Heat Island –> warm over city/ human activity - Chlorofil does not absorb green

Incoming Solar Radiation – Influenced by the curvature and axis of inclination

![[Pasted image 20240209120947.png]] - More intense sunlight (smaller illumination) at equator than poles that leads to a **temperature gradient and seasonal differences with latitude** - winds

More intense sunlight (smaller illumination) at equator than poles that leads to a temperature gradient and seasonal differences with latitude

![[Pasted image 20240209121127.png]] - Atmosphere and oceans redistribute heat - Greenhouse gases like a blanket, don't let heat escape - energy leaving earth is longwave infrared radiation - Organism (humans, earth) emit heat loss to the atmosphere (heat = infrared) - Hot air rise = rain at equator tropical forest and 60 degrees north at boreal forest - Cold air, fall = dry, deserts, Antarctic is driest, cuz convection

The Atmosphere Radiates IR or Heat

- The atmosphere radiates the equivalent of incoming sunlight back to space as heat (IR). This includes:
  - Energy that was absorbed by the atmosphere (particles, clouds, ozone)

    - Energy that was transferred to the atmosphere from the Earth's surface by evaporation and phase changes in water, conduction/convection, and thermal infrared radiation/latent heat.
- What happens to this heat heading back out to space?
    - Greenhouse Gases absorb a portion of this IR in the troposphere
    - Some of the thermal infrared energy escapes to space through a "window" effect

![[Pasted image 20240212114636.png]] - Evaporation = cooling, heat going to atmosphere - oceans will also get saltier from evaporation

Convective Currents Help to Redistribute Heat Energy

![[Pasted image 20240212115009.png]] - Warm air less dense, more energy, move more, High –> Low pressure

6 Giant Convection Cells Distribute Heat Toward Poles and Contribute to Long Range Transport

![[Pasted image 20240212115240.png]] - Warm air at the equator rises and cooler air at the poles descends. - So, low pressure = warm and humid and rain - Precipitation patterns leads to arid bands at defined latitudes.

Redistribution of Heat by the Thermohaline Gradient (Ocean Conveyor Belt)

- Thermohaline = heat salt, gradient = difference
- Driven by temperature and salinity differences
- Water changes to ice at polar regions and expels salts
- The colder denser water sinks to the sea floor pushing water
- In other areas of the ocean, upwelling brings nutrients back to the surface ![[Pasted image 20240212120417.png]]
- gives heat to Europe (hot body to atmosphere), moves cuz heat and winds, this heat generates evaporation, which generates more salty and heavy water
- The salty water in the arctic is now cold and create a huge waterfall
    - Need cold and salty water, it is dense
- melting glaciers make the water less salty, affecting conveyor belt

Upwelling, when conveyor belt heads toward landmass it rises - this recycles important nutrients for plants and animals

Outgoing IR is Absorbed/Re-emitted By Gases in the Atmosphere (Greenhouse Gases)

- Greenhouse gases are like a blanket, keep heat in
- 4 blankets, one naturally occurring and good, 3 are human caused
- Natural:
  - Composed of water, corban dioxide, and others
  - water vapour is largest contributor to warming influence : 65%
  - Carbon dioxide is 25%
- Human / Cultural:
  - Carbon dioxide blanket
  - CH4 and N2O blanket, and bad Ozone
    - CH4 (methane), like from cattle,
      - **high decomposition without oxygen = methane**
      - Only get halfway through decomposition reaction, not enough oxygen
      - Hydro is a major source of methane
      - Methane is 25x more powerful than carbon dioxide
    - N2O (nitrous oxide)
      - bacteria on land with ammonia creates it
      - 200-300x more powerful than carbon dioxide
  - CFC (chlorofluorocarbon)
    - in fridges, synthetic chemical
    - eat away ozone
    - 5000x more powerful than carbon dioxide

Today We Are In A State of Positive Radiative Forcing – Net increase in energy and temperature

![[Pasted image 20240216115941.png]]

Vostok Ice Cores Help to Reveal How GHG Concentrations Varied Pre-Historically

- Ice cores trap gases as they form and samples can be extracted for analysis
- 3600 meter core equates to 400,000 years ago.
- Ice cores also yield information about precipitation and temperature.

