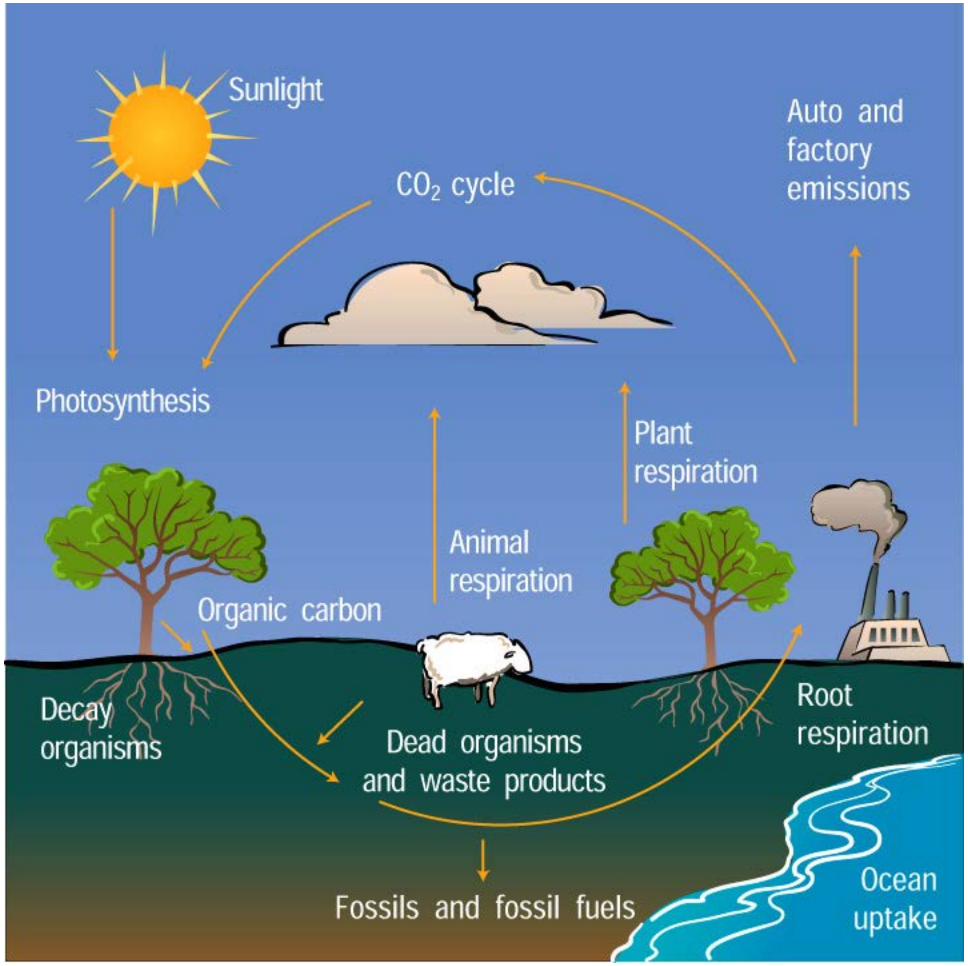
Welcome to the Biogeochemical Earth (OEAS540)



Today's Objectives

Course expectations, grades, etc.

Link among Solid, Fluid, and Biogeochemical "Earths"

What is Biogeochemistry? and Some fun Facts…

Briefly Review Key Concepts

Chapter 12 by Van Cappellen in Biomineralization (eds. Dove et al., 2003) - good introduction to global biogeochemical cycles and their feedbacks

Welcome to the Biogeochemical Earth

Goals:

- Basic understanding of biogeochemical cycling
- Make link between big scales and details
- See the connections with Solid and Fluid Earth
- Think like a scientist, speak like a normal person
- Intellectual intuition
- Finish the course knowing you know less than you thought you did when you started

Expectations:

