LECTURE 7:
MAY 15, 2014

ECOSYSTEMS AND MATTER CYCLING

BIOGEOCHEMICAL CYCLES

Text Reference: Dearden and Mitchell (2012), Ch. 4, pp. 114-135

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

Outline

- Upcoming:
  - **May 21 (Wed):**
    - Field Trip (Atlantic St WWTP)
    - (To be confirmed)
  - **May 22 (Thurs):**
    - Midterm exam
    - Format ….
- Today:
  - (discussion) de-brief on field trip to Waterfront and downtown north core
  - (lecture) biogeochemical cycles
  - Break (~ 12)
  - (lecture) biogeochemical cycles
  - (discussion: return of paper proposals)
  - (discussion: exam format and length)

Source: Dearden and Mitchell (2012)

Macro / Micro Nutrients

Table 4.1 | Relative Amounts of Chemical Elements That Make Up Living Things

Major Macronutrients (>1% dry organic weight)		Relatively Minor Macronutrients (0.2–1% dry organic weight)		Micronutrients (<0.2% dry organic weight)	
Name of Element	**Symbol**	**Name of Element**	**Symbol**	**Name of Element**	**Symbol**
Carbon	C	Calcium	Ca	Aluminum	Al
Hydrogen	H	Chlorine	Cl	Boron	B
Nitrogen	N	Copper	Cu	Bromine	Br
Oxygen	O	Iron	Fe	Chromium	Cr
Phosphorus	P	Magnesium	Mg	Cobalt	Co
		Potassium	K	Fluorine	F
		Sodium	Na	Gallium	Ga
		Sulphur	S	Iodine	I
				Manganese	Mn
				Molybdenum	Mo
				Selenium	Se
				Silicon	Si
				Strontium	Sr
				Tin	Sn
				Titanium	Ti
				Vanadium	V
				Zinc	Zn

Source: Kupchella and Hyland (1989).

Source: Dearden and Mitchell (2012)

Carbon / Nitrogen Stores

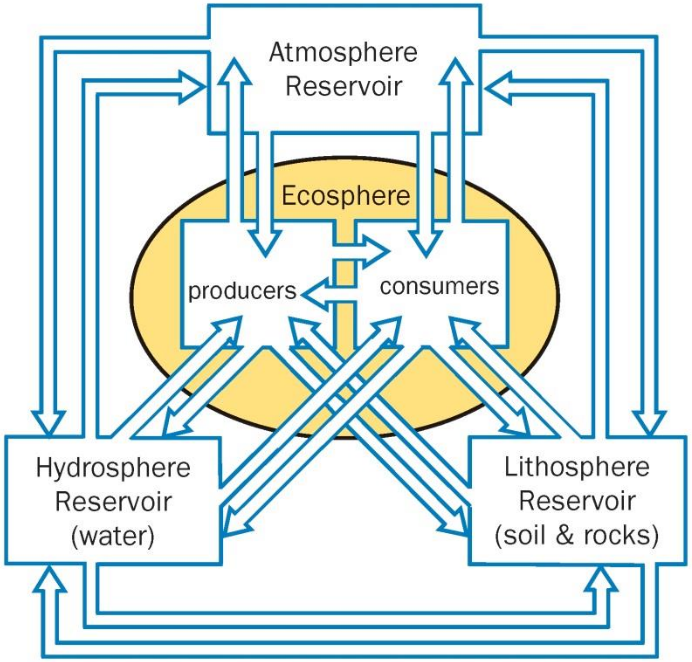


Figure 4.1 | Each nutrient is stored and released by components of the Earth's systems. Different nutrients follow slightly different paths through the systems and are stored and released at different rates.

Table 4.2 | Approximate Distributions of Carbon and Nitrogen in Temperate and Tropical Rain Forests

	Tropical Rain Forest	Temperate Rain Forest
Carbon in vegetation	75%	50%
Carbon in litter and soil	25%	50%
Nitrogen in biomass	50%	6%
Nitrogen in biomass above ground	44%	3%

Source: Dearden and Mitchell (2012)

- **<u>Gaseous Cycles</u>** (e.g., Nitrogen, Carbon)
  - Have most of their matter in the atmosphere
- **<u>Sedimentary Cycles</u>** (e.g. Phosphorus, Sulphur)
  - Hold most of their matter in the lithosphere;
  - Operate more slowly
  - Elements locked in geological formations for millions of years

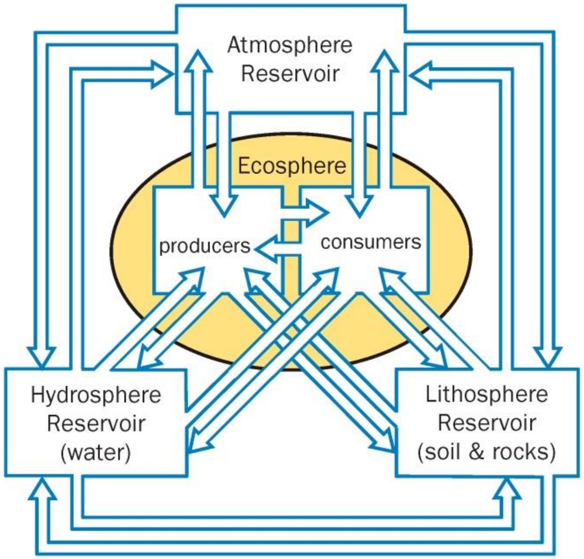


Figure 4.1 | Each nutrient is stored and released by components of the Earth's systems. Different nutrients follow slightly different paths through the systems and are stored and released at different rates.

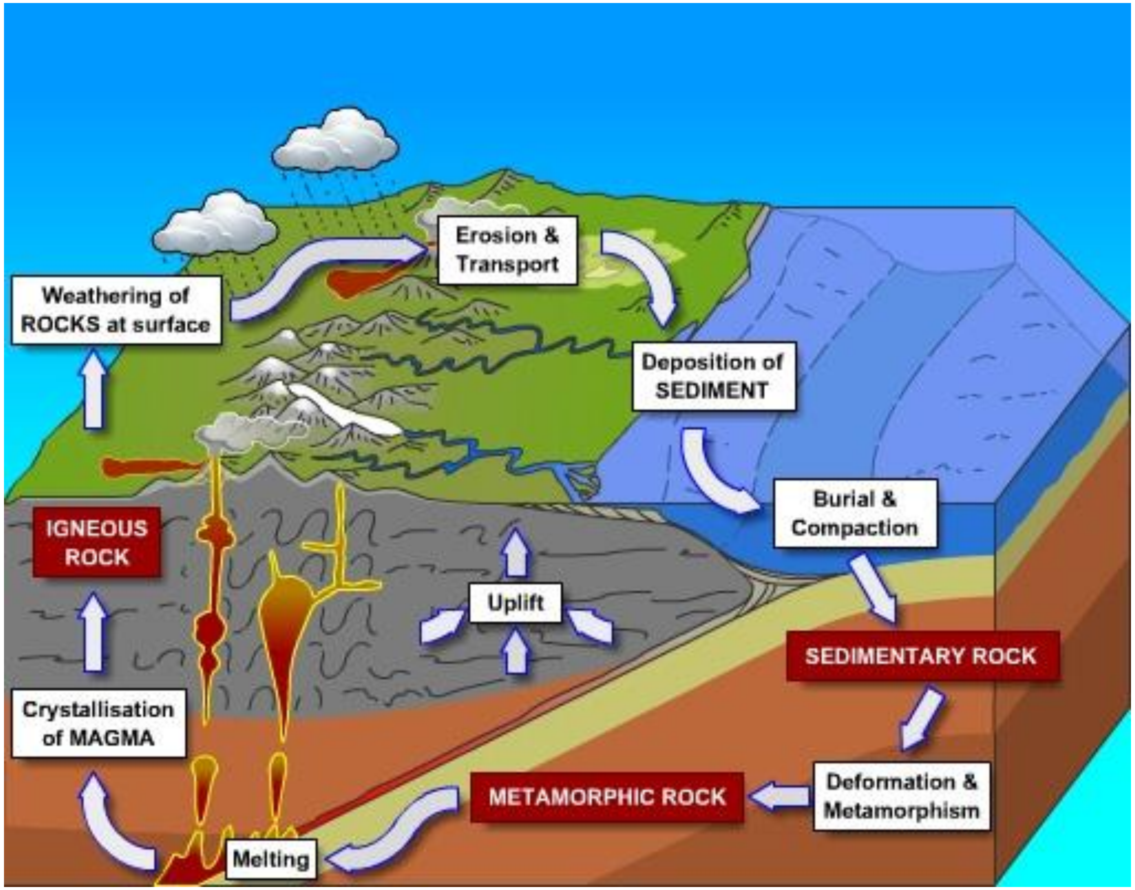
Source: Dearden and Mitchell (2012)

