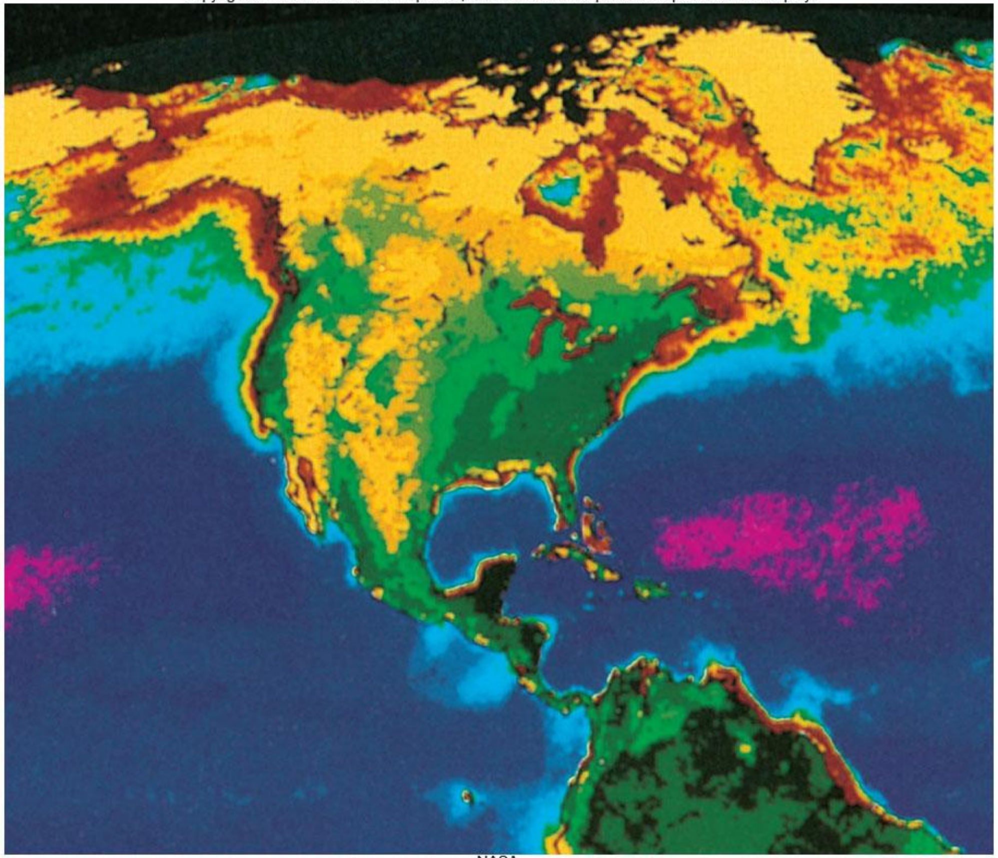
The Biosphere

Chapters 58,56,57



NASA

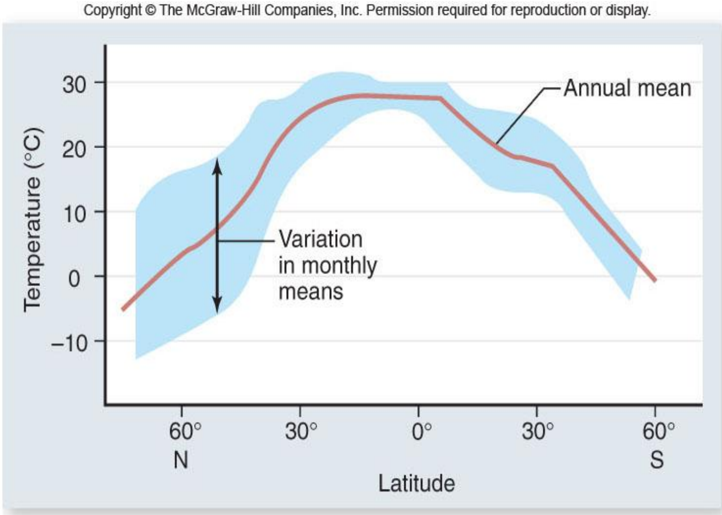
Effects of Sun, Wind, Water

- **Biosphere:** includes all living communities on Earth
- Global patterns of life on Earth are influenced by
  1. The amount of solar radiation that reaches different areas
  2. Patterns of global atmospheric circulation which influence oceanic circulation

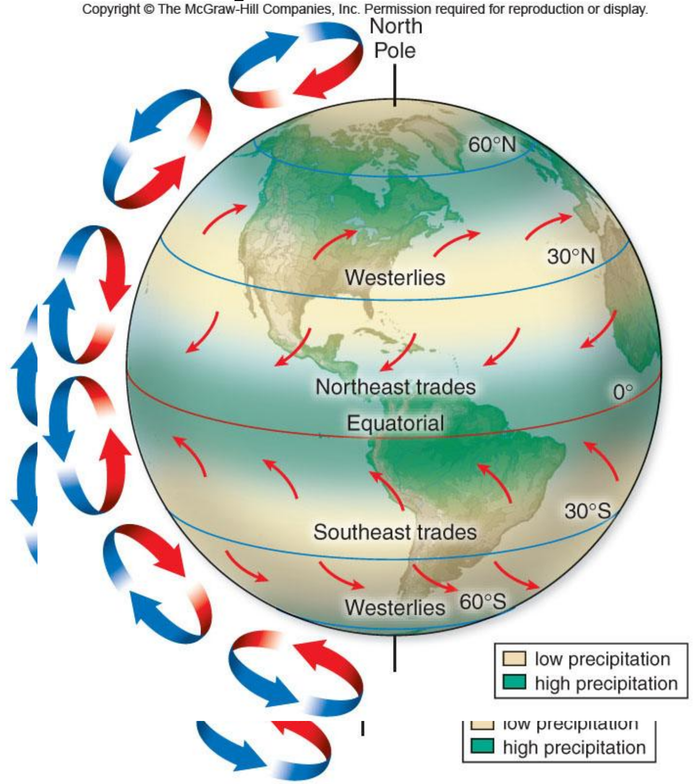
Effects of Sun, Wind, Water

- Global circulation patterns
  - Hot air rises relative to cooler air
  - Heating at the equator causes air to rise from the surface to high in the atmosphere
  - Rising air is rich in water vapor
    - Warm air holds more water than cold
    - Intense solar radiation at the equator provides the heat needed for water to evaporate

Effects of Sun, Wind, Water



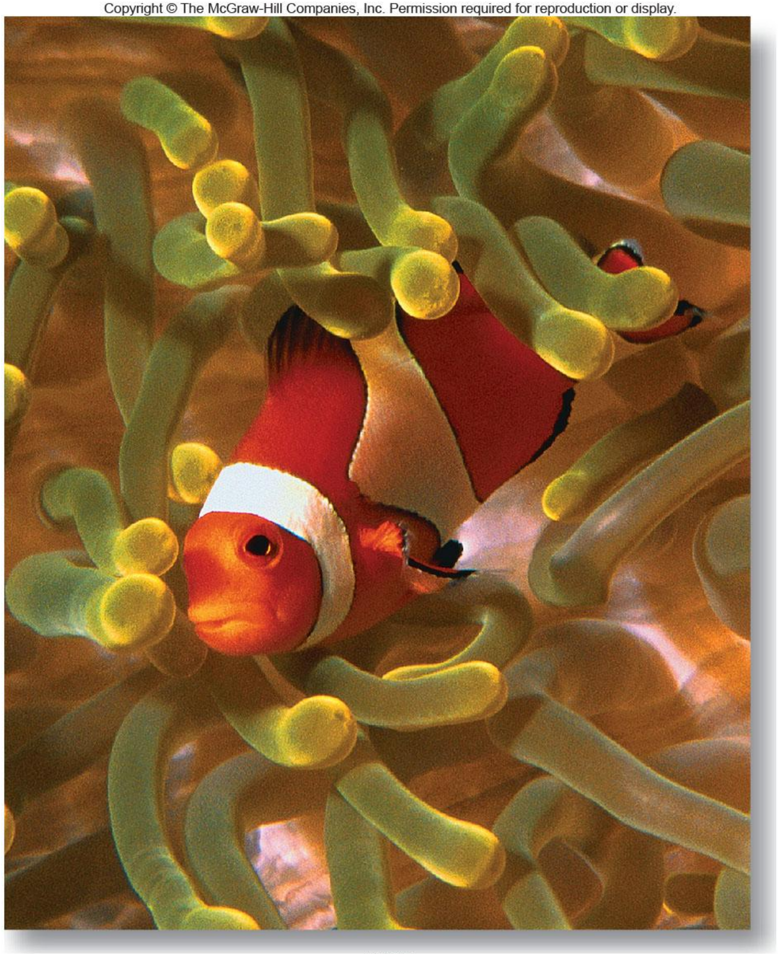
Annual mean temperature varies with latitude



Global patterns of atmospheric circulation

Community Ecology

Chapter 56



Biological Communities

Community: all the organisms that live together in a specific place

- Evolve together
- Forage together
- Compete
- Cooperate

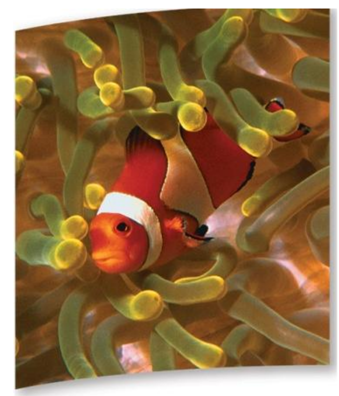
Biological Communities

- Communities can be characterized either by their constituent species or by their properties
  - **Species richness:** the number of species present
  - **Primary productivity:** the amount of energy produced
- Interactions among members govern many ecological and evolutionary processes

Biological Communities

- Interactions in a community
  - Predation

  - Mutualism



© Corbis

- Assemblage: the species included are only a portion of those present in the community

Biological Communities

- Two views of structure and functioning of communities
  - **Individualistic concept:** H.A. Gleason; a community is nothing more than an aggregation of species that happen to occur together at one place
  - **Holistic concept:** F.E. Clements: a community is an integrated unit; superorganism-more than the sum of its parts

Biological Communities

Most ecologists today favor the individualistic concept

- In communities, species respond independently to changing environmental conditions
- Community composition changes gradually across landscapes

