

- I. What is ecology and why do we study it?
 - A. Haeckel defined ecology in an explicitly evolutionary context.
 - B. The field of ecology can be subdivided many ways.
 - C. Ecological patterns and processes are best understood in the context of evolution by natural selection.
 - D. Ecology is the foundation of conservation biology; it helps us understand the potential implications of human activities.
- II. The abiotic environment shapes ecological patterns and processes in terrestrial and aquatic environments.
 - A. Life on land (Ch. 2)
 1. Soils are the foundation of terrestrial environments.
 2. Large-scale climate variation is due to the uneven heating of the earth's surface by the sun.
 3. The distribution of terrestrial biomes follows patterns of climate, but is also affected by topography and oceans.
 4. Terrestrial biomes are large-scale plant/animal assemblages united by relatively few common features of climate, soils, etc.
 - B. Life in water (Ch. 3)
 1. Water cycles among reservoirs.
 2. Oceanic environments are divided into vertical and horizontal zones.
 3. Physical conditions affect the ecological characteristics of oceanic environments.
 4. Nutrient cycling and retention is more "open" in oceanic than in terrestrial environments.
 5. Productive ocean systems are those with high rates of photosynthesis and good nutrient storage and retention.

I. Introduction to ecology

- A. Ernst Haeckel was the first to use the term ecology; he defined it in explicitly evolutionary terms when he wrote: "By ecology we mean the body of knowledge concerning the economy of nature – the investigation of the total relations of the animal both to its inorganic and its organic environment; including, above all, its friendly and inimical relations with those animals and plants with which it comes directly or indirectly into contact – in a word, ecology is the study of all those complex interrelationships referred to by Darwin as the conditions of the struggle for existence."
 1. **biotic** = living things; **abiotic** = non-living
 2. note relationship between ecology & evolution
 - a. ecological relationships = conditions of existence that determine selective pressures (i.e., what kinds of characteristics will be favored or not)

- b. evolutionary change may change ecological relationships, setting up new selection pressures
 - c. so get constant feedback: interactions ->selection pressures -> change ->new interactions -> new selection pressures, etc.
- B. Ecology as a biological discipline: huge field of study; can be broken down several ways:
1. by kinds of organisms/environments: small mammal ecology; desert ecology; benthic marine ecology; tropical plant ecology; etc.
 2. by level of biological organization
 - a. individual = physiological ecology, focuses 1' on interactions between individuals & abiotic environment; looks at physiological adaptations
 - b. population = focus on groups within species, usually on patterns/processes at relatively small spatial/temporal scales:
 - a) demography (patterns of abundance and distribution)
 - b) population growth and regulation
 - c. communities = focus on populations of multiple species living in same place
 - i) study interactions among populations (mutualisms, predator/prey, etc.)
 - ii) study patterns of community structure (e.g., species composition, niche relationships, trophic relationships, etc.)
 - d. ecosystems = communities + their abiotic environments; focus is often on how components of the community are connected by nutrient/energy flow
 - e. landscapes = large areas composed of a patchwork of different ecosystems
 - i) study how structure of systems affects processes within & among component communities/ecosystems
 3. Our goals for course
 - a. can't cover everything!
 - b. will focus on key ideas, principles, etc. at each of the major levels of organization
 - c. learn something about how ecology is done by looking at selected individual studies

