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

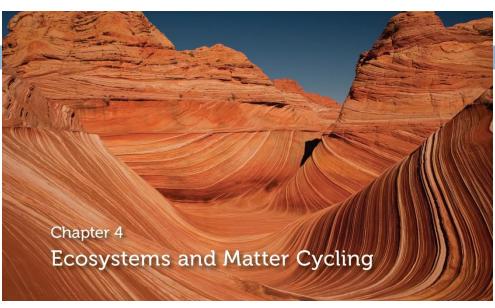
Outline

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)
- I (lecture) biogeochemical cycles
- (discussion: return of paper proposals)
- (discussion: exam format and length)



Macro / Micro Nutrients

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

Major Macro (>1% dry orga		Relatively Minor			Micronutrients (<0.2% dry organic weight)			
Name of Element	Symbol	Name of Element	Symbol	Name of Element	Symbol			
Carbon	С	Calcium	Са	Aluminum	AI			
Hydrogen	Н	Chlorine	CI	Boron	В			
Nitrogen	Ν	Copper	Cu	Bromine	Br			
Oxygen	0	Iron	Fe	Chromium	Cr			
Phosphorus	Р	Magnesium	Mg	Cobalt	Со			
		Potassium	К	Fluorine	F			
		Sodium	Na	Gallium	Ga			
		Sulphur	S	lodine	L			
				Manganese	Mn			
				Molybdenum	Мо			
				Selenium	Se			
				Silicon	Si			
				Strontium	Sr			
				Tin	Sn			
				Titanium	Ti			
				Vanadium	V			
				Zinc	Zn			

Source: Kupchella and Hyland (1989).

Carbon / Nitrogen Stores



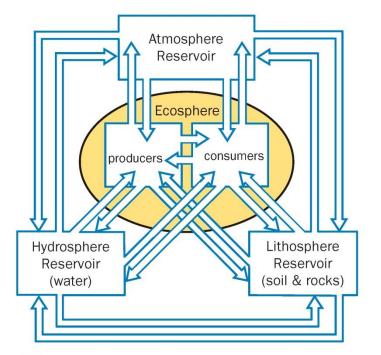


Figure 4.1 | Each nutrient is stored and released by components of the Earth's systems. Different nutrients follow slightly different paths through the systems and are stored and released at different rates.

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%

<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

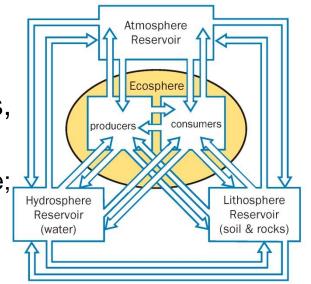


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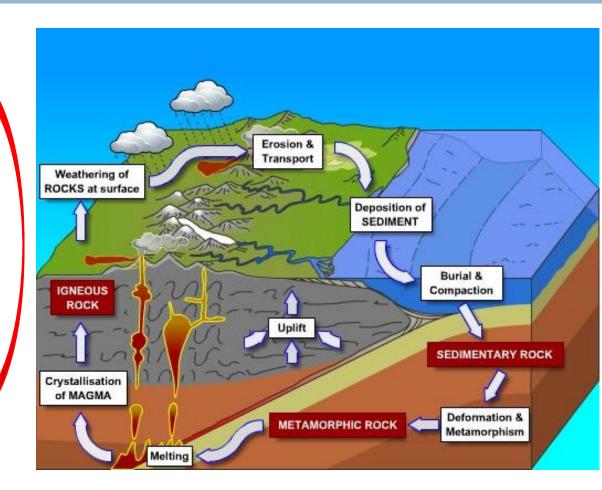
6 Sedimentary Cycles

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...