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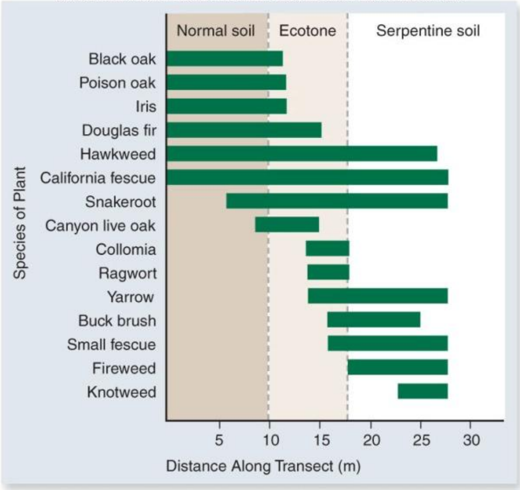
Biological Communities

Sometimes the abundance of species in a community does change geographically in a synchronous pattern

Ecotones: places where the environment changes abruptly



Change in community composition across an ecotone, from The Economy of Nature, 4e, by Robert E. Ricklets. Copyright 1973, 1979 by Chiron Press, Inc. © 1990, 2000 by W.H. Freeman and Company. Reprinted by permission

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Ecological Niche

- **Niche:** the total of all the ways an organism uses the resources of its environment
  - Space utilization
  - Food consumption
  - Temperature range
  - Appropriate conditions for mating
  - Requirements for moisture and more

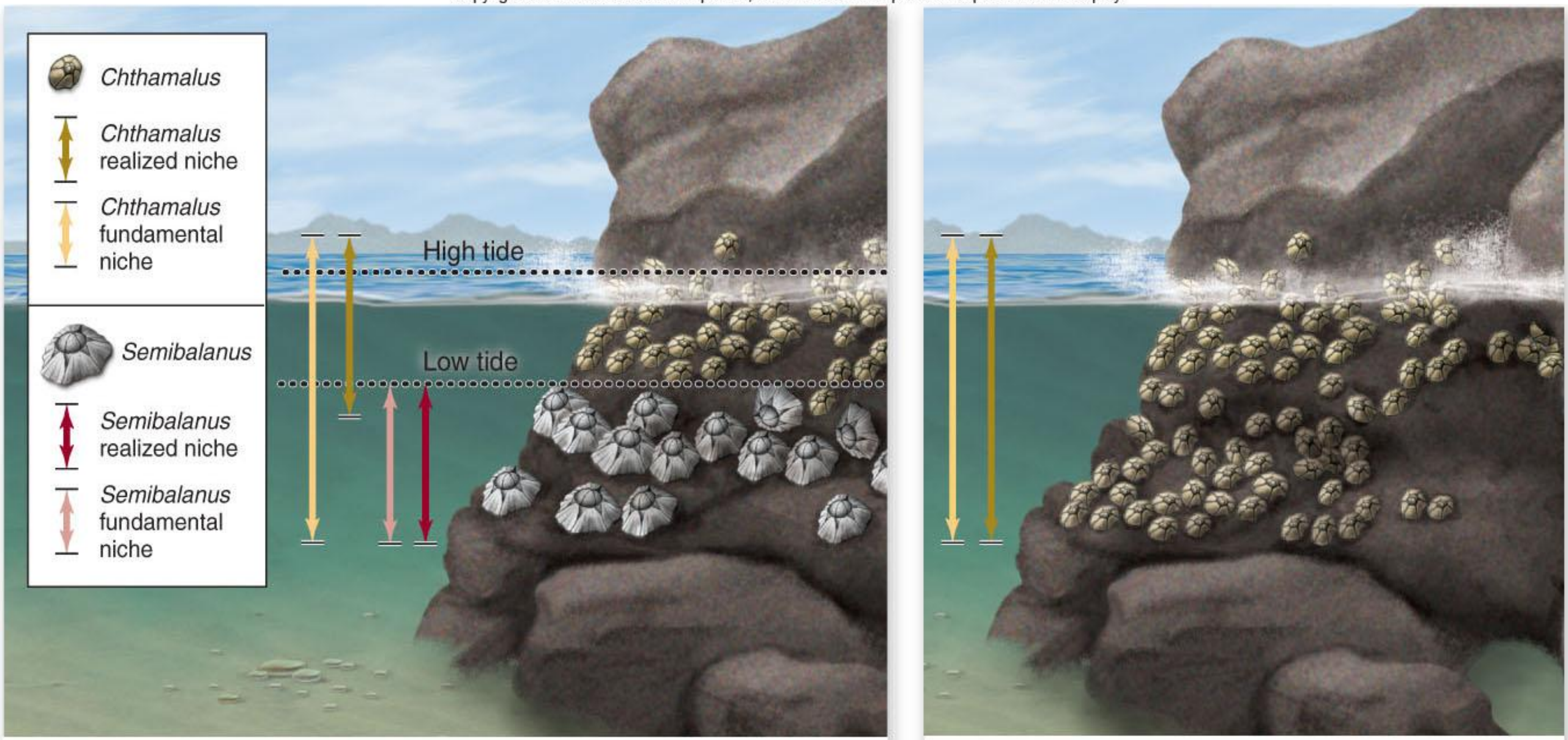
Ecological Niche

- **Interspecific competition:** occurs when two species attempt to use the same resource and there is not enough resource to satisfy both.
- The opposite of **Intraspecific competition**, which is between individuals of the same species.
- **Interference competition:** physical interactions over access to resources
  - Fighting
  - Defending a territory
  - **Competitive exclusion:** displacing an individual from its range

Ecological Niche

- **Fundamental niche:** the entire niche that a species is capable of using, based on physiological tolerance limits and resource needs
- **Realized niche:** actual set of environmental conditions, presence or absence of other species, in which the species can establish a stable population

Ecological Niche



S.balanoides and *C.stellatus* competing

C.stellatus fundamental and realized niches are identical when *S.balanoides* is removed.

Ecological Niche

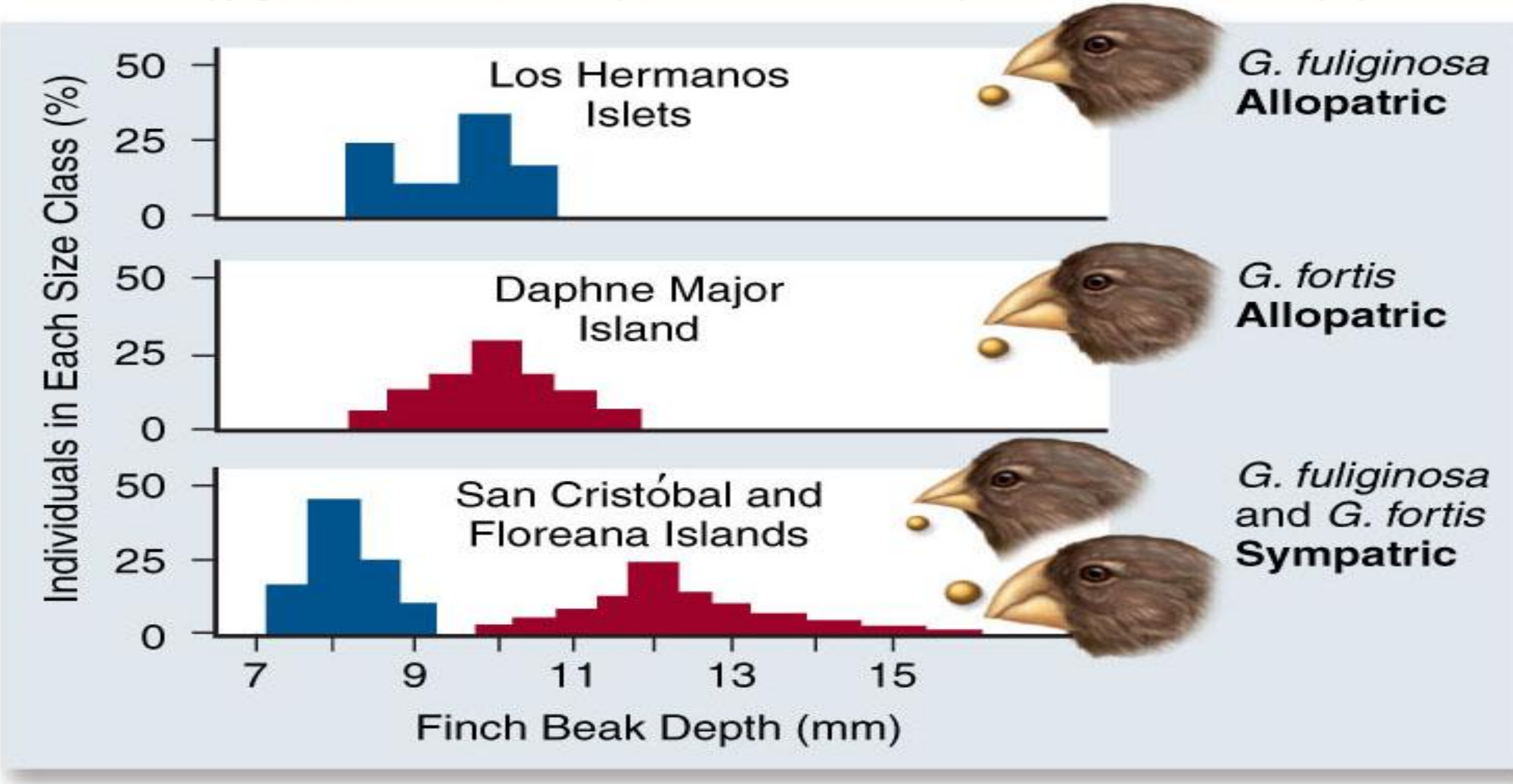
- Other causes of niche restriction
  - Predator absence or presence
- Plant species
  - Absence of pollinators
  - Presence of herbivores

Ecological Niche

- Niche overlap and coexistence
- Competitive exclusion redefined: no two species can occupy the same niche indefinitely when resources are limiting
- Species may divide up the resources, this is called resource partitioning
- Gause found this occurring with two of his *Paramecium* species

Ecological Niche

- Resource partitioning is often seen in similar species that occupy the same geographic area
- Thought to result from the process of natural selection
- **Character displacement:** differences in morphology evident between sympatric species
  - May play a role in adaptive radiation



Data from E.J. Heske, et al., Ecology, 1994. Figure 56.8: Data from E.J. Heske, et al., Ecology, 1994

Predator-Prey

- **Predation:** consuming of one organism by another
- Predation strongly influences prey populations
- Prey populations can have explosions and crashes
  - White-tail deer in Eastern US
  - Introduction of rats, dogs, cats on islands
  - New Zealand: Stephen Island wren extinct because of a single cat

Predator-Prey

- Introduction of prickly-pear cactus in Australia
  - The cactus population exploded
  - Introduced the predator a moth (caterpillar eats the cactus) and the population came under control