When CO2 is plotted with temperature, there is a strong correlation over 4 cycles.
![[Pasted image 20240216120220.png]]

Trends in Carbon Dioxide Concentrations – Modern Measurements

![[Pasted image 20240216120339.png]] - zig zag on annual basis from seasons, less CO2 in summer cuz photosynthesis

Positive Radiative Forcing – Net increase in energy and temperature results because of the energy imbalance between "what's coming in from the Sun and what's leaving from the surface and atmosphere ![[Pasted image 20240226114946.png]] - cant exceed 2 degree anomaly

Effects of Human-Induced Changes in the Climate Budget

- Energy imbalance means more of the outgoing infrared radiation is trapped in the lower atmosphere
- Interactions of this trapped energy leading to pronounced changes in the ecosystem
  - **Severe Weather -** Patterns and Occurrences
  - **Biosphere** – increase loss of species, change in distribution
  - **Pedosphere/Lithosphere** – Soil degradation and loss of agricultural production
  - **Cryosphere** (frozen water) and **Hydrosphere** – patterns in snow and ice melt; severe weather etc.

Arctic Amplification Relates to Ice-Albedo and Positive Feedback

![[Pasted image 20240226115316.png]]

Arctic amplification has resulted in >4oC annual temperature and far greater than anywhere else on the planet

![[Pasted image 20240226115404.png]] - Affects albedo, decreases, exposed water absorbs more, positive feedback

Arctic Amplification is Driven By and Resulting In Changes in the:

- **Sea Ice** – leads to a reduction in albedo and but reveals the underlying water that will rapidly warm because of positive feedback. This has driven the temperature anomaly now observed
- **Greenland Ice Sheet** – land-based ice that discharges freshwater into the Arctic ocean. The addition of this water is causing sea level to rise and concerns that the ocean conveyor speed will decline. Ocean circulation will be significantly reduced that will cool Europe and reduce fish production.
- **Permafrost Soils** – melting of the ice deep in soil profiles contributes to collapsing soils, production of carbon dioxide and likely methane. The latter would result in pronounced and rapid warming everywhere else on the planet

Sea Ice

![[Pasted image 20240226120713.png]]

- Extent of Arctic Ocean covered by ice is about ½ by the end of the animation (and therefore greater ocean absorption and heating)
- Thicker/old aged ice is attacked and thinned that would typically stabilize ice sheet when wave action could sheer ice into smaller pieces.
- End result – rapid warming; ice free Arctic Ocean projected in summer months.

Greenland (and Antarctic) Ice Sheets

- Land-based ice sheets
- melting adding about 2 mm sea level rise annually with estimates of 3 feet already committed but could increase with severity of melt
- Extreme flooding and risk must consider:
  - environmental refuges from islands and coastal regions
  - loss of important ecosystems flooded by salty water
  - changes to the ocean circulation affecting not only redistribution of heat but also ocean productivity of marine ecosystems
- Concern of incredible sea level rise should the Antarctic ice melt

Outcomes:

- Greenland ice sheet melting and discharging freshwater; calving ice at a faster rate
- Committed sea level rise of 3 m projected to 6 m that will result in catastrophic losses in coastal regions

Permafrost Melt

Carbon Emission (permafrost will no longer be a sink for carbon storage but a source!) - land is slumping and rates of soil erosion are alarming - Potential for enormous amounts of CH_4 and CO_2 to be released that will lead to "run-away" climate change for the rest of the world

Positive Feedback – Release of Carbon Dioxide and Methane in the Arctic

![[Pasted image 20240228121651.png]] - Twice as much carbon is stored deep in permafrost soils as is present in the atmosphere - Warming soils accelerates decomposition that releases CO_2 and methane - Expect a positive feedback response contributing increasing amounts of CO_2 and CH_4 to the atmosphere!

What are the impacts to us?

With a rapidly warming Arctic (and Antarctic) how will this cause problems for Humanity? - we have warmer oceans……causing? - we have more water in the oceans……leading to? - we have more moisture in the atmosphere…..causing? - we have more rapid melting of snow packs and glaciers - more heat in the atmosphere…..leading to? ![[Pasted image 20240228121824.png]]

What Can We Do?