Sedimentary Cycles

- Phosphorus (P)
- Sulphur (S)

Rock Cycle block diagram

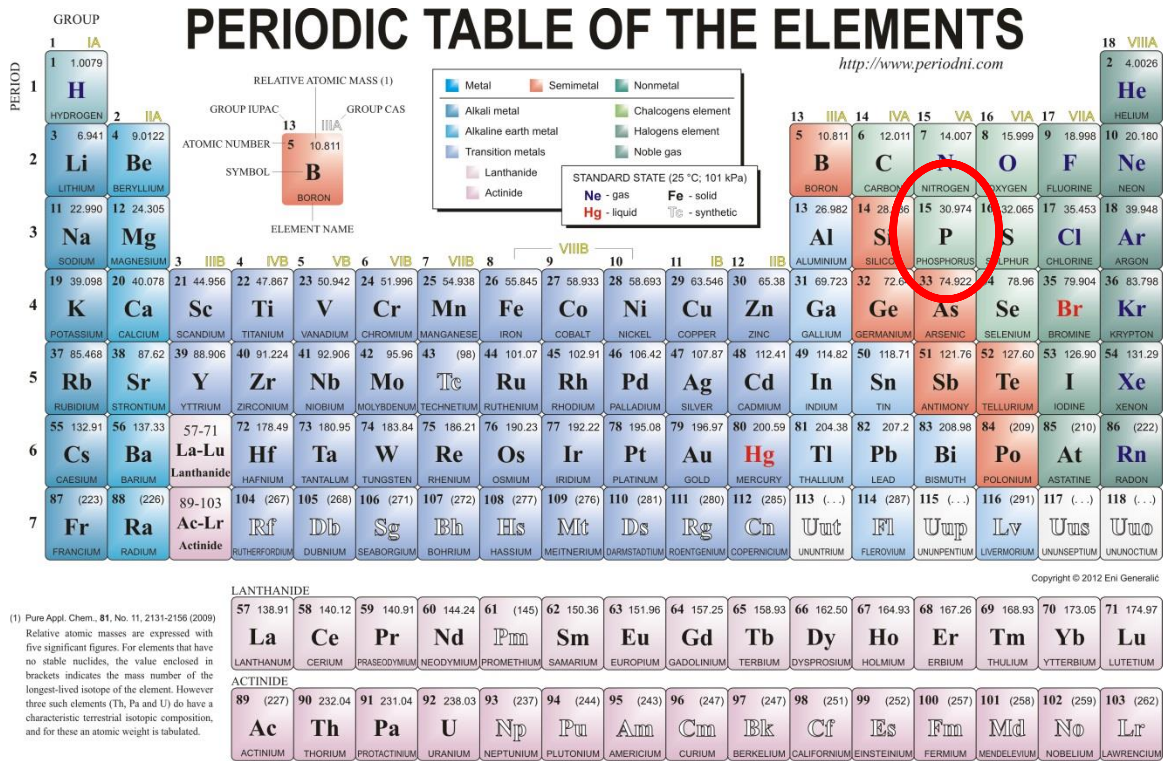
- Key Terms:
  - weathering;
  - erosion & transport;
  - sedimentation;
  - burial & lithification;
  - subduction zone;
  - uplift;
  - metamorphosis;
  - igneous processes (intrusive and extrusive forms);
  - fresh rock to surface



Source: The Geological Society – United Kingdom
http://www.geolsoc.org.uk/ks3/gsl/education/resources/rockcycle.html

Phosphorus (P) – importance of…

1. essential for metabolic energy use;
2. not very common → tendency of species to store and re-use P rather than outright discard;
3. P is a dominant ‘limiting factor’ in ecosystems;
4. agricultural productivity relies very heavily on external inputs of P



Source: www.periodni.com-

Phosphorus Cycle – key terms / concepts

5. main reservoir is ROCK;
6. uplift and weathering → soil;
7. uptake by plants, then → higher trophic levels;
8. plant decay / animal wastes and bones key return flow of P;
9. P enters streams & rivers → lakes & oceans;
10. productive estuarine and shallow coastal zones with high P

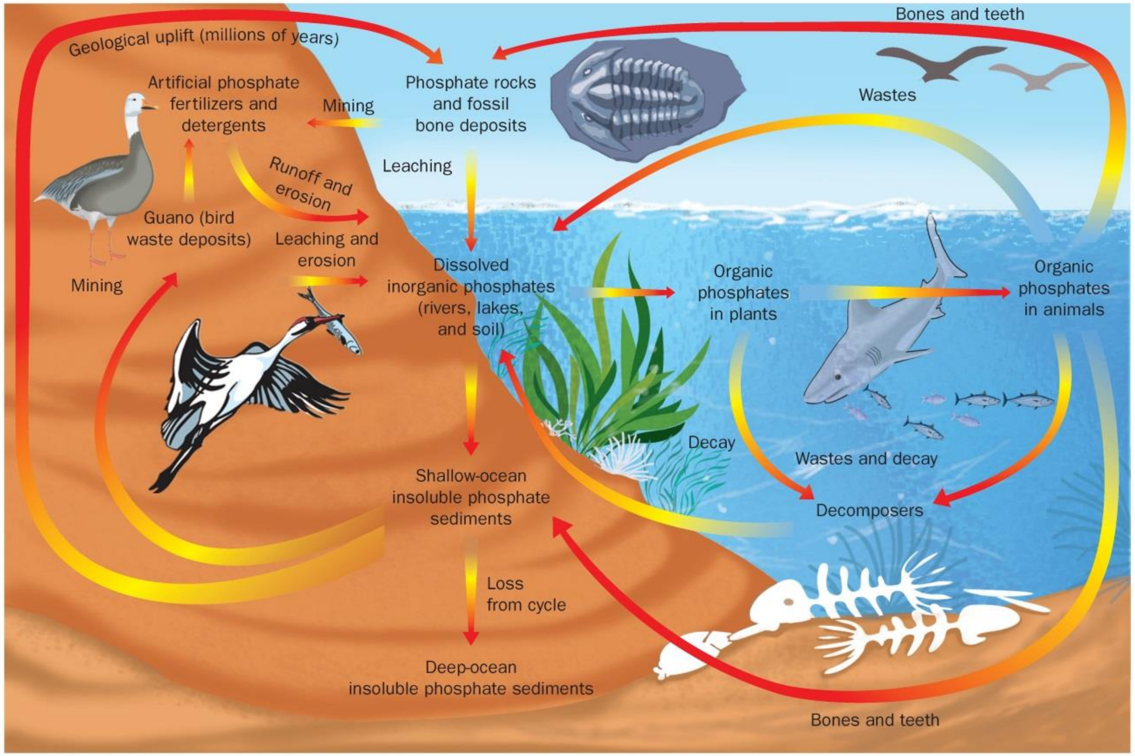
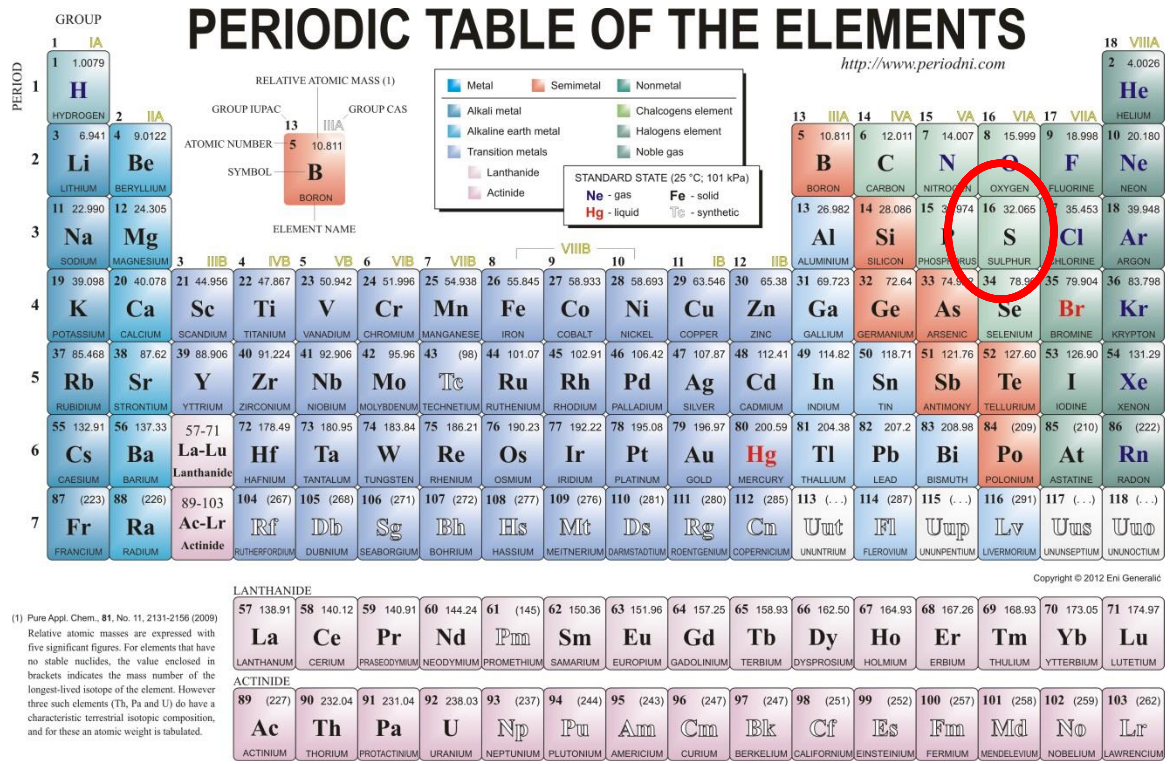


