LECTURE 3 & 4:
MAY 7, 2014

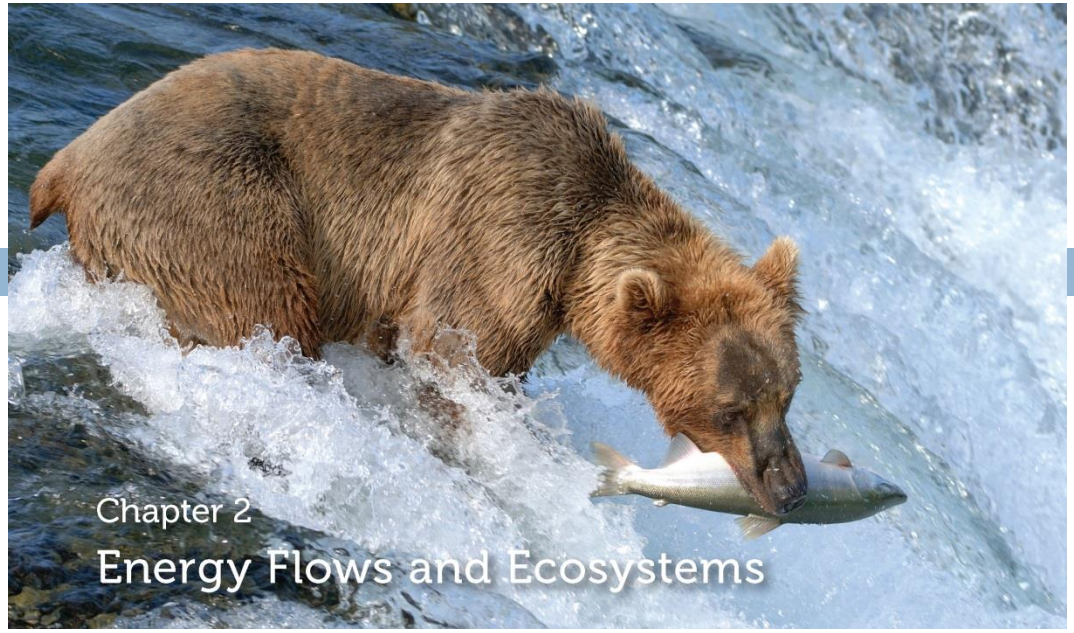
ENERGY FLOWS AND ECOSYSTEMS

ENERGY FLOWS IN ECOSYSTEMS, FOOD CHAINS

Text Reference: Dearden and Mitchell (2012), Ch. 2, pp. 49-80

Geography/Environmental Studies 1120
T. Randall, Lakehead University, SA 2014

Outline

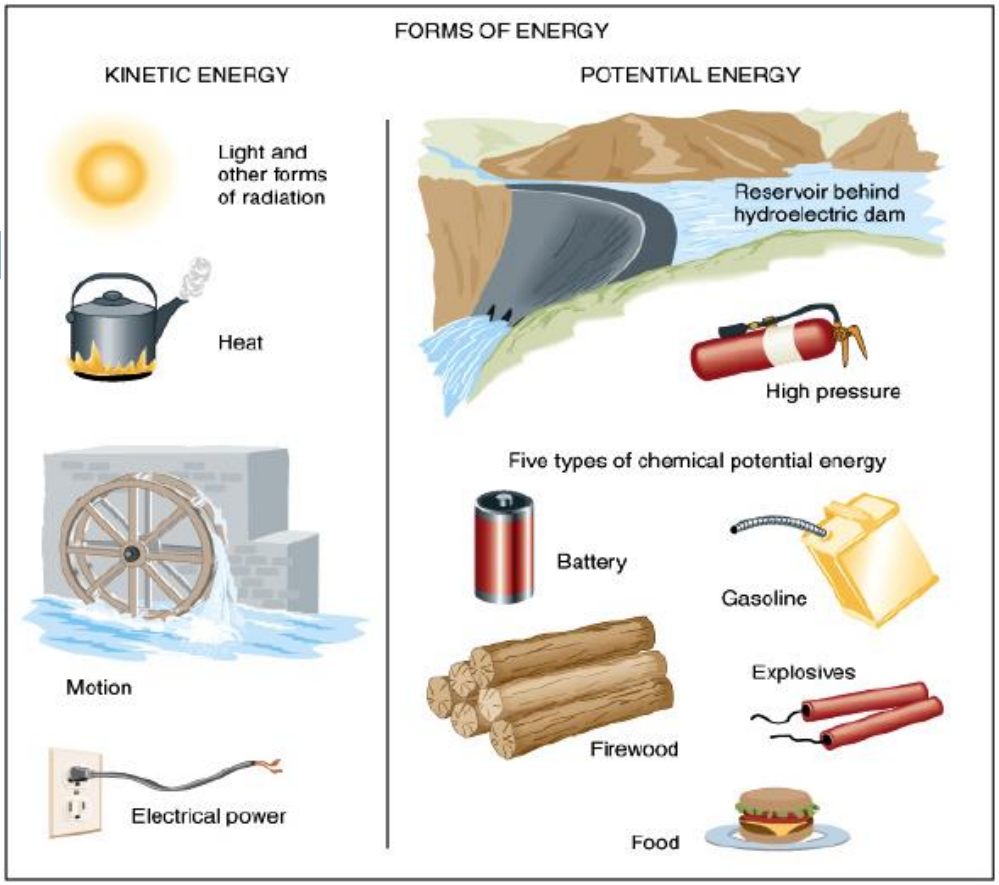


Source: Dearden and Mitchell (2012)

- Upcoming:
  - **May 8:** Fieldtrip: Western Grain Elevator (historical uses of Kam R waterfront)
  - **May 12 & 13:** ch. 3 (pp. 83→ Ecosystems are Dynamic (ecological succession; changing ecosystems)
    - Today:
      - Energy flows in ecosystems
      - Food chains, Food webs
      - Ecosystem structure; ecozones; biomes;
      - Abiotic & Biotic components of ecosystems
      - Biodiversity (intro only)
      - **Field trip logistics**
      - **Library Research Paper (journal searching skills cont'd);**

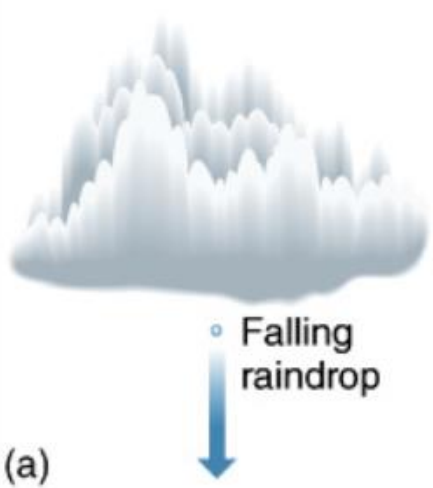
Energy

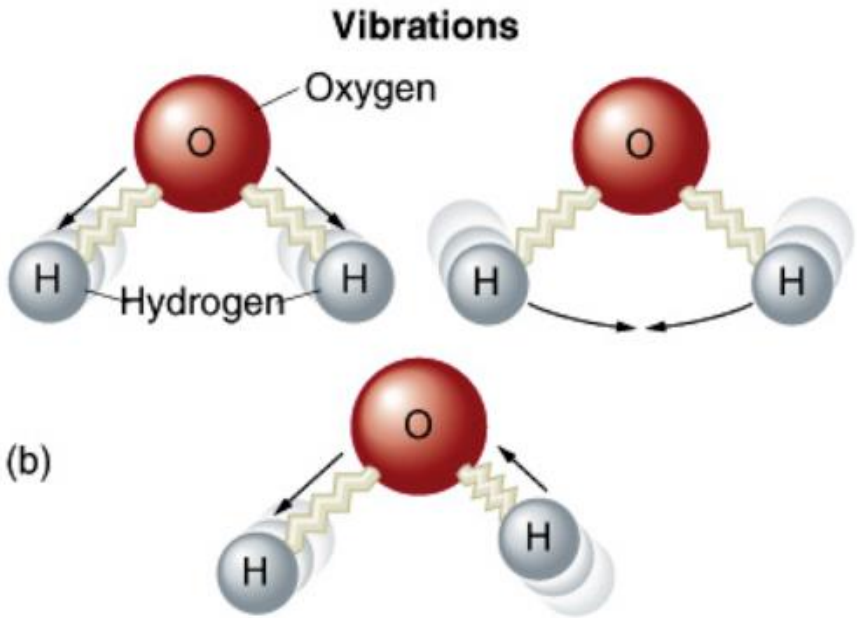
- Kinetic energy
- Potential energy

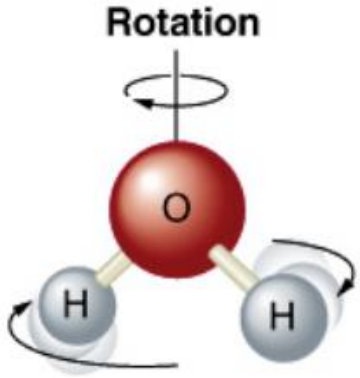


- Low-quality energy vs High-quality energy
  - diffuse, dispersed at low temperatures, hard to gather
  - e.g., heat within the ocean

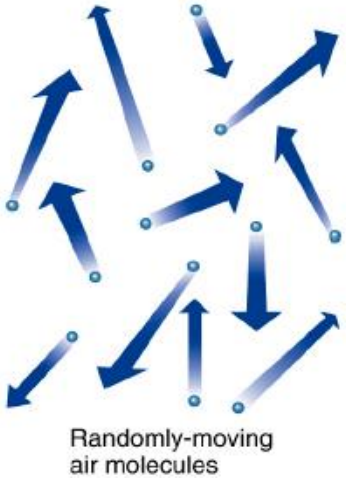
Examples of kinetic energy





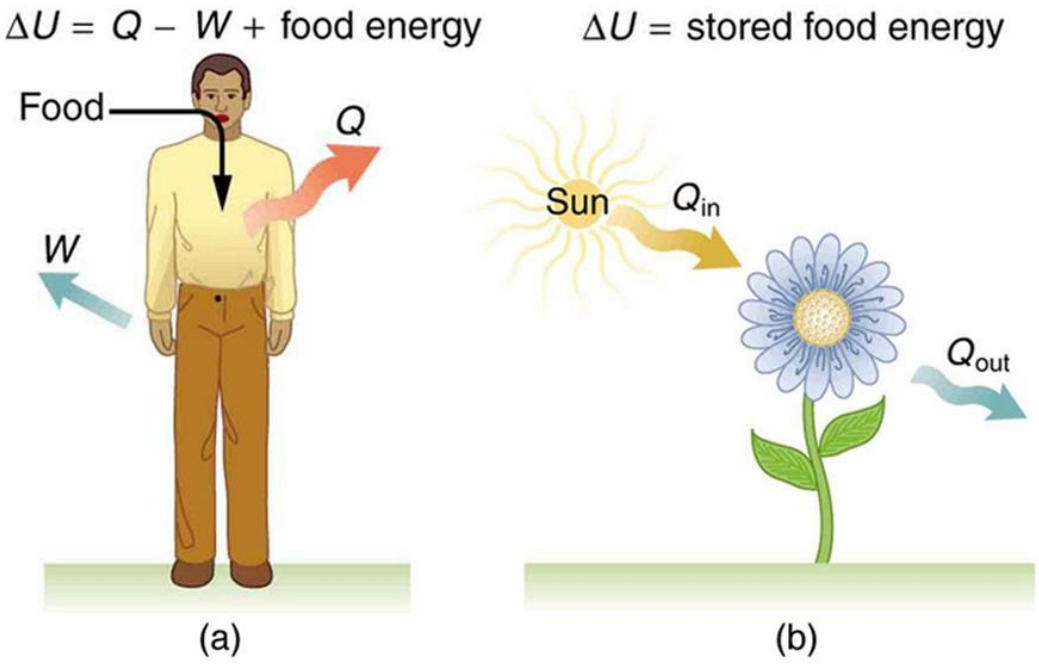


Gas molecules have no bonds to other molecules and as such they move in random motion