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

	GROUP		DE		OD		TΛ	DI			тυ		21 E	: NЛ С		ГС		
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3	Na	Mg		ELEM	MENT NAME				VIIIB			_	Al	Si	Р	S	Cl	Ar
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		20 40.078					10000		27 58.933				31 69.723	32 72.6	33 74.922		35 79.904	36 83.798
4	K	Ca	Sc	Ti	V	Cr	Mn	Fe	Co	Ni	Cu	Zn	Ga	Ge	As	Se	Br	Kr
	POTASSIUM 37 85,468	CALCIUM 38 87.62	39 88.906	TITANIUM 40 91.224	VANADIUM 41 92.906	<hr/>	MANGANESE 43 (98)	IRON 44 101.07	COBALT 45 102.91	NICKEL 46 106.42	COPPER 47 107.87	ZINC 48 112.41	GALLIUM 49 114.82	GERMANIUM	ARSENIC 51 121.76	SELENIUM	BROMINE 53 126.90	54 131.29
5	Rb	Sr 87.02	Y 80.900	Zr	Nb	42 95.96 Mo	43 (98) Tre	Ru	Rh	Pd		Cd		Sn	Sb	Te	33 120.00	Xe
	RUBIDIUM	STRONTIUM	YTTRIUM	ZIRCONIUM	NIOBIUM				RHODIUM	PALLADIUM	Ag	Ca	In	51 TIN	ANTIMONY	TELLURIUM	IODINE	XENON
		56 137.33	57-71	72 178.49	< <u> </u> ♦	\leftarrow	$\sim \rightarrow \sim$	\rightarrow	77 192.22	78 195.08	\sim	\sim	\sim	82 207.2	83 208.98		85 (210)	86 (222)
6	Cs	Ba	La-Lu	Hf	Та	W	Re	Os	Ir	Pt	Au	Hg	TI	Pb	Bi	Po	At	Rn
	CAESIUM	BARIUM	Lanthanide	HAFNIUM	TANTALUM	TUNGSTEN	RHENIUM	OSMIUM	IRIDIUM	PLATINUM	GOLD	MERCURY	THALLIUM	LEAD	BISMUTH	POLONIUM	ASTATINE	RADON
9292	87 (223)	88 (226)	09-105	104 (267)	105 (268)	106 (271)	107 (272)	108 (277)	109 (276)	110 (281)		112 (285)	113 ()	114 (287)	115 ()	116 (291)	117 ()	118 ()
7	Fr	Ra	Ac-Lr	IRſ	IDb	Sg	IBh	IHs	Mit	Ds	Rg	Cn	Uut	Fl	Uup	ILV	Uus	Uuo
	FRANCIUM	RADIUM	Actinide	RUTHERFORDIUM	DUBNIUM	SEABORGIUM	BOHRIUM	HASSIUM	MEITNERIUM	DARMSTADTIUM	ROENTGENIUM	COPERNICIUM	UNUNTRIUM	FLEROVIUM	UNUNPENTIUM	LIVERMORIUM	UNUNSEPTIUM	UNUNOCTIUM
				LANTHANI	IDE											C	opyright © 2012	? Eni Generalić
(1) Pure	Appl. Chem., 81	I. No. 11, 2131-7	2156 (2009)	57 138.91	58 140.12	59 140.91	60 144.24	61 (145)	62 150.36	63 151.96	64 157.25	65 158.93	66 162.50	67 164.93	68 167.26	69 168.93	70 173.05	71 174.97
Relat	tive atomic ma significant figur	asses are expre	essed with	La	Ce	Pr	Nd	IPm	Sm	Eu	Gd	Tb	Dy	Ho	Er	Tm	Yb	Lu
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Diaci	lets indicates t	are mass nume	Jet of the	ACTINIDE														

Source: www.periodni.com-

Am

Cm

Bk

Cf

Es

Fm

Md

NO

Lr

zest-lived isotope of the element. However 89 (227) 90 232.04 91 231.04 92 238.03 93 (237) 94 (244) 95 (243) 96 (247) 97 (247) 98 (251) 99 (252) 100 (257) 101 (258) 102 (259) 103 (262) three such elements (Th, Pa and U) do have a characteristic terrestrial isotopic composition, Ac and for these an atomic weight is tabulated