- Paris Agreement
- Individual actions
- Opportunities in technologies?
- Landscape alterations that alter carbon uptake/sequestration

Ecosystem Management is a Decision-Making Tool

- allows society to achieve societal goals
- How we implement sustainable development
- Is directly connected to the concepts of sustainability through the integration of:
  - ecological,
  - social, and
  - economic components
- Achieving societal goals in a defined geographic area for the interacting biotic communities and their abiotic attributes

  - Note that humans are a component of any ecosystem
- Used to enhance environment decision-making in societies best interest

12 Principles - 3 Important

- **Management with a focus on societal choices**
  - e.g., Should we develop the natural resource or preserve it? Should we prioritize conservation due to species at risk?
- **All encompassing in knowledge and inclusion of information**
  - not just scientific perspectives but Indigenous, Metis, Inuit; farmers and local land owners, foresters etc.
- **Everyone should be included and has a voice**

12 Principles are Developed Into 5 Steps (A-E)

Step A: Determining the main stakeholders, defining the ecosystem area, and developing the relationship between them **Step B:** Characterizing the structure and function of the ecosystem, and setting in place mechanisms to manage and monitor it **Step C:** Identifying the important economic issues that will affect the ecosystem and its inhabitants **Step D:** Determining the likely impact of the ecosystem on adjacent **Step E:** Deciding on long-term goals, and flexible ways of reaching them

Steps A & B most important

Step A: Geographic Boundary

- **Jurisdictional basis** – map with subdivision
  - e.g. Canada represents the management area; Province of Manitoba
- **Administrative basis** – districts/sub-zones within the province – conservation districts where there might be unique goals and objectives/priorities; a national or provincial park
  - national parks use administrative boundary
- **Ecological basis** – defined based on the ecological features
  - terrestrial; aquatic; species specific
  - more holistic
- **Combination of the above** – check out Royal-wood example from the textbook
  - combination of priorities/objectives

Step A - Identifying Stakeholders

- Government Agencies
  - National

  - Regional (State/Provincial)
  - Local
- Non-Government Organizations (NGO's)
- Business/Industry
- Residents of Cities, Towns, Villages
- Indigenous/Cultural/Religious Components
- Others
- Organized into Primary (Local Residents), Secondary (Government) and Tertiary (NGO) Stakeholders

Step B – Describe Features and Relate to Goals

- Characterize the main biotic/abiotic features of the ecosystem with stakeholders
  - Joint mapping, ground-truthing, exploratory walks
- Decide on management objectives as these relate back to the ecosystem structural and functional features
- Use baseline information from surveys of the ecosystem but also available knowledge from all stakeholders (builds trust)

Step C – What are the Key Economic Considerations

- Try to eliminate negative economic incentives (high taxes, environmental damages)
- Create positive economic incentives (subsides in beneficial development, awards, reduced taxes)

Step D - Adaptive Management

- What's happening to the adjacent ecosystems?
  - Minimise negative impacts

Step E - Over Time...

- Create long-term goals and flexible ways of reaching them

Canadian National Parks

- Country-wide system of representative natural areas
- protected by law, public understanding and appreciation are key BUT ecological integrity is maintained for the future

- **Ecological Integrity** means keeping ecosystems healthy and whole - a state where biodiversity, structure, and functions are unimpaired and will persist
  - Historical shift from ***monumentalism*** (gape in awe)

Case Study: Riding Mountain National Park (RMNP) in Manitoba

- can't have ecological integrity
- considered a biosphere reserve
- elk live in fragmented habitat (interactions between elk and cattle are problematic)
  - elk have pathogen (Bovine Tuberculosis), cattle will die
  - elk see good food off of park

Problem - RMNP is an Ecological Island

- Duck Mountain Provincial Park north of it
- Lots of vegetation there compared to surrounding area
- genetic inbreeding
- need to let them migrate

Ecological islands can be trees surrounded by crops, or roads disconnecting areas

Park Biologists (Have) Estimated the Minimum Viable Population (MVP) to Conserve Biodiversity

- MVP - smallest population that can maintain itself and its genetic variability indefinitely
- carrying capacity not necessarily the objective
- Researchers tracked elk to determine habitat range requirements and MVP
- Conclusion: Elk utilize more than protected area; engage with cattle in private lands, also in duck mountain
  - So, doesn't meet ecological integrity, not enough area for elk in RMNP

How to Solve the Problem (1): 'safe passage' by creating wildlife and conservation corridors

- corridors to connect fragmented pieces

Solve the Problem (2): Establish buffer zones and biosphere reserves

- diverging interests
- Create buffer zone around protected areas, where everyone works together
  - zone of cooperation: functionally extending area of the park ![[Pasted image 20240306120914.png]]

RMNP Biosphere Reserve:

- Cattle are relocated to government/crown land and public pastures to remove the threat of TB transfer between elk and cattle Park "behaves as though boundaries were extended an additional 12,000 km2 (black border).
  - fixing ecological integrity

