The Diversity and Composition of Life: Setting the Stage

Learning Objectives:

- What is an Ecosystem?
- The Tree of Life and Some Important Players
- From Life forms to Molecules to Elements
- RedOx the power of life
- Life in a currency of Elements

<u>What you should take away:</u>

General organization of life

What are some of the key players we will talk about this term

What are the key players made up of

Elements are important indicators of ecosystem processes

What is an Ecosystem?

"The more fundamental conception is… the whole system (in the sense of physics) including not only the organism-complex, but also the whole complex of physical factors forming what we call the environment… We cannot separate them from their special environment with which they form one physical system… It is the systems so formed which… [are] the basic units of nature on the face of earth… These ecosystems, as we may call them, are of the most various kinds and sizes."

Arthur G. Tansley, Ecology (1935)

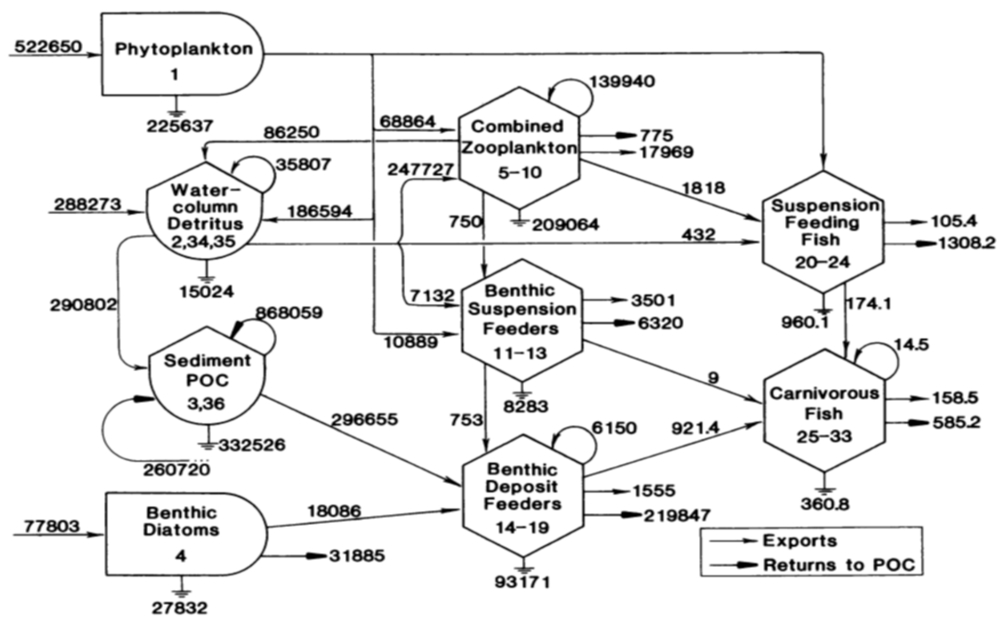
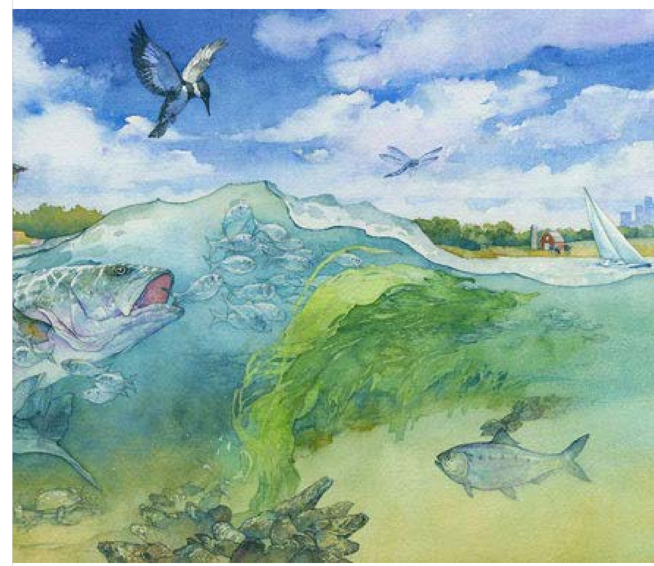


FIG. 13. A condensed representation of the flows among the heterotrophic compartments of the Chesapeake mesohaline ecosystem. Units are the same as in Fig. 7.



Baird and Ulanowicz 1989

Illustration by Greg Harlin, Wood Ronsaville Harlin, Inc.

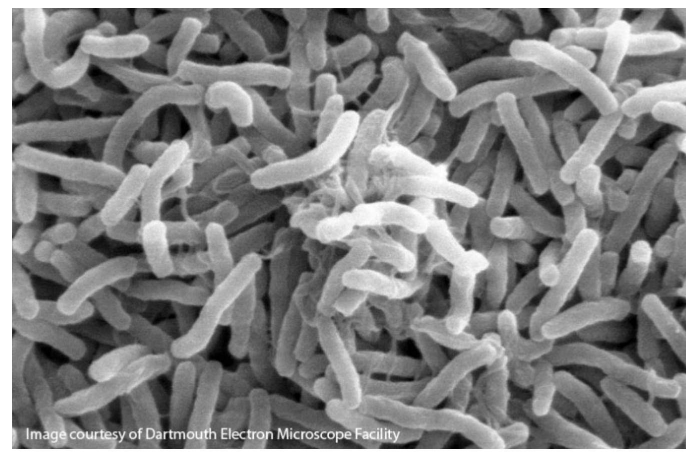
What is an Ecosystem?