Figure 4.2 | The phosphorus cycle.

Source: Dearden and Mitchell (2012)

Sulphur (S) – importance of…

1. like all macro-nutrients, an essential component for life;
2. a building component of proteins;
3. S not often a 'limiting factor' in ecosystems;



Source: www.periodni.com-

Sulphur Cycle – key terms / concepts

5. also has an 'atmospheric component'; thus better recycling potential (or rates);
6. S not available in the lithosphere;
7. more highly dependent on **microbial organisms** for movement in the 'cycle' (unlike P)
8. bacteria transform S into various forms in the soil;
9. transformations either under **aerobic or anaerobic** conditions (with or without Oxygen) leading to:
   - H_2S (gas) → atmosphere
   - 'sulphate salts' → remain in the soil

10. interaction of S cycle with other nutrient cycles creates added complexity (e.g. O, N)
    - e.g., SO_2 formation, acid rain

Source: Dearden and Mitchell (2012)

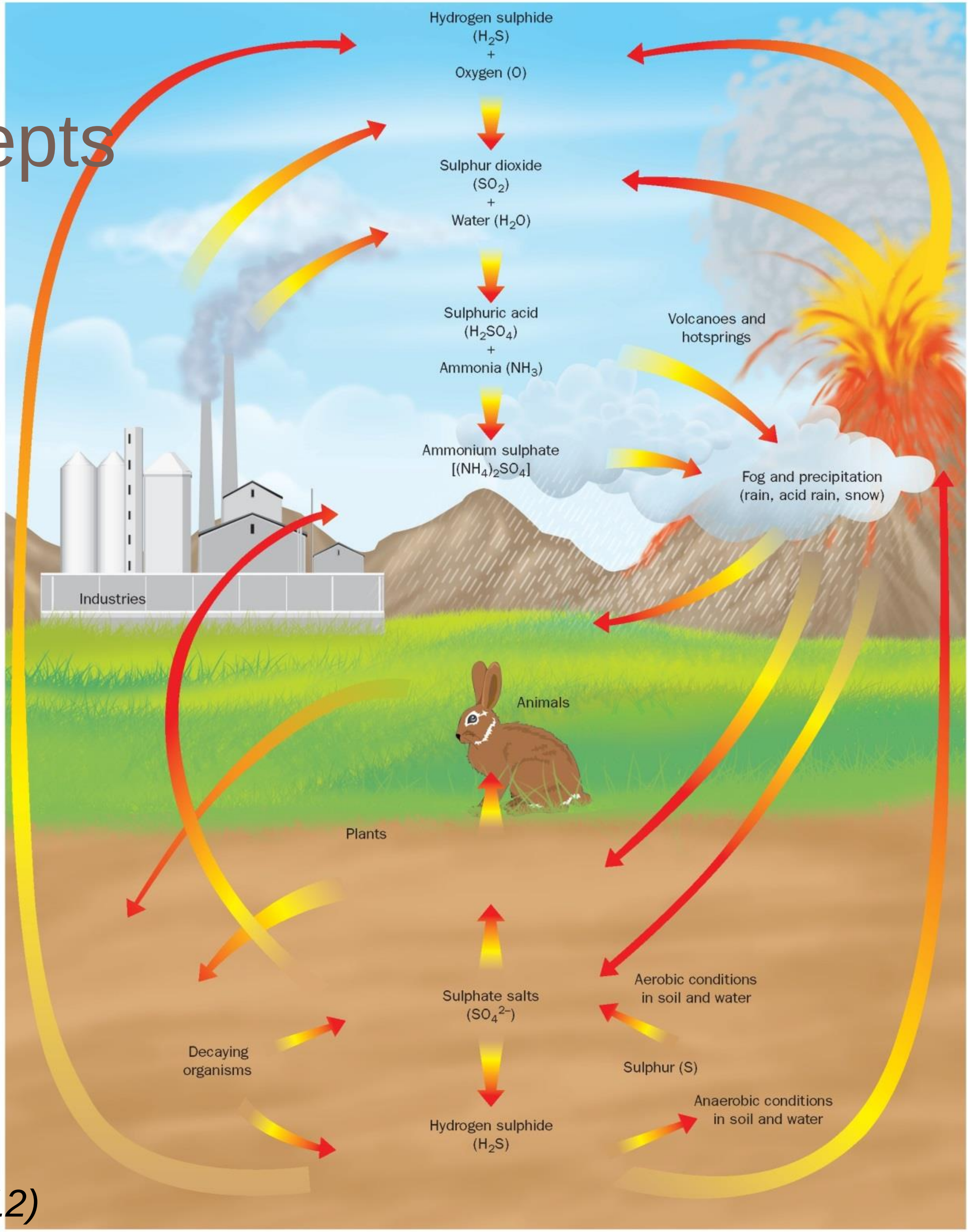


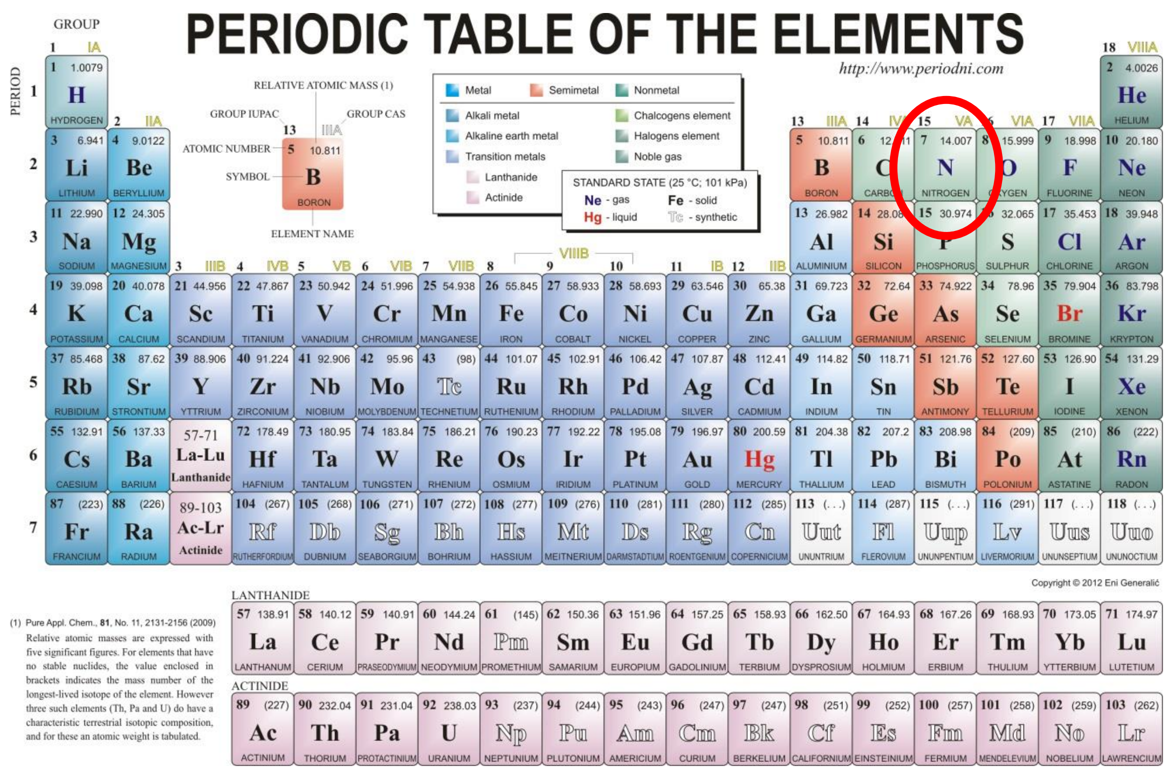
Figure 4.3 | The sulphur cycle.