Laws of Thermodynamics

- First Law: **Law of Conservation of Energy**
  - Energy can neither be created nor destroyed; it merely changes from one form to another.



https://www.boundless.com/physics/thermodynamics/the-first-law-of-thermodynamics/human-metabolism/

Earth's Energy Balance (an example of 1st Law of Thermodynamics)

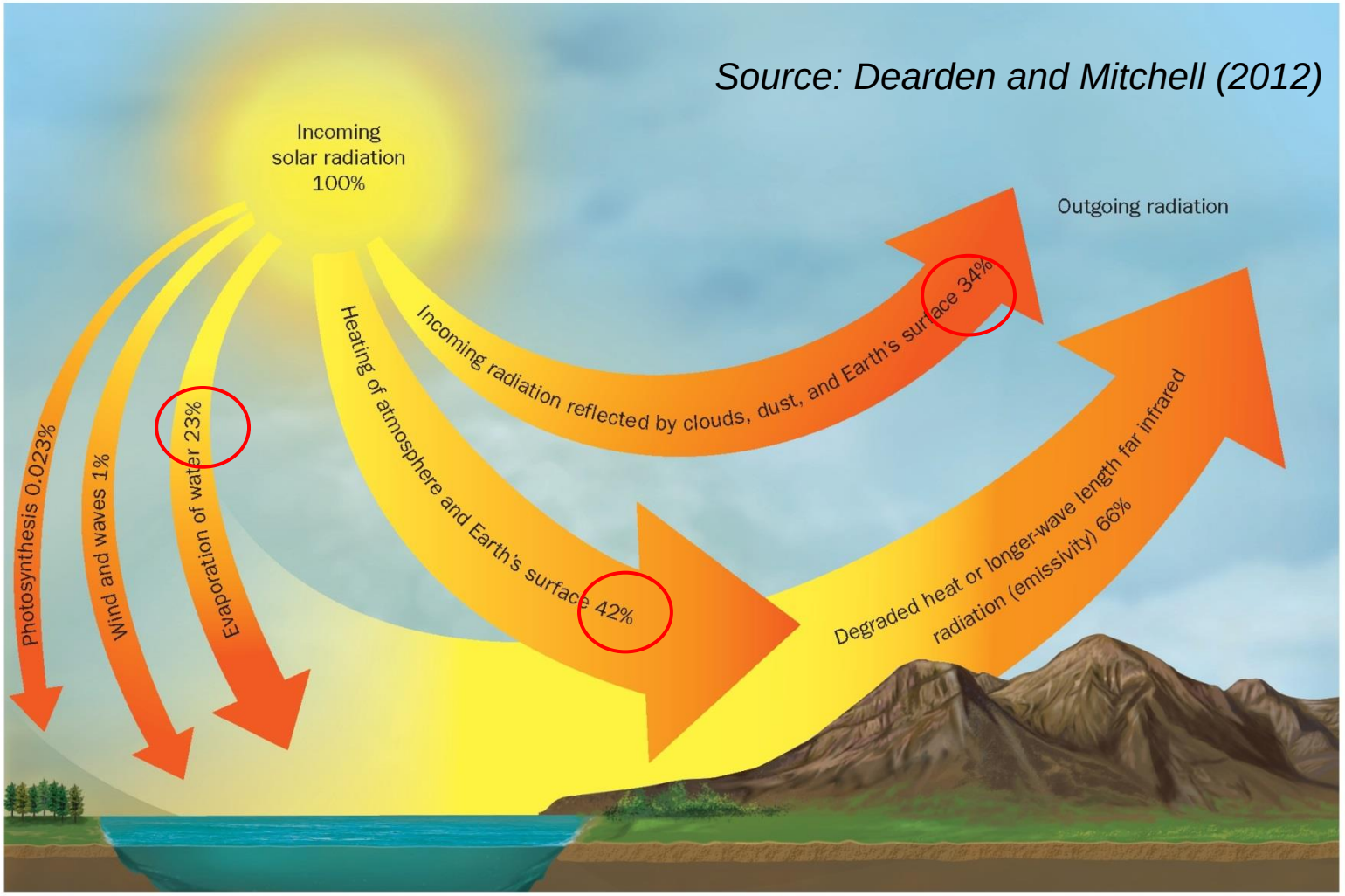


Figure 2.1 | The Earth's energy input and output, a good example of the first law of thermodynamics.

<1% of incident energy to power ecological production (photosynthesis)

Net all-wave radiation or Net radiation (Deficit = Surplus) 342 Wm^{-2}

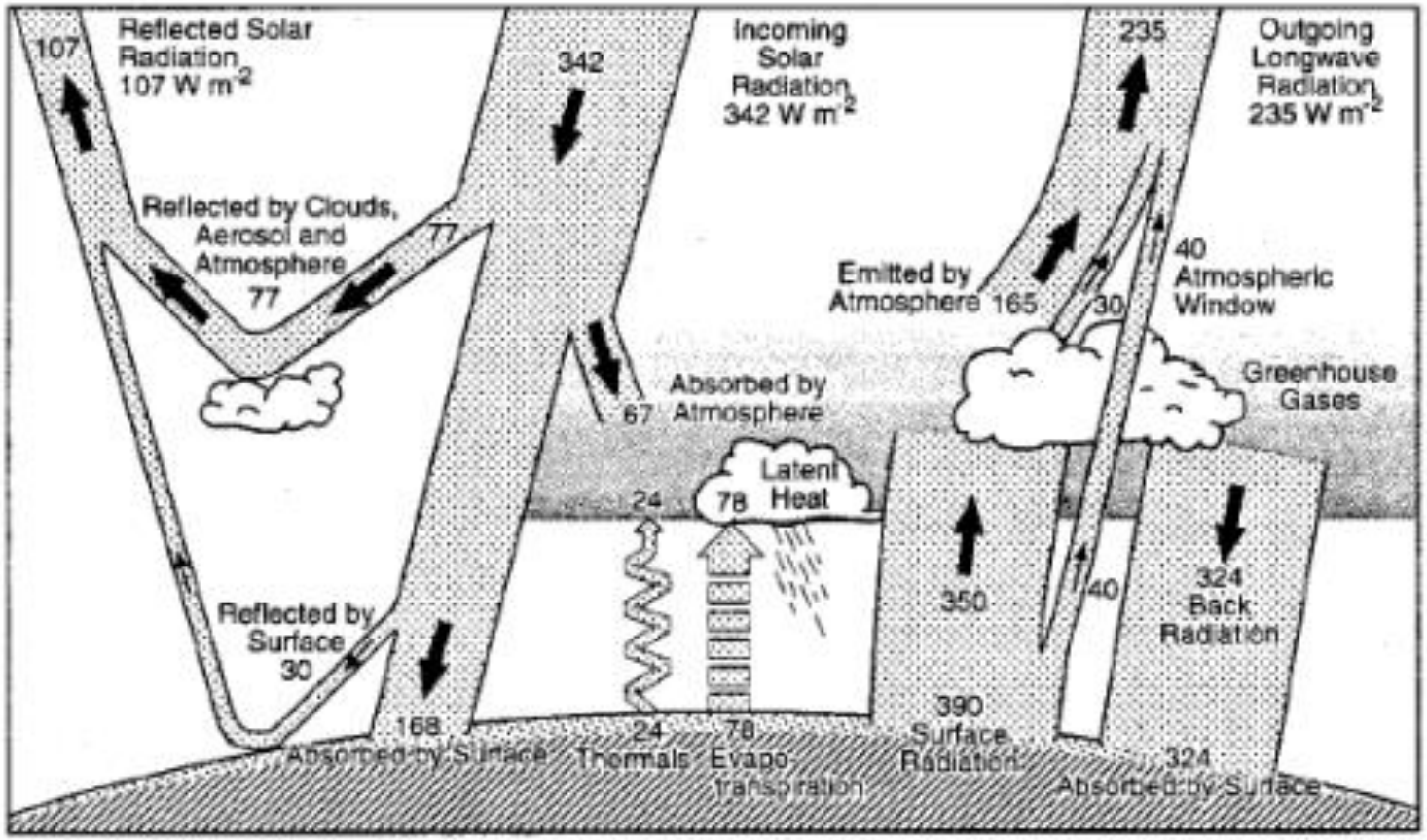


FIG. 7. The earth's annual global mean energy budget based on the present study. Units are W m^{-2}.

From Trenberth and Kiehl (1997)

Laws of Thermodynamics

- Second Law: **Law of Entropy**
  - During energy transformations, there is always a decrease in the *quality* of useable energy
  - Entropy is a measure of the disorder or randomness in a system

- Importance:
  - Re organisms must continuously expend energy for maintenance;
  - Energy cannot be recycled
  - In the geological sense, the energy input of millions of years has been released in ~250 years

Energy Flows in Ecosystems

- Producers (aka Autotrophs):
  - Chlorophylls (green pigment)
  - Photosynthesis

$$CO_2 + H_2O \rightarrow \text{Energy} + O_2$$

  - Respiration
  - Net Production
- Consumers (aka Heterotrophs): - various levels of 'consumers'

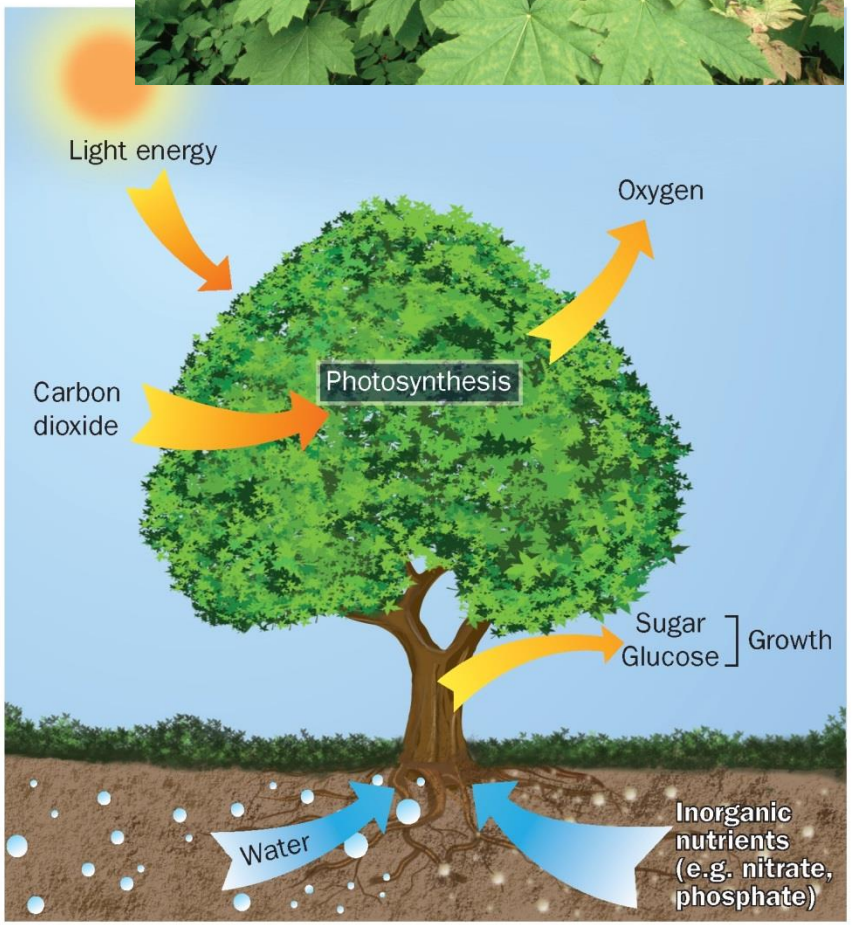


Figure 2.2 | The process of photosynthesis.