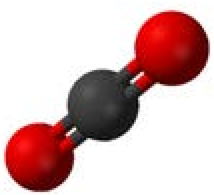
Primary Producer

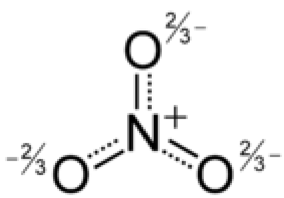
Primary Consumer

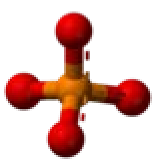
Secondary Consumer

Decomposer

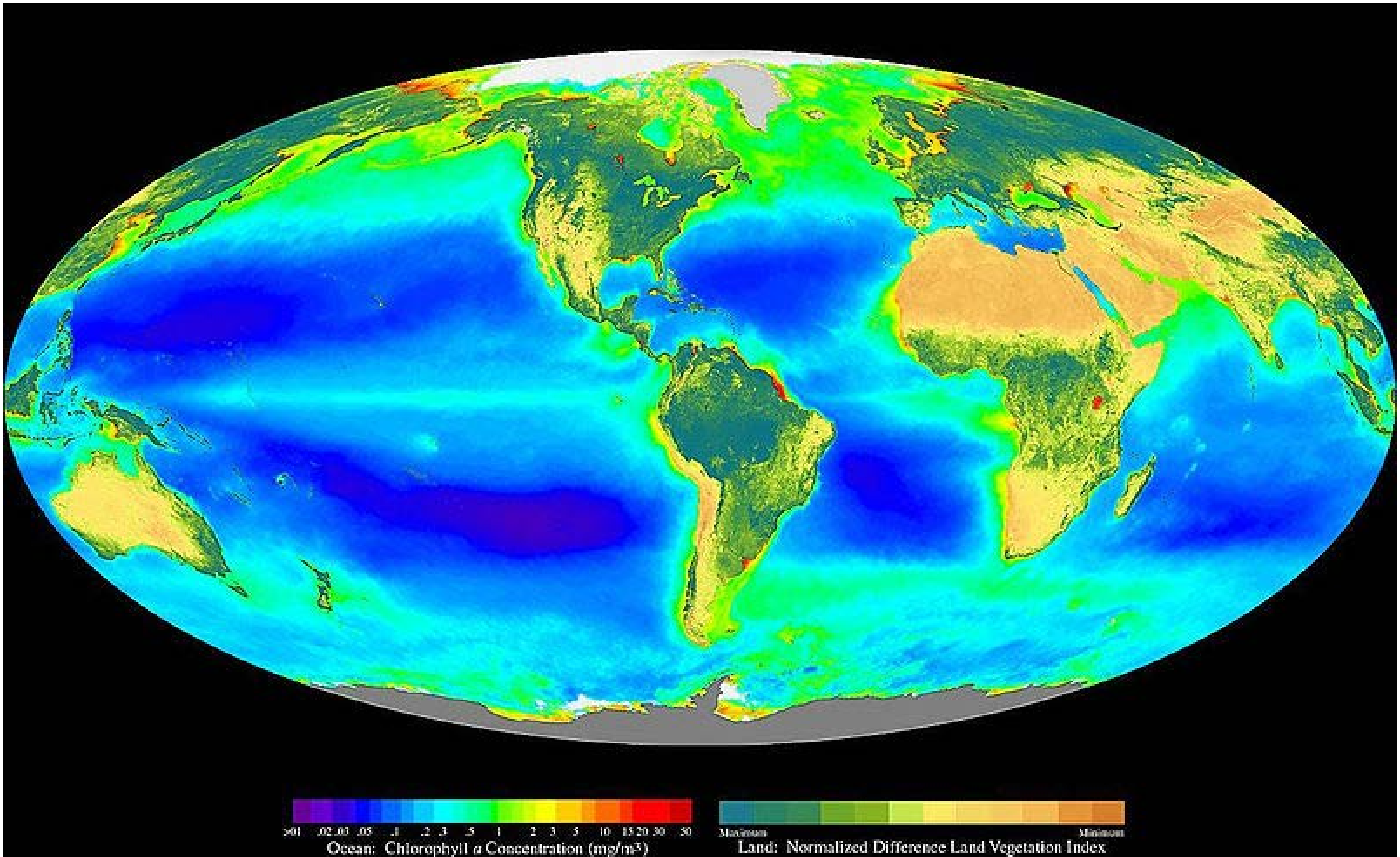








What is an Ecosystem?

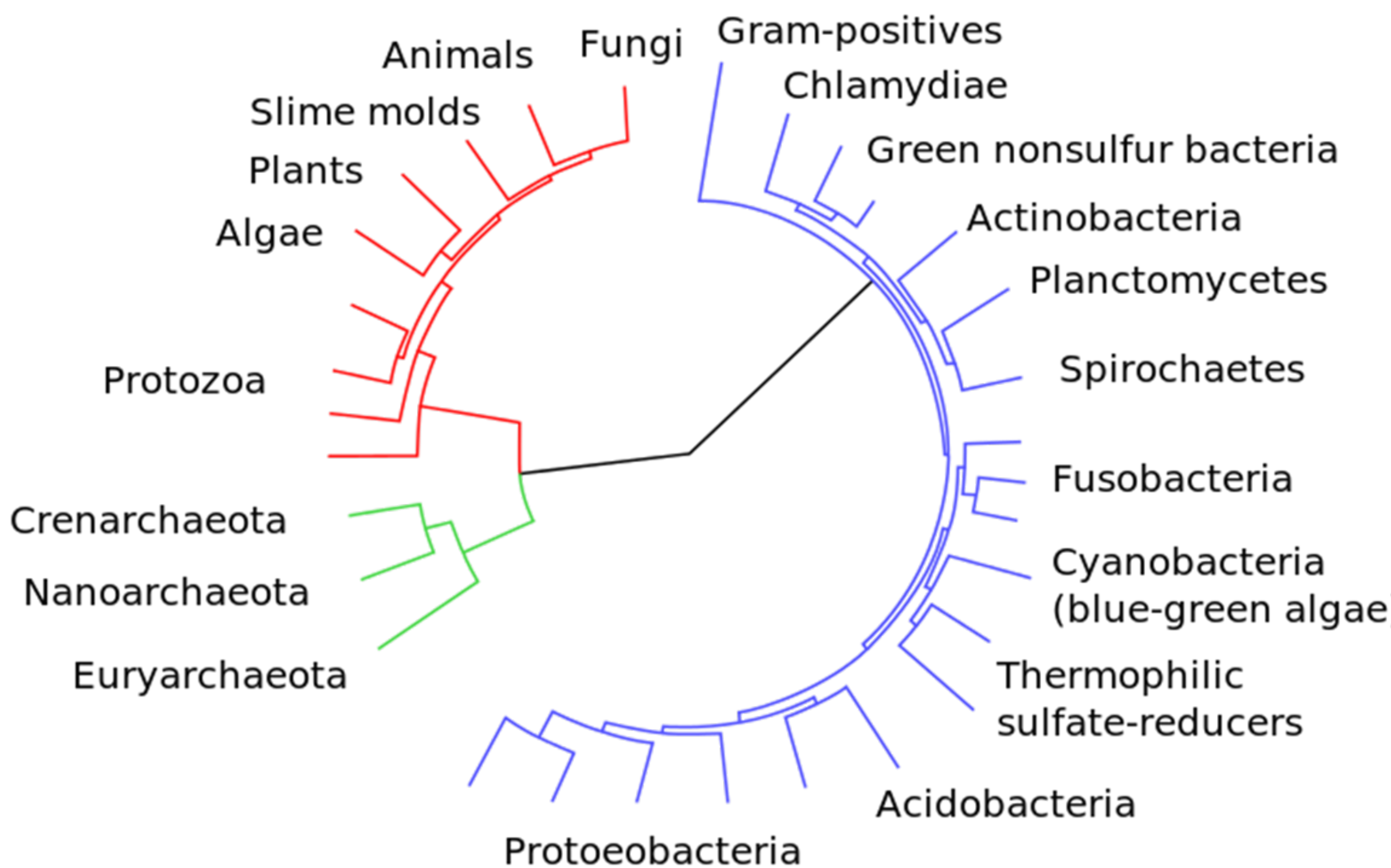


http://oceancolor.gsfc.nasa.gov/SeaWiFS/BACKGROUND/Gallery/index.html

	Land	Ocean
Production	120 PG C yr^{-1}	92 PG C yr^{-1}
Rate	~400 g C m^{-2} yr^{-1}	~100 g C m^{-2} yr^{-1}
Total Biomass	> 99%	0.2%