Predator-Prey

- Predation and coevolution
  - Predation provides strong selective pressure on the prey population
  - Features that decrease the probability of capture are strongly favored
  - Predator populations counteradapt to continue eating the prey
  - Coevolution race may ensue

Predator-Prey

- Plants adapt to predation (herbivory) by evolving mechanisms to defend themselves
  - Chemical defenses: secondary compounds
    - Oils, chemicals to attract predators to eat the herbivores, poison milky sap and others
  - Herbivores co-evolve to continue eating the plants

Predator-Prey

- Chemical defenses in animals
  - Monarch butterfly caterpillars feed on milkweed and dogbane families
  - Monarchs incorporate cardiac glycosides from the plants for protection from predation
  - Butterflies are eaten by birds, but the Monarch contains the chemical from the milkweed that make the birds sick

Predator-Prey

a. *b.*

Predator-Prey

Poison-dart frogs of the family Dendrobatidae produce toxic alkaloids in the mucus that covers their brightly colored skin

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© Brian Rogers/Natural Visions

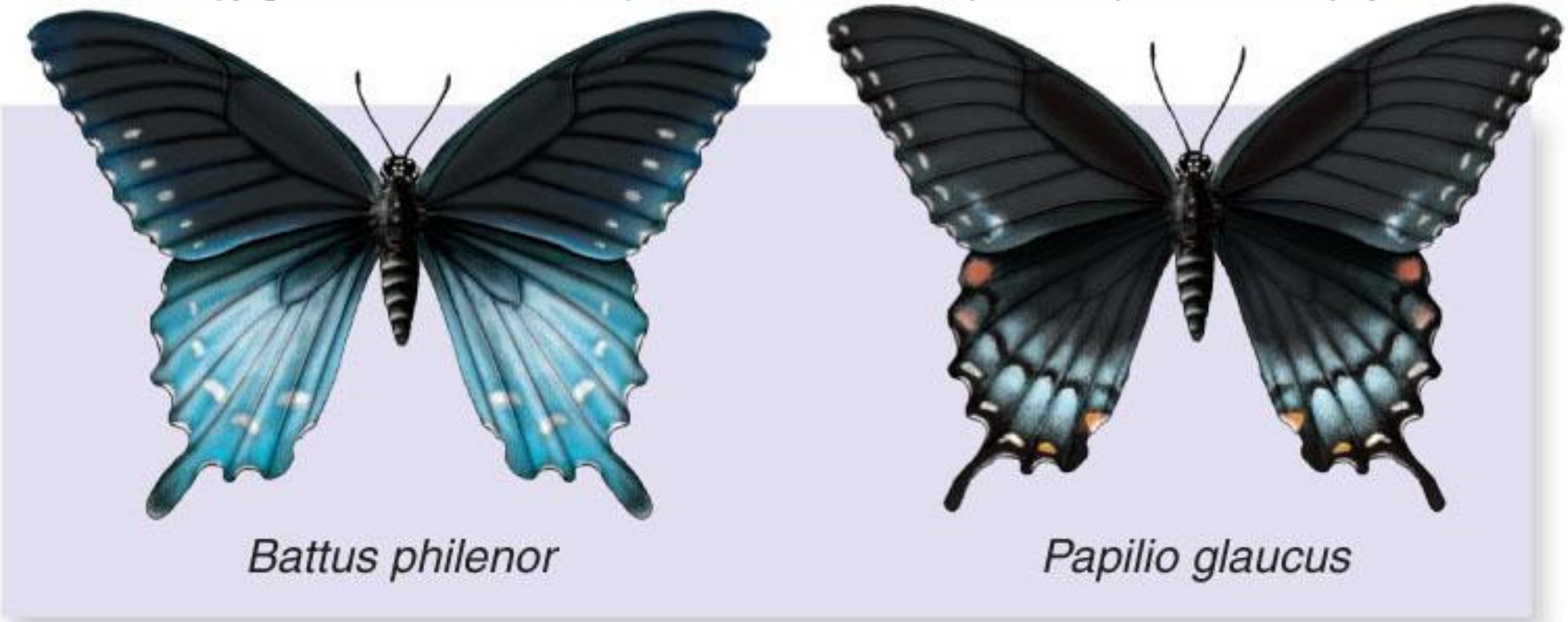
Predator-Prey

- Mimicry allows one species to capitalize on defensive strategies of another
  - Resemble distasteful species that exhibit warning coloration
  - Mimic gains an advantage by looking like the distasteful model
  - Batesian mimicry
  - Müllerian mimicry

Batesian Mimicry

- Batesian mimicry
  - Named for Henry Bates
  - Discovered palatable insects that resembled brightly colored, distasteful species
  - Mimics would be avoided by predators because they looked like distasteful species
  - Feed on plants with toxic chemicals

Batesian Mimicry

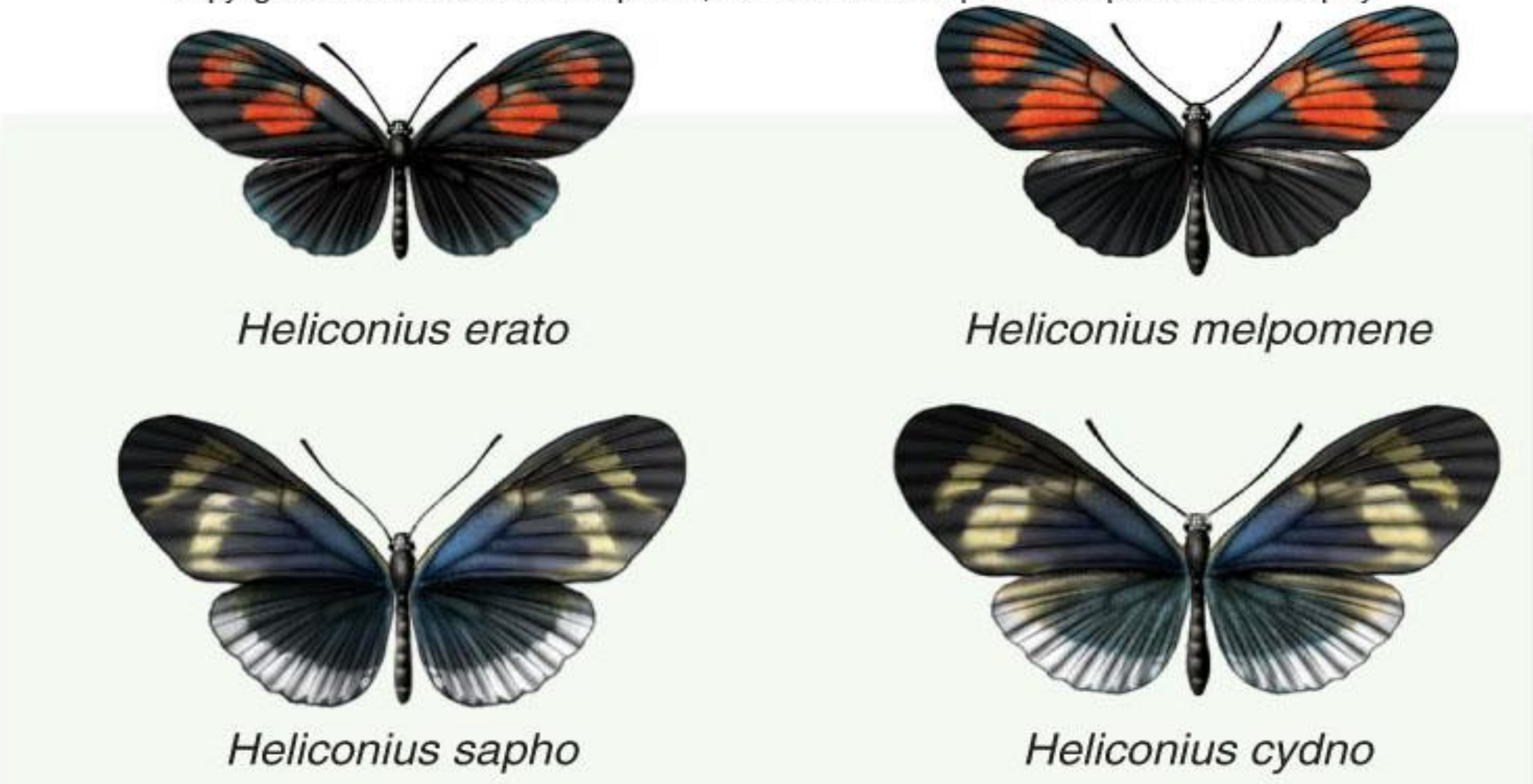


a. **Batesian mimicry:** Pipevine swallowtail butterfly (*Battus philenor*) is poisonous; Tiger swallowtail (*Papilio glaucus*) is a palatable mimic.

Müllerian Mimicry

- Müllerian mimicry
  - Fritz Müller
  - Discovered that several unrelated but poisonous species come to resemble one another
  - Predator learns quickly to avoid them
  - Some predators evolve an innate avoidance
- Both mimic types must look and act like the dangerous model

Müllerian Mimicry



***b.* Müllerian mimicry:** Two pairs of mimics; all are distasteful.

Species Interactions

- **Symbiosis:** two or more kinds of organisms interact in more-or-less permanent relationships
- All symbiotic relationships carry the potential for coevolution
- Three major types of symbiosis
  - Commensalism
  - Mutualism
  - Parasitism
  - Proto-cooperation

Commensalism

Commensalism benefits one species and is neutral to the other

- Spanish moss: an epiphyte hangs from trees

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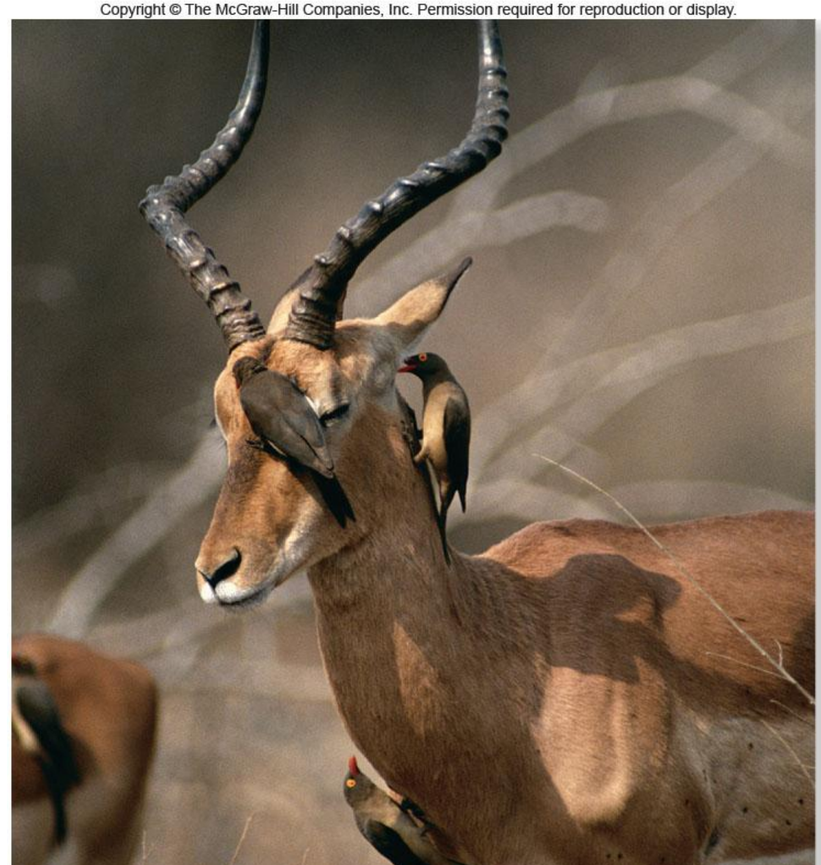
Species Interactions

- Oxpickers on an impala
- Is it commensalism, parasitism or mutualism ?