Source: Dearden and Mitchell (2012)

Food Chains & Food Webs

- **Trophic levels**: levels of the food chains
- Producers
- Herbivores
- Carnivores
- Onmivores
- Decomposers

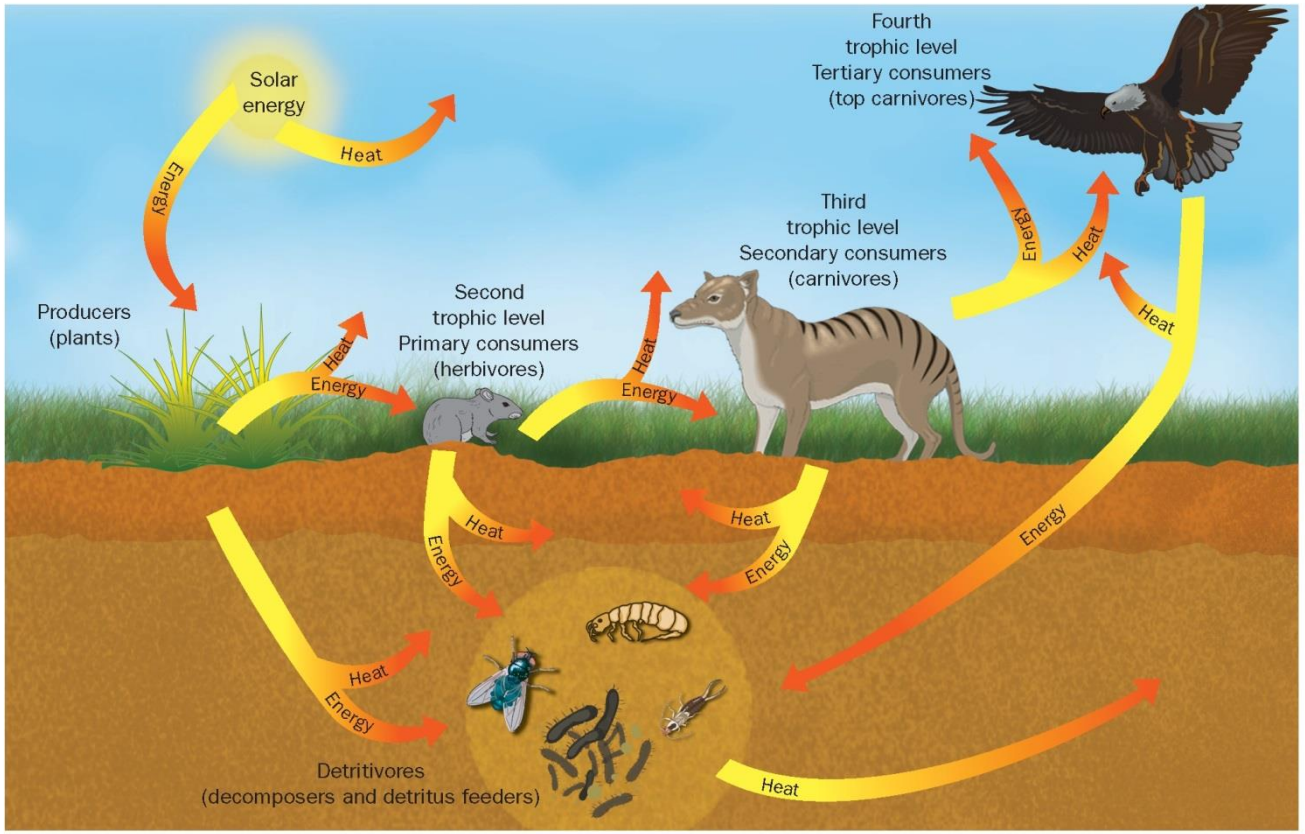
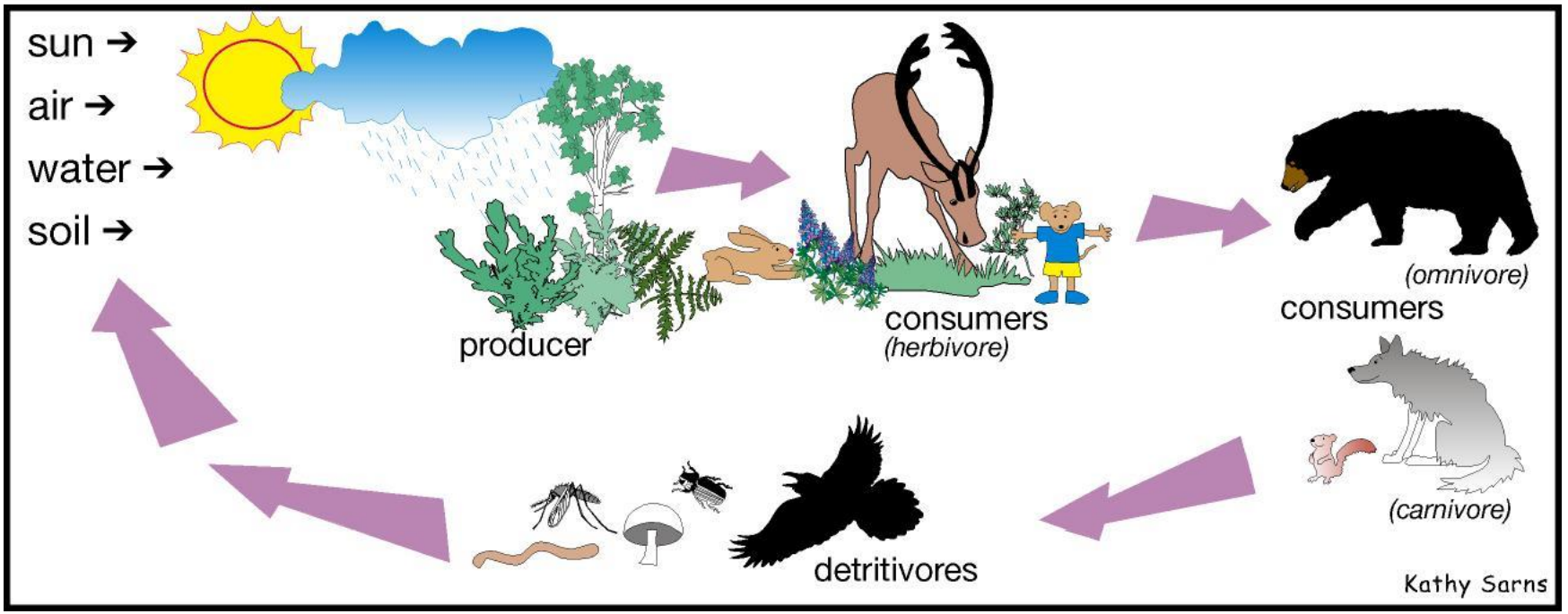


Figure 2.3 | A food chain.

Source: Dearden and Mitchell (2012)



http://fl1504015.edublogs.org/

Detritus-based food chains… consume 80% of primary production…

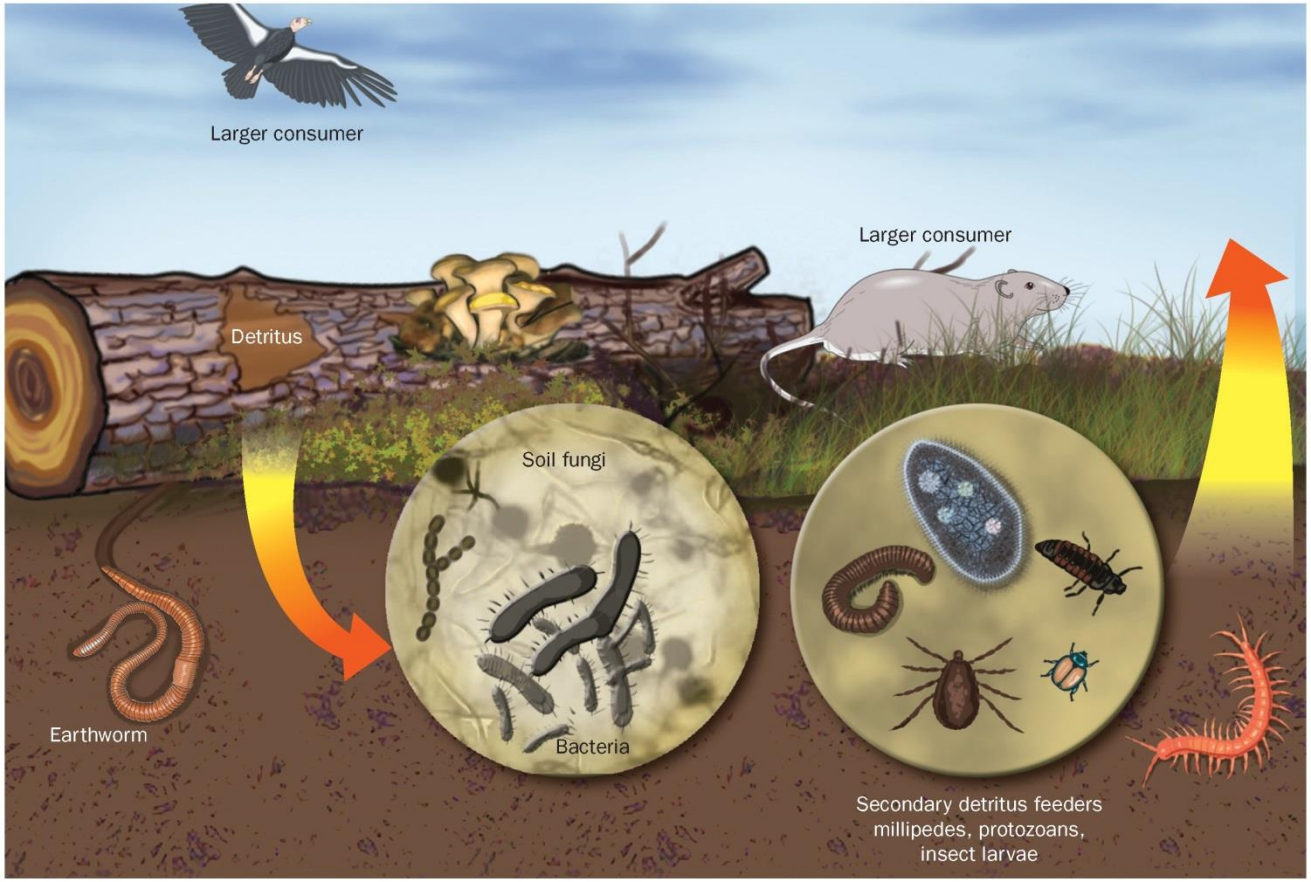


Figure 2.4 | Detritus-based food chain.