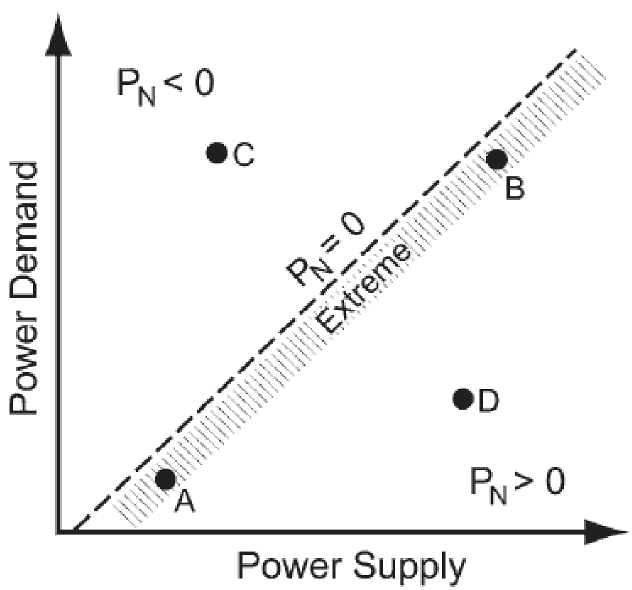
What is an Ecosystem?

Through the collective metabolic and growth activities of its trillions of organisms, Earth's biota move hundreds of thousands of tons of elements and compounds between the hydrosphere, atmosphere, and lithosphere every year. Naeem et al. 2002



What is life?

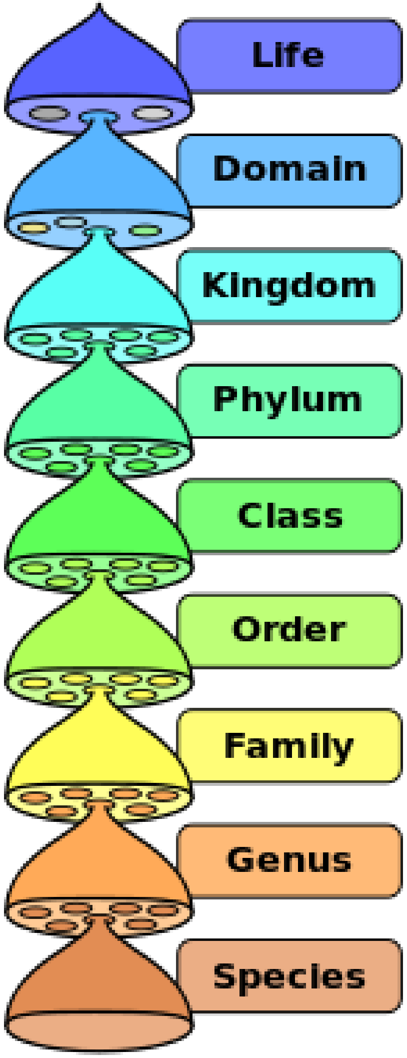
What are the biogeochemical challenges for life?



Shock and Holland 07

- Energy
- Material
- Protecting information

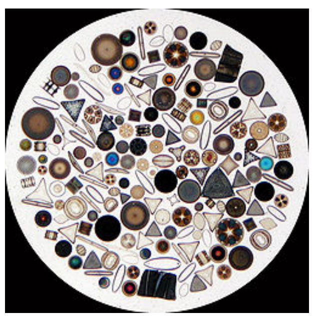
Tree of Life

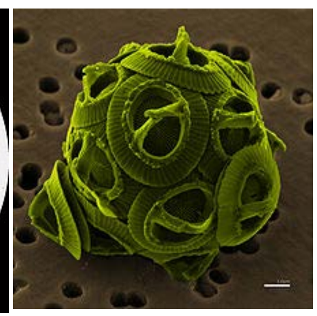


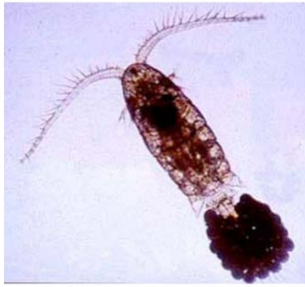
Bacteria, Archaea, Eukarya

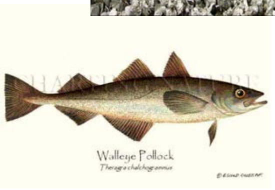
Animalia, Plantae, Fungi, Protista, Archaea, and Bacteria

Animalia (35), Plantae (11), Fungi (6), Protista (?), Archaea (5), and Bacteria (29)