Pa

U

Th

Np

Pu

Phosphorus Cycle – key terms / concepts

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

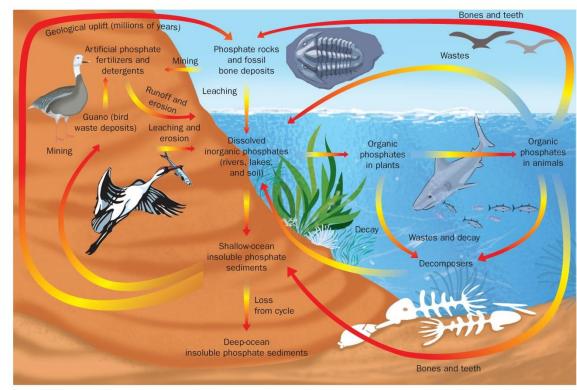


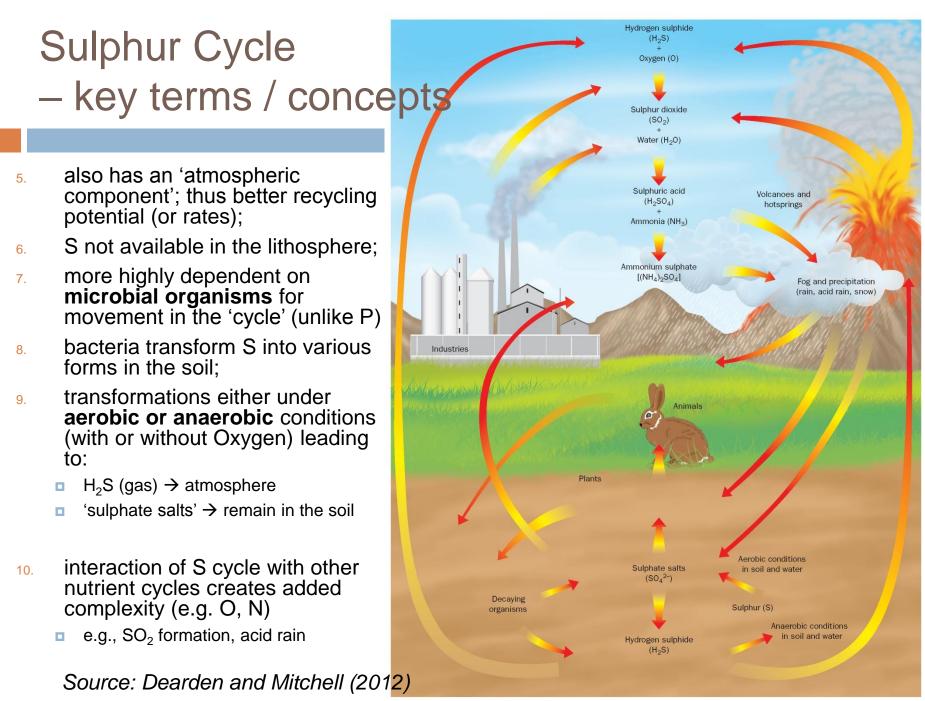
Figure 4.2 | The phosphorus cycle.

Sulphur (S) – importance of...

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

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	LITHIUM	BERYLLIUM		YMBOL	B			Lanthanide Actinide		DARD STATE	(25 °C; 101) Fe - solid	kPa)	BORON	CARBON	NITROC N	OXYGEN	FLUORINE	NEON
	11 22.990	12 24.305			BORON			, total loo		- liquid	Te - sond Te - synthe	tic	13 26.982	14 28.086	15 3 974	16 32.065	35.453	18 39.948
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	SODIUM	MAGNESIUM	0 1110	4 IVB	5 VB	6 VIB	7 VIIB	8	9	10	_	12 IIB	ALUMINIUM	SILICON	PHOSPH IRUS	\rightarrow		ARGON
	19 39.098	20 40.078	21 44.956	22 47.867	23 50.942	24 51.996	25 54.938	26 55.845	27 58.933	28 58.693	29 63.546	30 65.38	31 69.723	32 72.64	33 74.9 2	34 78.95	35 79.904	36 83.798
4	K	Ca	Sc	Ti	V	Cr	Mn	Fe	Co	Ni	Cu	Zn	Ga	Ge	As	Se	Br	Kr
	POTASSIUM	CALCIUM	SCANDIUM	TITANIUM	VANADIUM	· · · · · · · · · · · · · · · · · · ·	MANGANESE	IRON	COBALT	NICKEL	COPPER	ZINC	GALLIUM	GERMANIUM		SELENIUM	BROMINE	KRYPTON
5	37 85.468		39 88.906	40 91.224	41 92.906	42 95.96	43 (98)	44 101.07	45 102.91	46 106.42	47 107.87	48 112.41	49 114.82	50 118.71	51 121.76	52 127.60	53 126.90	54 131.29
Э	Rb	Sr	Y	Zr														
		~			Nb	Mo	Tc	Ru	Rh	Pd	Ag	Cd	In	Sn	Sb	Te	1	Xe
	RUBIDIUM	STRONTIUM	YTTRIUM	ZIRCONIUM	NIOBIUM	MOLYBDENUM	TECHNETIUM	RUTHENIUM	RHODIUM	PALLADIUM	SILVER	CADMIUM	INDIUM	TIN	ANTIMONY	TELLURIUM	IODINE 85 (210)	XENON
6	RUBIDIUM 55 132.91	STRONTIUM 56 137.33	<u>уттгіим</u> 57-71	ZIRCONIUM 72 178.49	NIOBIUM 73 180.95	MOLYBDENUM 74 183.84	TECHNETIUM 75 186.21	RUTHENIUM 76 190.23	RHODIUM 77 192.22	PALLADIUM 78 195.08	SILVER 79 196.97	CADMIUM 80 200.59	INDIUM 81 204.38	TIN 82 207.2	ANTIMONY 83 208.98	TELLURIUM 84 (209)	85 (210)	XENON 86 (222)
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Source: www.periodni.com-