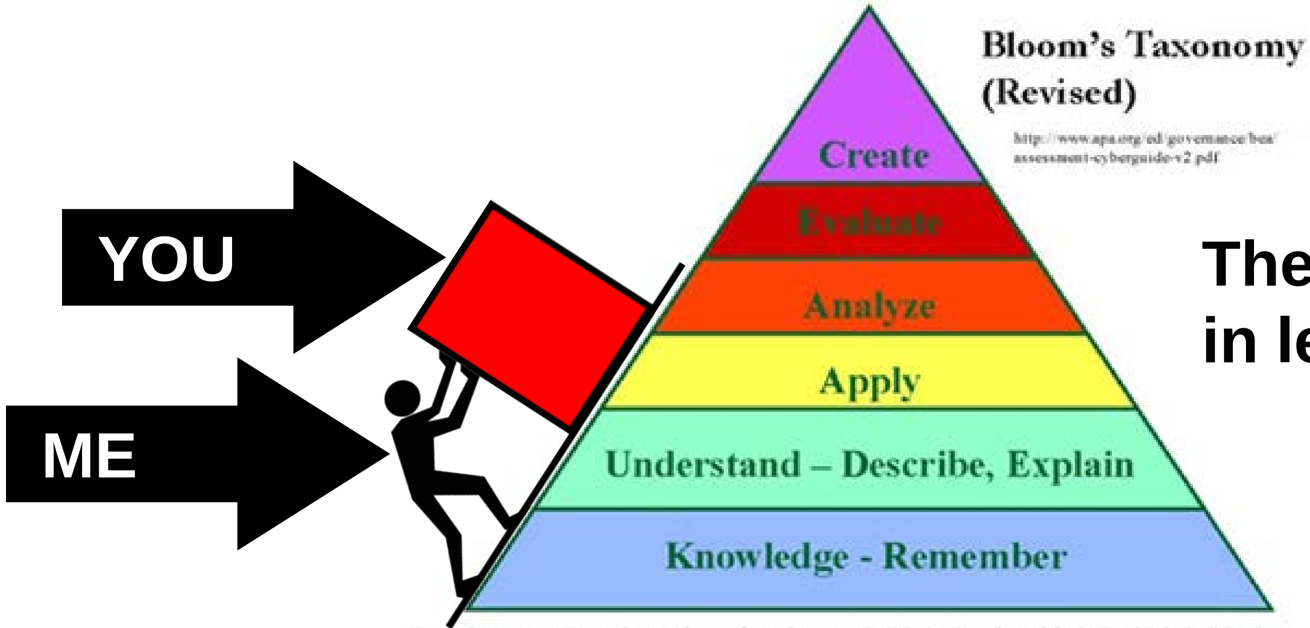
- Participate
- Ask questions if you are lost (come see us)
- Complete work and reading assignments
- Think carefully and creatively
- Ultimately, “Education is what remains after one has forgotten everything he learned in school.” (Einstein)

Barriers to Class Participation (study of 1550 college students)

Weaver and Qi (2005) Journal of Higher Education 76: 570-601.

- **Large class size, lack of opportunity (no effect)**
- **Perception of faculty authority (negative effect)**
- **Perception of faculty authority of knowledge (moderate negative effect)**
- **Interactions with faculty (positive effect)**
- **Fear of peer disapproval (negative effect- largest negative effect on confidence)**
- **Fear of professors' criticism (no effect)**
- **Para-participation (positive effect)**
- **Gender (no effect)**
- **Lack of preparation (indirect effect of confidence effect)**
- **Student confidence (strong positive effect)**

How to do well: Keep an open mind, be inquisitive, prepare for class, and respect "our" time.



Based on an APA adaptation of Anderson, L.W. & Krathwohl, D.R. (Eds.) (2001)

There is no comfort in learning!

Bloom Level	Action/Behavior Verbs
Creating: Can the learner create a new product or point of view?	Assemble, Construct, Create, Design, Develop, Formulate, Write
Evaluating: Can the learner justify a stand or decision?	Appraise, Argue, Defend, Judge, Select, Support, Value, Evaluate
Analyzing: Can the learner distinguish between different parts?	Compare, Contrast, Criticize, Differentiate, Distinguish, Examine, Experiment, Question, Test
Applying: Can the learner use or apply the information in a new way?	Choose, Demonstrate, Employ, Illustrate, Interpret, Operate, Schedule, Sketch, Solve, Use
Understanding: Can the learner explain ideas or concepts?	Classify, Describe, Discuss, Explain, Identify, Locate, Recognize, Report, Select, Translate, Paraphrase
Remembering: Can the learner recall or remember information?	Define, Duplicate, List, Memorize, Recall, Repeat, Reproduce