Outcomes of the RMNP Biosphere Reserve

- RMNP was able to maintain the ecological integrity of elk by allowing the animals to freely travel from the core area of the park to the Duck Mountains.
- The minimum viable population has been successfully maintained in the face of potential conflict.
- The landowners who were affected by bovine tuberculosis were able to move the cattle away from the high-risk areas.
- The First Nations representatives were able to satisfy their cultural pursuits by harvesting more elk around the park area

KNOW HOW MANAGEMENT STEPS WERE USED IN STUDY

National versus Provincial Parks

- **Provincial Parks Use a Model of Conservation**
  - Use a model based on the three pillars of SD: environment, social well-being, economic development
- **Federal Parks use a Model of Preservation**
  - Protects species or landscapes without reference to Human interests
  - Uses a **historical reference** to identify the features worthy of preserving
    - looks at past to see what to preserve, or goal
- **We see this difference in management philosophy as well:**
  - Federal Parks are limited in how tourism activities develop, cottage and recreational development is quite restricted; forestry, mining, and other resource extraction excluded from federal parks

    - Provincial parks will entertain all of these activities when it is deemed to be in Society's interest to do so. In some circumstances (e.g., species at risk), the protection of the species is a priority and other activities are excluded. Parks could be designated as wilderness only.

Population Loss - Major Threats to Biodiversity Leading to Extinction

- **Anthropocene Era**: Humans are responsible for the 6th mass extinction of biodiversity
- **Major Threats to Biodiversity include:**
    - overhunting, poaching and overfishing
    - air, water, and soil pollution
    - loss of habitat and fragmentation of existing habitat
    - climate change
    - introduced species that share the same ecological niche and able to outcompete
    - human population and overconsumption

Why are Some Species More Vulnerable Than Others?

- Long Lived and Delayed Maturity
- Low Reproductive Rates
- Limited Habitat Availability and Challenged to Establish New Locations
- Breed in Colonies - high density at seasonal times
- Specific Requirements at Life Stage - example is hibernating
- Niche specialisation

Animal Species in Trouble - Not tested on

![[Pasted image 20240308121048.png]]

Biodiversity Conservation

- Internationally **IUCN**, Convention on Biological Diversity
    - if IUCN classifies as endangered then so does Canada
- Canada, Biodiversity Strategy (SARA)
    - Provincially, endangered species act

For sustainable development

International Union for the Conservation of Nature (IUCN)

- Report status of species, endangered, health of biosphere
- How humans interact with species
    - Reported through Red List

SARA stuff is important # Canada's Species At Risk Act (SARA) - To **prevent** Canadian indigenous species, subspecies, and distinct populations from becoming extirpated or extinct - To provide for **recovery** of endangered or threatened species - To encourage **management** of other species to prevent them from becoming at risk

SARA Categories

- **Extinct** - A species that no longer exists.
- **Extirpated** - A species no longer existing in the wild in Canada, but occurring elsewhere. Could be province, or region as well
- **Endangered** - A species facing imminent extirpation or extinction.
- **Threatened** - A species likely to become endangered if limiting factors are not reversed. **This is where recovery strategy comes into play**
- **Special Concern** – A species particularly sensitive to human activities or natural events

RENEW Canada Program

(Recovery of Nationally Endangered Wildlife in Canada) - Component of SARA, to assist species to recover population sizes - Unique to SARA, other nations may not have recovery management

Woodland Caribou

- Roads allows deer and wolves into caribou area, so removed them
- encourage liken production in forestry
- Collared them to track, life stages, what they eat, disease.
- Stakeholders were indigenous, government, industry, feds, NGO's (non governmental organisations)

will ask about Wimby international park, mountain gorilla and woodland caribou, and Great Bear Rainforest

Step A: Geographic locations included, stakeholders Step B: Features/characteristics, abiotic & biotic environment

Invasive Species

- No natural predators
- outcompetes native species
- changes features of ecosystems (food web, physical processes)
- Kill biodiversity
- Originate from humans (ex plane)
- Economic losses
- Health concerns
- Recreational losses

Canada Particularly Vulnerable to Invaders from Southern USA

- Geographically, it is not difficult to transport invaders because the Mississippi watershed is in close proximity to the Great Lakes and Hudson Bay basins
- Public education is critical to stopping invaders at borders

Aquatic Invaders Came to North America Through Ship Ballast

- Cargo tankers take on water in their country of origin
- Ballast water stabilizes the ship
- Ship dumps ballast water at destination (Great Lakes)
- Around five billion tonnes of water, carrying a multitude of micro- organisms, eggs, larvae and larger organisms, are now transported annually as ballast

What is a Forest Ecosystem?