Source: Dearden and Mitchell (2012)

- More species in equatorial / tropical areas;
- Greater ‘resilience’ to stress, more ‘ecological redundancy’ in place

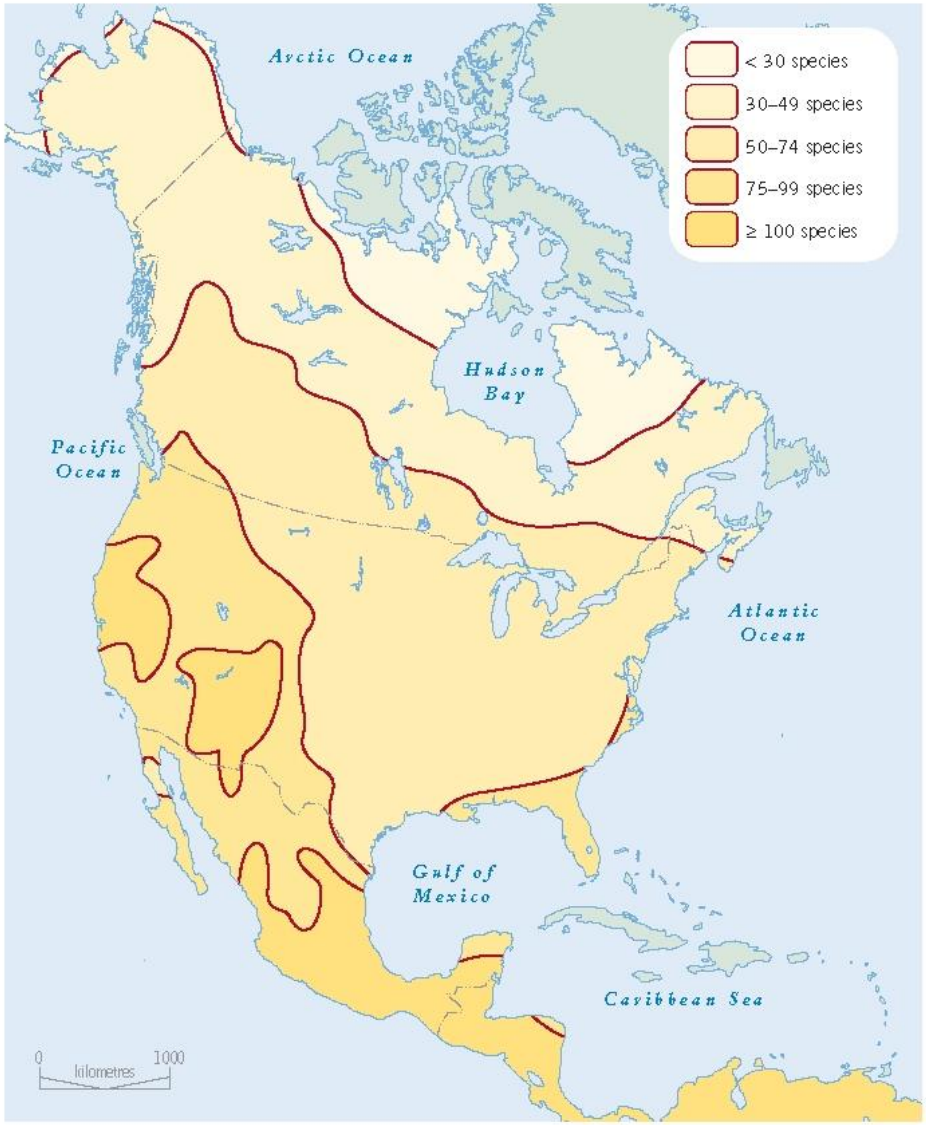


Figure 2.7 | The number of mammal species per latitude. *Source: After Simpson (1964).*

Source: Dearden and Mitchell (2012)

- **‘Food web’** better represents the many competing organisms and energy paths in ecological systems (vs simplified linear Food Chains)

Source: Dearden and Mitchell (2012)

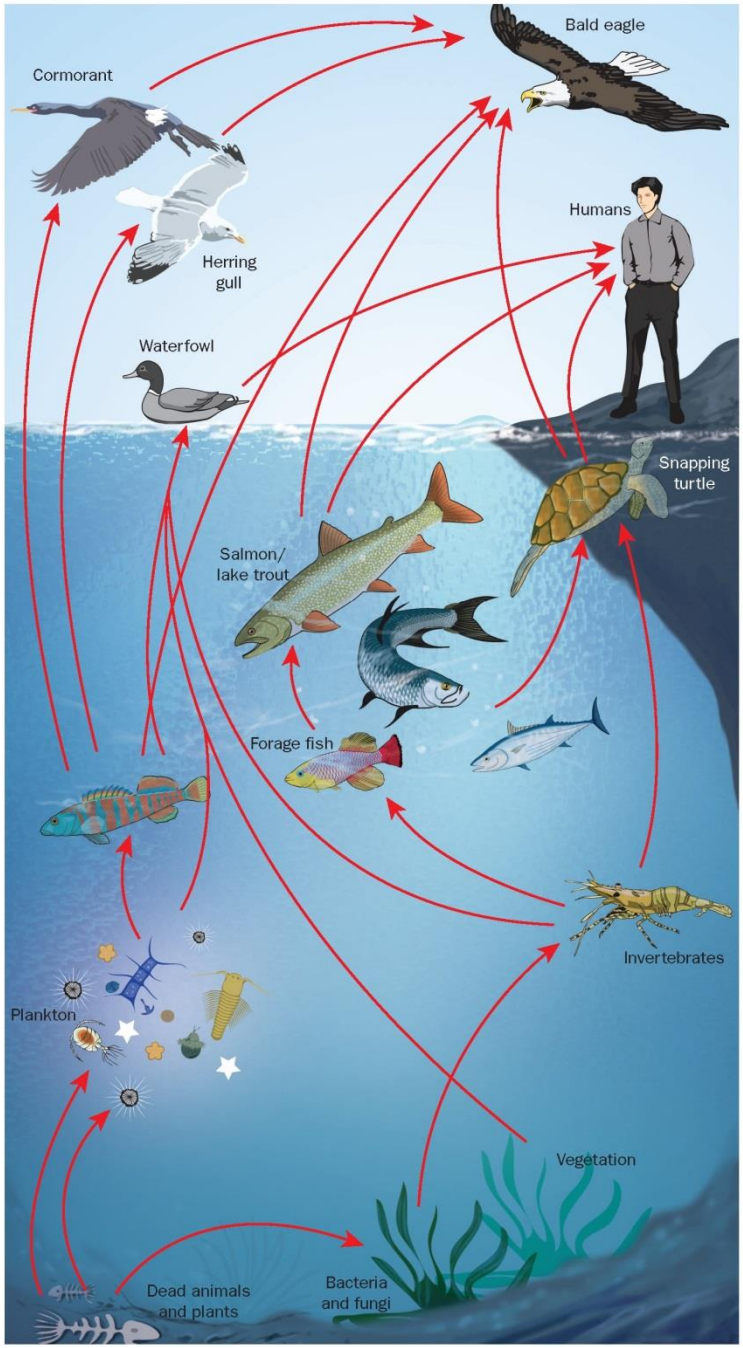


Figure 2.6 | A simplified Great Lakes food web. Source: Adapted from Environment Canada. 1991. *Toxic Chemicals in the Great Lakes and Associated Effects.* Toronto: Department of Fisheries and Oceans, Ottawa: Health and Welfare Canada.

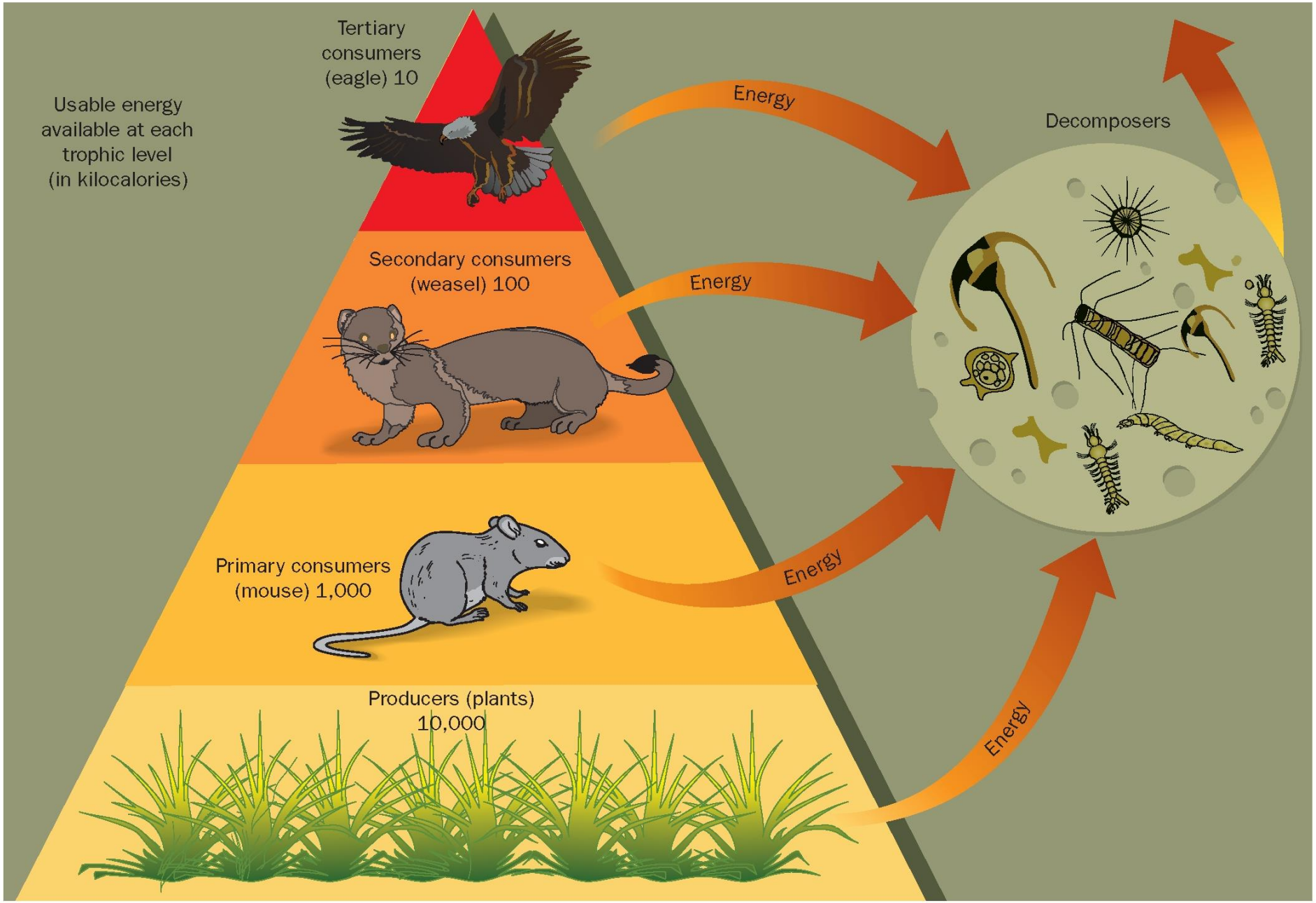


Figure 2.9 | Generalized pyramid of energy flow.