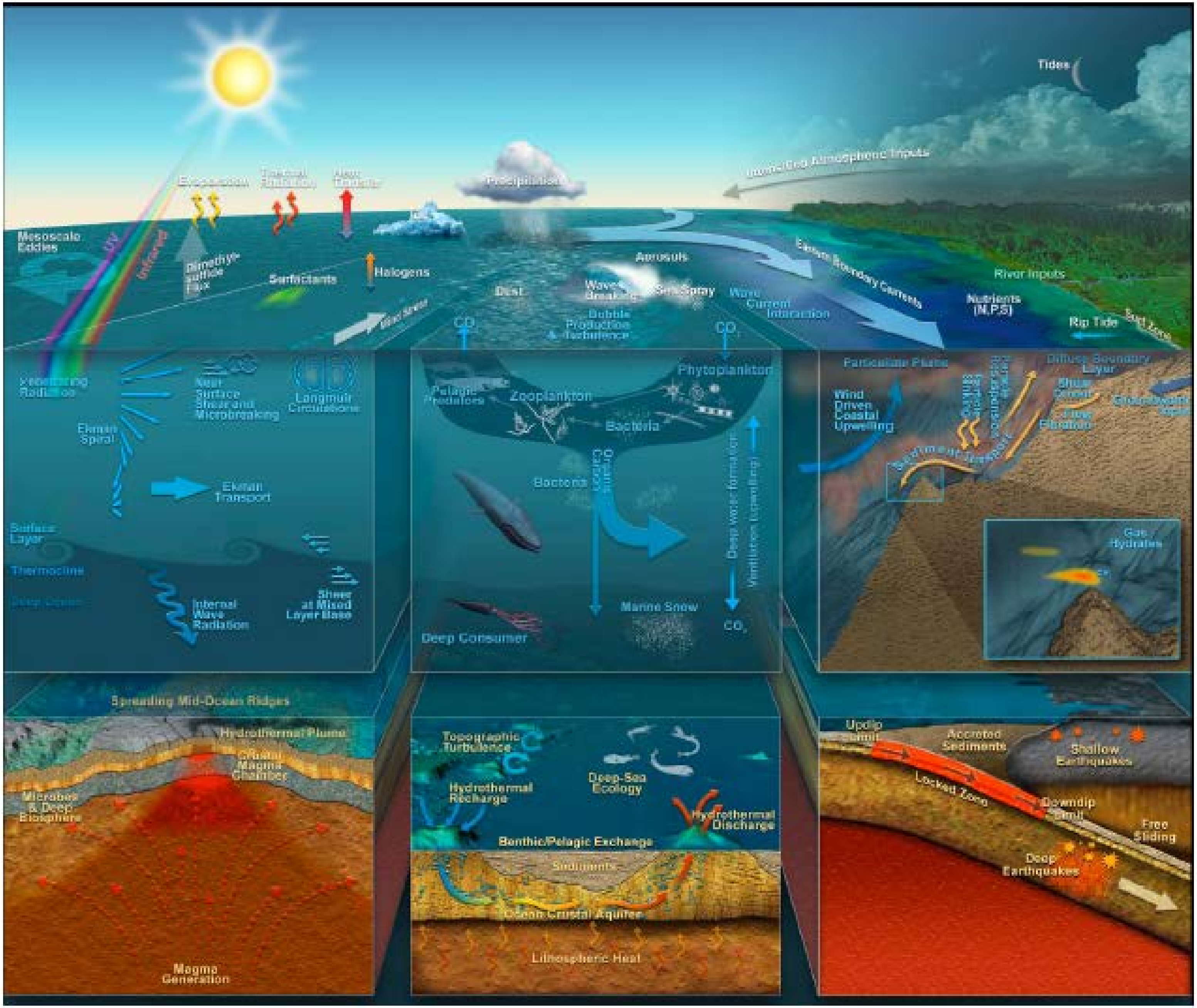
Your Grade in the Course will be based on:

- Wiki Project (30%)
- 10- 10 minute quizzes (10%)
- Lab Write-ups/ homework (30%)
- Class participation (10%)
- Final (20%)

What you should be developing in graduate school (and our course)-

- Intellectual Maturity and Discipline (focus)
- Curiosity and Critical Thinking
- Problem Solving Skills

Overview of Solid – Fluid – Biogeochemical Earth



A. Orientation for Biogeochemical Earth

- **Lecture 1**: Class Orientation and Overview of Expectations
- **Lecture 2**: The Diversity and Composition of Life
- **Lecture 3**: The Ocean in a Different Time: Anoxygenic Photosynthesis in the Proterozoic

B. Biogeochemical Overview

- **Lecture 4**: Biological Control on Saltiness of the Sea
- **Lecture 5:** Global Ocean Perspective I
- **Lecture 6**: Global Ocean Perspective II
- **Lecture 7**: Coastal and Estuarine Perspective

C. Life in a Fluid Medium

- **Lecture 7:** Biophysical Interactions and Consequences on Biogeochemistry

D. Autotrophy and Heterotrophy

- **Lecture 8:** Primary Production I (Light)
- **Lecture 9:** Primary Production II (Nutrients)
- **Lecture 10**: Respiration and Heterotrophy and Microbial Loop

E. The Carbon Biogeochemical Cycle

- **Lecture 11**: Global Carbon Budget (Overview)
- **Lecture 12:** Marine Inorganic Carbon Cycle
- **Lecture 13:** Biomineral Preservation/Dissolution
- **Lecture 14:** Organic Matter Preservation

F. Other Elemental Biogeochemical Cycles

- **Lecture 15:** Reduction-Oxidation
- **Lecture 16:** Nitrogen
- **Lecture 17:** Phosphorous
- **Lecture 18:** Silicon & Sulfur
- **Lecture 19**: Dissolved Gases

G. Structure and Function of Biomes

- **Lecture 20:** Upwelling vs. Gyres
- **Lecture 21:** Coastal Margins and Estuaries
- **Lecture 22:** Mesopelagic
- **Lecture 23:** Polar Oceans
- **Lecture 24:** Molecular Biology in the Coastal Margins
- **Lecture 25:** Polar Oceans
- **Lecture 26:** Biogeochemistry of Oyster Reefs

H. The Anthropocene and Change Through Time

- **Lecture 27:** Ocean Acidification and Hypoxia
- **Lecture 28:** Unintended Consequences of Geoengineering I
- **Lecture 29:** Unintended Consequences of Geoengineering II

What is Biogeochemistry?