Gaseous Cycles

- Nitrogen (N)
- Carbon (C)

Nitrogen (N) – importance of…

1. essential for life;
2. essential component of chlorophyll, proteins and amino acids;
3. atmosphere contains >78% N_2 gas as well as other gaseous N forms (e.g, NO_2 – nitrogren dioxide, NH_3 – ammonia)
4. excessive N equates to many environmental issues such as:
   - acid deposition;
   - ozone depletion;
   - global climate change;
5. N accumulation in the hydrosphere → "eutrophication"



Source: www.periodni.com-

Nitrogen Cycle
– key terms / concepts

6. N cycles between atmosphere and lithosphere; **most importantly via biological activity**;
7. most organisms <u>cannot</u> directly access atmospheric N (they need assistance of nitrogen fixators)
8. **<u>Nitrogen Fixation:</u>**
   - bacteria transform atmospheric N into various forms in the soil;
   - NH_3 (ammonia)
   - nitrates and 'ammonia salts' NH_4^+ (which are readily soluble)

Source: Dearden and Mitchell (2012)

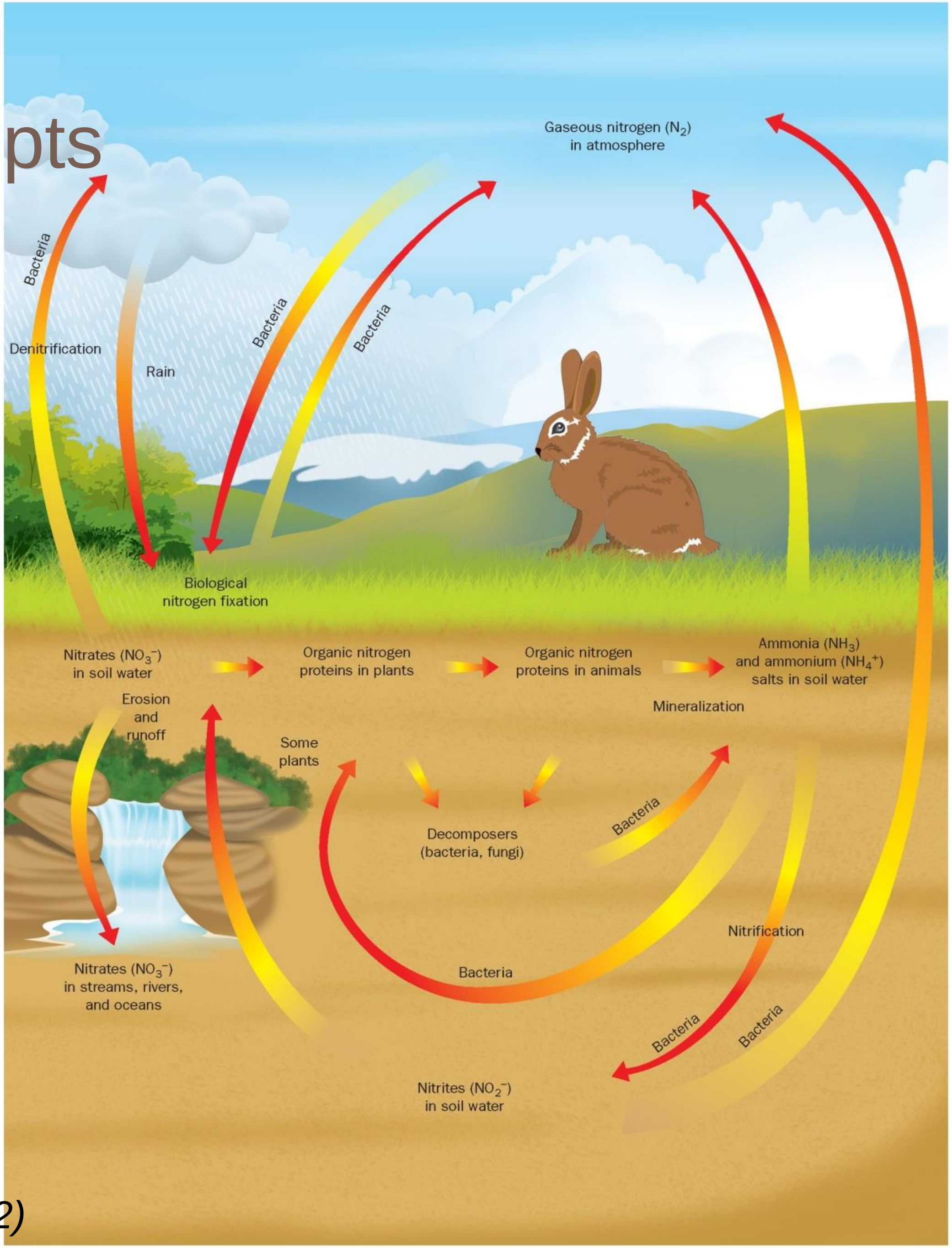


Figure 4.4 | The nitrogen cycle.