11

Figure 4.3 | The sulphur cycle.



Nitrogen (N) Carbon (C)

Nitrogen (N) – importance of...

three such elements (Th, Pa and U) do have a characteristic terrestrial isotopic composition,

and for these an atomic weight is tabulated

Th

Ac

Pa

U

Np

Pu

13

1. essential for life;

- essential component of chlorophyll, proteins and amino acids;
- 3. atmosphere contains >78% N₂ gas as well as other gaseous N forms (e.g, NO₂ – nitrogren dioxide, NH_3 – ammonia)
- excessive N equates to many environmental issues such as:
 - acid deposition;
 - ozone depletion;
 - global climate change;
- N accumulation in the hydrosphere → "eutrophication"

	GROUP		DE				ТЛ	DI	E (тυ	C C		: NЛ П		ге		
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	3 6.941	4 9.0122	ATOMIC N	13 JUMBER - 5				aline earth m			ens element		5 10.811	6 12 11	7 14.007	8 15.999	9 18.998	10 20.180
2	Li	Be					A	insition metals	5	Noble	gas		В	C	N	0	F	Ne
	LITHIUM	BERYLLIUM	5	YMBOL	B			Lanthanide Actinide			(25 °C; 101)	kPa)	BORON	CARBO	NITROGEN	YGEN	FLUORINE	NEON
	11 22.990	12 24.305			BORON		_	Acunide		- gas - liquid	Fe - solid	tic	13 26.982	14 28.08	15 30.974	32.065	17 35.453	18 39.948
3	Na	Mg		ELEN	MENT NAME								Al	Si		S	Cl	Ar
	SODIUM	MAGNESIUM	3 IIIB	4 IVB	5 VB	6 VIB	7 VIIB	8	VIIIB -	10	11 IB	12 IIB	ALUMINIUM	SILICON	PHOSPHORUS		CHLORINE	ARGON
		20 40.078			23 50.942		25 54.938		27 58.933	28 58.693	29 63.546	30 65.38	31 69.723	32 72.64	33 74.922	34 78.96	35 79.904	36 83.798
4	K	Ca	Sc	Ti	V	Cr	Mn	Fe	Co	Ni	Cu	Zn	Ga	Ge	As	Se	Br	Kr
	POTASSIUM	Calcium	SCANDIUM	TITANIUM	VANADIUM		MANGANESE	IRON	COBALT	NICKEL	COPPER	ZINC	GALLIUM	GERMANIUM		SELENIUM	BROMINE	KRYPTON
	37 85.468		39 88.906	X	41 92.906	42 95.96		44 101.07	45 102.91	46 106.42	47 107.87	48 112.41	49 114.82	50 118.71	51 121.76	52 127.60	53 126.90	54 131.29
5													-				T	
2	Rb	Sr	Y	Zr	Nb	Mo	Tc	Ru	Rh	Pd	Ag	Cd	In	Sn	Sb	Te	1	Xe
	RUBIDIUM 55 132.91	56 137.33	YTTRIUM	ZIRCONIUM 72 178.49	NIOBIUM 73 180.95	74 183.84	75 186.21	76 190.23	RHODIUM	PALLADIUM 78 195.08	SILVER 79 196.97	CADMIUM 80 200.59	INDIUM 81 204.38	TIN 82 207.2	ANTIMONY 83 208.98	TELLURIUM	10DINE 85 (210)	XENON 86 (222)
6			57-71 La-Lu												1.000			
0	Cs	Ba	Lanthanide	Hf	Та	W	Re	Os	Ir	Pt	Au	Hg	TI	Pb	Bi	Po	At	Rn
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-	87 (223)	88 (226)	89-103		105 (268)	106 (271)	107 (272)	108 (277)		110 (281)		112 (285)	113 ()	114 (287)	115 ()	116 (291)	117 ()	118 ()
7	Fr	Ra	Ac-Lr	Rſ	Db	Sg	IBh	IHS	Mít	Ds	Rg	Cn	Uut	161	Uup	Lv	Uus	Uuo
	FRANCIUM	RADIUM	Actinide	RUTHERFORDIUM	DUBNIUM	SEABORGIUM	BOHRIUM	HASSIUM	MEITNERIUM	DARMSTADTIUM	ROENTGENIUM	COPERNICIUM	UNUNTRIUM	FLEROVIUM	UNUNPENTIUM	LIVERMORIUM	UNUNSEPTIUM	UNUNOCTIUM
				LANTHANI	DE											С	opyright © 2012	? Eni Generalić
			1		58 140.12	59 140.91	60 144.24	61 (145)	62 150.36	63 151.96	64 157.25	65 158.93	66 162.50	67 164.93	68 167.26	69 168.93	70 173.05	71 174 97
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five	significant figur	es. For element	s that have	La	Ce	Pr	Nd	Pm	Sm	Eu	Gd	Tb	Dy	Но	Er	Tm	Yb	Lu
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long	est-lived isotope	of the element	. However		00 000 04	01 004 04	02 000 00	0.2 (007)	04 (044)	05 (040)	06 (047)	07 (047)	00 (054)	00 (050)	100 (057)	101 (050)	102 (050)	102 (000)