Species Interactions

- Mutualism benefits both species
- Coevolution: flowering plants and insects
  - Ants and acacias
  - Acacias provide hollow thorns and food
  - Ants provide protection from herbivores

© Michael Fogden/DRK Photo

Species Interactions

- Not all ant and acacia relationships are mutualism
- In Kenya, several species of ants live on acacias
  - One species clips the acacia branches to prevent other ants from living in the tree
  - Clipping branches sterilizes the tree
  - A parasitic relationship

Species Interactions

- External parasites:
  - **Ectoparasites:** feed on exterior surface of an organism
  - **Parasitoids:** insects that lay eggs on living hosts
    - Wasp, whose larvae feed on the body of the host, killing it
- Parasitism benefits one species at the expense of another

Species Interactions
Parasitic Plants

© David Moorhead

External parasite: the yellow vines are the flowering plant dodder, it is a parasite that obtains its food from the host plant it grows on

Species Interactions
Parasitic Plants

- Eastern Dwarf Mistletoe: Affects the Black Spruce trees from Maine to Minnesota.

Species Interactions

Internal parasites

Endoparasites: live inside the host

Extreme specialization by the parasite as to which host it invades

Structure of the parasite may be simplified because of where it lives in its host

Species Interactions

Many parasites have complex life cycles involving more than one host

- *Dicrocoelium dendriticum* is a flatworm that lives in ants as an intermediate host with cattle as its definitive host
- To go from the ant to a cow it changes the behavior of the ant
- Causing the ant to climb to the top of a blade of grass to be eaten with the grass

Species Interactions

- **Keystone species:** species whose effects on the composition of communities are greater than one might expect based on their abundance
- Sea star predation on barnacles greatly alters the species richness of the marine community
- Keystone species can manipulate the environment in ways that create new habitats for other species

Species Interactions

Beavers construct dams and transform flowing streams into ponds, creating new habitats for many plants and animals

Succession and Disturbance

Primary succession: occurs on bare, lifeless substrate

Open water

Rocks

Organisms gradually move into an area and change its nature

b.

© Tom Bean

c.

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d.

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Succession and Disturbance

- **Secondary succession:** occurs in areas where an existing community has been disturbed but organisms still remain
  - Example: field left uncultivated
  - Forest after a fire
- Succession happens because species alter the habitat and the resources available in ways that favor other species entering the habitat

Succession and Disturbance

a.

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b.

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Succession after a volcanic eruption

Succession and Disturbance

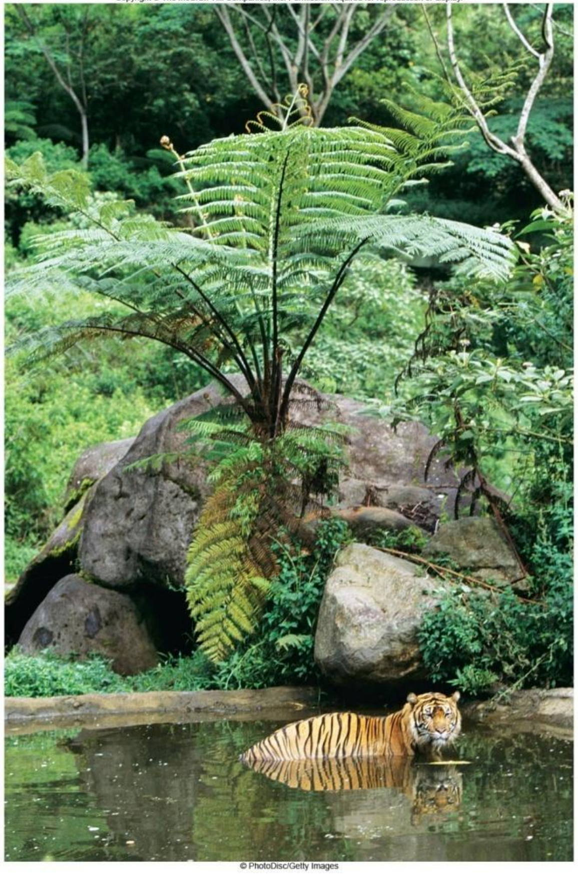
- Communities are constantly changing as a result of
  - Climatic changes
  - Species invasions
  - Disturbance events

d.

- Nonequilibrium models that emphasize change rather than stability are used to study communities and ecosystems

Dynamics of Ecosystems

Chapter 57



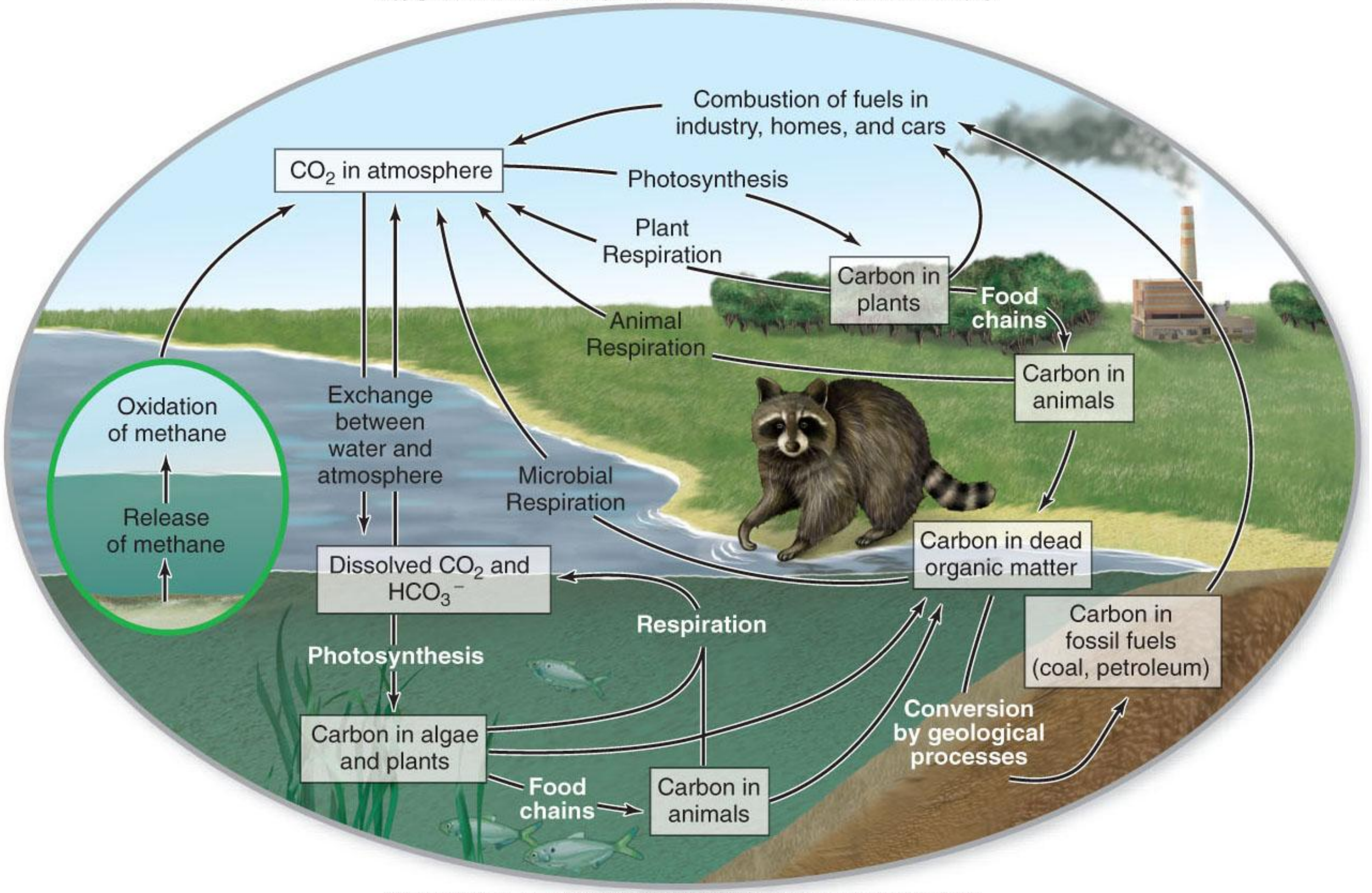
Biogeochemical Cycles

- **Ecosystem:** includes all the organisms that live in a particular place, plus the abiotic environment in which they live and interact
- Biological processing of matter: cycling of atoms in the environment and in living organisms
- **Biogeochemical cycles:** chemicals moving through ecosystems; biotic and abiotic

Biogeochemical Cycles

- Carbon is a major constituent of the bodies of organisms:
  - ~20% of weight of human body is carbon
  - Makes up 0.03% volume of the atmosphere; 750 billion metric tons

The carbon cycle



Data in: Begon, M., J.L. Harper, and C.R. Townsend, Ecology, 3/e, Blackwell Science 1996, page 715. Original Source: Whittaker, R. H.Communities and Ecosystems, 2/e Macmillan, London,1975.