- Plant community dominated by trees and woody plants, shrubs,
- vertical layers, floor, canopy
- Biodiversity, filter air, freshwater, build soils

Forest Regions in Canada

- Boreal Forest (70% of Canada)
  - little scrubby trees, wildfires, outcroppings(boulders)
  - Coniferous trees (Christmas), needles affect soils
- Deciduous Forest (South)
  - Leaves that fall, affects soils increase fertility

- Coastal Rainforest (West) (video)
  - Old growth temperate rainforest

Stresses to Canada's Forests

- Logging
  - Harvesting previously uneconomical trees
  - Cumulative impacts
  - Threatens biodiversity
- Mining
- Hydroelectric development
- Climate change (pine beetle)
- Acid precipitation (particularly for deciduous trees)

Forest Types

Secondary growth

- Regenerating forest after natural disturbances or forestry operations (10-50-100 years)
- Trees more closely spaced
- Rapid growth on forest floor, cuz of successional stage
- Less biodiversity than Old Growth, one canopy layer, fewer niches ## Old Growth
- Really old 100-500 years
- Matured to end stage, not much more growth
- Unique biological features
  - large live trees
  - large dead trees
  - Large logs on forest floor
- Multiple vertical layers, different trees species in some cases
- Tremendous number of ecological niches for biodiversity

Harvesting (Silvicultural) Systems

Clear Cut

- Mow everything down
- Forests have **even-aged** structure ## Selective Cut
- Figuring out what you want to take, size, quality
- Safe zone for wildlife
- forest regenerates naturally
- **Uneven-aged forest** is maintained
  - old and young trees

- Woodland caribou need 65% of boreal forest
- UofM researcher theorised if we could cut forest block such that it seemed like a wildfire, then the caribou would be fine, cuz caribou were used to it
- Found where all forest fires took place for 60 years ![[Pasted image 20240315115336.png]]
- Green is corridor retention
- Yellow is island retention
- Red is what you can cut
- Showed that forest won't recover the same way as a wildfire; no ash to stimulate growth
- so, they strip the tree branches and bark to decompose
- For some trees, the fire stimulates the seeds, thus growth