Source: www.periodni.com-

Am

89 (227) 90 232.04 91 231.04 92 238.03 93 (237) 94 (244) 95 (243) 96 (247) 97 (247) 98 (251) 99 (252) 100 (257) 101 (258) 102 (259) 103 (262)

Cm

Bk

Cf

Es

Fm

Md

NO

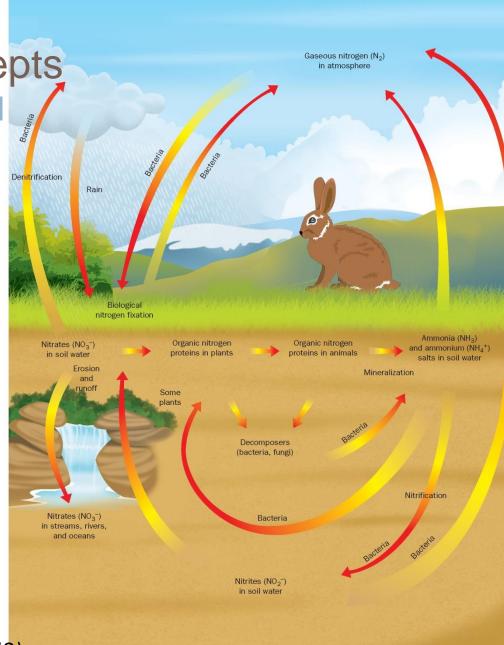
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Nitrogen Cycle – key terms / concepts

- 14
 - N cycles between atmosphere and lithosphere; most importantly via biological activity;
 - most organisms <u>cannot</u> directly access atmospheric N (they need assistance of nitrogen fixators)

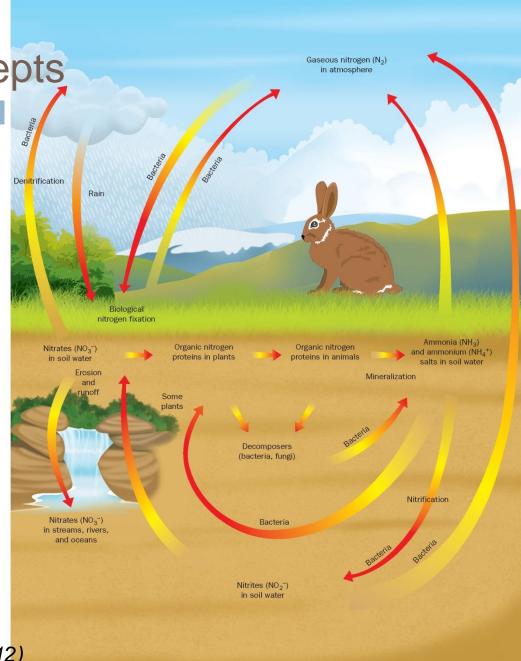
8. <u>Nitrogen Fixation:</u>

- bacteria transform atmospheric N into various forms in the soil;
- NH₃ (ammonia)
- nitrates and 'ammonia salts' NH₄ + (which are readily soluble)