The carbon cycle

- **Carbon fixation:** metabolic reactions that make nongaseous compounds from gaseous ones
- In aquatic systems inorganic carbon is present in water as dissolved CO_2 and as HCO_3^- ions
- CO_2 is used by algae and aquatic plants for photosynthesis

The carbon cycle

- Methane producers
  - Microbes that break down organic compounds by anaerobic cellular respiration provide an additional dimension to the carbon cycle
  - **Methanogens:** produce methane (CH_4)
  - Wetland ecosystems are a source of CH_4
  - CH_4 is oxidized to CO_2, but can remain as CH_4 for a long time

The carbon cycle

- Over time, globally, the carbon cycle may proceed faster in one direction
- This can cause large consequences if continued for many years
- Earth’s present preserves of coal, and other fossil fuels were built up over geological time
- Human burning of fossil fuels is creating large imbalances in the carbon cycle
- The concentration of CO_2 in the atmosphere is going up year by year

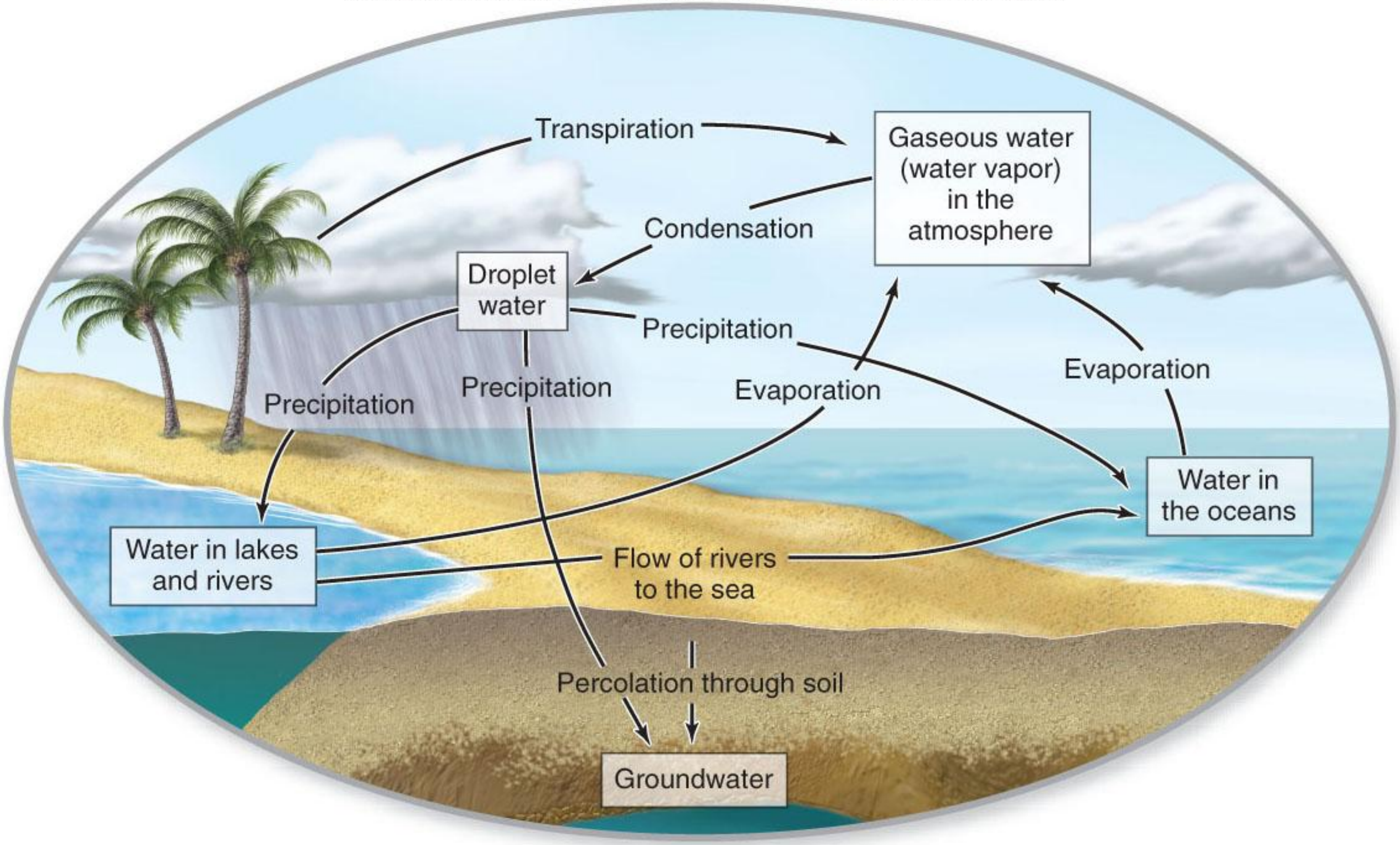
Water Cycle

- Water Cycle
  - All life depends on the presence of water
  - 60% of the adult human body weight is water
  - Amount of water available determines the nature and abundance of organisms present
  - It can be synthesized and broken down
    - Synthesized during cellular respiration
    - Broken down during photosynthesis

Water Cycle

- Groundwater: under ground water
  - **Aquifers:** permeable, underground layers of rock, sand, and gravel saturated with water
  - Important reservoir : 95% fresh water used in United States
  - Two subparts:
    - Upper layers constitute the water table
    - Lower layer can be tapped by wells

Water Cycle


Transpiration
Gaseous water (water vapor) in the atmosphere
Condensation
Droplet water
Precipitation
Precipitation
Precipitation
Evaporation
Evaporation
Water in the oceans
Water in lakes and rivers
Flow of rivers to the sea
Percolation through soil
Groundwater

- Changes in the supply of water to an ecosystem can radically alter the nature of the ecosystem
- ion disrupts the local water cycle
  - Water that falls as rain drains away

DeforestatTropical rain forest → semiarid desert

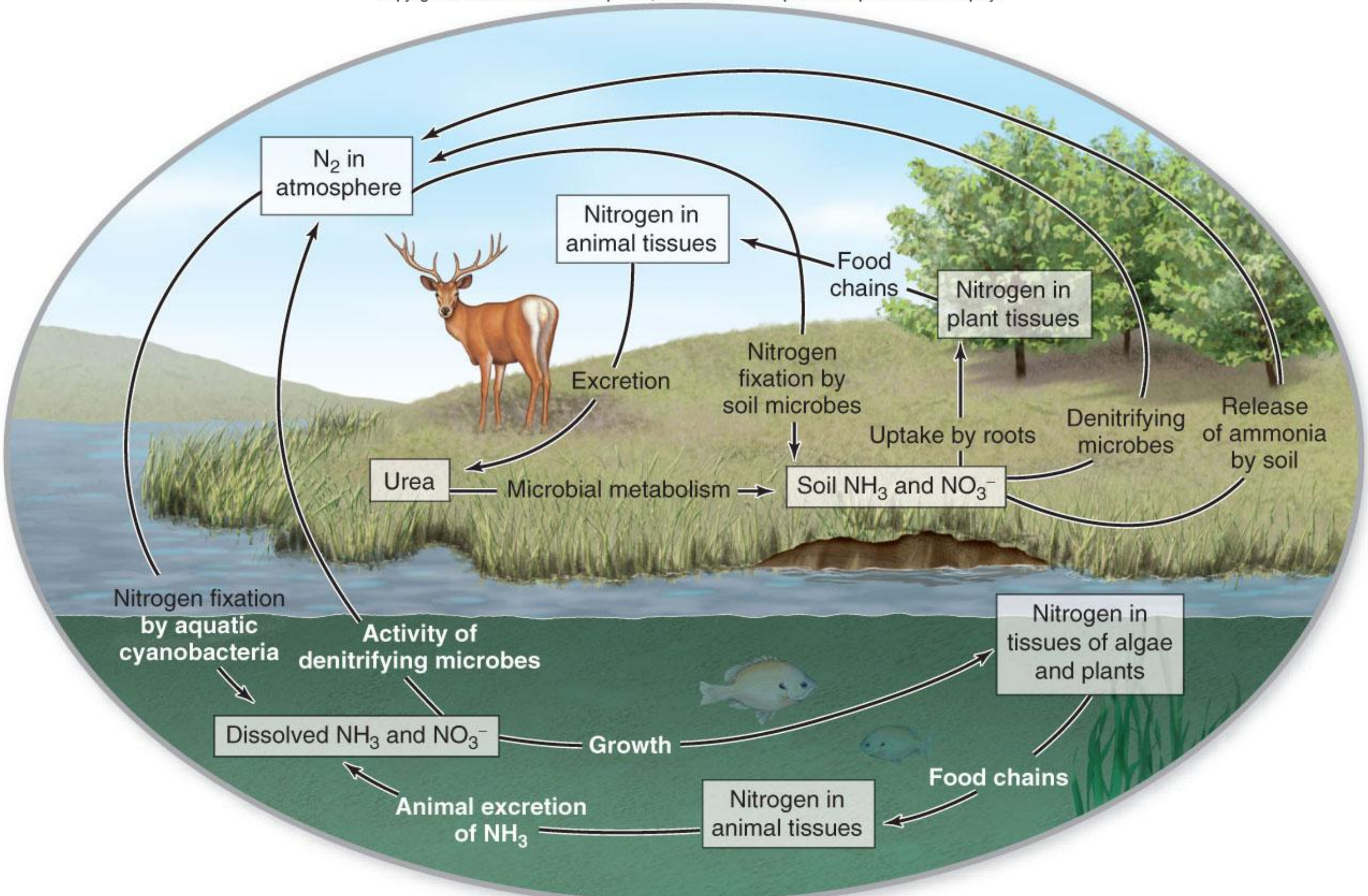
Nitrogen Cycle

- Nitrogen Cycle
  - Nitrogen is a component of all proteins and nucleic acids
  - Usually the element in shortest supply
  - Atmosphere is 78% nitrogen
  - Availability
    - Most plants and animals can not use N_2 (gas)
    - Use instead NH_3, and NO_3^-
- Nitrite / nitrogen should be below 90mg/l
- Nitrate levels below 10 mg / l

Nitrogen Cycle

- **Nitrogen N_2, Ammonium NH_3, Nitrites NO_2 and Nitrates NO_3:** Can cause a variety of problems.
- Brown blood disease in fish.
- Methemoglobin: destroys the ability for hemoglobin to transport Oxygen.
- Methemoglobinemia or "Blue Baby." nitrite levels over 1 mg/l

Nitrogen Cycle



Phosphorus cycle

- Phosphorus cycle
  - Phosphorus is required by all organisms
    - Occurs in nucleic acids, membranes, ATP
  - No significant gas form
  - Exists as PO_4^{3-} in ecosystems
  - Plants and algae use free inorganic phosphorus, animals eat plants to obtain their phosphorus

Phosphorus cycle

- **Total $P0_4$** should not exceed 0.1 mg/L in in streams that do not directly empty into a lake or reservoir.
- Can get into our water supplied from fertilizers. (Minnesota has a law that states no phosphates in lawn fertilizers.)
- Total Phosphates **should not be exceed** 0.05 mg/L in a stream at a point where it enters a lake or reservoir.
- **Animal wastes**: Essential in metabolism so it is present in animal waste.
- Barnyards feedlots, hog and dairy farms.

