Biogeography

Fig. 12 - 6a, p. 276

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Biogeographic Processes

- Energy and Matter Flow in Ecosystems
- Ecological Biogeography
- Ecological Succession
- Historical Biogeography
Biogeographic Processes

Biogeography examines the distribution of plants and animals. It identifies the processes that create those spatial and temporal distributions.
Biogeographic Processes

Ecological Biogeography – examines the impact of the environment on the spatial distribution of life on Earth

Historical Biogeography – examines how these spatial distributions change over time
Distribution of **Land** and **Ocean** at the Earth’s Surface

- Mount Everest: 8.8 km
- Mean land surface: 0.84 km
- Mean seafloor: -3.7 km
- Mariana Trench: -11.0 km
Distribution of Life at the Earth’s Surface

- Airborne bacteria and some birds
- Isolated communities at ridge, energy from heat and chemical reactions
- Most of biosphere occurs within this zone
- Bacteria down to several thousand meters
- Scattered bottom-living animals at the greatest depths reached by underwater cameras

- Highest mountains
- Upper limit of land animals
- Upper limit of most plants
- Upper limit of human habitation
- Upper limit of agriculture
Energy and Matter Flow in Ecosystems

- The Food Web
- Photosynthesis and Respiration
- Net Primary Production and Climate
- Biomass as an Energy Source
- Biogeochemical Cycles (Carbon, Nitrogen and Phosphorus)
An **Ecosystem** is defined by the interaction of a group of organisms with their environment.

The **Food Web** is the flow of food energy between different organisms within an ecosystem as a series of steps or levels.
The Start of the Food Web: The Carbon Cycle

Plants are **primary producers** (use sunlight, water and \( \text{CO}_2 \) to create carbohydrates)
These support all other organisms!!!!!!!
**Life on Earth:**

**Organic Compounds**

**Important Elements**

<table>
<thead>
<tr>
<th>Element (Symbol)</th>
<th>Human</th>
<th>Alfalfa</th>
<th>Bacteria</th>
</tr>
</thead>
<tbody>
<tr>
<td>Oxygen (O)</td>
<td>62.8%</td>
<td>77.9%</td>
<td>73.7%</td>
</tr>
<tr>
<td>Carbon (C)</td>
<td>19.4%</td>
<td>11.3%</td>
<td>12.1%</td>
</tr>
<tr>
<td>Hydrogen (H)</td>
<td>9.3%</td>
<td>8.7%</td>
<td>9.9%</td>
</tr>
<tr>
<td>Nitrogen (N)</td>
<td>5.1%</td>
<td>0.8%</td>
<td>3.0%</td>
</tr>
<tr>
<td>Phosphorous (P)</td>
<td>0.6%</td>
<td>0.7%</td>
<td>0.6%</td>
</tr>
<tr>
<td>Sulfur (S)</td>
<td>0.6%</td>
<td>0.1%</td>
<td>0.3%</td>
</tr>
</tbody>
</table>

Carbon is found in all organic compounds.
<table>
<thead>
<tr>
<th>Element</th>
<th>Symbol</th>
<th>Ratio</th>
</tr>
</thead>
<tbody>
<tr>
<td>Carbon</td>
<td>C</td>
<td>106</td>
</tr>
<tr>
<td>Nitrogen</td>
<td>N</td>
<td>16</td>
</tr>
<tr>
<td>Phosphorus</td>
<td>P</td>
<td>1</td>
</tr>
</tbody>
</table>

C:N:P = 106:16:1
The 'Biologic' carbon cycle.

Photosynthesis $\rightarrow$

$\lambda$ (light)

$CO_2 + H_2O \iff CH_2O + O_2$

Chemical (oxidative) energy

$\leftarrow$ Respiration
However, it’s a little more complicated than that, because in order to live and grow (form proteins, chlorophyll, ATP, etc.) a plant actually needs:

- Carbon dioxide
- Water
- Nutrients (N, P, trace elements)
- Light

which produces

- 'Plant' Biomass (CNP)
- Oxygen

If any of the inputs is missing, photosynthesis is 'limited'.
On land plant growth is largely limited by water. Secondarily, by nutrients and light.

In the ocean plant growth is limited by either light near the poles or nutrients elsewhere.
The Food Web

- Herbivores (plant eaters) are primary consumers
- Carnivores (meat eaters) are secondary consumers
- Decomposers (microorganisms and bacteria) consume detritus at all levels
The Food Web – Salt Water Marshes
Trophic Level

1
and 10,000 kilograms of primary producers.