d. application will focus on conservation issues

C. Ecological patterns and processes are best understood in the context of evolution by natural selection

1. "Nothing in biology makes sense except in light of evolution" - Dobzhansky
2. especially true w/ecology -- we'll focus repeatedly on trying to understand ecological patterns/processes in terms of natural selection, so need to be sure we all understand basics of selection!
3. Natural selection is a process that inevitably results when four basic conditions are met (as they always are for living things):
 - a. organisms vary
 - b. variation is heritable
 - c. organisms experience a "struggle for existence"
 - i) biotic interactions
 - a) "3 p's": predation, parasitism, pathogenesis
 - b) overproduction leading to competition (intra- and inter-specific)
 - ii) abiotic interactions (e.g., being exposed to extremes of temp, aridity, etc.)
 - d. ability to survive and reproduce (fitness) varies with variation in heritable traits
4. When those conditions hold, result = spread (or increase in frequency) of favorable traits throughout population over time
 - a. organisms better able to survive & **reproduce** leave relatively more offspring; those offspring tend to have the favorable traits
 - b. note emphasis on reproduction -- survival only helps insofar as it leads to increased reproduction (we'll look at this in more detail later)
5. e.g. -- spread of DDT resistance in mosquitoes
 - a. natural populations of Anopheles mosquitoes always had low frequency of individuals with DDT resistance (trait due to allele of gene for enzyme that breaks down the chemical)
 - b. trait low frequency because those individuals had slightly reduced fertility (not so low as to eliminate trait)
 - c. when DDT introduced to environment, those individuals had greater fitness;

trait spread

6. DDT example illustrates two **really** important points
 - a. selection can act only on existing genetic variation;
 - i) it does not *create* the variation (the allele already existed at low frequency; the presence of DDT did not create the allele)
 - ii) genetic variation is random with respect to the environment; one answer to “why doesn’t organism X have adaptation Y” may be that the appropriate genetic variation never existed
 - b. whether a trait is selectively beneficial or harmful depends on environmental conditions; those conditions may change!
7. Selection is powerful force for change and can explain much of what we see when we look at how organisms interact w/ each other and w/ the environment, but it has limits. Important ones for us this semester to bear in mind will be:
 - a. **“principle of allocation”**:
 - i) organisms can acquire only finite amounts of energy in their lifetimes
 - a) energy devoted to one function (e.g., survival) cannot be allocated to another (e.g., reproduction)
 - b) note, however, that energy invested in one function may result in a net increase in performance elsewhere
 - ii) therefore, see “tradeoffs” among traits: e.g., if energy for offspring biomass is limited, a tradeoff will exist between offspring size and offspring number
 - iii) tradeoffs will limit the range of adaptations we see
 - b. **“mechanical/developmental constraint”**:
 - i) the way organisms are “built” (materials from which constructed, how put together) limits what organisms can do
 - a) e.g. -- plants lacking xylem, phloem, can’t grow very tall
 - b) e.g. -- small female mammals have smaller litter masses than large female mammals (b/c smaller uteri)
 - ii) constraints, like tradeoffs, limit the range of adaptations we see
8. On your own – read two case studies (colonizing lizards, soapberry bugs) starting on

p. 204; answer review questions 8 & 9 p. 212

D. Ecology is the foundation of conservation biology; it helps us understand the potential implications of human activities.

1. Humans are not unique in altering our environment – virtually every organism does so to some extent.
2. Humans are unique in both the extent and rate of change we're currently inducing.
3. Read Peter Raven's AAAS Presidential Address, "Science, Sustainability, and the Human Prospect" to get a sense of the kinds of changes taking place and some of their consequences. Much of what you learn this semester will help you understand Raven's arguments.





II. The abiotic environment shapes ecological patterns and processes in terrestrial and aquatic environments.

A. Life on land (Ch. 2)

1. Soils are the foundation of terrestrial environments.
 - a. Soils = Mixture of organic & inorganic material created by interactions among living things, climate (weathering), parent material
 - b. General structure (simplest; may be much more complex than this!)
 - i) O = organic horizon:
 - a) fresh, "intact" organics on top
 - b) decomposition fragments organics; fragments = **humus** "mixed" by soil organisms to lower layers
 - c) note that agricultural, desert soils lack this layer
 - ii) A = topsoil
 - a) mixture of organics from O w/ weathered parent material (clay, silt, sand) from lower layers
 - b) generally rich in mineral and organic nutrients
 - c) action of HOH leaches ("drains") clays, minerals, humus to lower layers
 - iii) B = contains materials leached from A horizon