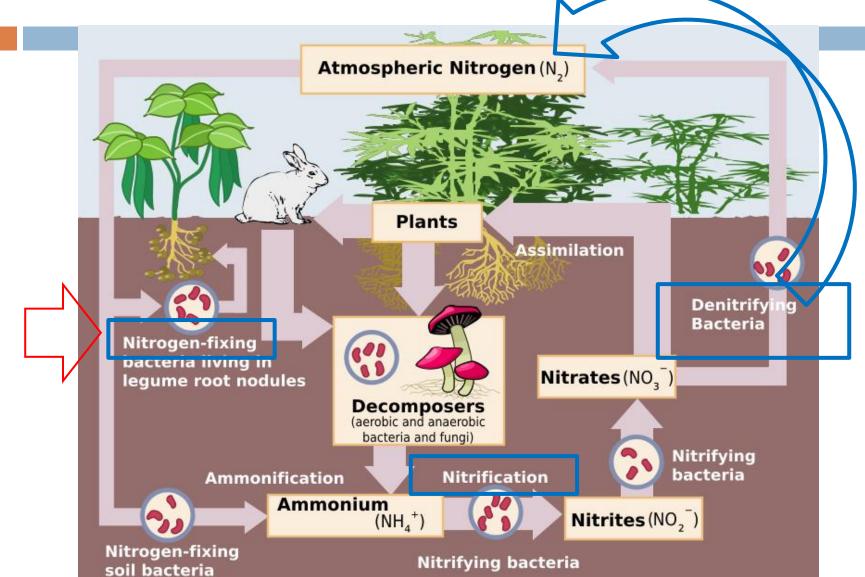


Nitrogen Cycle – key terms / concepts

- 15
- 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</u> <u>Denitrification:</u>



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;
- excessive CO₂ equates to global climate change;

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H	HYDROGEN	2 11A	GRC	UP IUPAC		ROUP CAS	10000	ali metal			gens elemen	t		14 IVA	VA I	16 VIA	17 VIIA	HELIUM
	3 6.941	4 9.0122	ATOMIC N				-	aline earth m		Haloge	ens element		5 10 11	6 12.011	7 14.007	8 15.999	9 18.998	10 20.180
2	Li	Be	s	YMBOL -	B			Lanthanide		-		<u> </u>	B	C	N	0	F	Ne
	LITHIUM	BERYLLIUM	Ĩ		BOBON		1.1	Actinide		- gas	(25 °C; 101) Fe - solid	(Pa)	BORO	CARBON	N ROGEN	OXYGEN	FLUORINE	NEON
	11 22.990	12 24.305			BORON					- liquid	Te - synthel	tic	13 26.98	14 28.086	30.974	16 32.065	17 35.453	18 39.948
3	Na	Mg		ELE	MENT NAME							_	Al	SI	Р	S	Cl	Ar
	SODIUM	MAGNESIUM	3 B	4 IVB	5 VB	6 VIB	7 VIIB	8	9 VIIIB	10	11 IB	12 IIB	ALUMINIUM	SILICON	PHOSPHORUS	SULPHUR	CHLORINE	ARGON
	19 39.098	20 40.078	21 44.956	22 47.867	23 50.942	24 51.996	25 54.938	26 55.845	27 58.933	28 58.693	29 63.546	30 65.38	31 69.723	32 72.64	33 74.922	34 78.96	35 79.904	36 83.798
4	K	Ca	Sc	Ti	V	Cr	Mn	Fe	Co	Ni	Cu	Zn	Ga	Ge	As	Se	Br	Kr
	POTASSIUM	CALCIUM	SCANDIUM	TITANIUM	VANADIUM		MANGANESE	IRON	COBALT	NICKEL	COPPER	ZINC	GALLIUM	GERMANIUM	ARSENIC	SELENIUM	BROMINE	KRYPTON
	37 85.468	38 87.62	39 88.906	40 91.224	41 92.906	42 95.96	43 (98)	44 101.07	45 102.91	46 106.42	47 107.87	48 112.41	49 114.82	50 118.71	51 121.76	52 127.60	53 126.90	54 131.29
5	Rb	Sr	Y	Zr	Nb	Mo	Te	Ru	Rh	Pd	Ag	Cd	In	Sn	Sb	Те	I	Xe
	RUBIDIUM	STRONTIUM	YTTRIUM	ZIRCONIUM	NIOBIUM		TECHNETIUM		RHODIUM	PALLADIUM	SILVER	CADMIUM	INDIUM	TIN	ANTIMONY	TELLURIUM	IODINE	XENON
	55 132.91	56 137.33	57-71	\sim	73 180.95	74 183.84		76 190.23		78 195.08	\sim		81 204.38	82 207.2	83 208.98	84 (209)	85 (210)	86 (222)
6	Cs	Ba	La-Lu	Hf	Та	W	Re	Os	Ir	Pt	Au	Hg	TI	Pb	Bi	Po	At	Rn
	CAESIUM	BARIUM	Lanthanide		TANTALUM	TUNGSTEN	RHENIUM	OSMIUM	IRIDIUM	PLATINUM	GOLD	MERCURY	THALLIUM	LEAD	BISMUTH	POLONIUM	ASTATINE	RADON
		88 (226)	89-103	<u> </u>	\rightarrow	106 (271)	107 (272)	\rightarrow	109 (276)	110 (281)	\rightarrow	112 (285)	113 ()	114 (287)	115 ()	116 (291)	117 ()	118 ()
7	Fr	Ra	Ac-Lr	IRſ	Db	Sa	IBh	IHs	Mit	Ds	Day	Cn	Uut	ान्ना	Uup	Lv	Uus	Uuo
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				LANTHANI	DE											C	opyright © 2012	Eni Generalić
(1) Pure	Appl. Chem., 81	I. No. 11. 2131-	2156 (2009)	57 138.91	58 140.12	59 140.91	60 144.24	61 (145)	62 150.36	63 151.96	64 157.25	65 158.93	66 162.50	67 164.93	68 167.26	69 168.93	70 173.05	71 174.97
	tive atomic ma			La	Ce	Pr	Nd	1Pmm	Sm	En	Gd	Th	Dv	Ho	Er	Tm	Yb	Lu