Source: Dearden and Mitchell (2012)

Predator – Prey Relationships

- Ecologists debate whether ecosystems are mostly controlled by predators (*top-down control*) or by prey populations (*bottom-up control*)

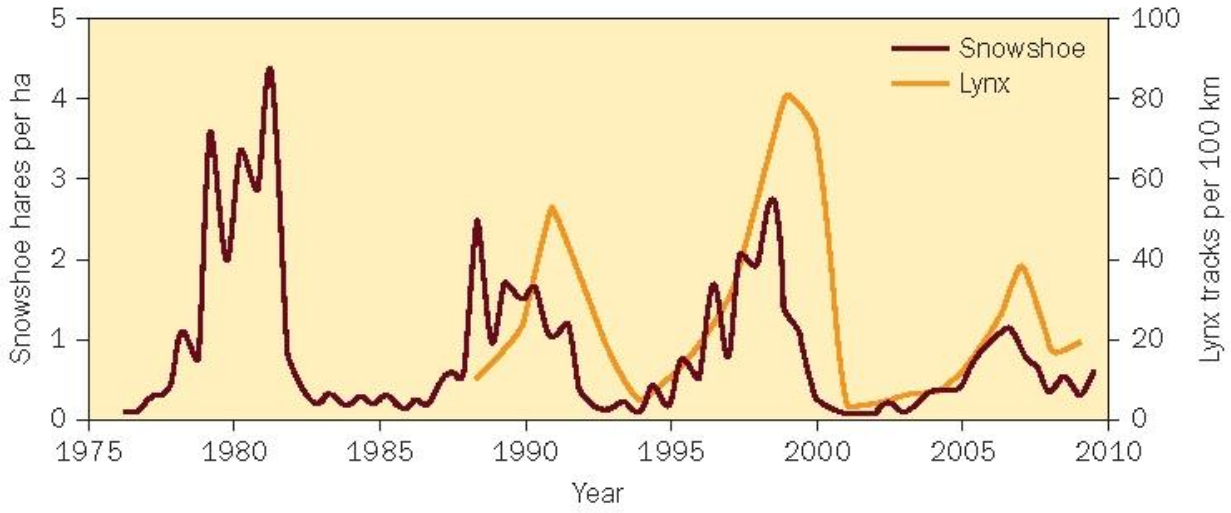
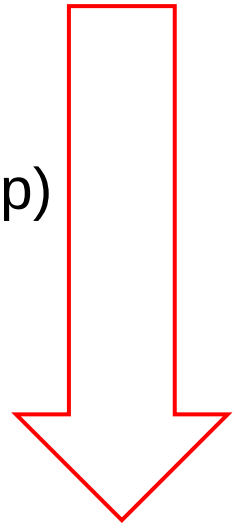


Figure 2.8 | Snowshoe hare and lynx cycles, boreal forest, Kluane, Yukon. *Source: Federal, Provincial, and Territorial Governments of Canada (2010: 101).*

Source: Dearden and Mitchell (2012)

Ecosystem Structure

- Organism – individual
- Population – group of individuals (same spp)
- Community – all populations of all spp

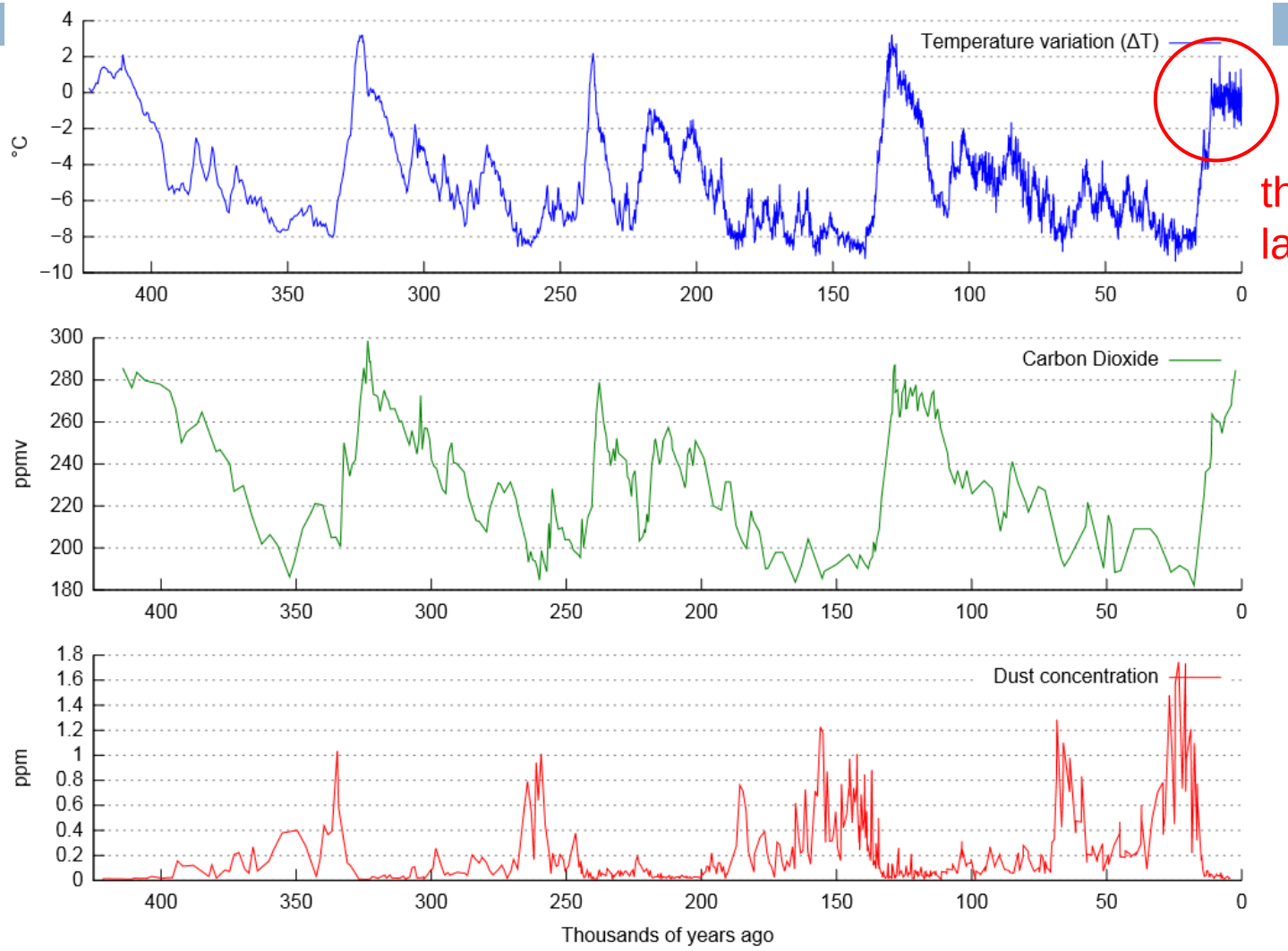


- **Ecosystem:** a collection of communities interacting with the physical environment
  - Ecosystem boundaries are not precisely determined….though convention to do so …
  - Similar ecosystems are grouped as “ecozones”
  - Brief aside on “glaciation” ….

Canada's Ecozones

- There are 15 ecozones (Figure 2.12 and 9.2) although the majority of Canada's forests lie within 8 of them.
- Relationship to recent glaciations…

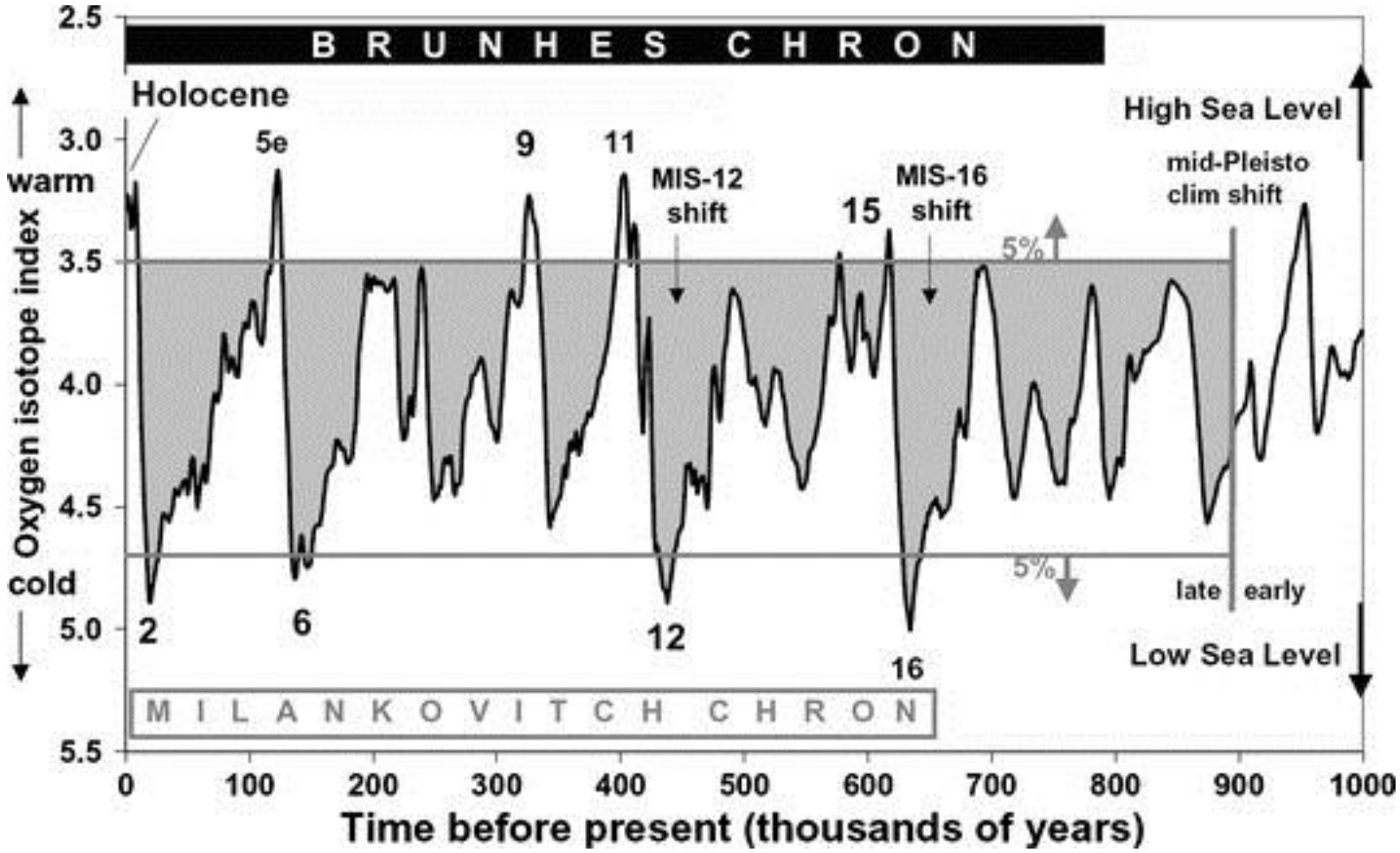
Time Scales: the Quaternary – primarily glacial (last 2 million years)