2
and 1,000 kilograms of small herbivores,

3
and 100 kilograms of small fish,

4
roughly 10 kilograms of midsize fish must be consumed,

5
For each kilogram of tuna,

A tuna sandwich 100 g (1/4 pound)

- Tuna (top consumers)
- Midsize fishes (consumers)
- Small fishes and larvae (consumers)
- Zooplankton (primary consumers)
- Phytoplankton (primary producers)
# Net Primary Production

<table>
<thead>
<tr>
<th>COMMUNITY</th>
<th>NOTE PRIMARY PRODUCTIVITY (gC/m²/yr)</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>OCEAN COMMUNITIES</strong></td>
<td></td>
</tr>
<tr>
<td>Coral reef</td>
<td>880–2,200</td>
</tr>
<tr>
<td>Kelp bed</td>
<td>400–1,900</td>
</tr>
<tr>
<td>Shelf plankton</td>
<td>90–270</td>
</tr>
<tr>
<td>Open ocean</td>
<td>1–180</td>
</tr>
<tr>
<td><strong>LAND COMMUNITIES</strong></td>
<td></td>
</tr>
<tr>
<td>Rain forest</td>
<td>460–1,600</td>
</tr>
<tr>
<td>Temperate forest</td>
<td>270–1,140</td>
</tr>
<tr>
<td>Freshwater swamp</td>
<td>360–1,820</td>
</tr>
<tr>
<td>Cropland</td>
<td>45–1,820</td>
</tr>
</tbody>
</table>

We express primary productivity in grams of carbon bound into organic material per square meter of ocean surface area per year (gC/m²/yr).

(c) Net annual primary productivity in some marine and terrestrial communities.

ALL OCEAN = 120 (average)  
ALL LAND = 150 (average)
Net Terrestrial Production and Climate

Climates tend to develop regions of productivity (units = grams of carbon per m$^2$ per year)

Wet Equatorial – over 800
Wet-dry – 400 to 600
Mediterranean – 200 to 400
Dry Tropical and Boreal – 100 to 200
Net Production and Precipitation

Net production increases rapidly with increasing precipitation, but levels off at higher values.
July
January
Mean annual precipitation (NCEP2)
(mm/hour)
Mean Annual Net Assimilation

(moles C/m²/sec)
Mean annual C4 net assimilation
(moles−C/m2/sec)
Biomass as an Energy Source

Direct conversion by burning wood, vegetation and other organic materials such as crop residues

Bacterial decomposition to generate fuels – methane gas, charcoal and alcohol

Burning fossil fuels – coal, oil, natural gas
Biomass as an Energy Source

Pyrolysis – controlled partial burning in an oxygen-deficient environment creates free carbon or charcoal (more efficient than direct burning)

Useful to reduce emissions of carbon dioxide from the burning of fossil fuels
Biogeochemical Cycles

Atoms and molecules of elements move through ecosystems and other systems (e.g. atmosphere, oceans, etc.)

Pools (reservoirs or stocks) where elements remain for short or long-terms

Examples: carbon, nitrogen, oxygen cycles, hydrological and sedimentary cycles
Jacob Priestly is credited with the discovery of Oxygen.
What happens if there is only a mouse?

......mouse dies

What happens if there is only a plant?

What happens if there are a lot more mice?
The ‘Biologic’ carbon cycle.

Photosynthesis →

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

λ (light)

Chemical (oxidative) energy

← Respiration
The 'Non-Biologic' carbon cycle.

Carbon dioxide dissolves in water →

\[ \text{CO}_2 + \text{H}_2\text{O} \iff \text{H}_2\text{CO}_3 \]

← Carbon dioxide bubbles out of water
The Redfield Ratio

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<th>Symbol</th>
<th>Abundance</th>
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<tbody>
<tr>
<td>Carbon</td>
<td>C</td>
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C:N:P = 106:16:1
The Carbon Cycle

Carbon exchanged between the atmosphere, oceans, biosphere and lithosphere

Figure 8.10, p.289
The Nitrogen Cycle

Nitrogen exchanged between the atmosphere, oceans, biosphere and lithosphere

Figure 8.11, p.292
Ecological Biogeography

Basic Terms

**Habitat** – refers to the preferences and needs of an organism or group of organisms with respect to such factors as conditions of slope, water drainage, and soil type.

**Ecological Niche** – describes how a species obtains energy and how it influences other species within its own environment.