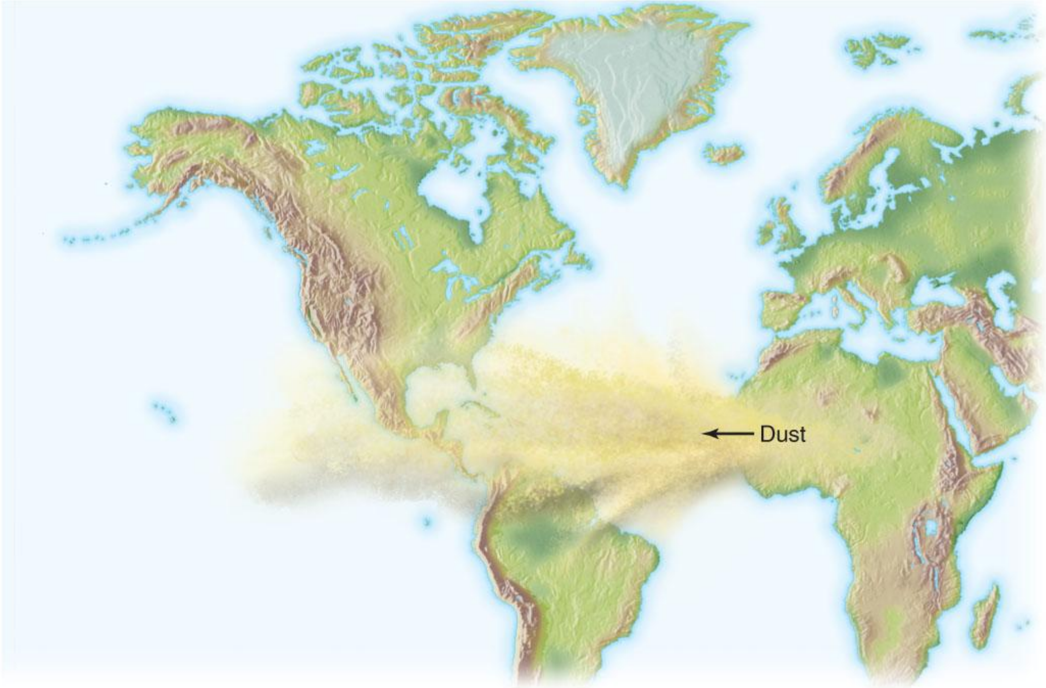
Phosphorus cycle

- **Paved Surfaces**: Development will expose and release phosphorous through soil erosion. If wetlands are drained phosphorous that was buried can be exposed also with no area to act as a filter.
- **Forest fires**: Causes soil erosion thus releasing Phosphorous.

Phosphorus Cycle

- **Limiting nutrient:** weak link in an ecosystem; shortest supply relative to the needs of organisms
- Iron is the limiting nutrient for algal populations
- **Nitrogen and phosphorus** can also be limiting nutrients for both terrestrial and aquatic ecosystems

Biogeochemical Cycles



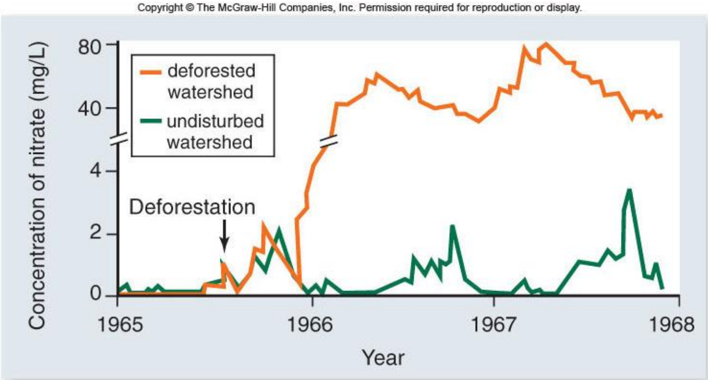
Every year millions of metric tons of iron-rich dust is carried by the trade winds, from the Sahara Desert, across the globe to as far as the Pacific Ocean

Biogeochemical Cycles

- Biogeochemical cycling in a forest ecosystem--Hubbard Brook Experiment
- Undisturbed forests are efficient at retaining nutrients
- Disturbed (cut trees down) amount of water runoff increased by 40%
  – Loss of Ca; increased nine fold
  – Loss of Phosphorus did not increase
  – Loss of NO_3^-; 53kg/hectare/yr

Biogeochemical Cycles

a.



b.

The Hubbard Brook Experiment

38-acre watershed. Orange curve shows nitrate concentration in the runoff water from the deforested watershed. Green curve shows the nitrate concentration in runoff from an undisturbed watershed

Flow of Energy in Ecosystems

- Energy is never recycled
- Energy exists as;
  - Light
  - Chemical-bond energy
  - Motion
  - Heat
- **First Law of Thermodynamics:** energy is neither created nor destroyed; it changes forms

Flow of Energy in Ecosystems
Food Chains and Food Webs

- Organisms cannot convert heat to any of the other forms of energy
- Second Law of Thermodynamics: whenever organisms use chemical-bond or light energy some is converted to heat (entropy)
- Earth functions as an open system for energy
- Sun our major source of energy

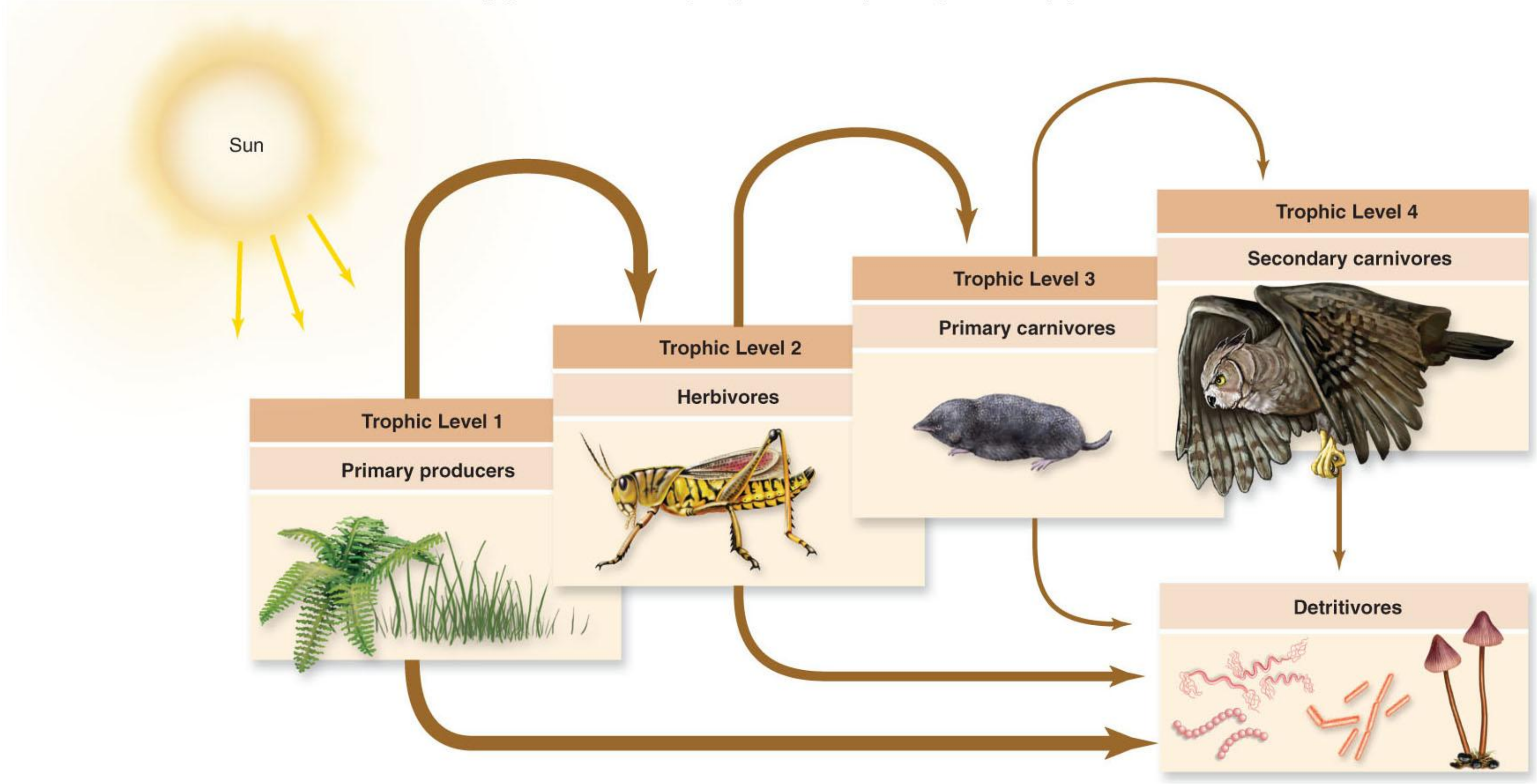
Energy Flow

- **Trophic levels:** which level an organism "feeds" at
- **Autotrophs:** "self-feeders" synthesize the organic compounds of their bodies from inorganic precursors
  - **Photoautotrophs:** light as energy source
  - **Chemoautotrophs:** energy from inorganic oxidation reactions
    - prokaryotic

Energy Flow

- **Heterotrophs:** cannot synthesize organic compounds from inorganic precursors;
  - animals that eat plants and other animals;
  - fungi that use dead and decaying matter (detritivores)