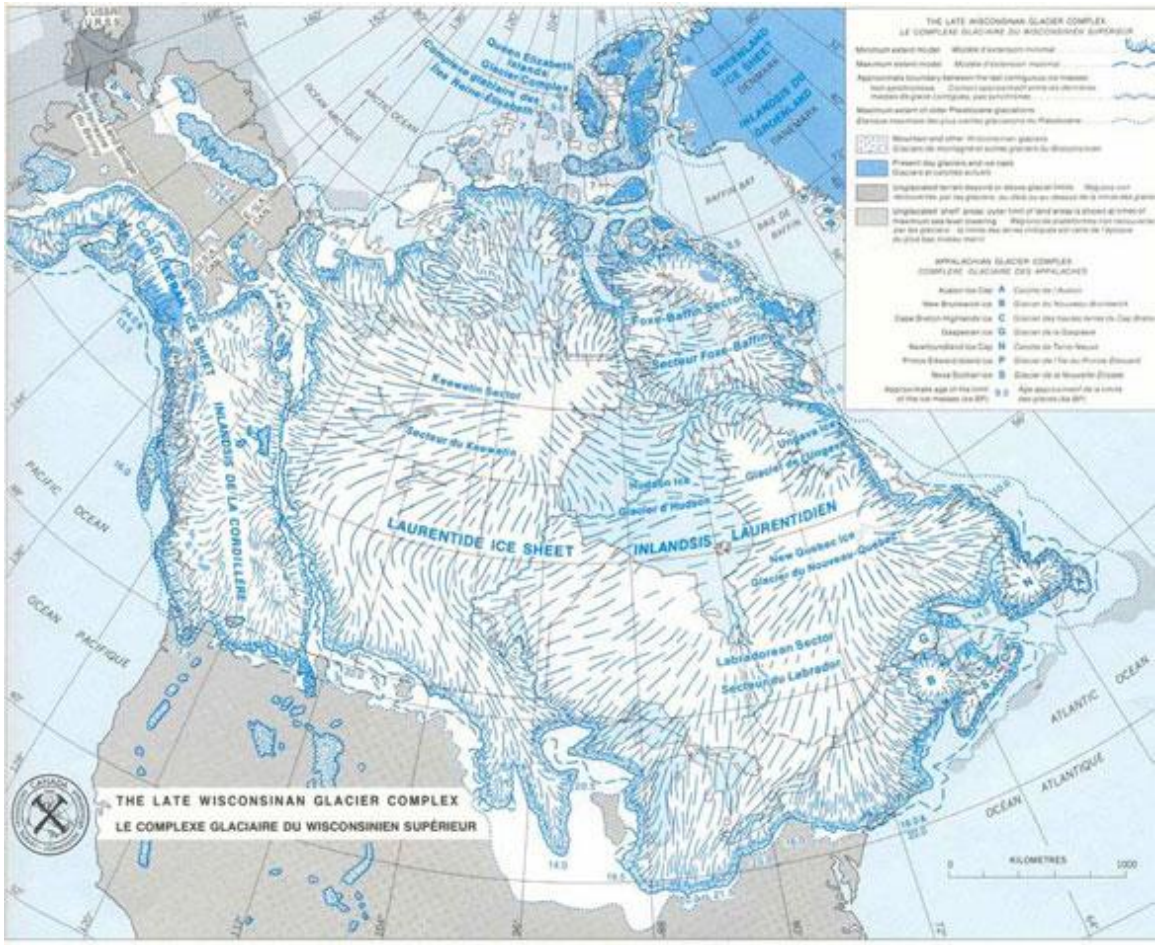
the Holocene last 10,000 yrs

Reconstructed from Antarctic ice sheet core data; note: co-variation in CO_2 + deltaT.

Recent climate history (last 1 million years) – Quaternary is last 2 million

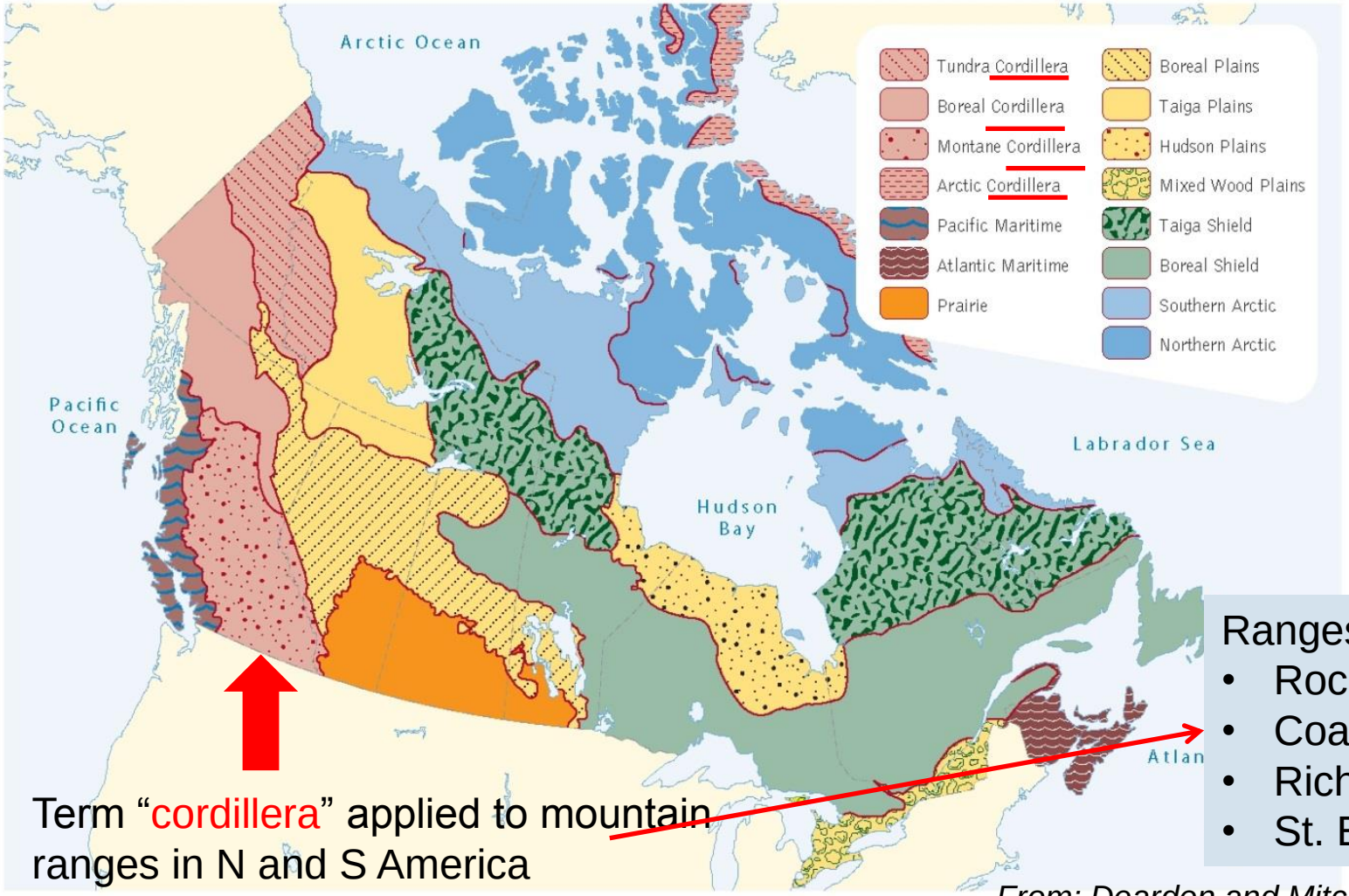


Last Glacial Maximum – 2 main ice masses (Laurentide Ice Sheet and the Cordilleran Ice Sheet)



Credit to: Canadian Geological Survey; retrieved from: http://www.mikehorn.com/en/yep/pangaea-classroom-club/Nunavut,%20Canada%20-%20Canada%20Arctic/

Terrestrial Ecozones of Canada



Term "cordillera" applied to mountain ranges in N and S America

Ranges:
- Rockies
- Coast Mts.
- Richardson Mts.
- St. Elias Mts.

From: Dearden and Mitchell (2012)

Figure 9.2 | Terrestrial ecozones of Canada. *Source: Wiken (1986).*

Main factors controlling biome distribution are ***water availability*** and ***temperature***.

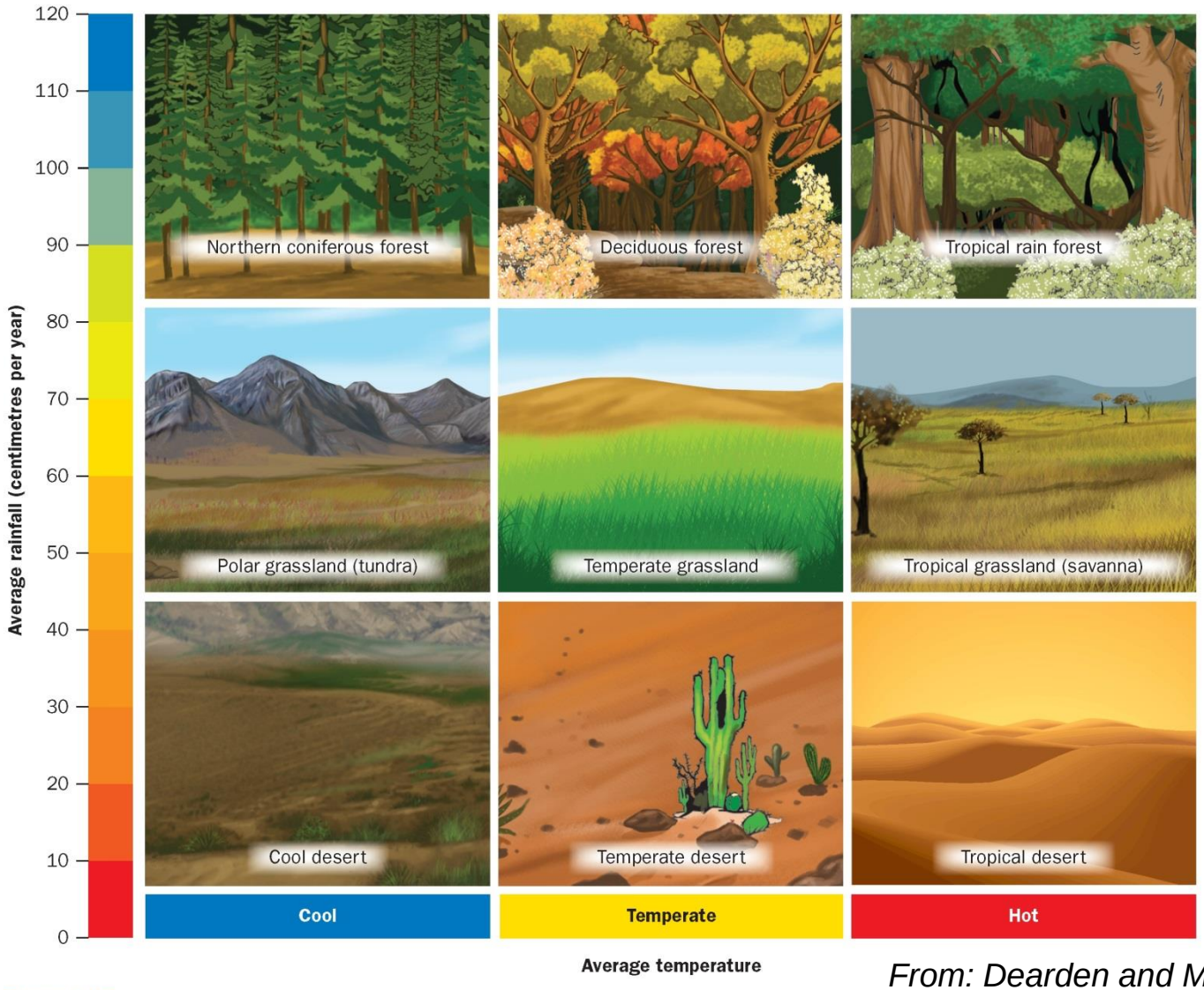


Figure 2.13 | Influence of temperature and rainfall on biome.