Study of the properties and interactions (biological, chemical, and geological) of substances and the distributions and movement among compartments.

http://en.wikipedia.org/wiki/Biogeochemistry

We are concerned with:
Reservoirs
Rates
Reactions

We will be studying:
Budgets (big scales)
Speciation (small scales)
Links among life, energy, and matter

Key Points from Reading (Family Feud Style):

What does this illustration mean to you?

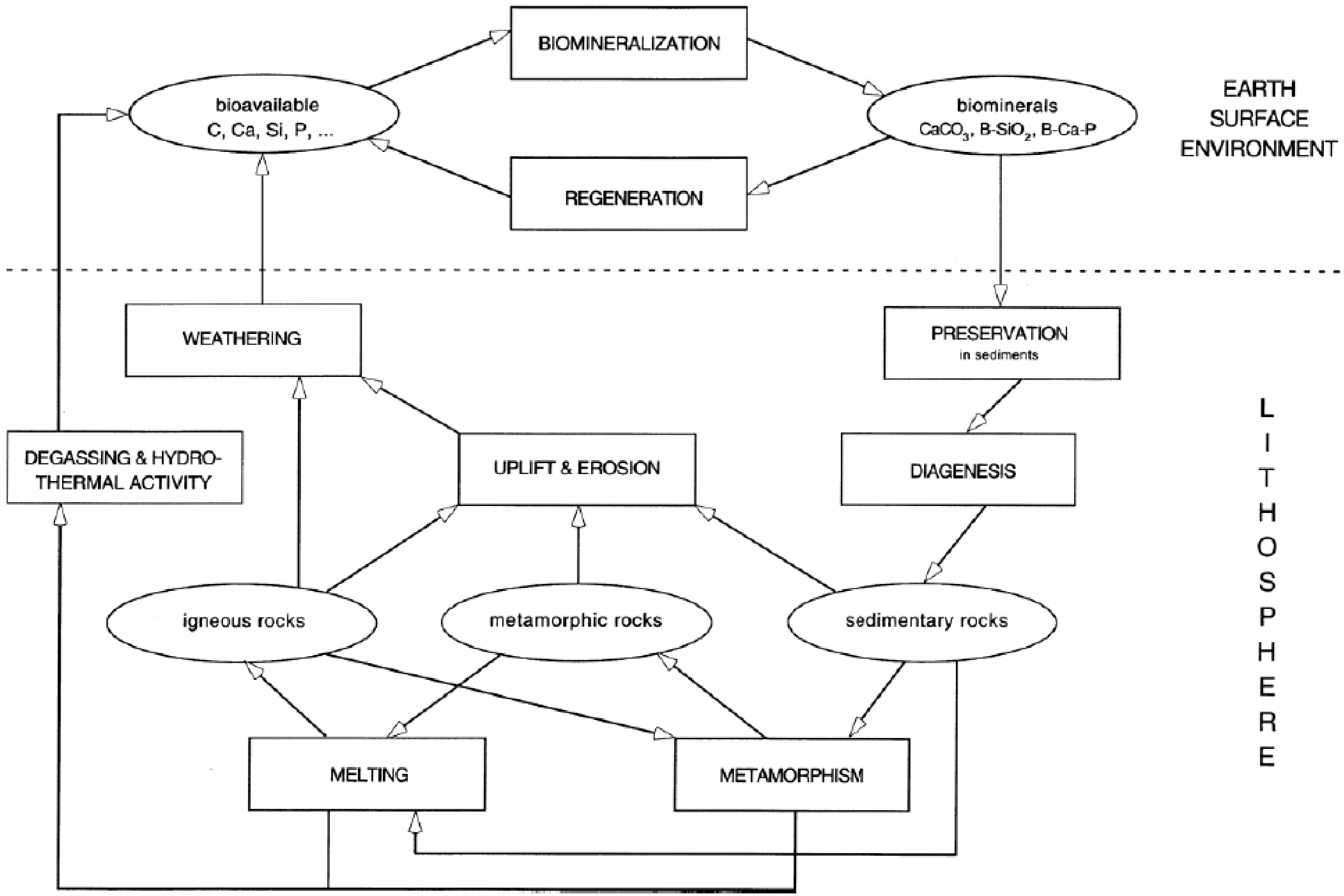
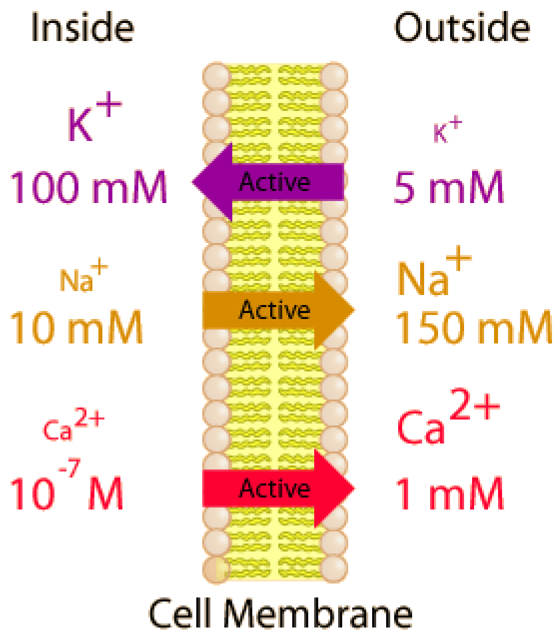


Figure 2. Biomineralization and the rock cycle. On geological time scales, the rock cycle regulates the supply of biomineralizing elements from the lithosphere, as well as their removal from the earth surface environment.