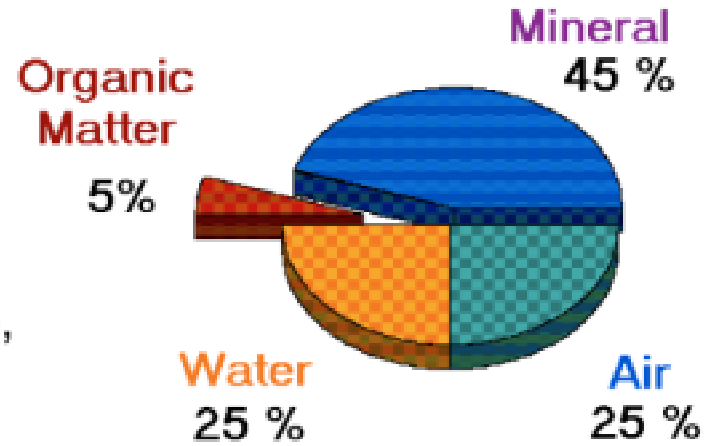
Soil Features

- **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

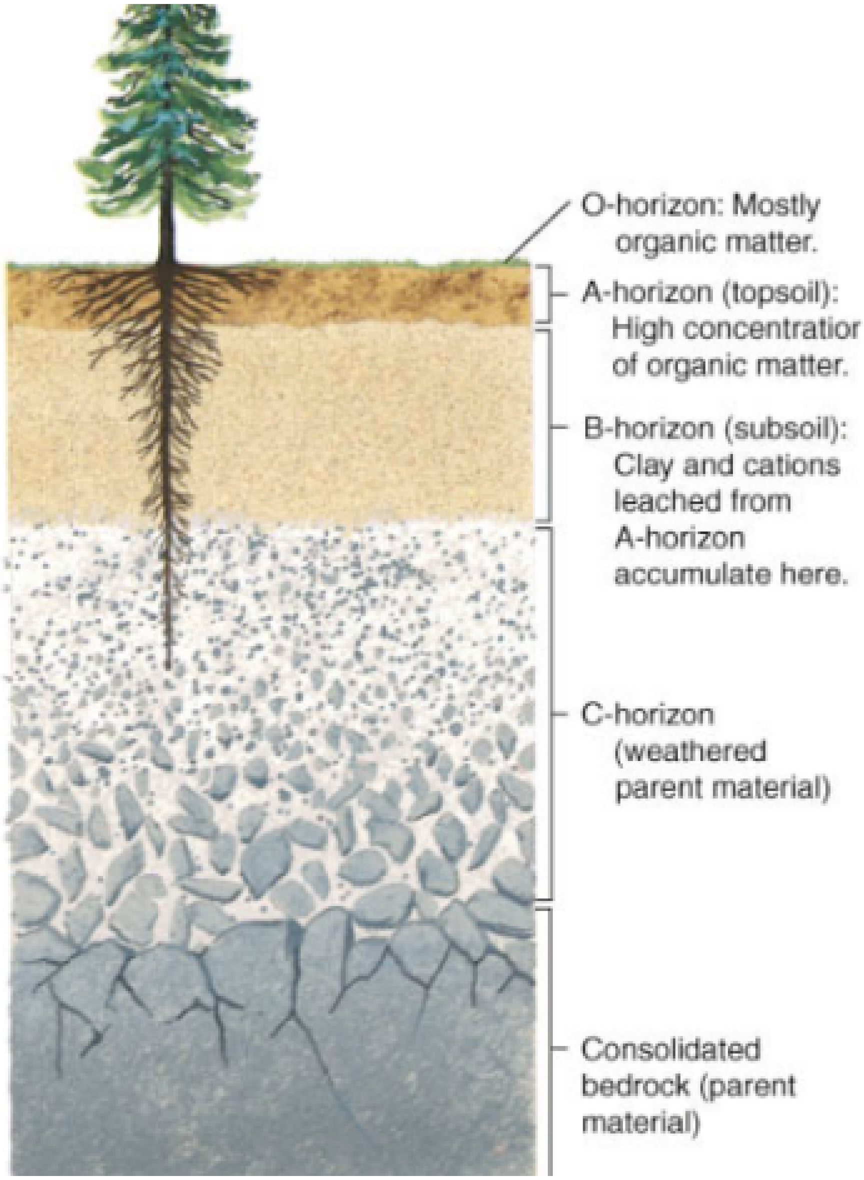
- balance between physical features
  - moisture and ability for water to infiltrate
  - degree of aeration that promote health root
- 4 major components:
  - Soil organic matter (SOM) - 5%
  - minerals - 45%
  - water - 25%
  - air - 25%



- 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



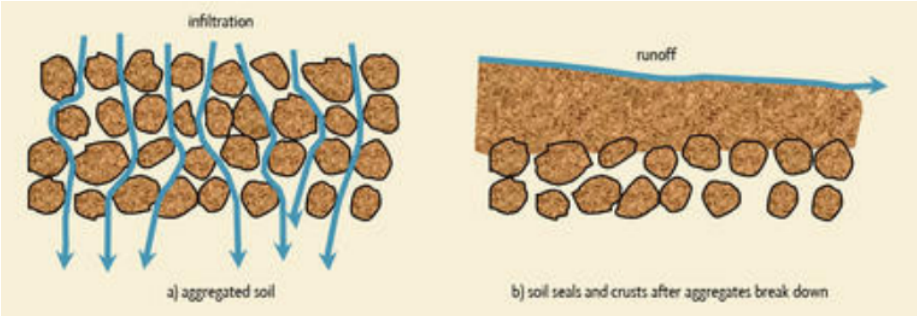
Soil Texture

- 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 $\neq$ 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

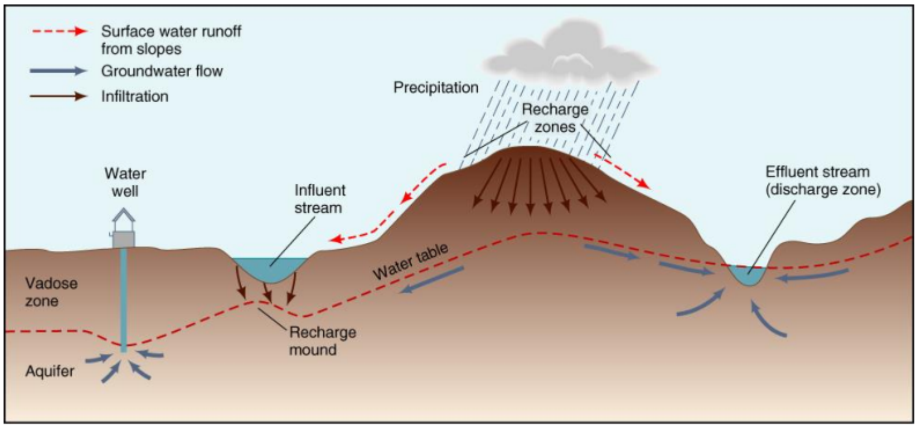
- can happen in water if too much decomposition
- opposite of photosynthesis reaction # Properties of Water
- High heat capacity - holds lots of energy
- Ice expand when freezes - floats on water
- Moderates climate
- Universal solvent - dissolve almost anything