From: Dearden and Mitchell (2012)

Ecosystem Structure – abiotic components

- **Abiotic components** play an important role in determining how the living or **biotic components** of ecosystems are distributed
- **Key abiotic factors**: light, temperature, wind, water, and soil characteristics
- Soil type is critical in determining the kind and extent of vegetation growth of an area

Biological Soil

- Created from weathered “parent material”, including
  - Bedrock
  - Sediments from ‘geomorphological processes’ (wind, water, ice, landslides …)
- Soil Profile
  - Soil horizons
  - Varied transition from ‘parent material’ and organic content (humic materials)
  - Soil formation a lengthy process (e.g., 200-300 years for 1 cm to form in moist tropical soils)…

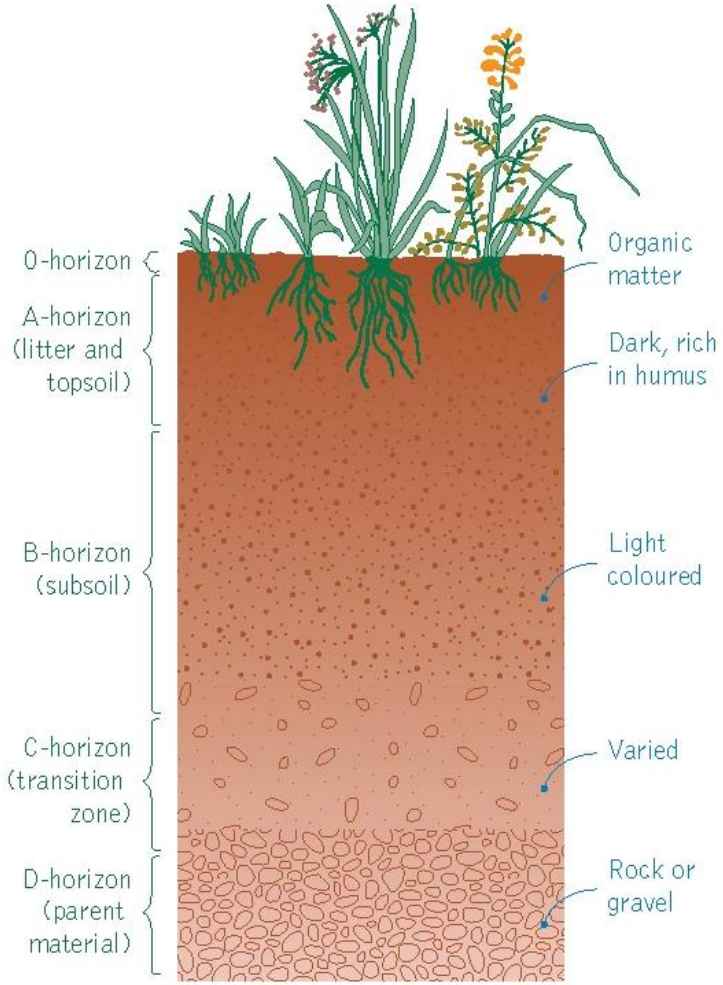
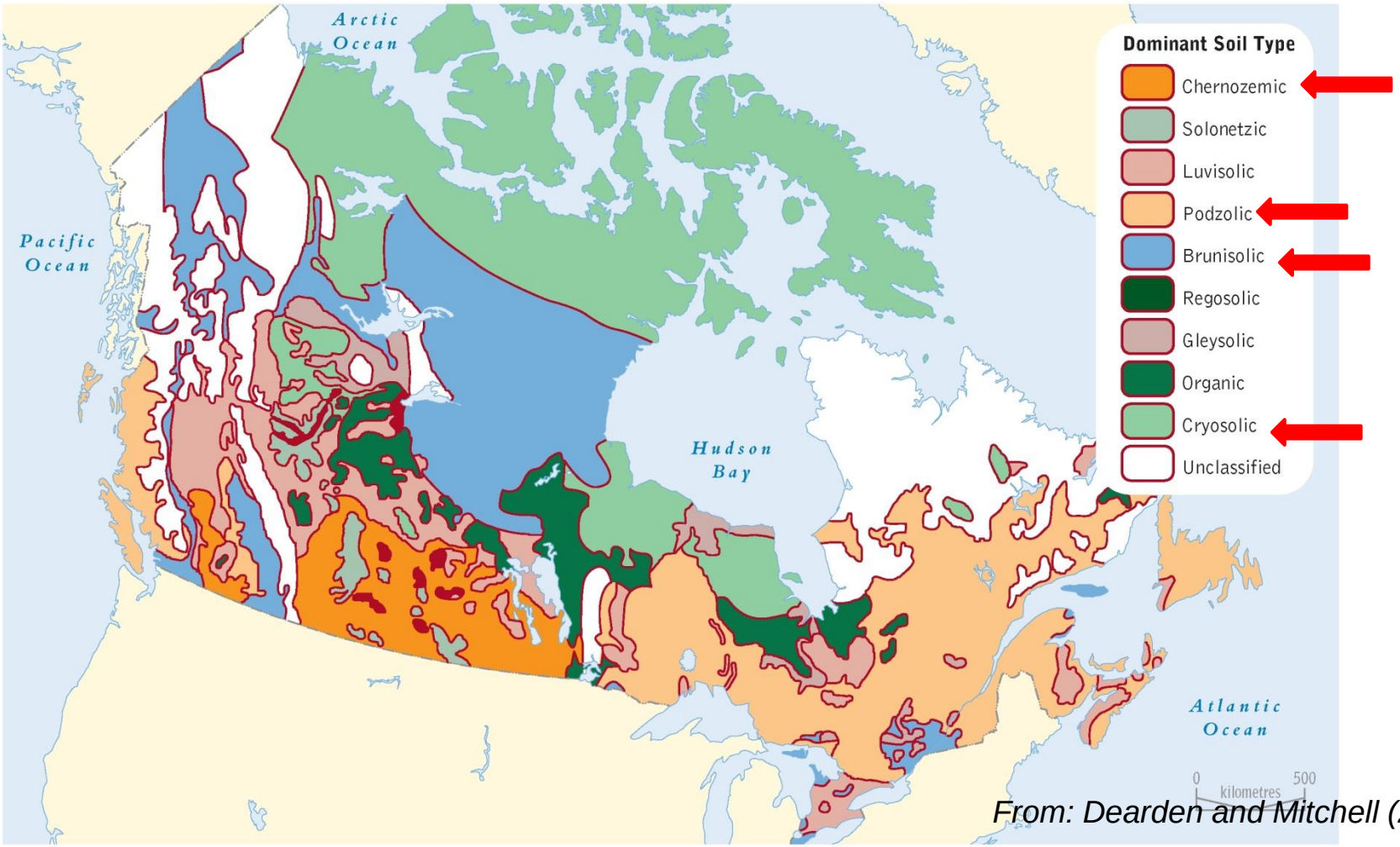


Figure 2.15 | Generalized soil profile.

From: Dearden and Mitchell (2012)

Soil Zones of Canada

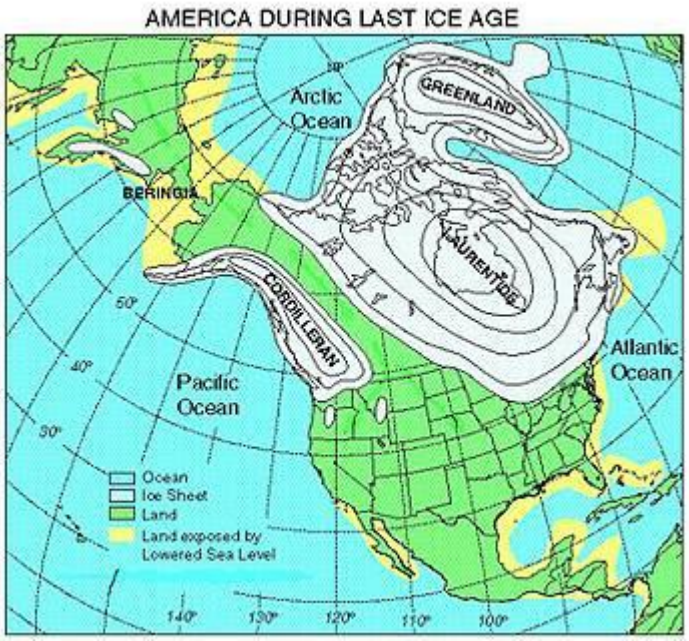
- Most common: cryosols
- Most productive: chernozems
- Associated with forests: brunisols & podzols (rel. nutrient poor)

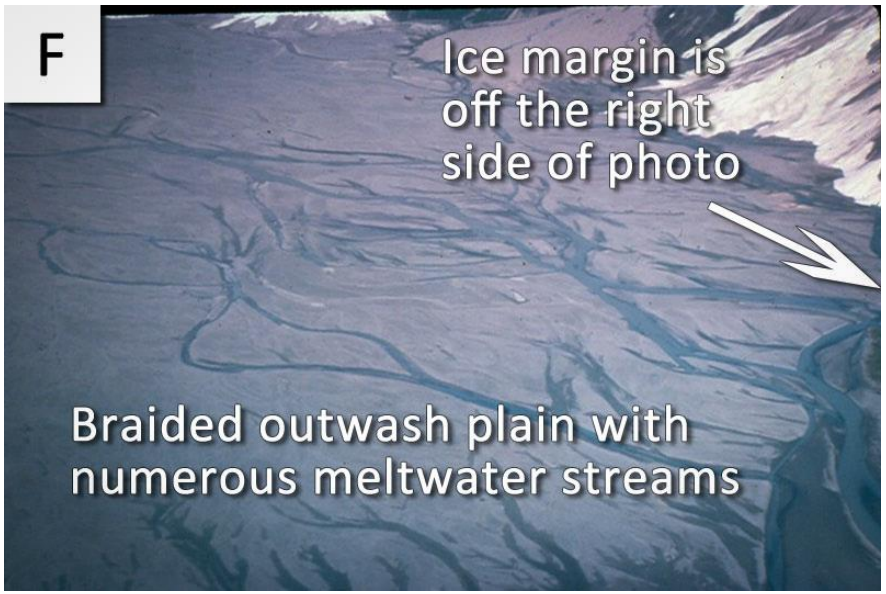


From: Dearden and Mitchell (2012)