- a) often richest in mineral nutrients
- b) often major horizon for plant roots
- iv) C = lowest horizon contains mostly light-moderately weathered parent material; little mineral nutrients
- c. Closer look at organic, inorganic components:
 - i) organic component
 - a) living organisms from microscopic to macroscopic
 - b) dead plant and animal matter
 - c) soil organisms comprise complex food webs/communities of their own; we don't know nearly as much about these as we'd like!
 - ii) inorganic component
 - a) **parent material** = mineral/"rock" (of all different types) in various stages of **weathering** (breakdown into increasingly small fragments by actions of plants, water, wind, etc.)
 - b) particle size of parent material has major effects on soil properties due to (generally) negatively-charged surfaces
 - (1) decrease particle size ->increase area of negatively-charged sites
 - (2) charged sites attract HOH and cations (H⁺ & mineral nutrients Ca²⁺, K⁺, Mg²⁺, etc.)

(3) general rule: gradient of sizes, properties

type	size	SA	HOH capacity	nutrient capacity
clay	smallest	largest	highest	highest
silt				
sand				
gravel	largest	smallest	lowest	lowest

c) “complications”/exceptions to rule

(1) acid soils have lower nutrient capacities than would otherwise expect

- i) acids (from, e.g., conifer needles) enter soil by leaching
- ii) break down clays, helping them leach out of upper horizons
- iii) H⁺ ions have high binding affinities; “kick” off other cations (especially Ca²⁺)
- iv) mineral nutrients kicked off surfaces leached away from zones where plant roots live

(2) water capacity complicated --not all soil HOH is equally available to plants

- i) imagine soil with varying particle size; will have spaces of various sizes between soil particles
- ii) if pore spaces very large, relatively little HOH will be bound to surfaces; gravity will drain that HOH from soil
- iii) if pore spaces very small, get very thin layers of HOH very tightly bound to soil particles; plants can’t “pull hard enough” to transport that HOH into root system
- iv) “medium” pore spaces will hold HOH too tightly for gravity, but not too tightly for plant roots
- v) therefore, even though, e.g., clay soils have high capacity for HOH, “pure” clay soils make relatively little HOH available to

plants

- d. Note that soil structure and properties will be influenced by anything that influences either organic or inorganic components; major influences are
 - i) parent material
 - ii) climate (affects weathering)
 - iii) topography (affects weathering)
 - iv) time
2. Large-scale climate variation is due to the uneven heating of the earth's surface by the sun.
- a. Variation in climate is largely responsible for variation in the abundance and distribution, interactions of organisms across the globe
 - b. Variation in climate is largely due to the uneven heating of earth's surface by the sun
 - i) earth is tilted on axis relative to plane of rotation around sun
 - ii) causes seasonal variation in the amount of sunlight (variation increases from equator poleward)
 - iii) causes seasonal variation in temperature, daylength
 - iv) also causes variation in precipitation via affects of uneven heating on global air circulation
 - a) basic principles:
 - (1) equator receives most heat energy, poles least
 - (2) air flows, on average, from areas of high air temperature (equator) to areas of low air temperature (poles)
 - (3) warm air has a higher capacity for HOH than does cold air
 - b) result = pattern of circulation cells (3 in each hemisphere)
 - (1) @ equator, warm air rises & moves poleward; as it rises, it cools and loses HOH as rain -> band of warm, wet climate around equator
 - (2) cool air descends (still moving poleward); as it descends, it warms and absorbs HOH from earth's surface -> bands of arid climate (deserts) at ~ 30° N, S lat.