Pure Appl. Chem., 81, No. 11, 213-2168 (2000) Relative atomic masses are expressed with five significant figures. For elements that have no stable multides, the value enclosed in brackets indicates the mass number of the longest-lived isotope of the element. However three such elements (Th, Pa and U) do have a characteristic terrestrial isotopic composition, and for these an atomic weight is buladed.

La ce ING 161001 SIII Eu Ga ID Dy **H**0 Ŀr Im **YD** LANTHANU GADOLINIUM ACTINIDE 89 (227) 90 232.04 91 231.04 92 238.03 93 (237) 94 (244) 95 (243) 96 (247) 97 (247) 98 (251) 99 (252) 100 (257) 101 (258) 102 (259) 103 (262 Pa Pu Th Np Am Cm Bk Es Fm Md NO Lr Ac

Source: www.periodni.com-

Carbon Cycle – key terms / concepts

18

- 4. **<u>photosynthesis</u>**: uptake of CO_2 from atmosphere and emit O_2 ;
- 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. $respiration returns CO_2 to the atmosphere$
- 8. decay from dead organisms releases both CO_2 and Methane (CH_4) – both greenhouse gases

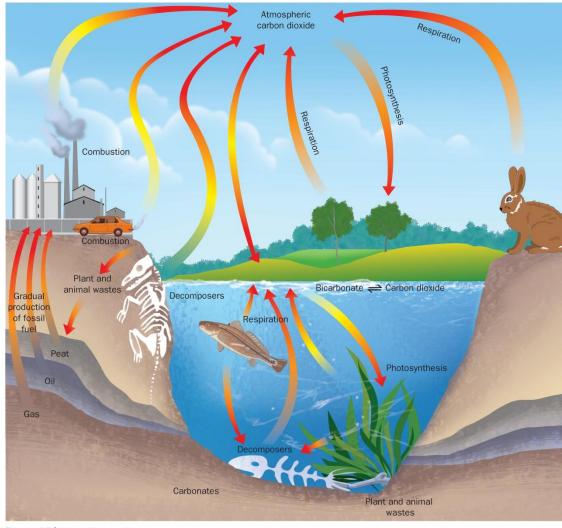


Figure 4.7 | The carbon cycle.