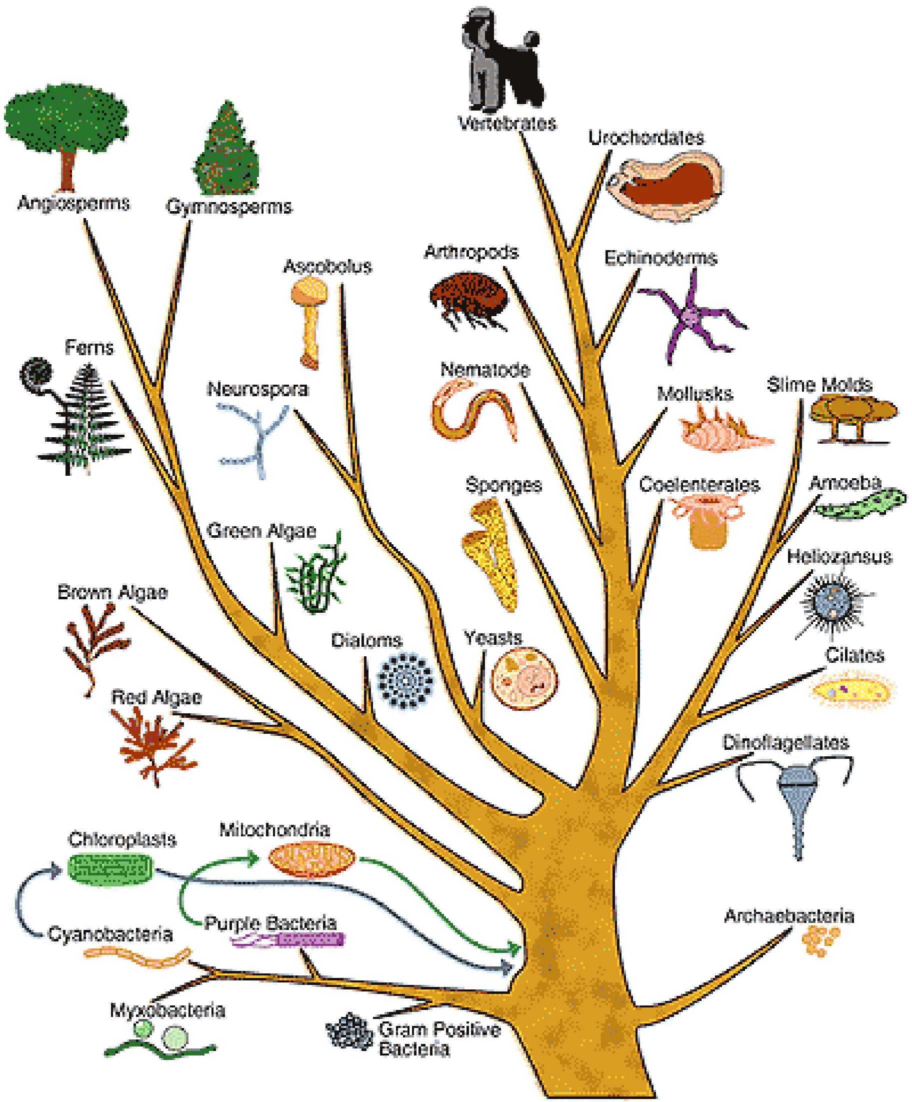








Tree of Life



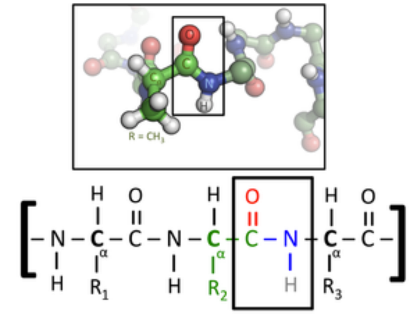
http://chewedcrayons.tumblr.com/

All of these organisms are made up of similar elements, but in different proportions and arrangements.

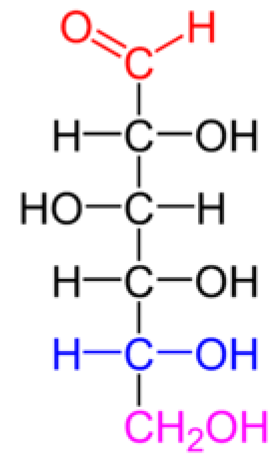
Mostly C, N, H, O, and P, arranged in molecules of proteins, carbohydrates, lipids, nucleotides.

Molecules and Elements: A review to offend you Organic Chem Prof.

Proteins > Amino Acids > Amines and Carboxyl groups > NH_2 & COOH



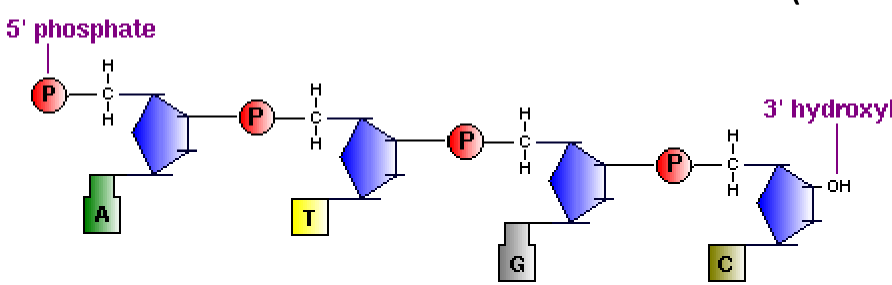
Carbohydrates > Simple or Complex Sugars > $C_x(H_20)_y$

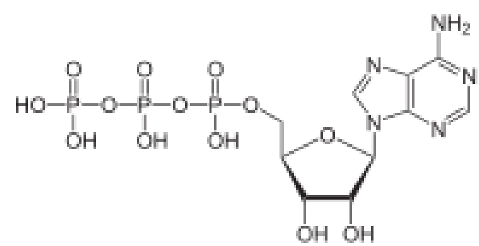


Lipids > (storage or structural) > Carbon rich

A free fatty acid

Nucleic Acids > DNA & RNA > nucleotides (also ATP) > Phosphorous bonds





So we can agree that maybe knowing something about C, N and P cycling could be important to life…

So how does life build these molecules and protect the code to do so?