Nitrogen Cycle
– key terms / concepts

9. N is quickly depleted in soil, especially in lands under cultivation;
10. farmers ‘rotate’ in crops like alfalfa and clover, which can build up nitrates in soils;
11. early colonizers in ecological succession are also key nitrogen fixator species – to provide nutrients for subsequent species
12. **<u>Nitrification and Denitrification:</u>**

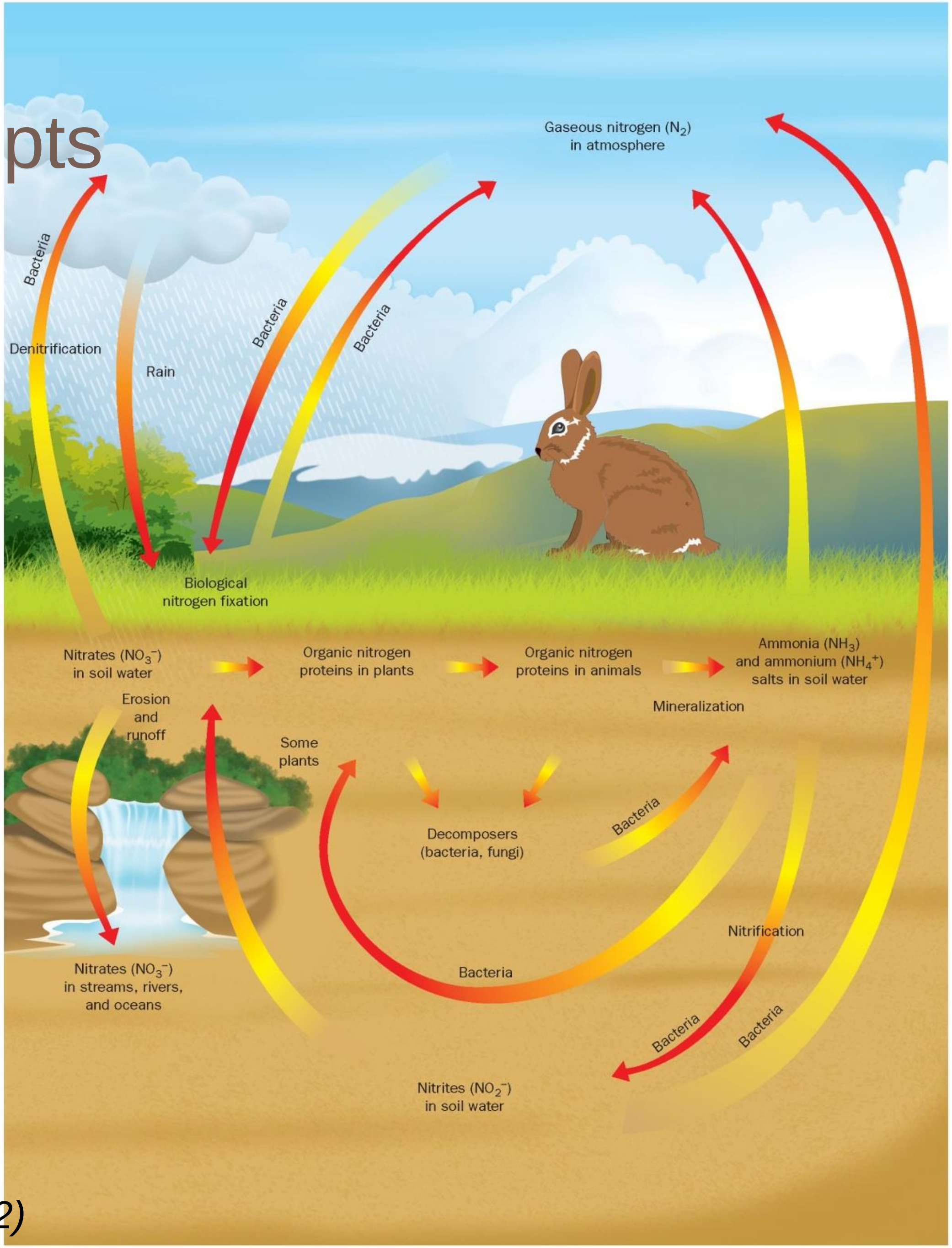
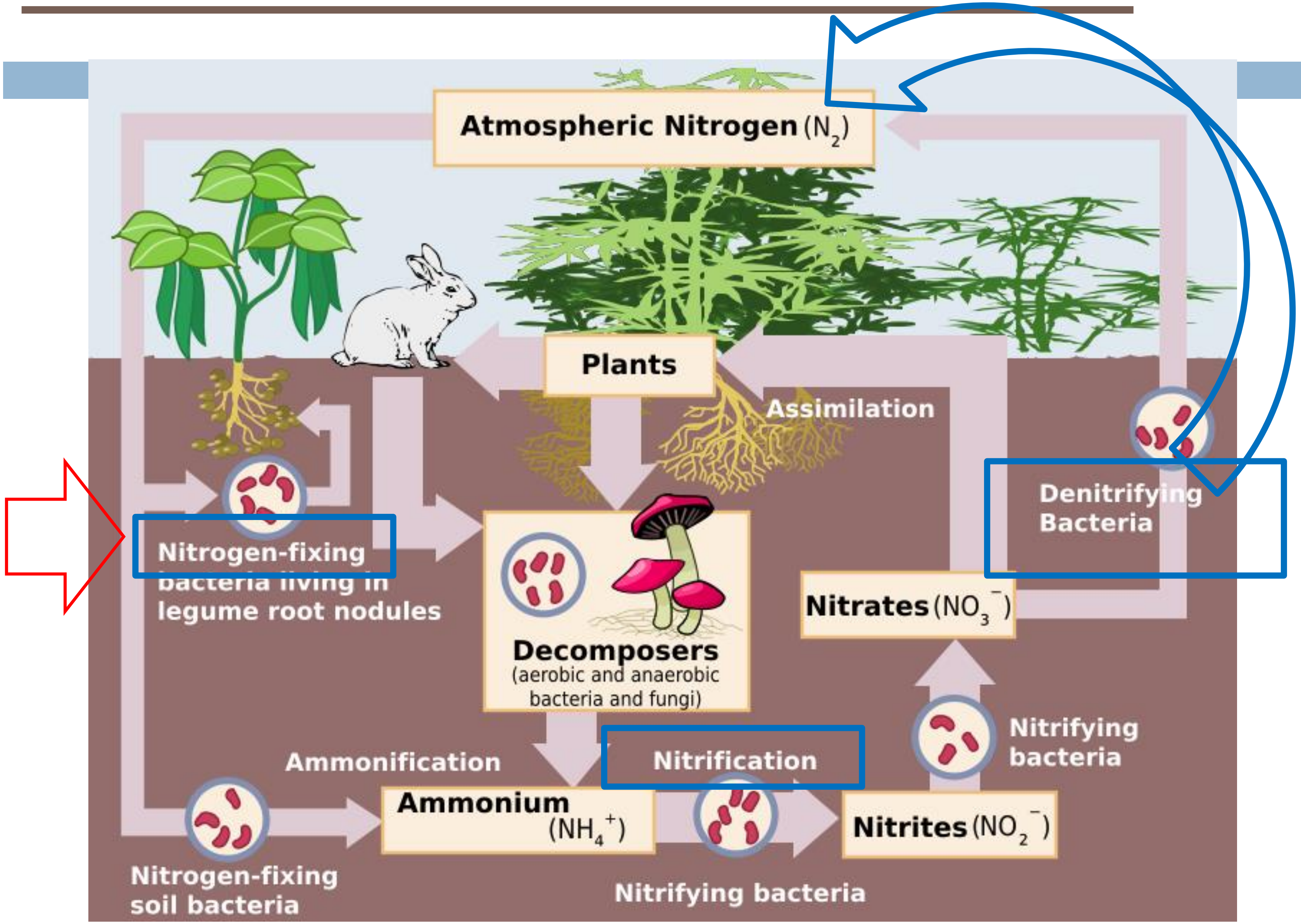


Figure 4.4 | The nitrogen cycle.