- (3) warming air rises (still moving poleward), cools, drops moisture in band of cooler, wetter climates around 60° N & S lat.
- c. earth's rotation causes prevailing winds to blow at angles; this important for producing surface ocean currents (below)
- 3. The distribution of terrestrial biomes follows patterns of climate, but is also affected by topography and oceans.
 - a. Vegetation tends to follow patterns of climate (see biome map), but note don't get "perfect" bands w/ variation in latitude -- why?
 - b. topography: mountains produce rainshadow effects, producing dry habitats at higher latitude than might otherwise be expected in N and S America
 - c. oceans have major effects on coastal climate:
 - i) high heat capacity of water cause coastal areas to have, generally,
 - a) fewer extremes of temperature than inland
 - b) less variation in temperature than inland
 - ii) patterns of ocean circulation (diagram) generally draw warm water from equator along eastern continental margins; cold water from poles along western continental margins (note lots of exceptions to this!!!!)
 - a) so on eastern margins, may get more moderate climate further north than "expected"
 - b) get colder climates than expected along western margins
- 4. Terrestrial biomes are large-scale plant/animal assemblages united by relatively few common features of climate, soils, vegetation type, and vegetation structure
 - a. climate (temp, ppt), soils interact to determine
 - i) types of plants that can live (species, growth forms, etc.)
 - ii) amount of PSN = amount of fixed C and chemical energy available to rest of system (relates to density, diversity of organisms)
 - iii) Note esp. that soils (mostly) act as nutrient reservoirs, holding nutrients within systems & allowing them to be recycled within the system
 - b. E.g.s of interactions: compare and contrast (from text) four biomes: for each, note **general climatic conditions** (temp, rainfall), approximate **location**

(latitude, continents), **soil properties** (not technical names), general **types of vegetation** (not species names), level of **plant diversity** (high, low)

- i) Tropical rain forest - pp. 20-22
- ii) Temperate grassland - pp. 32-34
- iii) Temperate forest - pp. 34-36
- iv) Boreal forest - pp. 36-38

B. Life in water (Ch. 3)

1. Water cycles among reservoirs ("forms")

- a. oceans ~ 97.25%
- b. polar ice caps, glaciers ~ 2%
- c. actively exchanged groundwater ~ 0.7%
- d. so fresh HOH lakes, rivers, streams, etc. make up only about 0.05% of water on Earth – of that,
 - i) ~ 60% in lakes
 - ii) ~ 33% in the form of soil moisture (very important for helping to regulate flood/drought cycles)
 - iii) ~ 1% rivers
 - iv) ~ 6% is in the atmosphere
- e. HOH cycle among reservoirs in process called the hydrologic cycle (see HO's)
- f. cycling (turnover) rate varies among reservoirs:
 - i) atmospheric HOH cycles every ~ 9 days; oceans ~ 3,000 yearsII.

2. Oceanic environments are divided into vertical and horizontal zones

- a. **littoral** = intertidal zone
- b. **neritic** = oceans from littoral to margin of continental shelf
- c. **oceanic** = everything beyond continental shelf; divided horizontally into layers based on depth:
 - i) **epipelagic** = top ~ 200 m
 - ii) of that, approximately top 150 m gets enough light for PSN = **photic zone**

- iii) below 200 m, several depth classifications; we'll call it all **aphotic** (not enough light for PSN)
- d. oceanic zones also classified based on where organisms live:
 - i) **benthic** = anywhere on the bottom (whether shallow or deep)
 - ii) **pelagic** = anywhere off the bottom (whether shallow or deep)
- 3. Physical conditions affect the ecological characteristics of oceanic environments
 - a. light is critical for PSN
 - i) rapidly absorbed in HOH – assuming no/minimal turbidity,
 - a) about 80% of incident sunlight is absorbed within the top 10m
 - b) red, orange, yellow, and green absorbed most rapidly
 - c) below ~ 50 m only blue wavelengths left
 - d) below ~150 m, no PSN
 - b. temperature affects rates of PSN, nutrient transport, and distributions of organisms
 - a) generally, get layer of warm HOH “floating” on a layer of cold HOH
 - b) thermocline = layer of HOH through which temp. changes rapidly with depth separates warm & cold HOH, keeps them from mixing (important!)
 - c) thermal stratification is ~ permanent feature of tropical HOHs; tends to break down in fall, winter in temperate zones (permits mixing)
 - c. chemical composition
 - i) primary salts = Na⁺, Mg²⁺, Cl⁻
 - ii) concentration varies as a function of precipitation & evaporation
 - iii) regardless of total concentration, relative proportions tend to be fairly uniform
 - d. Oxygen concentration varies with depth
 - i) tends to be highest at surface (why?), declining with depth to some intermediate depth (as decomposers break down detritus “raining” from upper layers)
 - ii) after that, actually increases with depth (so deep HOHs are oxygen-rich)
 - e. ocean currents have important consequences
 - i) 3 basic types