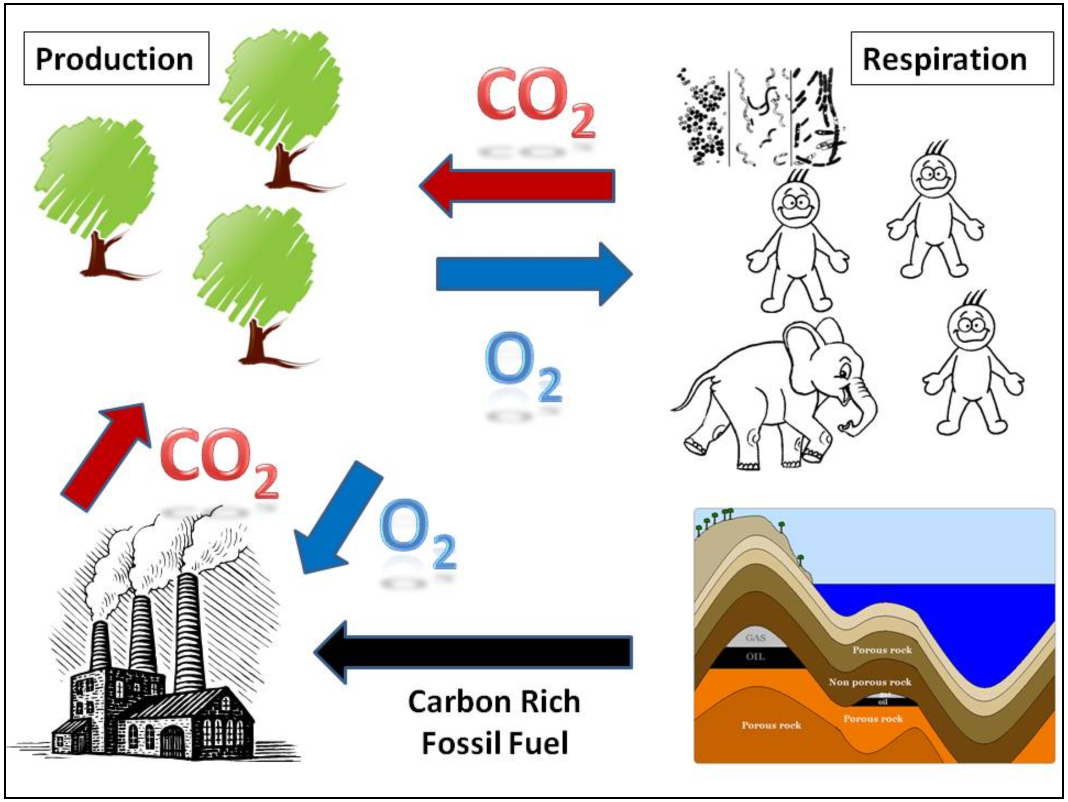
Redox Reactions Abound

Photosynthesis

$$CO_2 + H_2O \Rightarrow CH_2O + O_2$$

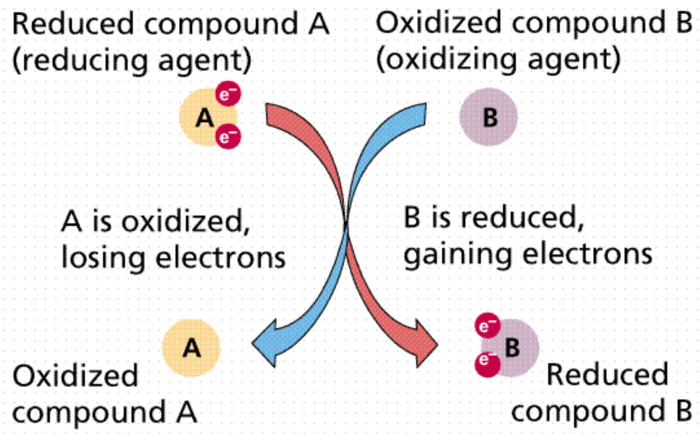
Respiration

$$CH_2O + O_2 \Rightarrow CO_2 + H_2O$$



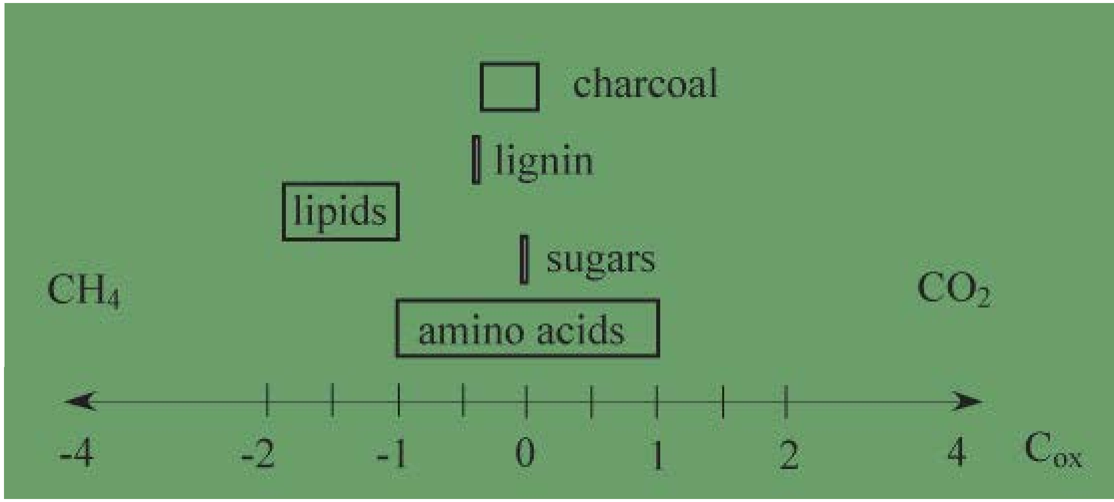
From a Redox perspective what is happening with respect to the burning of fossil fuels?

RedOx



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

Oxidation States of Carbon

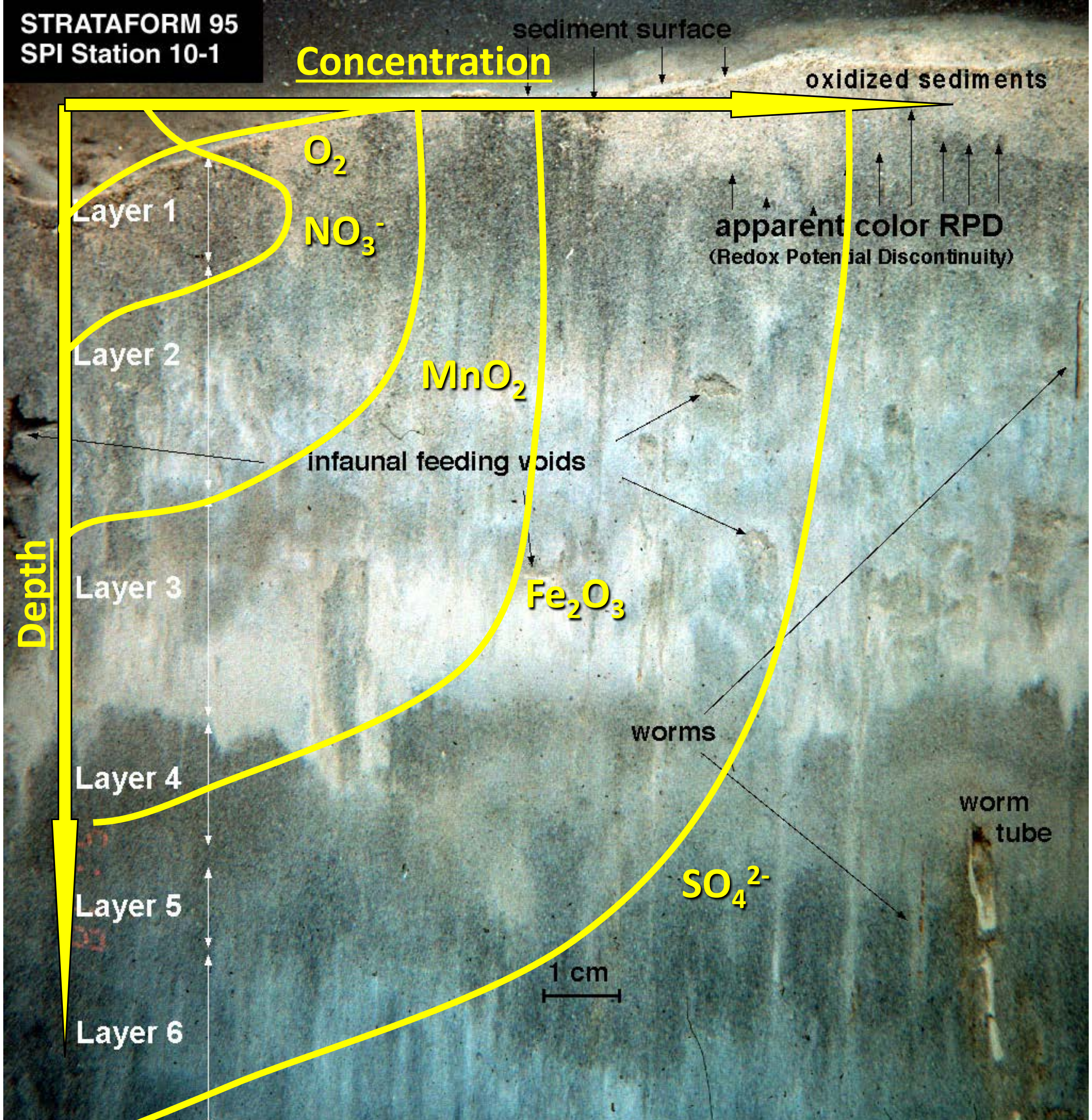


http://terra.rice.edu/department/faculty/masiello/RIGG/html/research/cox.html

L.E.O. goes G.E.R.