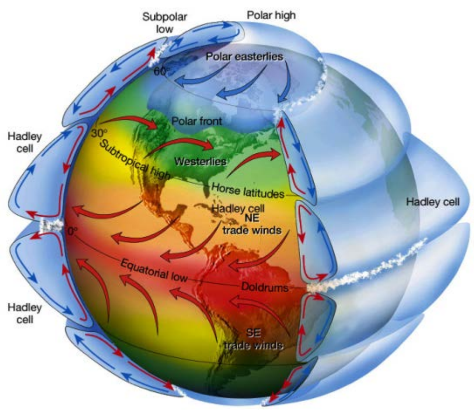
Gradients, gradients, gradients…

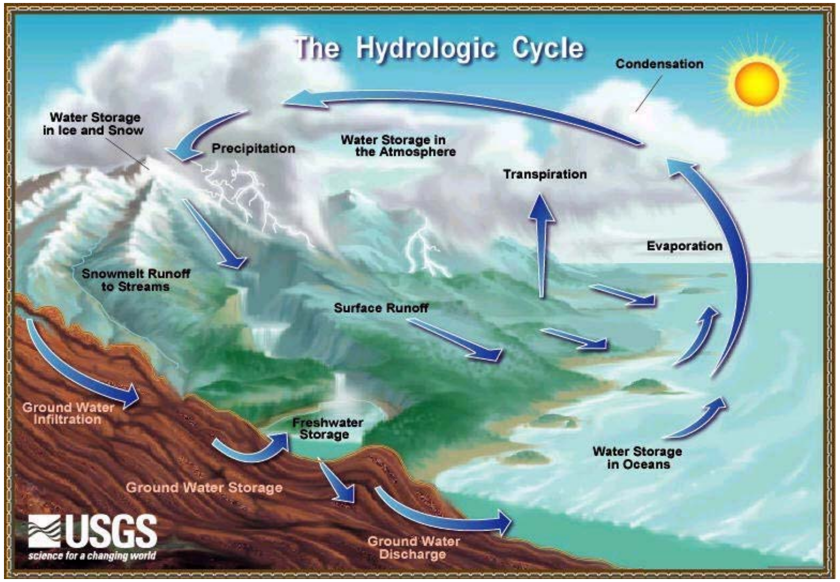
From Cells…



http://hyperphysics.phy-astr.gsu.edu/hbase/biology/actran.html

…to the Planet

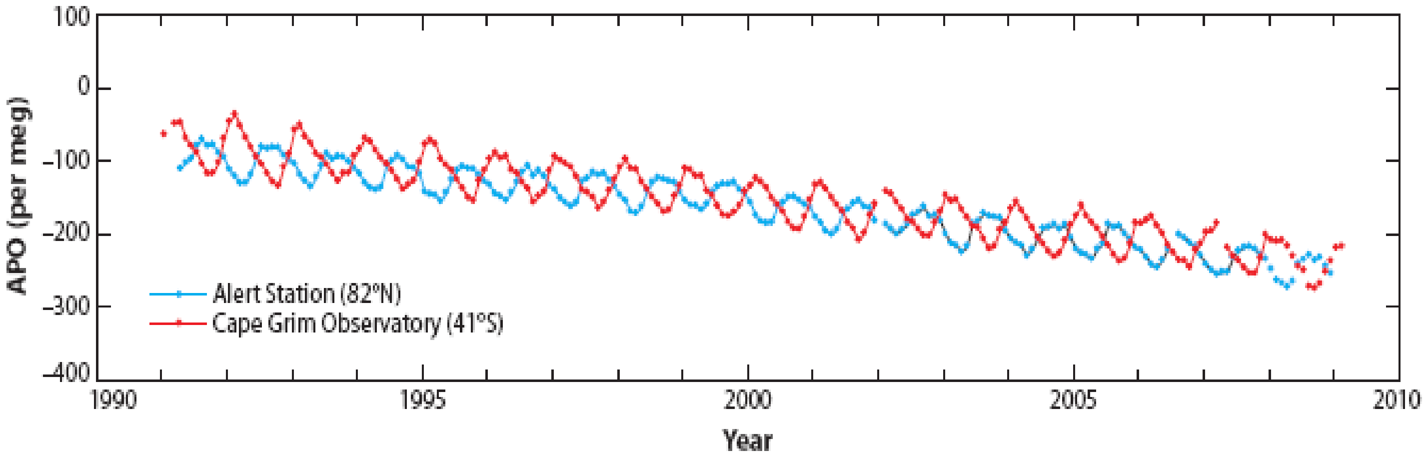




Biogeochemical gradients- energy needed to counter what force?

Facts and Trivia about Oxygen (O) Biogeochemistry

Where does almost all of the O_2 we breathe come from?



