Chapter 1: An Introduction to Environmental Science

- Everything is connected!
- Understanding these connections and their context is key to understanding how it functions
- Everyone has a role to play – everyone contributes to a community
- "The environment" is a complex concept
- The way we relate to the environment shapes (and IS shaped) by our world view
- Environmental science seeks to understand natural patterns and human influences on them
- The world faces a number of "wicked problems"
- We differ in how we perceive and prioritize environmental problems
- The interdisciplinary nature of environmental science makes it well suited to address complex problems
- Environmental science helps us understand our relationship with the environment and informs our attempts to solve and prevent problems.
- The global community faces many challenging environmental problems –science can help us find balanced, sustainable solutions.

Chapter 2: Matter, Energy, and the Physical Environment

- Science is a process and a body of knowledge
- The scientific method is a series of steps to evaluate hypotheses
- Descriptive studies have their place, but hypothesis testing is the foundation of science
- Experiments are good at determining causality, but not always possible
- Correlational studies can be problematic if we have confounding variables
- Scientific hypotheses are provisional explanations for observations
- A null hypothesis is a statement of no effect; it's necessary for statistical comparisons
- Scientific hypotheses must be testable and falsifiable
- Avoiding cognitive biases in science is a challenge, but overall... SCIENCE WORKS
- The environment is made up of matter
- Matter is organized into fundamental building blocks that combine into larger components
- We make synthetic compounds that can be problematic
- Earth and the other objects in our solar system formed around 4.6 Ga ago, according to the Nebular Hypothesis.
- The planets of our solar system –including Earth –retain characteristics of their early origins.
- Earth's characteristics provide the foundation for everything living on this planet.
- Earth lost its primary atmosphere and formed a new one that was not very hospitable to life.
- Oceans accumulated once the surface had cooled sufficiently.
- The water molecule has chemical and physical characteristics that are crucial for support of life.
- Atmosphere –hydrosphere –geosphere interacted in a state of dynamic equilibrium.
- There are many possible ways that life could have originated on this planet.
- The fossil record is the history of life on Earth.

- The atmosphere, hydrosphere, and geosphere have evolved chemically, in dynamic equilibrium.
- Life has played a central role in the chemical evolution of Earth's environmental systems, primarily through buildup of oxygen in the atmosphere and removal of carbon dioxide from the atmosphere
- Over geologic time, these complex systems have interacted to give us the environment of today.
- Earth has several characteristics that make it unique among known planets, and uniquely capable of supporting life.
- Earth's major geological cycles –the rock cycle and the tectonic cycle –are interconnected and connected with the hydrological cycle.
- Geological cycles are powered by both internal and external sources of energy.
- The tectonic cycle is powered mainly by internal energy.
- The rock cycle is powered by internal and external energy.
- The geological cycles provide the physical foundation for environmental processes and support all life on this planet.
- The rock cycle describes mostly near-surface geological processes, driven by both internal and external energy sources.
- The rock cycle produces the three major rock families: igneous rock, sedimentary rock, and metamorphic rock
- Energy from Earth's interior drives processes that shape and influence the surface, including plate motion, earthquakes, volcanic eruptions, and mountain-building.
- Scientists use many tools and approaches, both direct and indirect, to learn about Earth's interior.
- Earthquakes release energy as seismic waves that travel through the planet. These provide an important tool for understanding Earth's interior.
- Earth's layers from the inside out are the core, the mantle, and the crust. The lithosphere is the crust + outermost part of the mantle.
- The mantle is hot and mobile (but mostly solid), and convecting.
- The lithosphere is thin, relatively cold, and brittle. It has broken into about 15 major fragments, called plates.
- Plates carry either mainly oceanic or mainly continental crust.
- Convection in the mantle is responsible for causing the plates to shift their positions.
- Most (though not all) geological activity, such as earthquakes and volcanic eruptions, happens along plate boundaries.
- Plate boundaries are divergent (plates moving apart; continental or oceanic) or convergent (plates moving together: continental collision (continent-continent), subduction zone (ocean-continent or ocean-ocean) or transform fault (plates moving sideways, horizontally past each other)

Chapter 3: Earth Systems and Ecosystems

- Environmental problems are complex and require a systems approach
- Systems can be closed or open
- Feedback loops are common features of systems
- Negative feedback loops are homeostatic