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

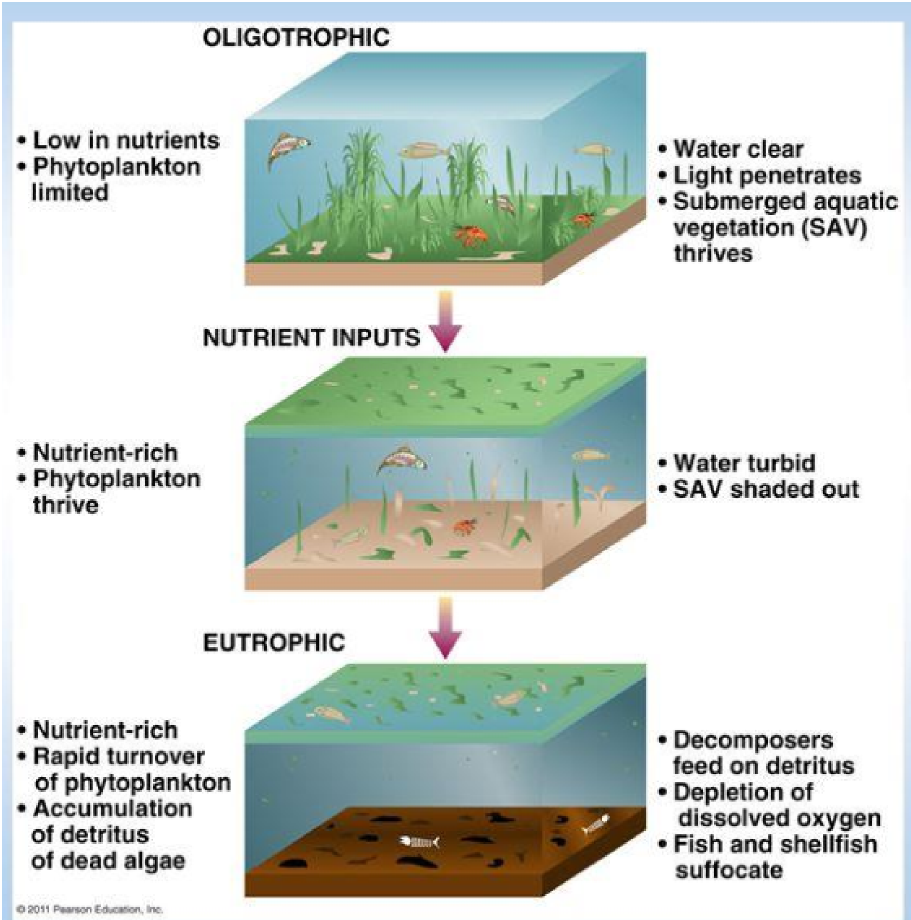
  - **Dead Stuff (Organic Carbon) -** energy
- **Biotic Responses - plants** like algae(influence oxygen), **fish** are good, **bacteria** (eat dead stuff, demand oxygen, suffocate fish)