Carbon Cycle – key terms / concepts

- 9. residence times of C in the lithosphere:
 - buried organisms in peat bogs (prior to decomposing)
 - I 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';

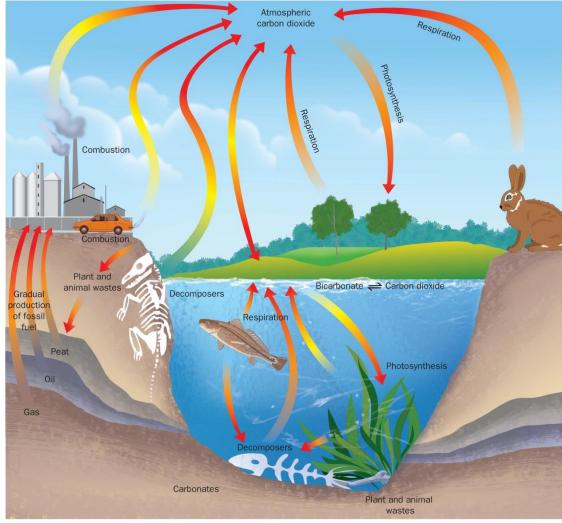


Figure 4.7 | The carbon cycle.

20 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)
- 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

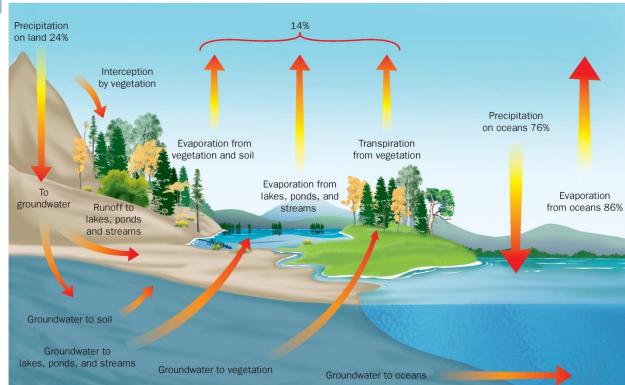
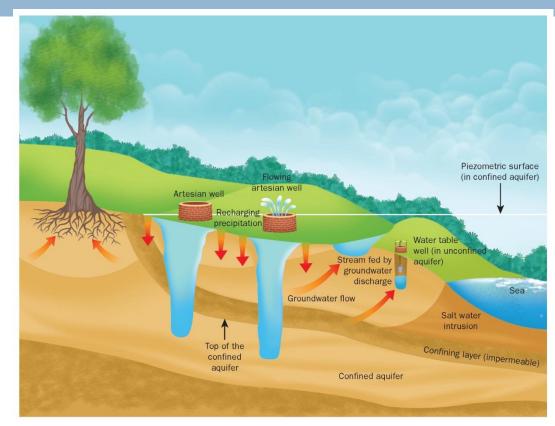


Figure 4.8 | The hydrological cycle. Water moves through the hydrological cycle as a liquid, as a vapour, and as snow.

Groundwater Flow – key terms / concepts

** Augment with board sketch **

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





Source: Dearden and Mitchell (2012)

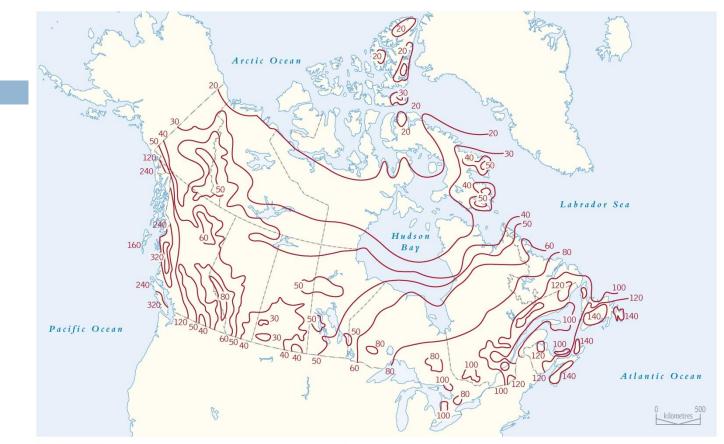


Figure 4.10 | Average annual rain and snow for Canada (cm). Source: Phillips (1990: 210).

- maritime areas wetter especially West Coast
- Iow 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 Dischargeto the Oceans for Selected Canadian Rivers

Watershed Area (km²)	Discharge (m ³ s ⁻¹)
90,100	1,820
1,026,000	9,860
281,300	1,200
722,600	2,370
133,900	1,400
133,400	2,550
297,300	2,320
219,600	3,540
154,600	2,800
984,195	10,800
	Area (km ²) 90,100 1,026,000 281,300 722,600 133,900 133,400 297,300 219,600 154,600

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

Looking Ahead to the next lectures

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

Read ahead (Chpt. 4, pp. 114 \rightarrow)

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 \rightarrow 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'}