- a) surface currents = **gyres** caused by wind within major ocean basins
 - (1) these generally transport warm HOH from equator poleward, moderating climate at temperate latitudes)
- b) deep HOH currents caused as cold polar HOH sinks and moves equator-ward (big piece of global climate patterns)
- c) upwelling brings deep, cold, nutrient and oxygen rich HOH's to surface,
 - (1) especially along W. coasts of continents & Antarctica (so these tend to be highly productive waters)
 - (2) major cause = winds blowing HOH away from continents, "removing" surface HOH and allowing deep HOH up
- ii) movement has major consequences:
 - a) moderates climate
 - b) transports oxygen, nutrients, heat (has a "fertilizing" effect)
 - c) stimulates PSN (via fertilizing effect)
 - d) promotes gene flow among marine populations by transporting organisms
- 4. Nutrient cycling and retention is more "open" in oceanic than in terrestrial environments
 - a. although productivity of ocean systems like terrestrial in that it's a function of PSN, one major difference = nutrient cycling & storage
 - b. in terrestrial systems, nutrients can be stored and recycled between living organisms and soils -- tend to stay in system
 - c. in oceanic systems, cycling much more "open"; nutrients hard to "keep" where PSN occurs: (see diagram at end of notes)
 - i) PSN occurs in upper layers
 - ii) nutrients input from terrestrial systems taken up by plankton (PSN), but normal feeding patterns and decomposition cause nutrients to "fall" out of upper layers and ultimately be deposited as sediments
 - iii) only way to get nutrients from bottom to top = upwelling
 - d. consequently, ocean waters tend to be nutrient poor; all else being equal, this means low productivity
- 5. Productive ocean systems are those with high rates of photosynthesis and good

nutrient storage and retention.

a. estuaries/salt marshes/mangrove forests

- i) concentrated along sandy shores of low-lying coasts in temperate - high latitudes (low latitudes/tropics get mangrove swamps)
- ii) complex landscape includes tidal creeks, basins, etc.; whole system floods at high tides, drained at low tide
- iii) dominated by herbaceous vegetation; diversity not high, but productivity very high
 - a) physical conditions highly variable; often very good for PSN
 - (1) light ranges from high (low tide) to low (high tide), but often high
 - (2) temperature fluctuates with tide, but will get extended periods of warm temps; also, shallow HOH will warm more rapidly
 - (3) salinity varies with tides; organisms must be tolerant of variation
 - b) highly variable physical conditions explain relatively low diversity: relatively few organisms are adapted to them
 - c) tidal action major reason for high productivity: tides bring in nutrients (via nearshore sediments), oxygen & remove wastes
 - d) "tight" nutrient recycling also important: large community of mud-dwelling detritivores keep many nutrients within the community (vs. washing out with the tides)