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

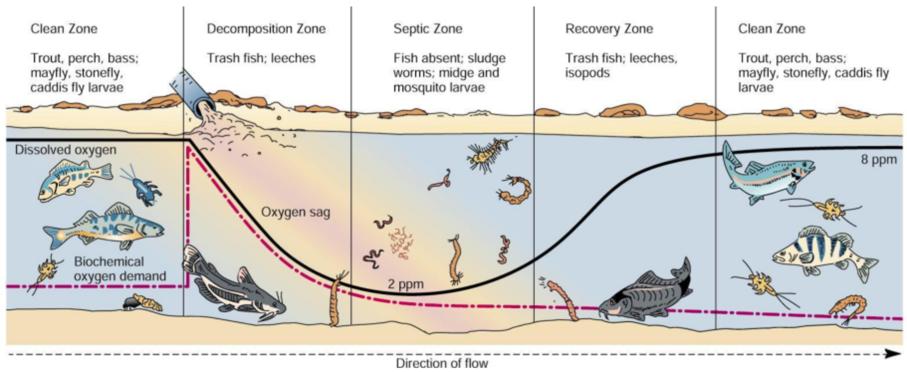


- after all dead, decomposers take all the oxygen for their decomposition reaction, anoxia, no oxygen, eutrophication kills fish, ** # Decomposition and Oxygen Sag
- uses DO, dissolved oxygen
- Org-C + DO → $CO2$ + $H2O$
- More food (Org-C) for decomposers = higher decomposition rate
- Sources of Org-C
  - 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

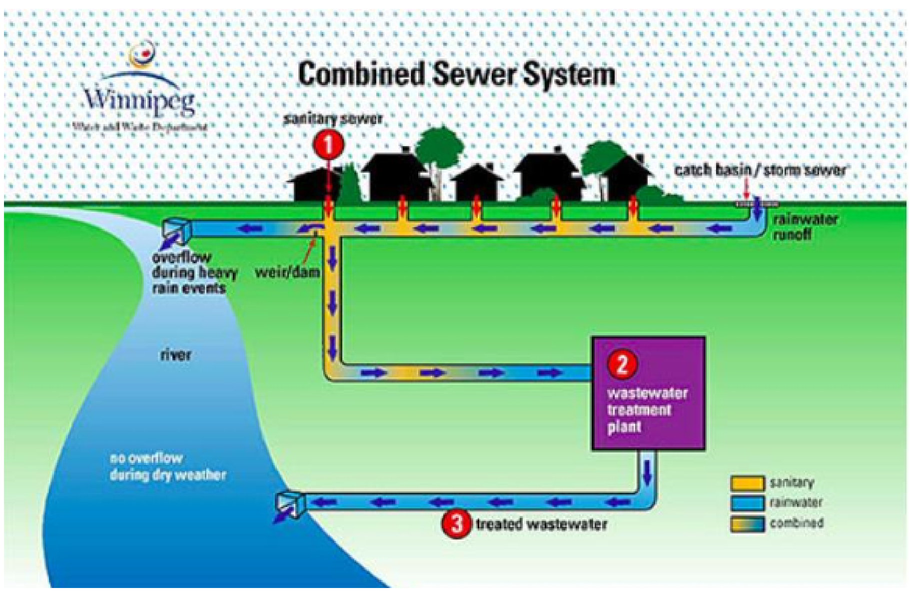
Municipal Sewage Treatment

- 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 CO_2

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

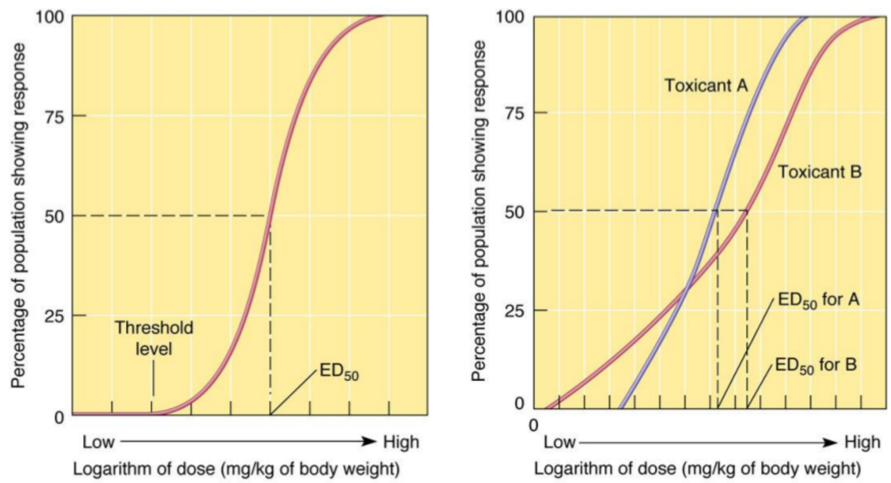
- Mutant individuals become resistant over repeated exposure, evolution
- Over time they become majority of population
  - Rebound: after pesticide, mutants multiply/reproduce
- New or more pesticides required

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 does 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 ![[Unit 8 - Ecotoxicology 2024-04-10 11.29.14.excalidraw]] # 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