Keeling et al., Ann Rev Mar. Sci. 2: 199-229, 2010

Where is it going?

- 0.095% Decrease since pre-industrial
- 20.9% now
- OSHA notes 19.5% in confined spaces may be hazardous…
- spontaneous fires if >30%

Burning issue. Can marine-based oxygen regulation prevent global conflagration? Too much oxygen, and the Earth's forests would have been consumed by wildfire; too little oxygen and fires are unsustainable. Nutrient recycling and retention by marine sediments may act as part of a feedback mechanism to control atmospheric oxygen concentration. [Photo: E. R. Degginger/Photo Researchers Inc.]

Kump & MacKenzie, Science 271, 459-60, 1996

Facts and Trivia about Nitrogen (N) Biogeochemistry

40-60% of the N in your body was produced in a factory (Haber-Bosch Process)

Without industrial produced fertilizer, the world's population would be 60% of current;
Uptake efficiency by crops is ~20-40%, the rest is "lost" (**cultural eutrophication**)

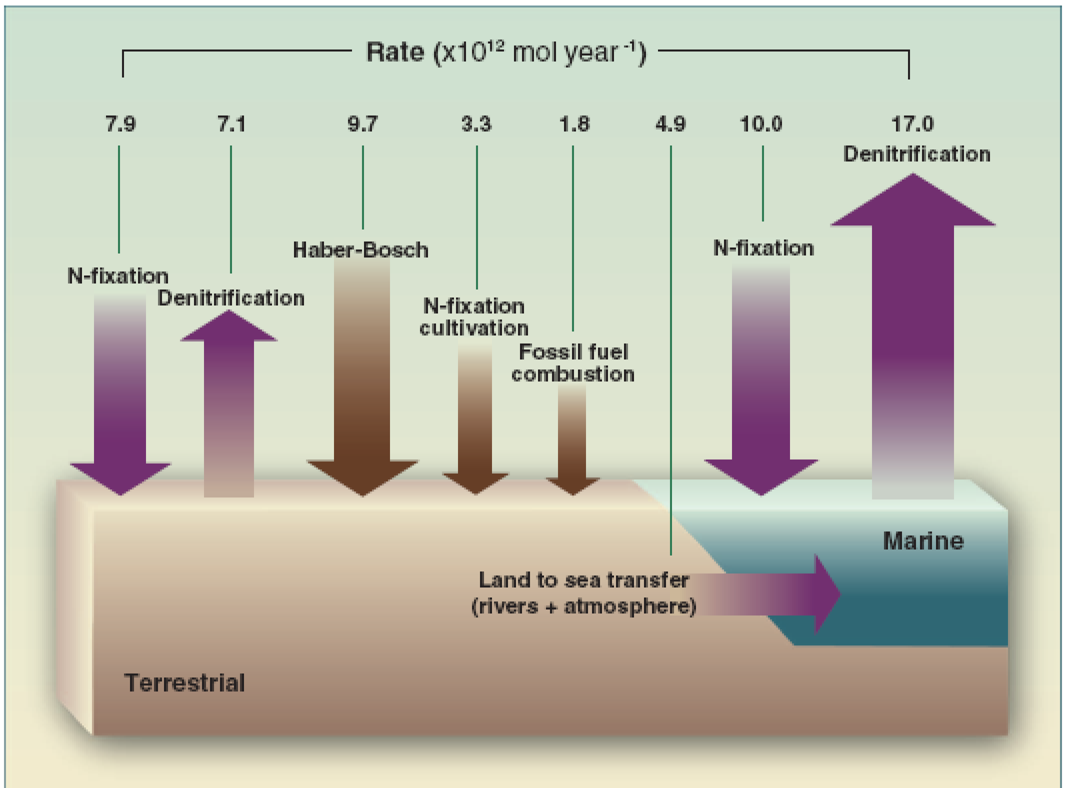


Fig. 4. Rates of nitrogen flux in the modern nitrogen cycle depend on the efficiency of the transformations between reservoirs. Arrow size reflects relative size of the flux. The dark brown arrows represent anthropogenic inputs (*25, 45, 46, 52, 53, 68, 69*).