- Positive feedback loops are self-reinforcing and common in perturbed systems
- Systems are nested, hierarchical and function on multiple scales
- Systems have emergent properties
- There are many cycles & sub-cycles in the Earth's system
- We use models to depict & understand the properties of cycles
- Box models have properties that make them effective ways to model environmental processes
- Box models are made of reservoirs and fluxes
- Fluxes in and out of a reservoir determine if a reservoir is a source or a sink
- Residence time and turnover time describe the speed at which substances move through the system
- Box models are useful as null models for evaluating the effects of perturbations
- Ecosystem ecology focuses on processes and functions
- Ecosystems support us by providing ecosystem services
- Ecosystems function on multiple spatial and temporal scales
- Primary productivity by autotrophs is the "engine" that supplies energy to ecosystems
- Ecosystems vary in their levels of productivity (limited by temperature, light and nutrient availability)
- The hydrologic cycle influences all other cycles
- Biogeochemical cycles lay the foundations for life on Earth
- The carbon, nitrogen, and phosphorus cycles all have unique properties (largest reservoir, fluxes in and out)
- Humans have mobilized elements and changed the properties of reservoirs in the global biogeochemical cycles
- Fossil fuel burning, deforestation, and agriculture contribute significantly to changes in biogeochemical cycles

Chapter 4: Evolution, Biodiversity & Population Ecology

- Evolutionary change is change in the genetic composition of a population over time
- Migration, random drift, mutation, natural selection are all mechanisms of evolution
- Only natural selection can give rise to adaptations
- Adaptations are traits that help you survive and reproduce
- The environment exerts selective pressure on organisms
- Unrelated organisms may acquire similar traits (convergent evolution)
- Selection may be directional, stabilizing, or disruptive in terms of trait evolution
- Speciation can occur sympatrically or allopatrically
- Adaptive radiation is rapid diversification (usually in new environments)
- Most extinction is "background" extinction – but there have been a few huge mass extinction events
- Some species have traits that make them more vulnerable to extinction than others
- Populations vary in size & density
- Dynamics of populations (change over time) depends not just on numbers of individuals, but on spatial distribution of populations, age & sex distributions, and life-history patterns
- Growth rates can be calculated on a per-capita or whole-population basis

- Exponential growth rate is unsustainable
- Carrying capacity is the maximum population size an environment can support
- Density-dependent and density independent factors control population sizes

Chapter 5: Species Interactions and Community Ecology

- An ecological niche is the role that an organism plays in an ecological community
- Realized niches are shaped by competition; thus, competition has great importance in structuring communities
- Resource partitioning is a way that organisms can avoid competition
- Resource partitioning can result in character displacement
- Species interactions shape ecological communities
- Interactions can be understood in the context of positive/negative outcomes for each participant
- Interactions create selective pressures that lead to coevolutionary "arms races"
- All communities are structured into trophic levels
- Ecological inefficiency means that most energy "leaks" out of a trophic pyramid
- Food webs describe the feeding relationships among species
- Keystone species are species that have a disproportionately large impact on the structuring of ecological communities
- Trophic cascades can produce dramatic shifts in ecosystems
- Disturbance in communities is common; many are adapted to periodic disturbance
- Healthy ecosystems demonstrate resistance & resilience
- Succession is a series of communities that develop following disturbance
- Invasive species are having significant and increasing effects on communities
- The terrestrial environment is organized into several biomes

Chapter 6: Human Population

- Humans are members of a small and ancient branch of the mammalian tree
- We diverged from our closest relatives (chimps) about 5-7 MYA
- We differ from chimps mostly in terms of speech, brain size & bipedalism
- Neoteny & truncated gestation play a large role in driving the development of brain size
- *Homo sapiens sapiens* is the only extant branch on the human family tree
- Modern humans left Africa ~150-200KYA
- Low genetic diversity among humans is consistent with being a young species
- Humans have been modifying the environment for many millennia
- Demography is the study of human populations
- Age structure & fertility rates have profound effects on growth rates
- The demographic transition model describes patterns of birth & death rates with increasing technological development
- We increasingly live in dense cities
- Population growth rate is decreasing, but the population is still growing
- Malthus' warning is wrong on two counts
- Humans have been able to affect carrying capacity through technological innovations
- The IPATS model describes root factors of environmental degradation