**Community** – an assemblage of interacting organisms that live in a particular habitat.
Ecological Biogeography

*Factors controlling distribution of plants and animals*

Water, Temperature and Other Climatic Factors

Bioclimatic Frontiers

Geomorphic and Edaphic (Soil) Factors

Interaction among Species
Water Requirements

plants adapted to drought (xerophytes) characterized by waxy coating on leaves, reduced leaf area, needle-like leaves or spines, light colored to reflect light, water filled stems or deep roots
Water Need

**Phreatophytes** - plants with roots that access groundwater

**Succulents** – plants with thickened leaves and stems

**Xeric** animals can cope with water shortages (e.g. cooler burrows), nearly solid pee
<table>
<thead>
<tr>
<th>Introduced Grasses</th>
<th>Native Grasses</th>
</tr>
</thead>
<tbody>
<tr>
<td>BIG BLUESTEM</td>
<td>BIG BLUESTEM</td>
</tr>
<tr>
<td>SMOOTH BROME</td>
<td>SIDEOATS GRAMA</td>
</tr>
<tr>
<td>CANADA THISTLE</td>
<td>KENTUCKY BLUEGRASS</td>
</tr>
</tbody>
</table>

- **BIG BLUESTEM**: 4 ft
- **SMOOTH BROME**: 1 ft
- **SIDEOATS GRAMA**: 8 ft
- **KENTUCKY BLUEGRASS**: 1 ft
Temperature

temperature affects other variables e.g. humidity

colder climate generally fewer species

cold-blooded animals lack the ability to internally control temperature (e.g. reptiles)

Warm-blooded animals create their own heat, but need more food (e.g. mammals)

characteristics such as fur or feathers, and behavior such as sweating or panting
Other Climatic Factors

In mid to high latitudes light controls seasonal activity of plants in through changes in photoperiod or daylight length.

Deciduous vegetation in mid-latitudes responds to changes both light and temperature with seasons.

Change in day length and temperature also impact a variety of animals inducing some to hibernate.
**Bioclimatic Frontiers**

*where can a plant survive?*

Critical level of climatic stress beyond which a species cannot survive.

Spatially, this is referred to as a bioclimatic frontier.

E.g. Distribution of ponderosa pine controlled by rainfall.
Geomorphic Factors

slope **steepness** and aspect (the orientation of the sloping ground surface with respect to geographic north)

**edaphic** (soil) factors (e.g. soil conditions including texture and its impact on drainage influence plants, and therefore ecosystems)
Interaction among Species

competition – negative interaction between species (interspecific)

intraspecific competition – competition between individuals of same species
Interaction among Species

Predation – one species feeds upon another

Parasitism – one species gains nutrition from another without the immediate death of the host
Interaction among Species

Herbivory – animal grazing reduces the plant population viability

Allelopathy - chemical toxins produced by a plant inhibit the growth of another, e.g. oaks, chestnuts, pines
Interaction among Species

Symbiosis

Commensalism - one species benefits while the other is unaffected

Protocooperation - both species benefit from the relationship

Mutualism – one or both species cannot survive without the other
Succession, Change and Equilibrium

Where vegetation changes over time, often beginning after it is removed due to a catastrophe such as a forest fire, flood or volcanic eruption

First fireweed, knapweed, etc.
Succession, Change and Equilibrium

Primary succession – where all previous vegetation is removed

Secondary succession – where some remnants of the prior ecosystem remain

Old-field succession – on abandoned farmland
Succession, Change and Equilibrium

Figure 8.24, p.306
Historical and Pre-Historical Biogeography

- Evolution
- Speciation
- Extinction
- Dispersal
- Distribution Patterns
- Biogeographic Regions
Evolution

Darwin – survival and reproduction of the fittest – natural selection

variation occurs by mutation and recombination

mutation results when DNA is changed

Recombination – offspring receive two different copies or alleles of each gene
Speciation

Process by which species are differentiated and maintained

**Geographic isolation** – when populations become isolated allopatric speciation in which genetic flow between populations stops

**Sympatric speciation** – occurs within a larger population

**Polyploidy** – in plants, two closely related species can cross
Extinction

Changes in environments can result in extinction

Competition from other species can result in extinction

Currently, extinction is promoted by habitat destruction by humans.

Rare but extreme events may also promote mass extinction such as the meteorite impact related to the extinction of dinosaurs.
Mass Extinctions:
Death and Destruction
Dispersal

movement of individuals from source location

slow extension of species over long periods = dispersal

e.g. diffusion of oaks

Figure 8.31, p.315
Biogeographic regions – same or closely related plants and animals tend to be found together

Biodiversity - Human activity on Earth is rapidly decreasing biodiversity by contributing to extinctions through dispersing competing organisms, hunting, fire, habitat alteration, and fragmentation