HOME SEARCH The New York Times

OP-ED CONTRIBUTORS

We Need a New Green Revolution

1. Tearful Obama, Announcing Control Steps, Condemns Shootings

The Opinion Pages | OP-ED CONTRIBUTORS

We Need a New Green Revolution

By PHILLIP A. SHARP and ALAN LESHNER JAN. 4, 2016

Smil 1999, Fryzuk 2004, Canfield 2010

Relative Percent for Each Element

Rank	Earth's Crust		Ocean		Atmosphere		Human	
1	**Oxygen**	46.0000%	**Oxygen**	86.0000%	**Nitrogen**	78.1%	**Oxygen**	61.0000%
2	Silicon	27.0000%	Hydrogen	11.0000%	**Oxygen**	20.9%	**Carbon**	23.0000%
3	Aluminum	8.1000%	Chlorine	2.0000%	Argon	0.96%	Hydrogen	10.0000%
4	Iron	6.3000%	Sodium	1.1000%	Hydrogen	??	**Nitrogen**	2.6000%
5	**Calcium**	5.0000%	Magnesium	0.1300%	**Carbon**	??	**Calcium**	1.4000%
6	Magnesium	2.9000%	Sulfur	0.0930%			**Phosphorus**	1.1000%
7	Sodium	2.3000%	Potassium	0.0420%			Sulfur	0.2000%
8	Potassium	1.5000%	Bromine	0.0067%			Potassium	0.2000%
9	Titanium	0.6600%	**Carbon**	0.0028%	***CO2***	***0.039%***	Sodium	0.1400%
10	**Carbon**	0.1800%	Strontium	0.0008%		ppmv	Chlorine	0.1200%
11	Hydrogen	0.1500%	Boron	0.0004%			Magnesium	0.0270%
12	Manganese	0.1100%	**Calcium**	0.0004%			Silicon	0.0260%
13	**Phosphorus**	0.0990%	Fluorine	0.0001%			Iron	0.0060%
14	Fluorine	0.0540%	Silicon	0.0001%			Fluorine	0.0037%
15	Sulfur	0.0420%	**Nitrogen**	0.0001%			Zinc	0.0033%
16	Strontium	0.0360%	Argon	0.0000%			Rubidium	0.0005%
17	Barium	0.0340%	Lithium	0.0000%			Strontium	0.0005%
18	Vanadium	0.0190%	Rubidium	0.0000%			Bromine	0.0003%
19	Chlorine	0.0170%	**Phosphorus**	7.×10-6%			Lead	0.0002%
20	Chromium	0.0140%	Iodine	6.×10-6%			Copper	0.0001%

Anatomy of a Chemical Equation

http://en.wikibooks.org/wiki/General_Chemistry/Chemical_equations

$$E_{x(s)}^{y}$$

Element, Charge, Moles, and State

$$CO_{2(g)} + H_2O_{(l)} \Leftrightarrow CH_2O_{(s)} + O_{2(g)}$$

The symbols in parentheses (in subscript below each species) indicate the physical state of each reactant or product.
(s) means solid
(l) means liquid
(g) means gas
(aq) means aqueous solution (i.e. dissolved in water)

Mass and Unit Conversions

250 mmol $CaCO_3$ to Bombs HH Beer

Ca = 40 g/m
C = 12 g/m
O = 16 g/m x3

webelements.com

$$250\ mmol\ CaCO_3\ \ X$$

A Review of Key Concepts

Law of Conservation of Mass- Antoine Lavoisier (1789)

"Nothing Comes from Nothing"
- Empedolces (490-430 BCE)

"The totality of things was always such as it is now, and always will be"
-Epicurus (341-270 BCE)

Law of Conservation of Energy

"besides the 54 known chemical elements, there is in the physical world one agent only, and this is called *Kraft*. It may appear, according to circumstances, as motion, chemical affinity, cohesion, electricity, light and magnetism; and from any one of these forms, it can be transformed into any of the others." -Karl Friedrich Mohr (1837)

Electroneutrality (charge balance)

In seawater chemistry (and in natural systems), positive and negative charges have to equal.

A Review of Key Concepts

First Law of Thermodynamics-

Energy cannot be created or destroyed, only transformed

Second Law of Thermodynamics-

All systems will move towards increasing ***Entropy*** (*or decrease in order)*

Gibbs Free Energy = Enthalpy – Entropy

Energy available for work = Total Energy – Energy not available

$\Delta G = \Delta H - T\,\Delta S$

$\Delta G = \Delta G_{products} - \Delta G_{reactants}$

IF ΔG is negative, the reaction is "spontaneous" or favored.

$$CO_{2(g)} + H_2O_{(l)} \Rightarrow CH_2O_{(s)} + O_{2(g)}$$

$\Delta G =$

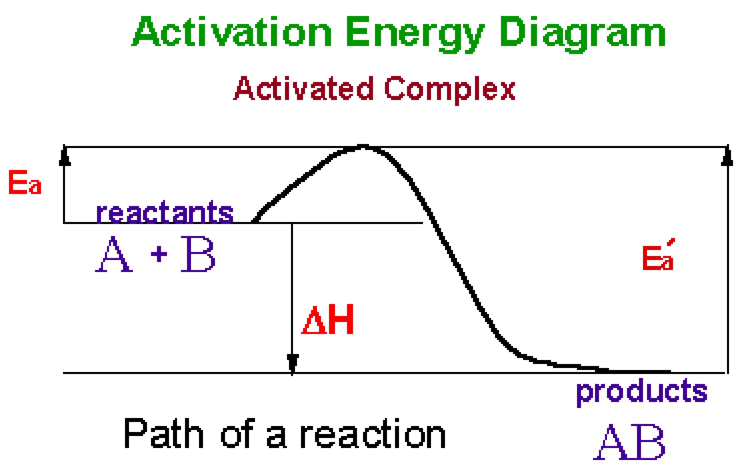
$$CH_2O_{(s)} + O_{2(g)} \Rightarrow CO_{2(g)} + H_2O_{(l)}$$

$\Delta G =$ **-** ??? KJ

How Fast?