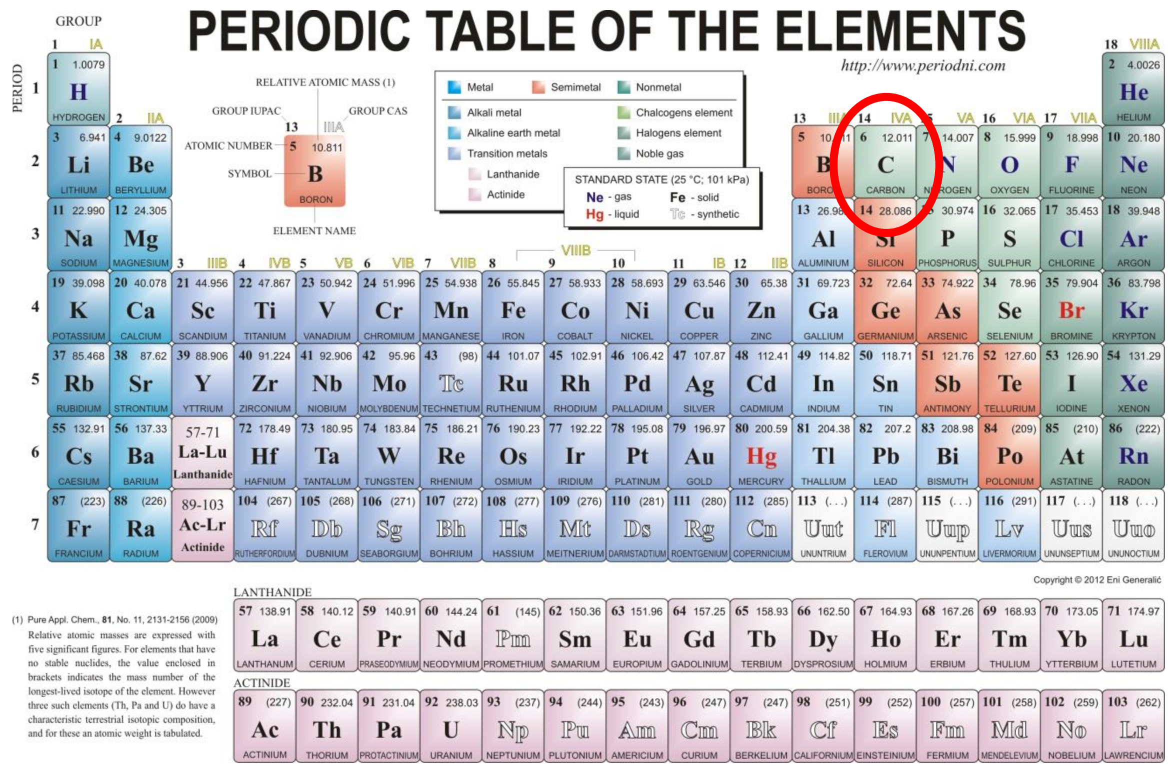
Source: Dearden and Mitchell (2012)

Nitrification and Denitrification:



Carbon (C) – importance of…

1. although a small fraction of the atmosphere (CO_2 <0.03%), it is the main C reservoir available to biosphere;
2. building block for all necessary fats, proteins and carbohydrates that are needed to sustain life;
3. excessive CO_2 equates to global climate change;



Source: www.periodni.com-

Carbon Cycle – key terms / concepts

4. **photosynthesis**: uptake of CO_2 from atmosphere and emit O_2;
5. carbon incorporated into the 'food chain' (carbohydrates passed along)
6. residence times of C in the biosphere vary:
   - old growth forests (100s of years)
7. **respiration** by organisms returns CO_2 to the atmosphere
8. decay from dead organisms releases both CO_2 and Methane (CH_4) – both greenhouse gases

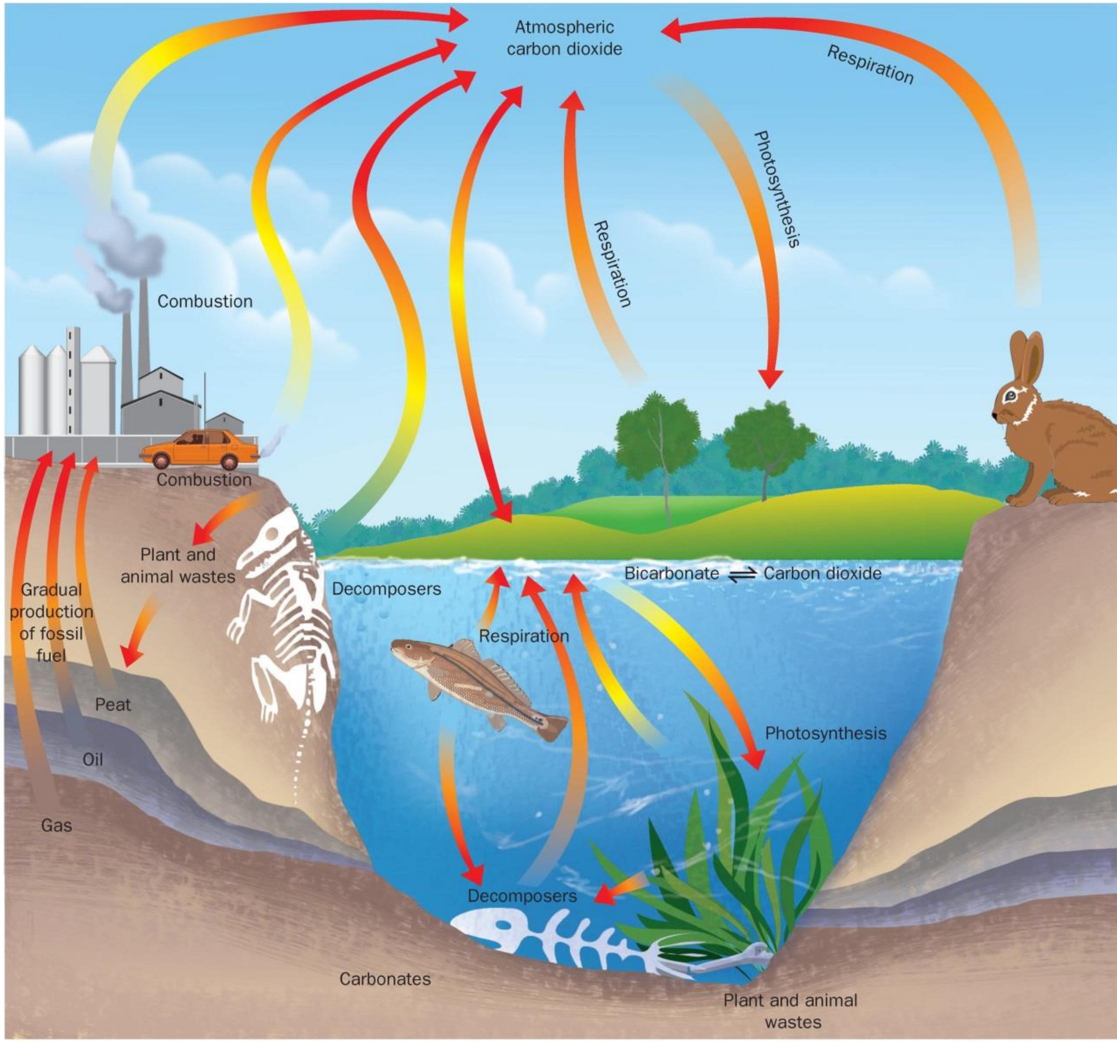


Figure 4.7 | The carbon cycle.

Source: Dearden and Mitchell (2012)

Carbon Cycle
– key terms / concepts

9. residence times of C in the lithosphere:
   - buried organisms in peat bogs (prior to decomposing)
   - fossil fuels contain millions of years of photosynthetic energy → which we are releasing much more rapidly than they are being taken up by oceans and other 'sinks';