- Ecological footprint estimates the impact of consumption and waste on ecosystems
- Biocapacity is decreasing because of human activities
- The "great acceleration" of human impacts on ecosystems has profoundly altered the natural world

Chapter 7: Soil and Soil Resources

- Soil is a complex material with both organic and inorganic components
- Regolith is the bedrock foundation for soil
- Physical. chemical & biological weathering breaks down rock into regolith
- Soil is organized into horizons that may take millennia to develop
- There are many different soil types
- Soil texture & structure depends on particle size, pore spaces & amount of organic matter
- Base cations are biologically important molecules that affect the fertility of soil
- Cation exchange capacity is a measure of the ability of soil to retain critical nutrients
- Soils store a lot of the nutrients in an ecosystem
- Soils are lost through erosion
- Soils are being compacted, depleted of nutrients (often due to human activity)
- Human activities toxify soils by affecting pH, salinity and other contaminants
- Human- accelerated soil degradation is having critical impacts on ecosystems and food systems
- Desertification is a complex process with many feedbacks
- The Dust Bowl was caused in part by poor agricultural practices
- Soil properties and processes are fundamental for plant growth and agriculture
- Soil loss, erosion, and degradation are global problems
- Sustainable land management practices are effective in conserving soil and soil biodiversity

Chapter 8: Agriculture, Food and Biotechnology

- Many people are both under- and over-nourished
- Rural & urban poor; victims of catastrophes are vulnerable to hunger
- Food security depends on production & distribution
- Food security is constrained by the 5 As
- The Green Revolution dramatically increased food production and alleviated starvation
- The Green Revolution involved both intensification & extensification
- The Green Revolution brought increased productivity with negative environmental impacts
- Livestock agriculture is both a problem of intensification & extensification
- Population increases and rising wealth leads to increasing demand for meat
- CAFOs have many environmental consequences
- GMOs are transgenic organisms
- There is little evidence that GMOs cause ill health; may have health benefits
- There are many legitimate concerns about the implications of GMOs regarding intensification of pesticide use, genetic pollution and increasing inequities in the developing world

- Agriculture must be both efficient and sustainable to support the human population
- Sustainability involves pollinator protection; less use of agrochemicals; preservation of crop diversity & careful use of biotechnology
- Aquaculture is necessary to ease the pressure on wild fisheries
- Modern intensive aquaculture is still in its early developmental stages
- Aquaculture's large ecological footprint is NOT sustainable
- It's important to manage existing wild fisheries that cannot be replaced

Chapter 9: Conservation of Species and Habitats

- The biodiversity crisis threatens our wellbeing
- Biodiversity provides a wealth of goods and services– it's critical to our survival
- World-view and philosophy affect how we relate to and value biodiversity
- Abundance, richness & evenness are important dimensions of biodiversity
- Alpha, beta & gamma diversity describe spatial patterns of species diversity
- The SLOSS debate is concerned with the optimal spatial design of conservation areas
- The number of species in an area is a function of area size & proximity to a source of immigrants
- Habitat fragmentation reduces and changes habitats (edge vs core)
- Small, isolated fragments lose biodiversity; corridors can help
- Biodiversity is highest in areas with high productivity, high seasonal predictability, and long evolutionary histories – thus, tropics are high in biodiversity
- We are in the 6th mass extinction; caused by human activity
- Exploitation, habitat loss, climate change, invasive species, pollution & disease are the drivers of biodiversity loss
- Countries with biodiversity hotpots need commitment from the global community to preserve them
- There is hope, but we need political will to turn things around

Chapter 10: Forests and Forest Management

- Forests cover a large part of the globe – but are disappearing
- Forests are structurally and functionally complex ecosystems
- Forests provide a huge number of ecosystem services
- Forests play a large role in local and global water systems
- Tropical forests contain an enormous amount of terrestrial biodiversity
- Tropical forests are structurally complex
- High productivity leads to soil depletion
- Tropical forests have complex food webs and adaptations in the biota
- Temperate deciduous and boreal forests are adapted to seasonal changes; cold winters and a period of dormancy
- Temperate deciduous and boreal forests are economically important and significant carbon sinks
- Tropical deforestation leads to loss of biodiversity and disruption of the water cycle
- Fire is a normal part of many ecosystems, and fire suppression may lead to catastrophic fires

