Lecture 16: Introduction to Ecology and the Biosphere

March 11, 2005

Hierarchical Organization and Ecology
Glacier Bay, Alaska

One successional pathway:

- Soils exposed less than 20 years: willow and Dryas
- Soils exposed 45-80 years: sitka alder, scattered cottonwood
- Soils exposed 100 years: sitka, alder, scattered spruce
- Soils exposed 150-200 years: dense sitka spruce and western hemlock

Direction of glacial retreat

20 km

Figure 50.12a
### Primary Succession at Glacier Bay

- **Alder** – roots fix nitrogen
- **Hemlock**
- **Spruce**

**Figure 50.12**

#### Nitrogen Concentration

- (g per m² of surface)
- **In forest floor**
- **In mineral soil**

#### Year

- 1 50 100 150 200

#### Nitrogen Fixation Enzyme

- Substrate, \( \text{N}_2 \)
- \( \equiv N \equiv N \)
- Binding of Substrate
- Reduction

#### Release of Product

- Product: Ammonia, \( \text{NH}_3 \)
- \( \equiv N \equiv N \)
- Reduction

- Free Nitrogenase can bind another molecule of \( \text{N}_2 \)

The Global Nitrogen Cycle

Gigatons yr⁻¹

1 Gt “gigaton”
= 10⁹ ton
= 10¹⁵ g
= 1 billion

Industrial N fixation
100

Biological fixation
140

Denitrification
200

SOIL

ATMOSPHERE

OCEANS

Groundwater

Internal cycling
1200

36 river flow

110 biological fixation

15 biological fixation

Industrial N fixation
100

Nitrogen “Cycle” Without Microbes

<3 fixation by lightening

Denitrification

Burial

River flow

Internal cycling
8000

Nitrogen “Cycle” Without Microbes

Denitrification

Burial

River flow

Internal cycling
1000

8000 internal cycling

ATMOSPHERE

OCEANS
Life on Earth Today: Abridged

(Photosynthesis = Respiration)

Photosynthesis

Plants
Phytoplankton

CO₂ + H₂O → “CH₂O” + O₂

Carbon dioxide + Water → Organic carbon + Oxygen

Respiration

Animals
Bacteria

Chemical energy or heat

Solar energy

Freeman, Figures 6.9, 7.10a, and 7.13
The Global Carbon cycle

Combustion: 5.3 GtC yr\(^{-1}\)

Land use changes: 0.6-2.6 GtC yr\(^{-1}\)

Respiration: 90-120 GtC yr\(^{-1}\)

Photosynthesis: 100-120 GtC yr\(^{-1}\)

Gas exchange between air and ocean

Net accumulation in ocean: 1.6-2.4 GtC yr\(^{-1}\)

Biological Pump Circulation

Geological Reservoir

After Post et al., 1998
**EARLY Life on Earth: Abridged**

*(Photosynthesis > Respiration)*

**Photosynthesis**

- **Plants**
- **Phytoplankton**

\[
\text{CO}_2 + \text{H}_2\text{O} \rightarrow \text{"CH}_2\text{O"} + \text{O}_2
\]

- Carbon dioxide (gas)
- Water
- Organic carbon (mass)
- Oxygen

**Respiration**

- **Animals**
- **Bacteria**

- Chemical energy or heat

**Emergent Property**

**CO₂ Concentration in Atmosphere (parts per million)**
8

Banded iron formations

Red beds

Oceanic origin

Terrestrial origin

Absorption of Oxygen Released to Primitive Atmosphere

Fe$^{2+}$ + O$_2$ $\rightarrow$ FeO$_3$
Present Day Planetary Atmospheres

<table>
<thead>
<tr>
<th></th>
<th>Mars</th>
<th>Earth</th>
<th>Venus</th>
</tr>
</thead>
<tbody>
<tr>
<td>CO₂</td>
<td>95 %</td>
<td>0.035%</td>
<td>98 %</td>
</tr>
<tr>
<td>N₂</td>
<td>2.5 %</td>
<td>78 %</td>
<td>2 %</td>
</tr>
<tr>
<td>O₂</td>
<td>0.25 %</td>
<td>21 %</td>
<td>Trace</td>
</tr>
<tr>
<td>H₂O</td>
<td>0.1 %</td>
<td>1 %</td>
<td>0.05 %</td>
</tr>
<tr>
<td>Temp (°C)</td>
<td>-53</td>
<td>16</td>
<td>474</td>
</tr>
</tbody>
</table>


The same processes operate at all scales
Molecular Ecology

Viewing the Biosphere as a network of genes

A Sea of Organisms Is...
A Network of Genes ("dissolved information")

- 1 billion microbes per liter
- 99.9% have not been cultivated
- Information content of 1 liter = that in human genome
- Most of unknown function
Scorcerer II Expedition

Overview

The Scorcerer II Expedition is the brainchild of Craig Venter, PhD. Dr. Venter is well known as the scientist who pioneered methods of rapid genome analysis used to disclose the human genome. His team developed revolutionary techniques and used a host of the art technology and mathematical algorithms that led to the sequencing of dozens of genomes, including viral genomes such as the smallpox and the mouse. He is at the cutting edge, computer, and outdoor enthusiasts. In addition, he has long been known as an

In one drop of water are found all the secrets of the oceans.

— Ralph Waldo Emerson
Sorcerer II Expedition
World Sampling Route

Challenger Expedition
Craig Venter Takes on the Challenge

Environmental Genome Shotgun Sequencing of the Sargasso Sea

1.2 million new genes
1800 new ‘species’

2 April 2004 Science

Take Home Messages

- Ecology – life at different scales
- Emergent Properties
- Organism ↔ Environment TWO WAY
- Life has shaped Earth’s features
- Biosphere - geosphere have co-evolved
- Genetic inventory unknown
- Microbes Rule!