Thermodynamics is the study of equilibrium (K_{equil}), it does not speak to the rate at which reactions happen, only whether they can or cannot happen.

Kinetics is the study of the rates ($k_{forward}$, $k_{reverse}$) and mechanisms of reactions. The change in concentration over time.



of hand grenades and doughnuts…

If respiration is thermodynamically favored, why doesn't all organic matter just explode?

If formation of calcium carbonate is favored in the oceans why aren't they just full of sea shells?

Biology (life) takes advantage of these favored reactions, that happen at slower rates to ride the energetic gradients.

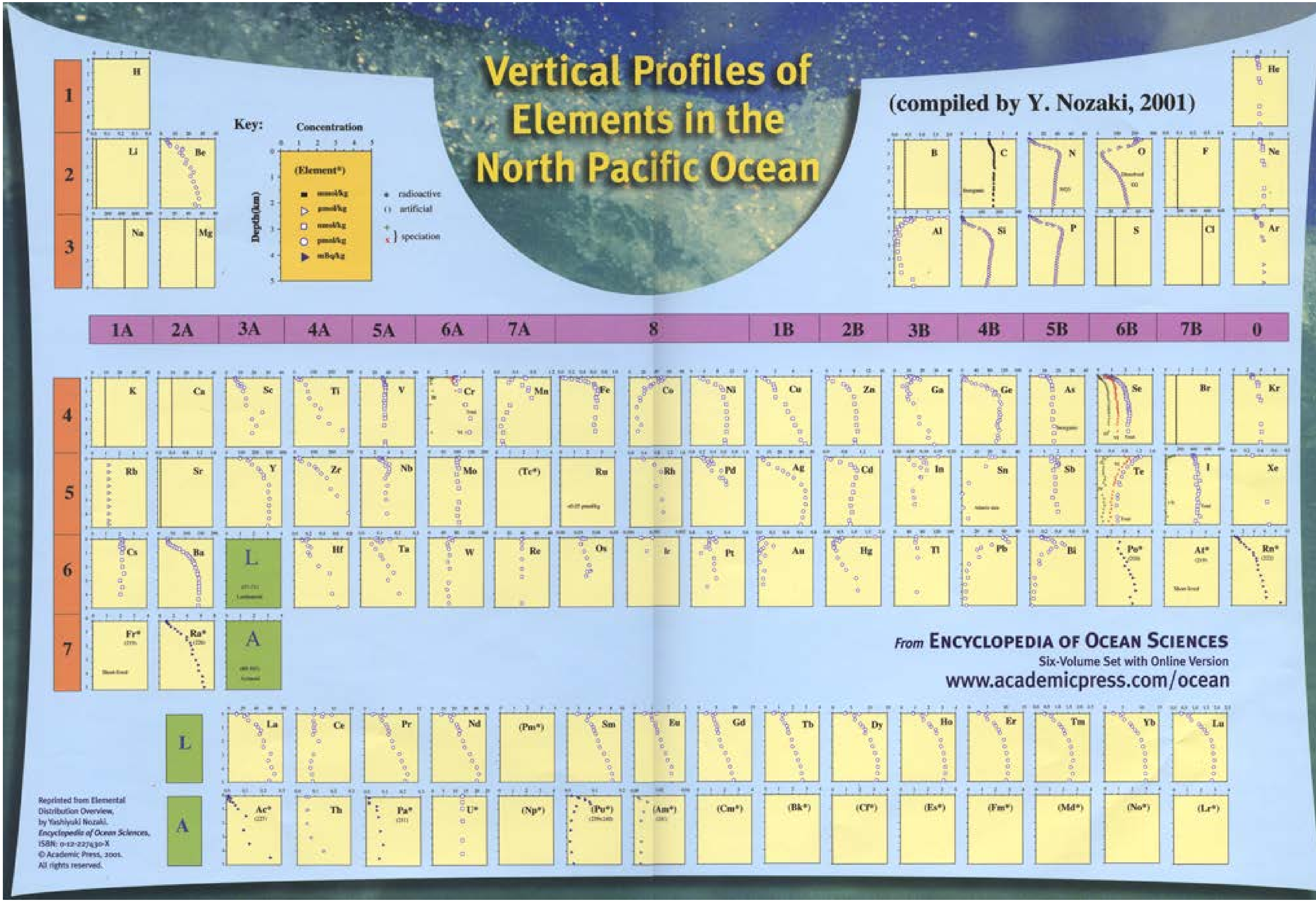
Conservative vs non-conservative elements

(http://www.mbari.org/chemsensor/pteo.htm)

- emphasis on the latter in this course

Conservative: generally controlled by physical properties

Non-Conservative: generally biology alters distribution



Conservative vs. Non-Conservative

One last concept to brush up on: Dimensional Analysis

Base Measurements (length, mass, time, charge, temperature, luminosity)
and **Dimensions**

Area	$= L^2$
Volume	$= L^3$
Velocity	= L / Time
Concentration	= Mass / Volume
Flux	= ??