Red(uction)**ox**(idation) sensitive elements (C, N, S, O … typically not P under ‘normal’ earth conditions

- e.g.: $Fe^{+3} + e^- \rightarrow Fe^{+2}$
- but reduction must be paired with an oxidation, e.g. $H_20 \rightarrow ½\ O_2 + 2H^+ + 2e^-$
- yields: $2Fe^{+3} + H_2O \rightarrow 2Fe^{+2} + ½\ O_2 + 2H^+$



Adapted from Kristensen 2000 and Diaz (http://www.vims.edu/bio/benthic/st95spi.html)

Aerobic Respiration "Oxygen Reduction"
ΔG = -3190 KJ

Mn Reduction
ΔG = -3090 KJ

Denitrification
ΔG = -3030 KJ

Fe Reduction
ΔG = -1410 KJ

Sulfate Reduction
ΔG = -380 KJ

Fermentation
ΔG = -350 KJ

Stoichiometry

Law of Definite Proportions
Proust 1797

Eighty years of Redfield

The outstanding lifespan of the canonical Redfield ratio has shown the power of elemental stoichiometry in describing ocean life. But the biological mechanisms governing this consistency remain unknown.

In 1934, Alfred C. Redfield reported a suite of dissolved nitrate, phosphate and oxygen measurements from various depths in the Atlantic, Pacific and Indian oceans. These data showed a remarkable consistency, with nitrate and phosphate occurring in a ratio of about 20:1 in most of these samples[1]. Later refined to 16:1, and expanded to include a ratio of carbon to phosphate of 106:1, this Redfield ratio has come to define our understanding of ocean biogeochemical cycling. Along with this issue, we present a web focus (http://www.nature.com/ngeo/focus/redfield/index.html) showing that just as the identification of this near-constant ratio laid the foundations for the twentieth-century advances in our understanding of marine biogeochemistry, deviations from this ratio are now providing twenty-first-

The work done by Alfred Redfield (left) paved the way for our understanding of how the runoff of nitrogen and phosphorus from fertilized lands fuels phytoplankton blooms like those near the mouth of the Mississippi River (right). Left photo courtesy of the Woods Hole Oceanographic Institution Archives; right photo © NASA/Landsat/Phil Degginger/Alamy.

Nature Geosciences 2014

Stoichiometry and Ecosystems

Photosynthesis

$$CO_2 + H_2O \Rightarrow CH_2O + O_2$$

Respiration

$$CH_2O + O_2 \Rightarrow CO_2 + H_2O$$

Same as Above

$$6CO_2 + 12H_2O \Rightarrow C_6H_{12}O_6 + 6H_2O + 6O_2$$

Organisms are more than simple sugars though…

Redfield-Ketchum-Richards (**RKR**) Model stoichiometry

$$\mathbf{106CO_2 + 16HNO_3 + 1H_3PO_4 + 122H_2O \leftrightarrow (CH_2O)_{106}(NH_3)_{16}(H_3PO_4) + 138O_2}$$

Stoichiometry and Ecosystems

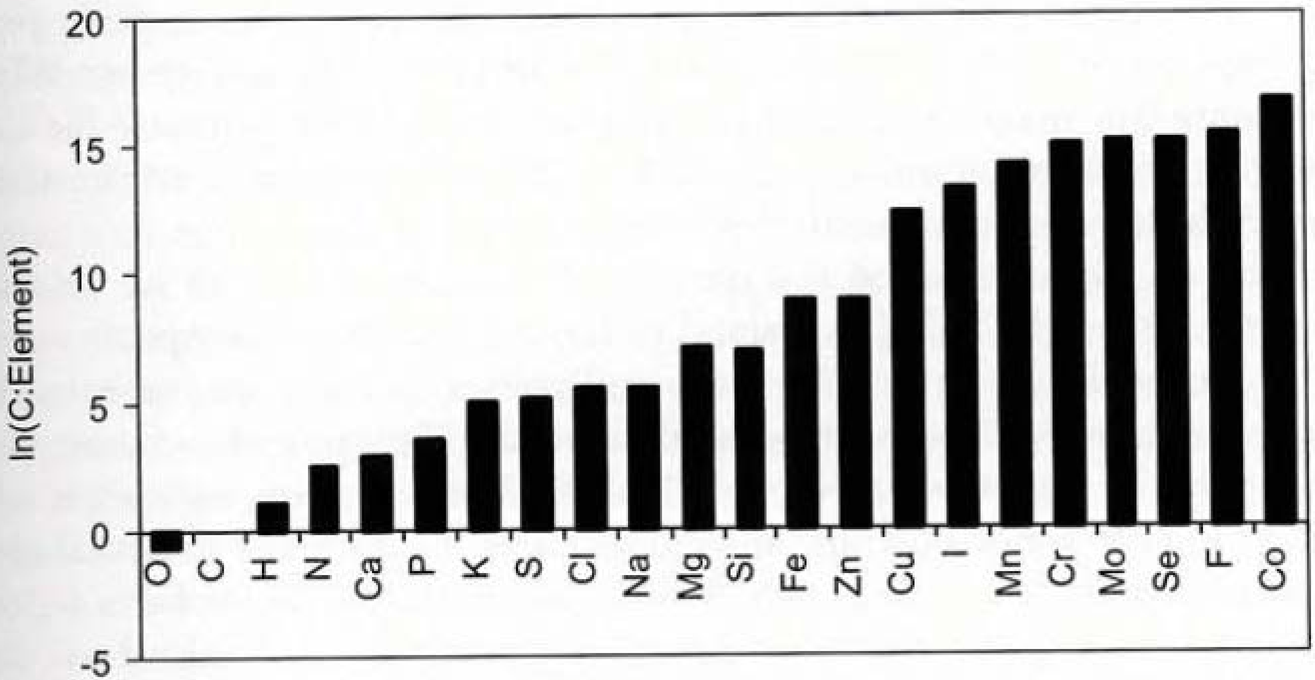


Fig. 1.2. Abundance of 22 elements in humans, expressed relative to carbon (mass:mass) and natural-log-transformed for clarity. High values indicate substances in low relative abundance. Data obtained from two sources, with averages taken when multiple values were available (Heymsfield et al. 1991; Williams and Fraústo da Silva 1996). For a historical presentation of similar information, see Fig. 2.1.

Stoichiometry and Ecosystems: Consumers and Resources

<u>Some key vocabulary:</u>

Stoichiometry
Homeostasis
Consumer
Producer
Proportion vs. Abundance!