Trophic levels within an ecosystem



Trophic Levels

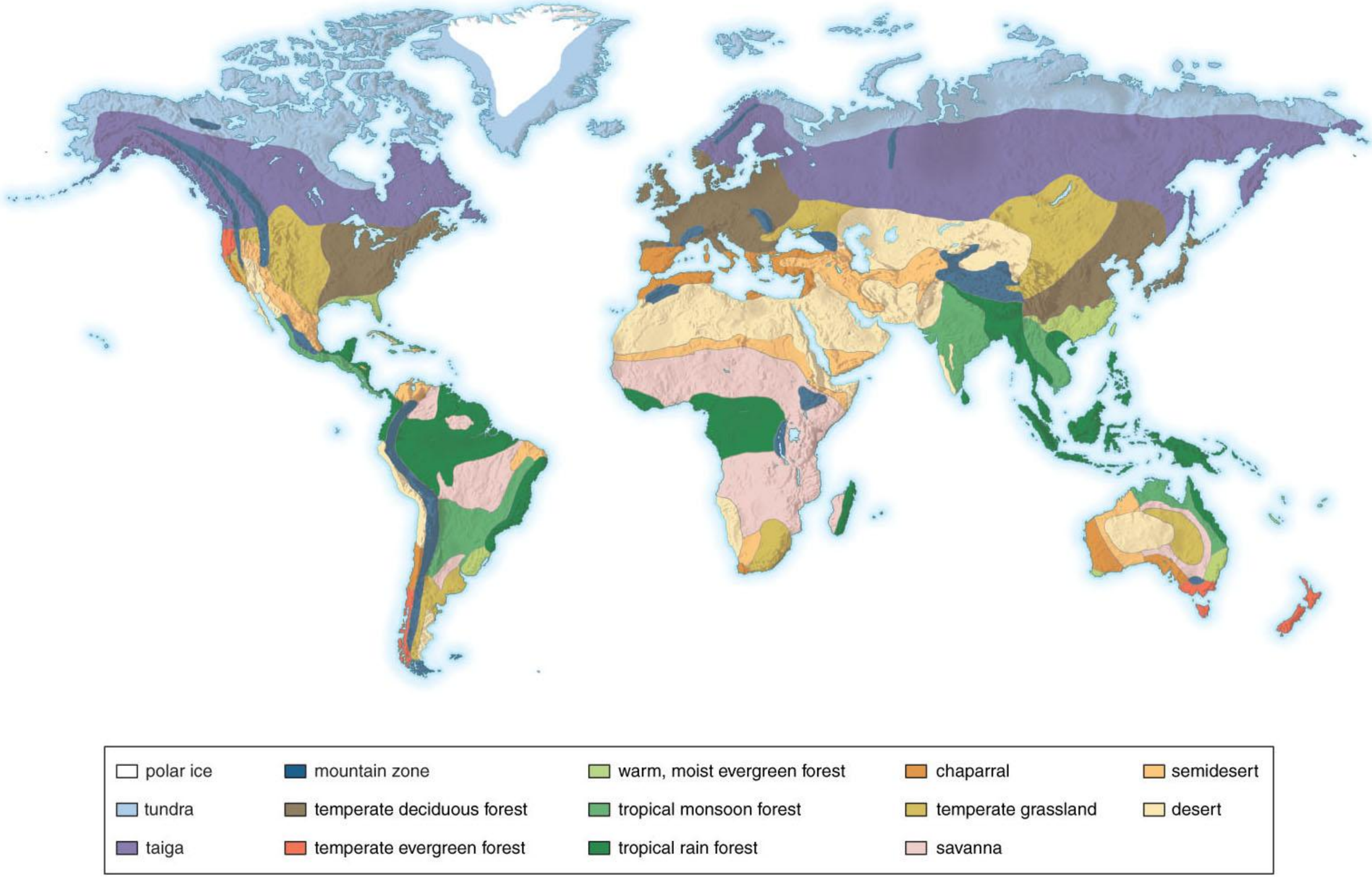
- **<u>Types of Aquatic Food Chains:</u>**
- All food chains need to begin with photosynthesis so that food substances can be made and Oxygen can be used for respiration.
- In **Standing Water** systems Photosynthesis from producers is the most common way to create Oxygen. (Plants and Algae)
- In **Fluvial Systems** most Oxygen is put into the water though aeration.
- (Some producers like blue-green algae, green algae, diatoms, and mosses that are attached to rocks make oxygen.) Water is moving to fast for rooted plants.

Trophic Levels

- **Autotrophic Food Chain**: Self Feeding Food Chain
- Algae ----- Snails ------- Fish ------ Otter
-
- **Detritus Food Chains:** Dead organic material enters from the surrounding environment into the water.
- Grass clippings------ Scavengers----- Carnivore
-
- **Heterotrophic Food Chain:** Small animals that are not aquatic enter the water supply.
- Insect falls in the water------ fish------ Otter

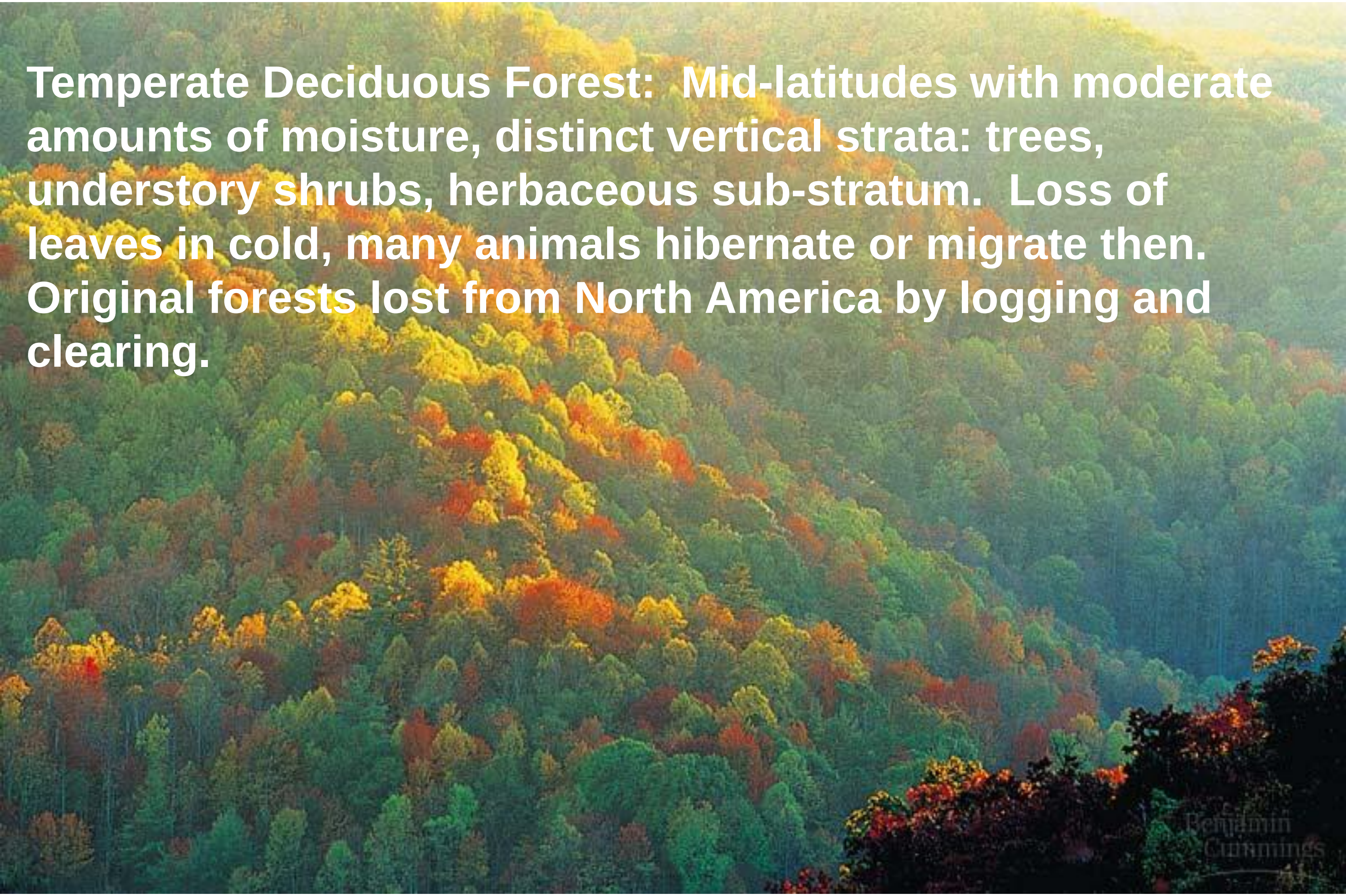
Biomes

- **Biomes:** a major type of ecosystem on land
- Each biome has a characteristic appearance
  - Defined largely by sets of regional climatic conditions
- Biomes are named according to their vegetational structures
- Eight principle biomes


polar ice
tundra
taiga
mountain zone
temperate deciduous forest
temperate evergreen forest
warm, moist evergreen forest
tropical monsoon forest
tropical rain forest
chaparral
temperate grassland
savanna
semidesert
desert

<u>Prairie or Temperate Grassland</u>: Marked by seasonal drought and fires, and grazing by large animals. Rich habitat for agriculture, very little prairie exists in US today.

Temperate Deciduous Forest: Mid-latitudes with moderate amounts of moisture, distinct vertical strata: trees, understory shrubs, herbaceous sub-stratum. Loss of leaves in cold, many animals hibernate or migrate then. Original forests lost from North America by logging and clearing.



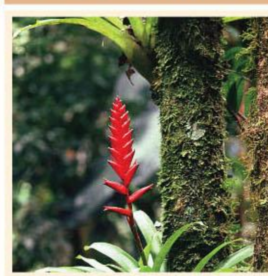
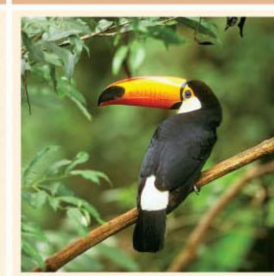
Coniferous forest or Tiaga: Largest terrestrial biome on earth, old growth forests rapidly disappearing, usually receives lots of moisture as rain or snow.

Tundra: Permafrost (Permanent frozen ground), bitter cold, high winds and thus no trees. Has 20% of land surface on earth.