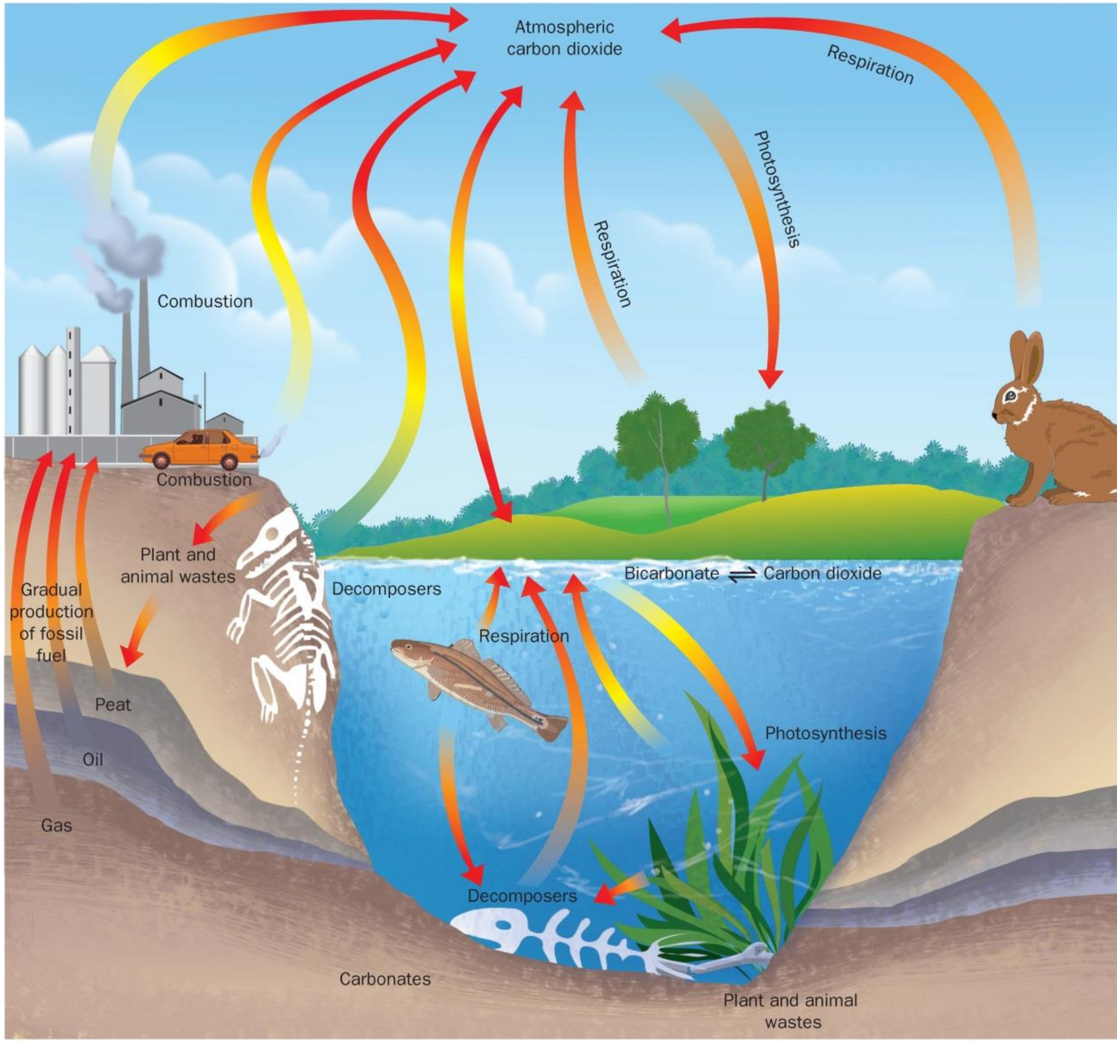


Figure 4.7 | The carbon cycle.

Source: Dearden and Mitchell (2012)

The Hydrological Cycle

Hydrological Cycle – importance of…

1. necessary for life;
2. humans are 70% H_20;
3. Earth is unique in its having liquid water (unlike Mars, Venus)
4. most is stored in oceans;
5. cycling from these reservoirs varies (some residence times in deep oceans is 30,000 + years; while atmosphere is 9-12 days)

Table 4.3 | Global Water Storage

Reservoir	Average Renewal Rate	Per Cent of Global Total
World oceans	3,100 years	97.2
Ice sheets and glaciers	16,000 years	2.15
Groundwater	300–4,600 years	0.62
Lakes (freshwater)	10–100 years	0.009
Inland seas, saline lakes	10–100 years	0.008
Soil moisture	280 days	0.005
Atmosphere	9–12 days	0.001
Rivers and streams	12–20 days	0.0001

Source: www.periodni.com-

Hydrological Cycle – key terms / concepts

- precipitation
- interception
- evaporation
- evapotranspiration
- infiltration (to gdw)
- condensation (onto 'condensation nuclei') and forms clouds

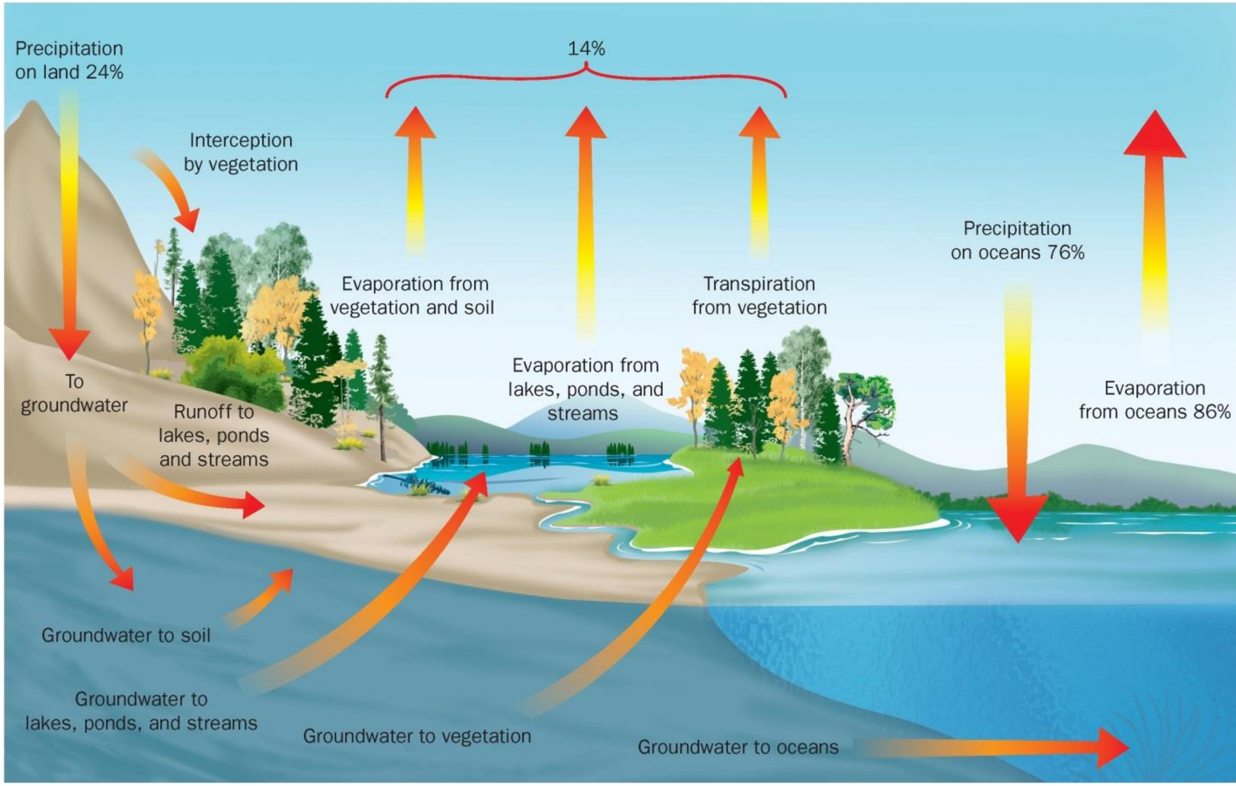


Figure 4.8 | The hydrological cycle. Water moves through the hydrological cycle as a liquid, as a vapour, and as snow.