<u>How does elemental composition change with resource?</u>

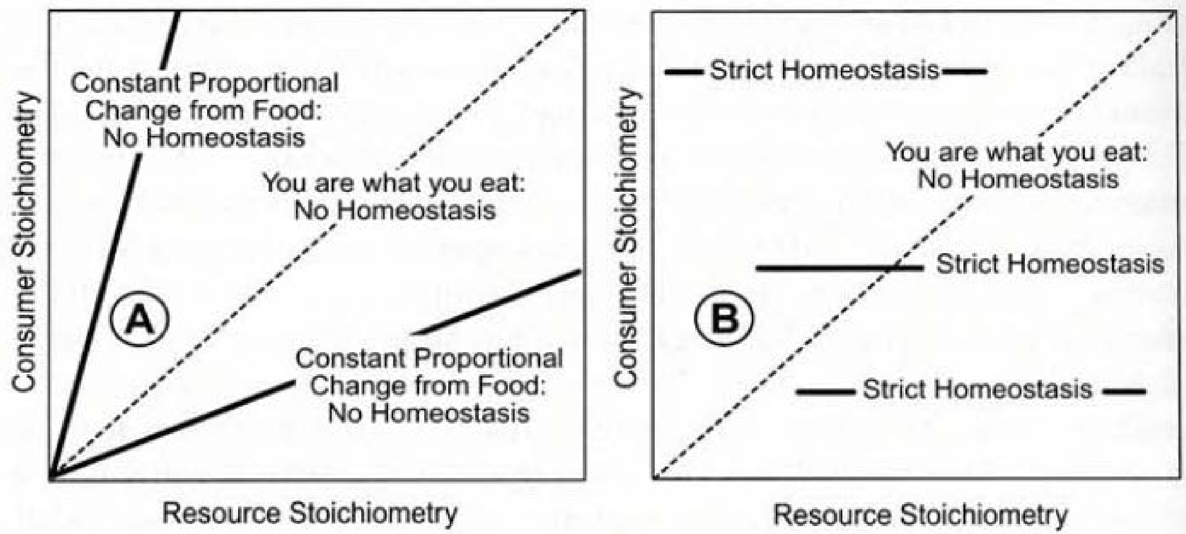


Fig. 1.3. Generalized stoichiometric patterns relating consumer stoichiometry to resource stoichiometry. Horizontal and vertical axes are any single stoichiometric measure, such as N content or C:P ratio. A. Points on the 1:1 line (slope 1, intercept 0) represent identical stoichiometry in consumer and resources. This dashed line represents a consumer with stoichiometry that always matches the stoichiometry of its resources. This is the "you are what you eat" model. The solid lines represent consumers that perform constant differential nutrient retention. These represent the "constant proportional model." B. Strict homeostasis is defined as any horizontal line segment (slope 0, intercept > 0).

Stoichiometry and Ecosystems: Homeostasis in Graphs

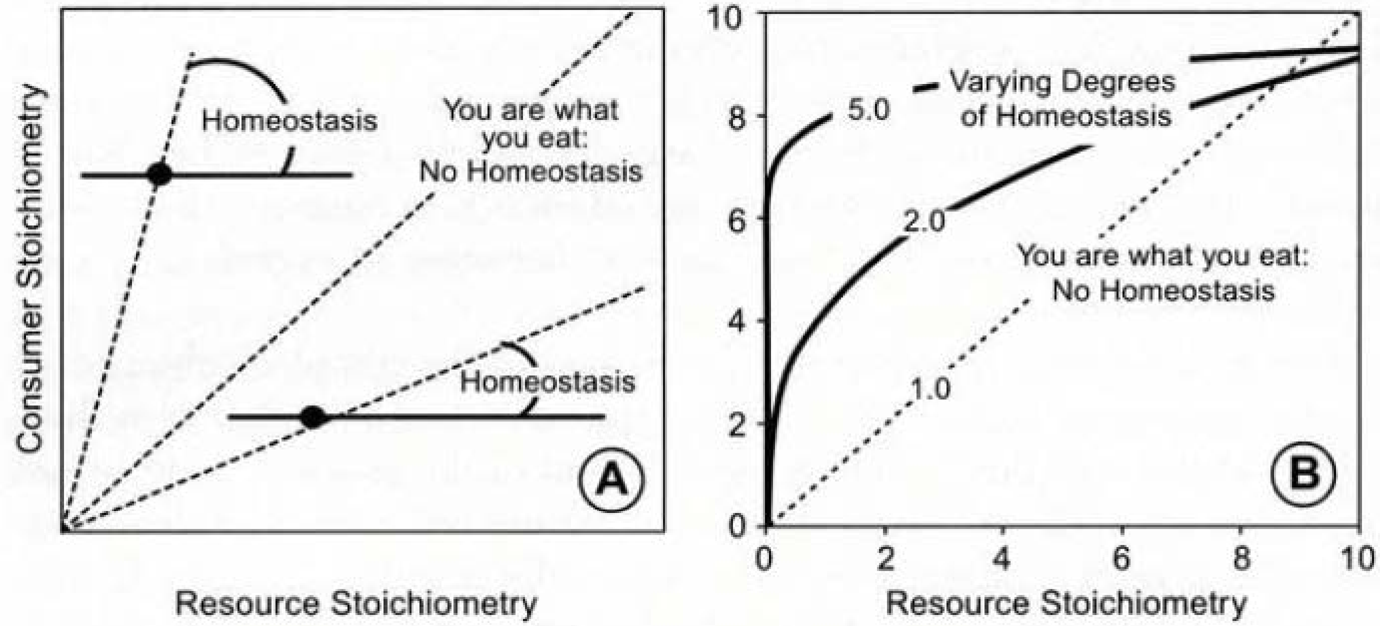
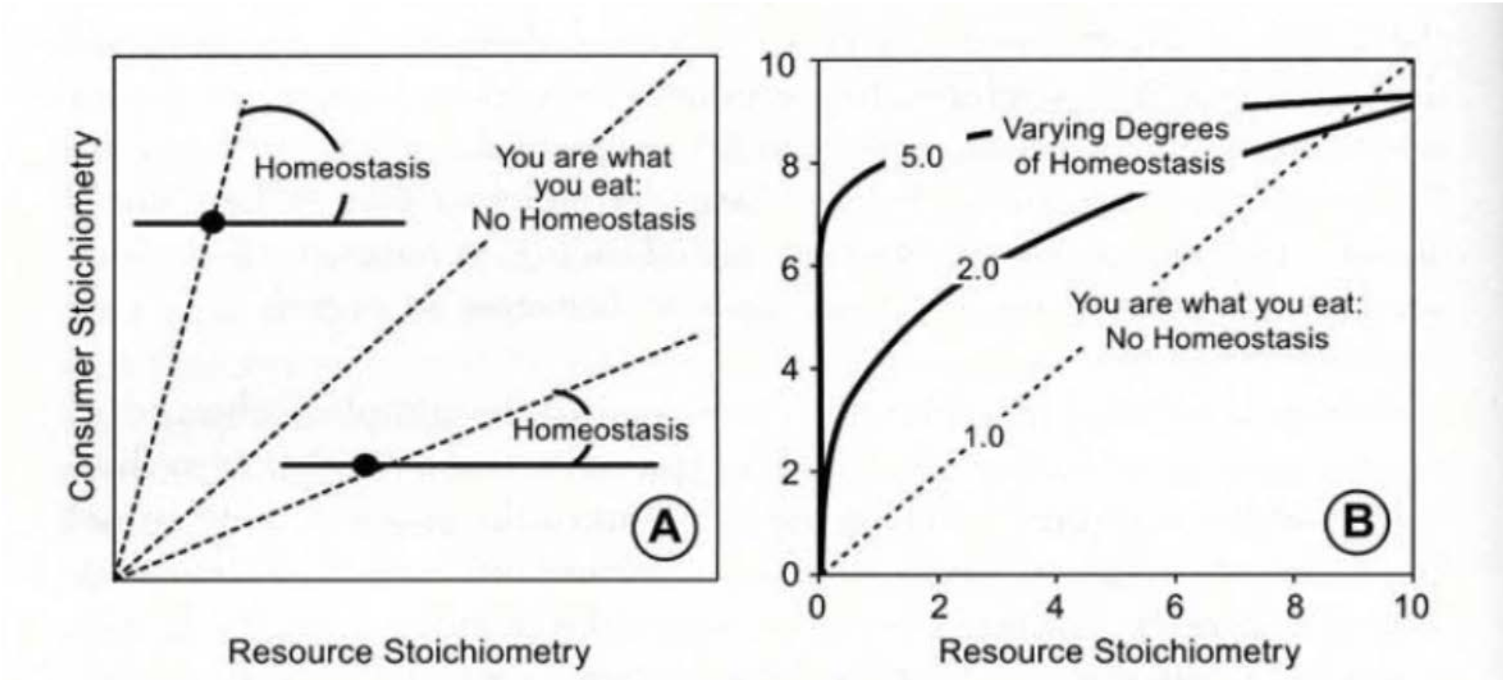