- Adaptive management/ecosystem-based management is the most sustainable approach to forest management
- Timber harvesting & fire management approaches are critical to sustainable management
- Canada is a leader in sustainable forest management

Chapter 11: Freshwater Systems and Water Resources

- Water exists in 3 states and is distributed around the globe
- The hydrologic cycle drives the climate system
- The hydrologic cycle is driven by solar energy and gravity
- Most water is in the oceans; most freshwater is locked up in glaciers and ice caps
- Lotic systems shape and influence the surface of the Earth
- Watersheds are systems that maintain a balance of inputs and outputs
- Humans alter the course and quality of surface waters
- Dams significantly alter the ecology of lotic systems
- Lakes are transient features that vary seasonally; undergo succession
- Wetlands are highly productive ecosystems that provide many ecosystem services
- Groundwater is a critical resource that is slowly recharged in the water cycle
- Lakes face multiple threats
- The Great Lakes are improving in some indicators, but worsening in others
- Ontario is rich in wetlands, but they are at risk due to many factors (mostly land conversion)
- There are many point and non-point sources of surface and groundwater pollution
- Groundwater withdrawal can cause many problems
- Water scarcity is a huge problem for many
- Climate change will exacerbate many of these problems
- Canada lacks a comprehensive water policy
- Changes in the last decade significantly weakened environmental protection of water resources; some of those decisions are being reversed
- First Nations suffer disproportionately in terms of water protections
- Action is needed to protect water as a public good

Chapter 12: Marine and Coastal Systems and Fisheries

- The ocean covers most of our planet and consists of several large, interconnected basins.
- Ocean-floor bathymetry is diverse and complex, and largely controlled by plate tectonics.
- The ocean contains more than just water –organic matter, mineral sediment, dissolved salts, and dissolved gases are important components.
- The ocean is vertically structured.
- Layering of ocean water is defined by differences in temperature, density, and salinity.
- Ocean water flows both vertically and horizontally.
- Water is pushed by the wind, creating waves and surface currents.
- A gyre is a large, rotating surface current, where marine debris sometimes accumulates.
- Deep currents in the global thermohaline circulation are controlled by density, which in turn is controlled by temperature and salinity.
- Some ocean zones support more life than others.

- Zones are defined by light, depth, proximity to the shore, and bottom vs open water.
- Ocean organisms have different ways of moving –some are sessile, some are motile; some are planktonic, some are nektonic.
- Ocean organisms are adapted to the specific conditions of the zone where they live. Deep-ocean organisms are adapted to particularly extreme conditions.
- Coral reefs are very important for biodiversity and as environmental indicators. There are three main types of reef.
- Coral reefs are under threat because of environmental changes, leading to bleaching.
- Intertidal zones, estuaries, and mangroves are important coastal environments with complex habitats.
- Coastal zones in general are threatened because of pollution, development, and aquaculture.
- Humans rely on the ocean for a wide range of crucial, life-supporting resources.
- Human activities have significant negative impacts on the ocean.
- Coastal zones are most susceptible to the impacts of human activity, but the deep ocean is also affected.
- Many types of marine pollution from various sources threaten ocean ecosystems and resources.
- Some causes for concern are plastics; sewage and other nutrients, leading to red tides and algal blooms; and chemical contamination, including oil spills and runoff.
- Global marine capture fisheries are under a lot of pressure.
- Industrialized fishing practices can be very harmful.
- Some stocks are declining or collapsing, even while yields remain stable –a function of increased fishing effort, among other factors.
- It is important that we –as consumers –choose fish that have been harvested sustainably.
- The collapse of the Atlantic cod fishery was one of the great environmental disasters.
- Cod have only made a partial recovery.
- Fishing technologies, greater fishing effort, political inaction, misconceptions about the resource, underfunding of monitoring –all played a role.
- Modern fisheries management is very cautious.
- Tragedy of the Commons tells us why commonly-held resources are susceptible to being mismanaged.
- Marine reserves and protected areas can provide full or partial protection for important ocean ecosystems.
- They can be controversial and hard to police.
- Providing protection for marine species has been shown to increase their availability for harvest, rather than decreasing it.
- Only a very small % of the world ocean is currently protected.
- Large, connected reserves are better than many small, disconnected reserves.