Source: Dearden and Mitchell (2012)

Groundwater Flow – key terms / concepts

** Augment with board sketch **

- water table
- aquifer
- permeability
- recharge zone
- confined vs unconfined aquifers
- piezometric surface
- artesian well

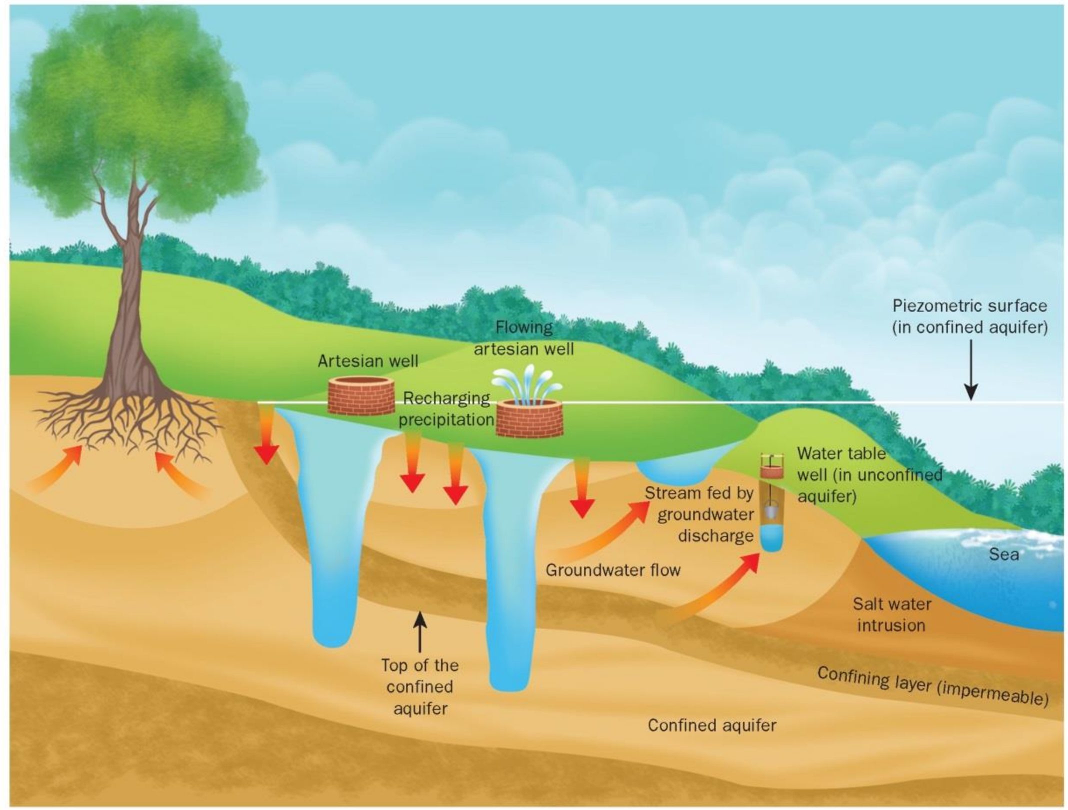


Figure 4.9 | Groundwater flow.

Source: Dearden and Mitchell (2012)

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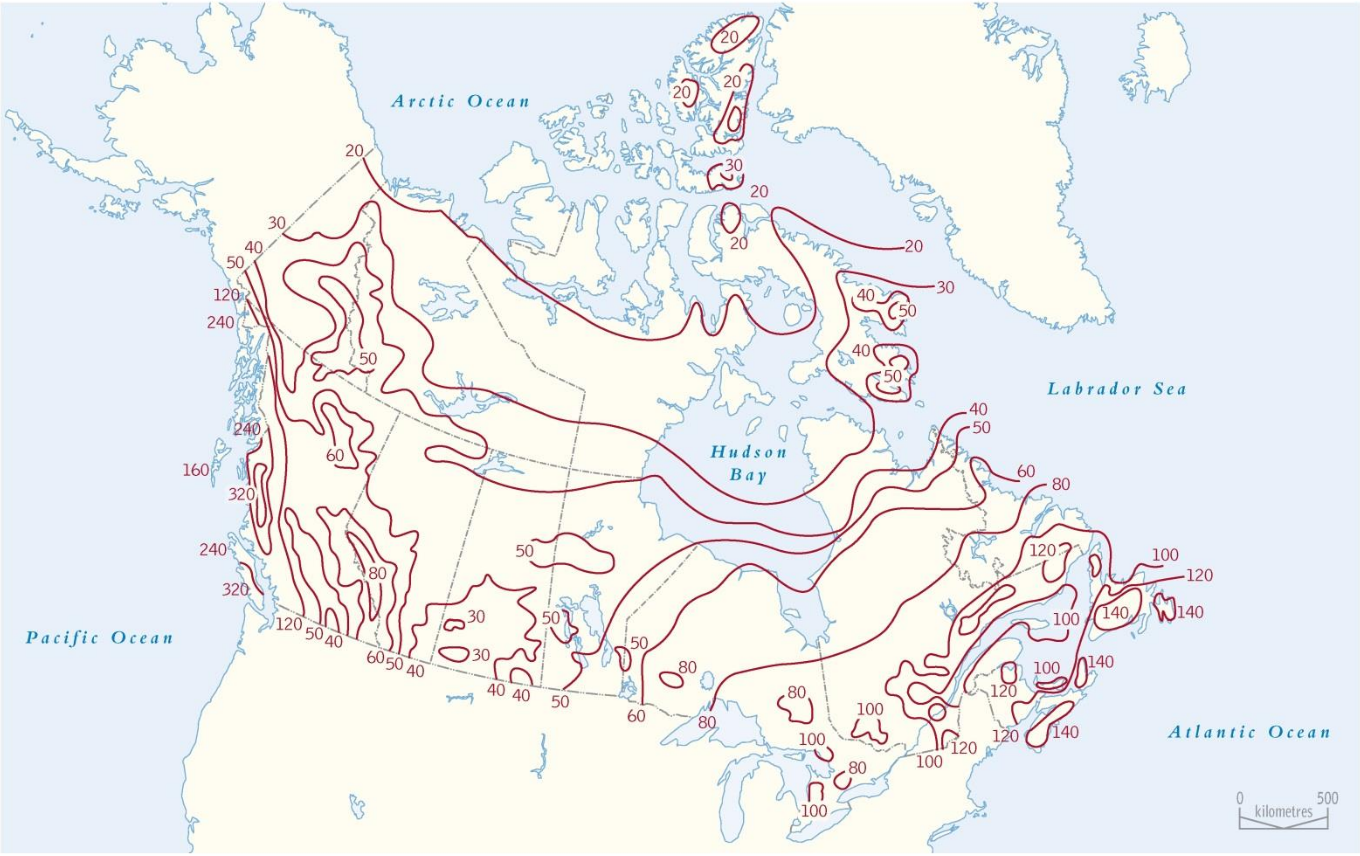

Figure 4.10 | Average annual rain and snow for Canada (cm). *Source: Phillips (1990: 210).*

- maritime areas wetter – especially West Coast
- low precipitation in Prairies
- “polar desert”

- Canada is 8% fresh water lakes;
- Despite apparent abundance, 75% of surface water discharge is to Arctic watersheds; while 90% of the population is within 300 km of the US border;
- **Our influence on the hydrological cycle and other biogeochemical cycles to be covered next time.**

Table 4.4 | Mean Annual Stream Discharge to the Oceans for Selected Canadian Rivers

River	Watershed Area (km^2)	Discharge (m^3s^{-1})
Saguenay	90,100	1,820
St Lawrence	1,026,000	9,860
Churchill	281,300	1,200
Nelson	722,600	2,370
Albany	133,900	1,400
Koksoak northern QC	133,400	2,550
Yukon (at Alaska border)	297,300	2,320
Fraser	219,600	3,540
Columbia (at Washington border)	154,600	2,800
Mackenzie	984,195	10,800

Source: Briggs et al. (1993: 206).

Source: Dearden and Mitchell (2012)

Looking Ahead to the next lectures

May 20: Ecosystems & Material Cycling: Human Activity & Impacts on Biogeochemical Cycles

Read ahead (Chpt. 4, pp. 114 →)

May 21:(Field trip, **to be confirmed**): ***Atlantic Street WWTP, East End and Neebing Spillway***

May 22: Mid-term exam (**covers to end of Chapter 4**)

May 26 & 27: Planning and Management: Adaptive Management and Impact & Risk Assessment

** Case Study: Skagit Valley Landslide*

Read ahead (Chpt. 6, pp. 172 →197)

References

- Dearden, P and Mitchell, B. 2012. *Environmental Change and Challenge*, Fourth Edition, Don Mills, Ontario: Oxford University Press {Chapter 4: 'Ecosytems and Matter Cycling'}