Fig. 1.4. Homeostatic regulation of elemental content. A. Graphically, homeostasis at a point x,y can be defined as a slope between 0 and y/x. B. Degrees of homeostatic regulation based on models with constant coefficient of regulation [H, Eq. (1.3)]. The three curves use values for the coefficients of c and H of 1 and 1, 2 and 3, and 5 and 6, and they are labeled by their value of H. The line marked "1.0" represents no homeostatic regulation. Increasing values of H mean increased regulatory strength.

y = Consumer Stoichiometry
x = Resource Stoichiometry

Stoichiometry and Ecosystems: Homeostasis in "Maths"



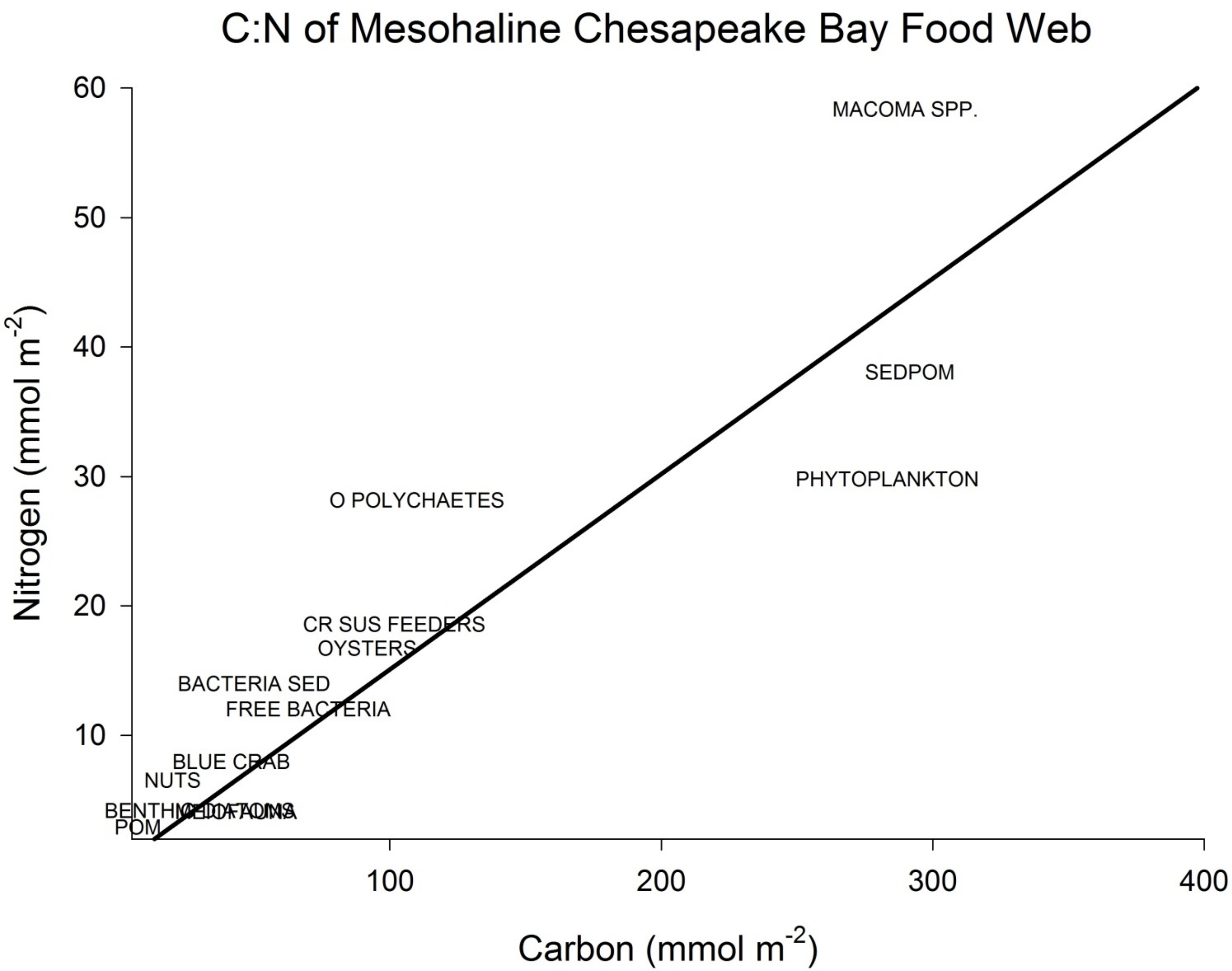
$$\frac{dy}{dx} = \frac{1}{H}\frac{y}{x}$$

$$y = cx^{\frac{1}{H}}$$

$$\log(y) = \log(c) + \frac{\log(x)}{H}$$

y = Consumer Stoichiometry
x = Resource Stoichiometry
H = Regulation Coefficient

Stoichiometry and Ecosystems: Food Webs



SEDPOM X 10^2
NUTS X 10^2
POM X 10^2

What do the position of consumers and producers tell you?