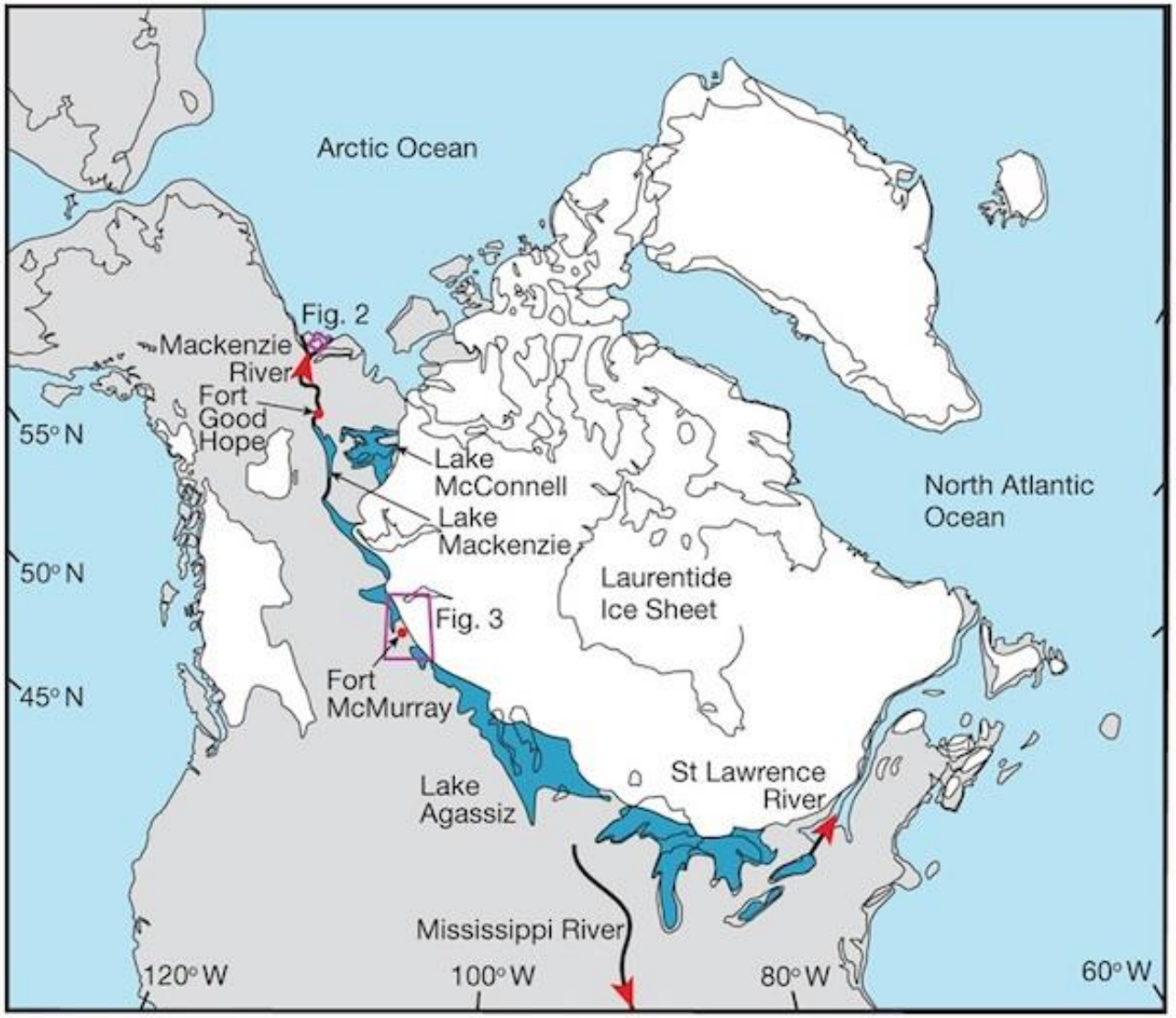
Where are best soils in Canada found?

- Prairies
- Southern Ontario and Southern Quebec
- SW British Columbia





Vast pro-glacial lakes as ice melted.



Ecosystem Structure – biotic components

- **Niche:** specific combination of the physical, chemical, and biological conditions for growth;
- **Habitat:** where the species lives
- **'Competitive Exclusion Principle'**
  - No 2 species can occupy the same niche in the same area
  - Consider "alien species"?
- Specialist spp:
  - Narrow niche, vulnerable to environmental change (e.g. Panda)
- Generalist spp:
  - Broad niche (e.g. Black Bear)

Biodiversity

Biodiversity:

- Involves the variety of life (within ecosystems) at various scales….
- Evolved over long periods of time via interactions between abiotic and biotic components of ecosystems;

- **Genetic diversity:** variability in genetic makeup among individuals of the same species;
- **Species diversity (spp richness):** the total number of species in an area
  - Global estimates 5 to 20 million
- **Ecosystem diversity (richness)**: the variety of ecosystems in an area.

Canada vs Global biodiversity

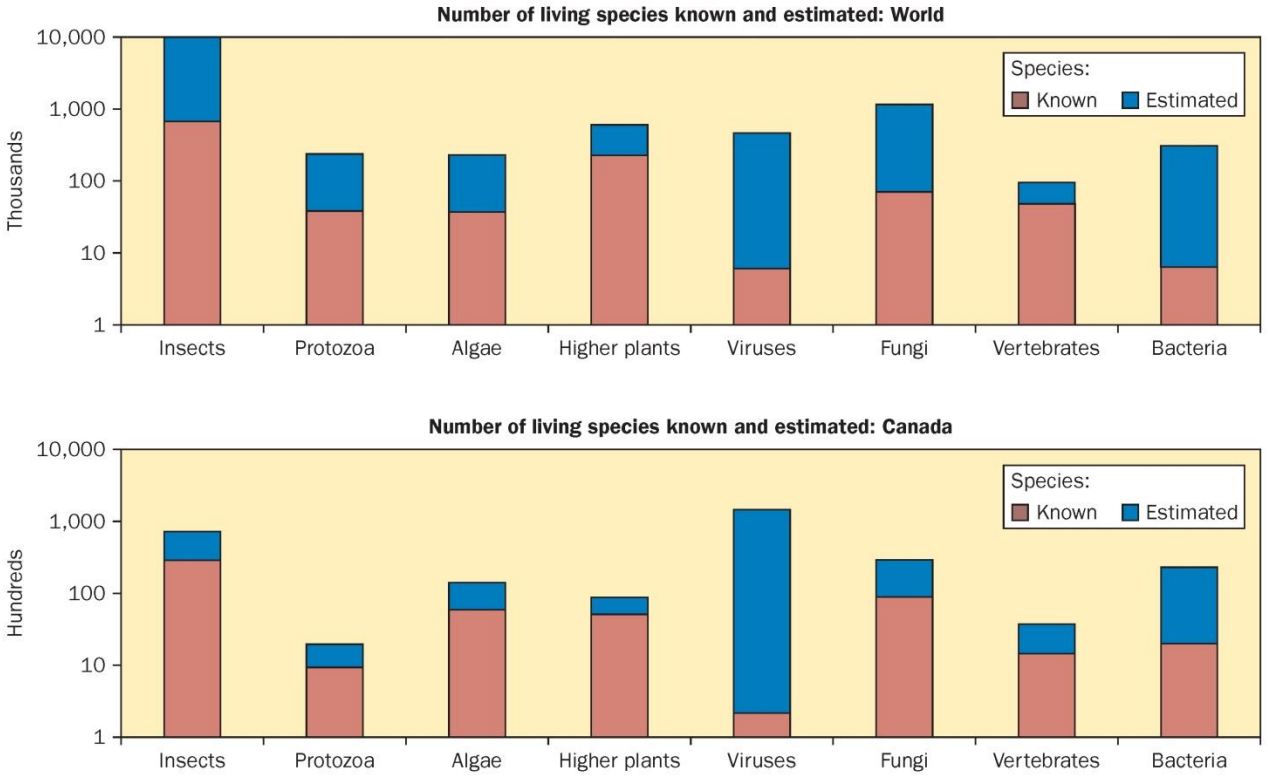


Figure 2.17 | Numbers of known and estimated living species in the world and in Canada. Source: B. Groombridge. 1992. *Global Biodiversity: Status of the World's Living Resources*, p. 17. London: Chapman and Hall. Reprinted with kind permission of Springer Science and Business Media B.V.

- Canada occupies a temperate local – modest biological productivity;
- Note Order of Magnitude on vertical axes;

From: Dearden and Mitchell (2012)

International Convention on Biodiversity

- to develop biodiversity strategies, identify and monitor important components of biodiversity, develop endangered species legislation and protected areas, and promote environmentally sustainable development
- Canada a signatory
- Canadian 'Biodiversity Strategy' (c.1996) for action to conservation and sustainable use.
- 1st self assessment by Canada (c2010) on efforts not promising

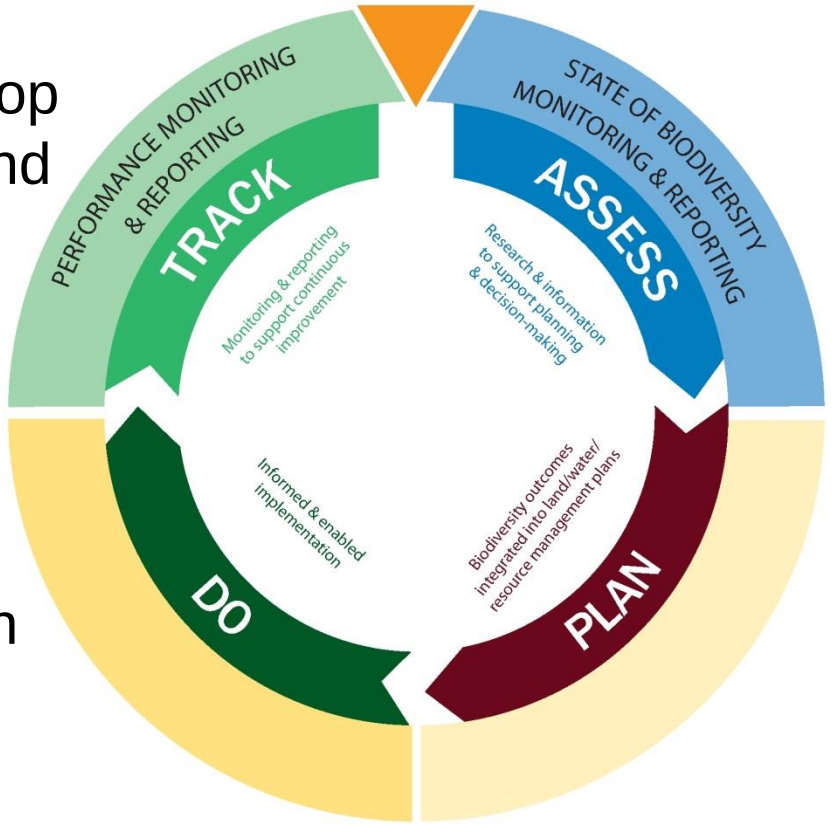


Figure 2.19 | Ecosystem approach and adaptive management used to achieve shared outcomes. *Source: Environment Canada (2009c: 43).*

From: Dearden and Mitchell (2012)

Looking Ahead to the next lectures

May 12 & 13: Ecosystems are Dynamic (ecological succession; changing ecosystems)

Read ahead (Chpt. 3, pp. 83 →)

References

- Dearden, P and Mitchell, B. 2012. *Environmental Change and Challenge*, Fourth Edition, Don Mills, Ontario: Oxford University Press {Chapter 2: 'Energy Flows and Ecosytems'}