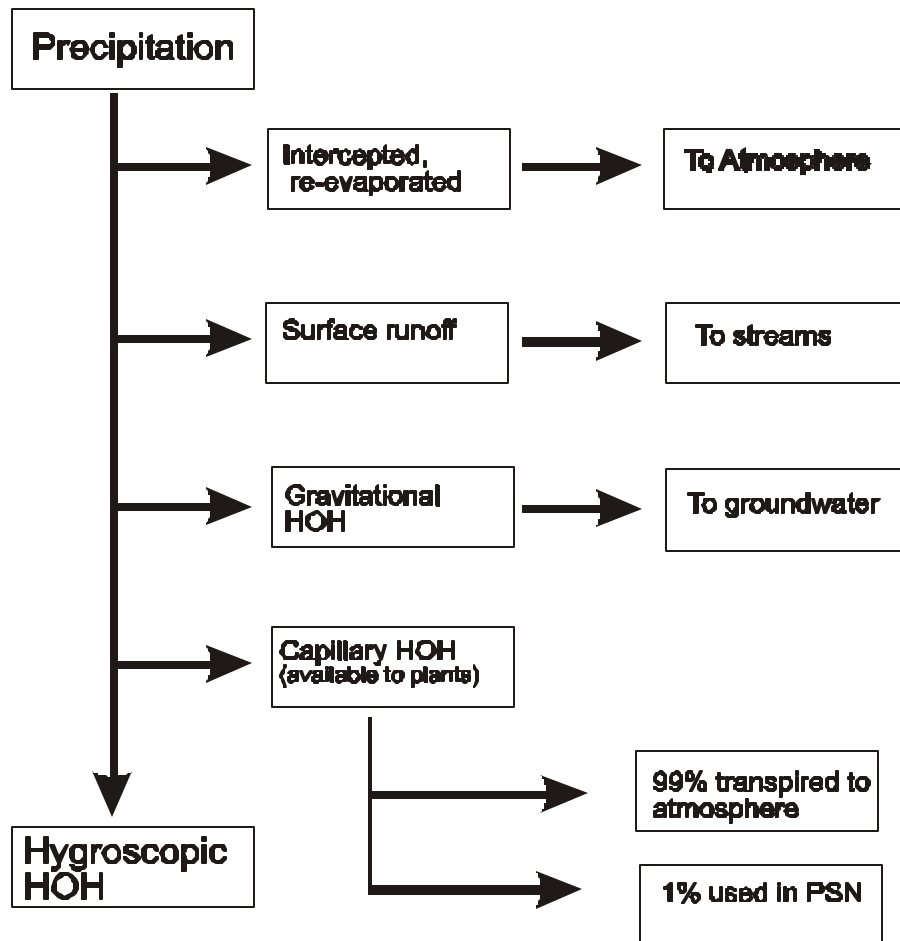
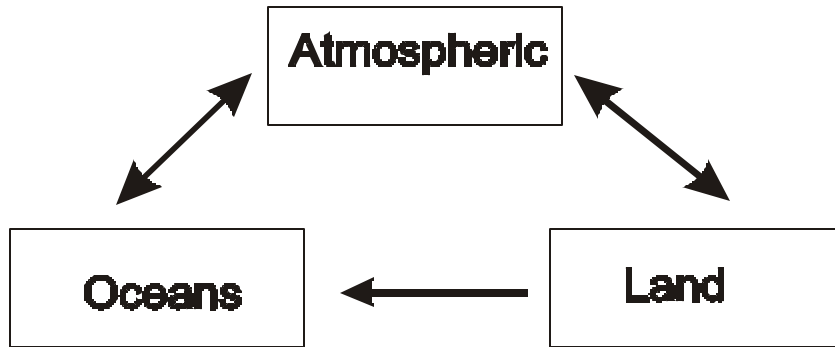
b. coral reefs

- i) coral is found only where conditions favorable to polyps and symbiotic algae (zooxanthellae) = warm, shallow HOH with lots of light and little variation in salinity (shallow tropics)
- ii) extremely diverse systems ("the oceans rainforests")
- iii) productivity high because
 - a) physical conditions favor PSN (light, temp)
 - b) symbiosis between coral, zooxanthellae recycles nutrients efficiently
 - (1) zooxanthellae PSN by day, transferring C-compounds to polyps
 - (2) polyps feed on zooplankton, transferring nitrates, phosphates to

zooxanthellae (helping to maintain high PSN levels)

- c) reef acts as physical nutrient (detritus) trap
- d) reef provides structural support for lots of other PSN organisms
(micro and macro algae, sea grasses, etc.)

Hydrologic
cycles



Nutrient flow in ocean systems