Biomes

Tropical rain forests

- 140-450 cm rain/yr
- Richest ecosystems on land
- High temperature and high rainfall
- Very high diversity: 1200 species of butterflies in a single square mile

Biome	Climate	Example Location	Characteristic Flora	Characteristic Fauna	
Tropical Rain Forest	High temperatures year round	 Brazilian rain forest	 Plant Species	 Animal Species	

(left to right): © age fotostock/SuperStock; © Luiz C. Marigo/Peter Arnold; © age fotostock/SuperStock

Biomes

- Savanna
  - 50-120 cm rainfall/yr
  - Tropical or subtropical grasslands
  - Occur as a transition ecosystem between tropical rainforests and deserts
  - Serengeti of East Africa

Biome	Climate	Example Location	Characteristic Flora	Characteristic Fauna	
Savanna	Warm temperatures year round	 Serengeti	 Plant Species	 Animal Species	

(left to right): © Mitsuaki Iwago/Minden Pictures; © Konrad Wothe/Minden Pictures; © age fotostock/SuperStock

Biomes

- Deserts
  - 25-40cm rainfall/yr; unpredictable
    - Plants and animals cannot depend on any rainfall
  - 30˚N and S latitudes, rainshadows
  - Vegetation sparse, animals adapted to little water availability

Biome	Climate	Example Location	Characteristic Flora	Characteristic Fauna	
Desert	Warm and cool temperatures	 Mojave	 Plant Species	 Animal Species	

Biomes

- Temperate grasslands: prairies
  - Rich soils
  - Grasses with roots that penetrate deep into the soil
  - In North America converted to agricultural use
  - Adapted to periodic fire

Biome	Climate	Example Location	Characteristic Flora	Characteristic Fauna	
Temperate Grasslands	Warm summers cool winters	 South Dakota prairie	 Plant Species	 Animal Species	

Aquatic Biomes

- **<u>Aquatic Biomes</u>**: 75% of the Earth is covered with water.
- About 95 of this water is from oceans and seas.

Aquatic Biomes

- **1. <u>Freshwater Biomes</u>** 5% of the water supply. Rivers, streams, glaciers, groundwater, and lakes.
- Good source of drinking water and food. Only .1% of this water is easily obtainable for consumption.
- <u>Glaciers hold most of the fresh water on the earth</u>.

Aquatic Biomes

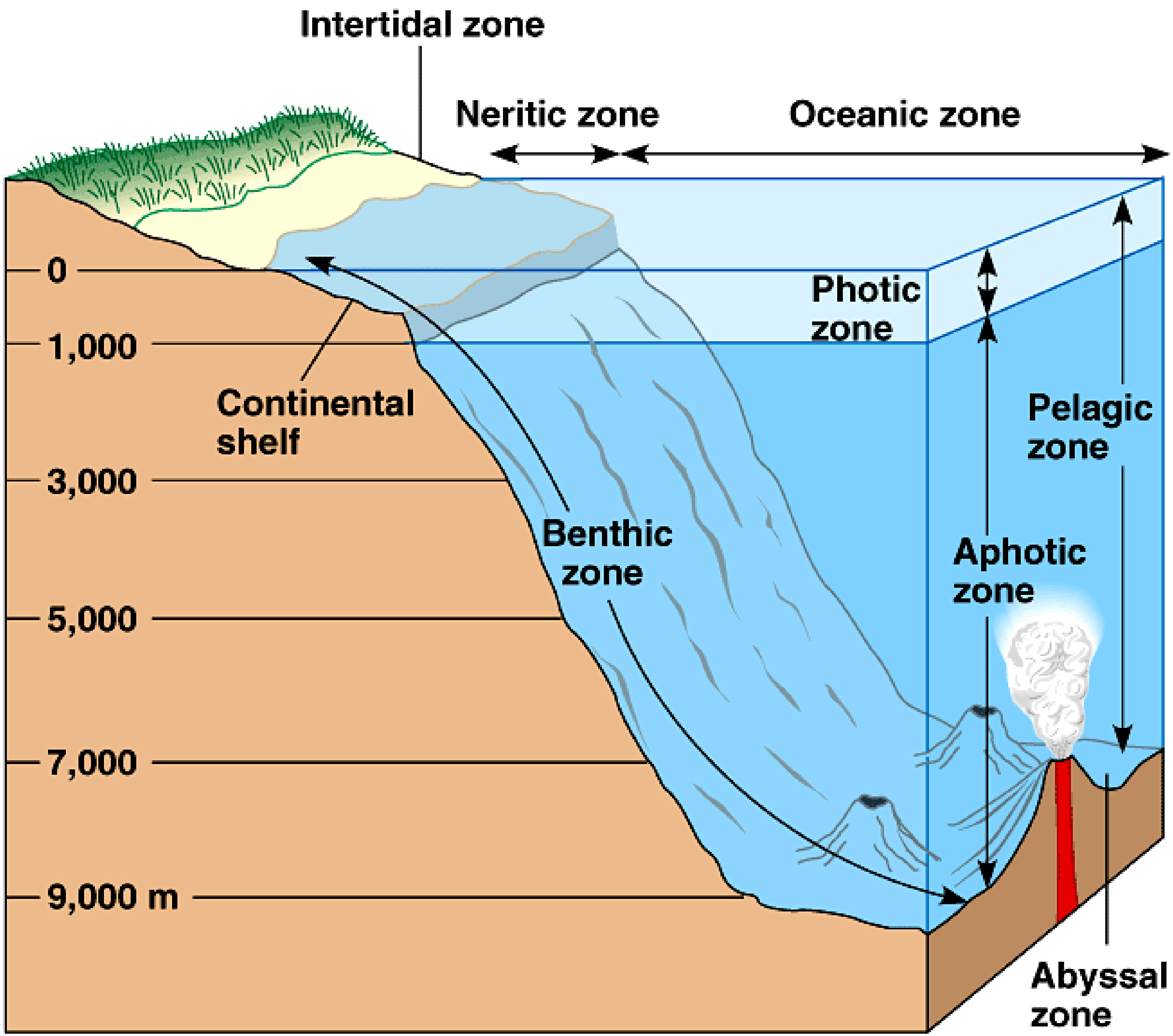
Marine Biomes: 95 % of the water supply. Oceans & Seas

- **4** Zones to marine Biomes

- 1. **Intertidal Zone**: Most difficult zone for animals to live in.
- Organisms must be able to adapt to extreme changes daily.
- (Water, sunlight, and wave action.)

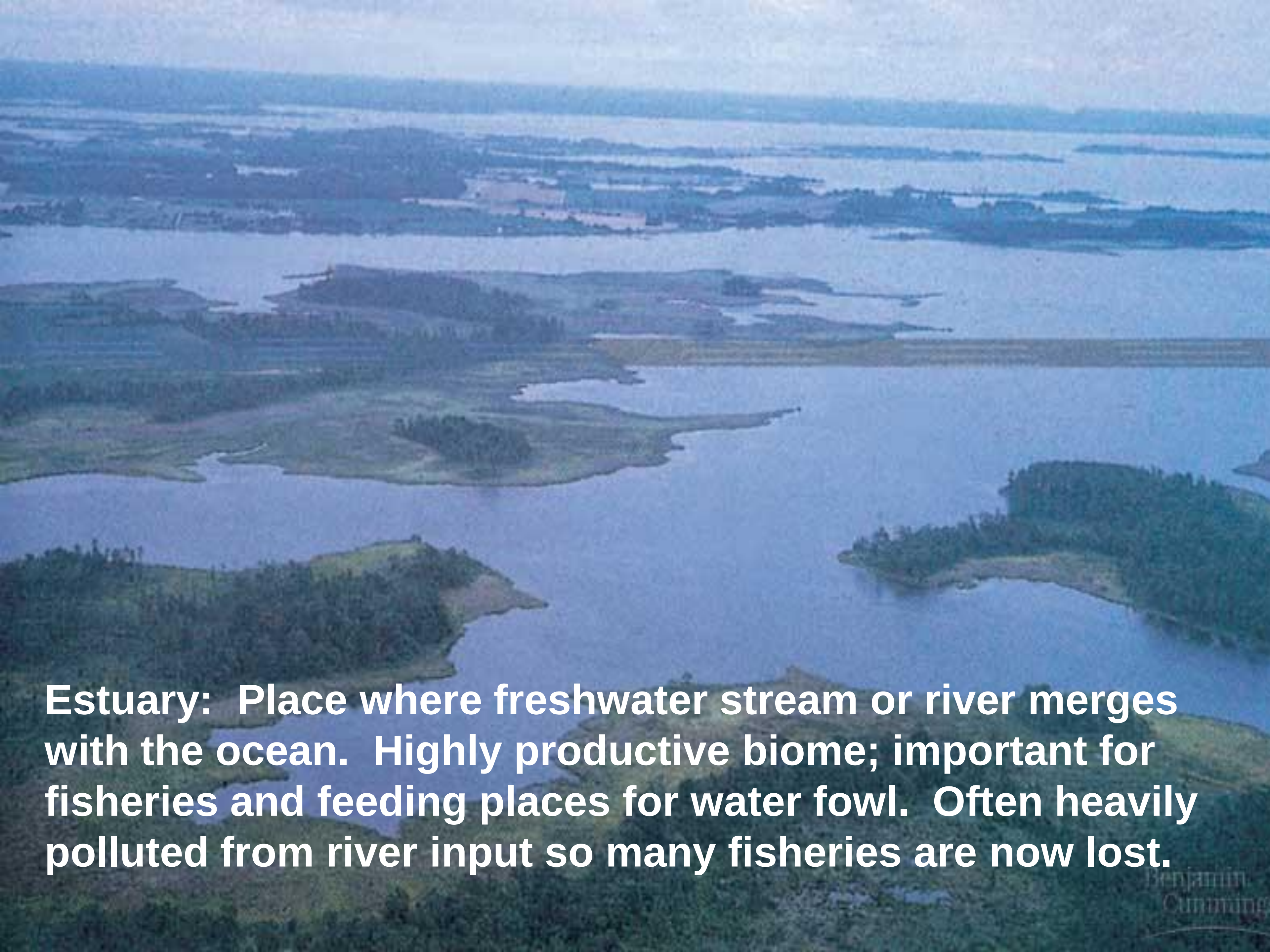
- 2. **Neretic Zone:** Extends from the low tide area to the open sea area. Seaweed such as brown kelp, animals like the lobsters crabs and many Species of fish etc are found here.

Coral Reefs: occur in neretic zones of warm, tropical water, dominated by cnidarians (corals); very productive, protect land from storms; most are now dying from rise in global temperatures


Intertidal zone
Neritic zone
Oceanic zone
Photic zone
Pelagic zone
Aphotic zone
Benthic zone
Continental shelf
Abyssal zone
0
1,000
3,000
5,000
7,000
9,000 m

Aquatic Biomes

- 3. **Open- sea Zone**: Phytoplankton is found in great abundances.
- 80 to 90 % of earths photosynthetic activity takes place here.
- **Animals** :Whales dolphins, large fish, sea birds.
- Not enough food for too many animals.
- 4. **Deep-Sea Zone**: High pressure, very cold, total darkness.
- Many strange looking animals.



Estuary: Place where freshwater stream or river merges with the ocean. Highly productive biome; important for fisheries and feeding places for water fowl. Often heavily polluted from river input so many fisheries are now lost.

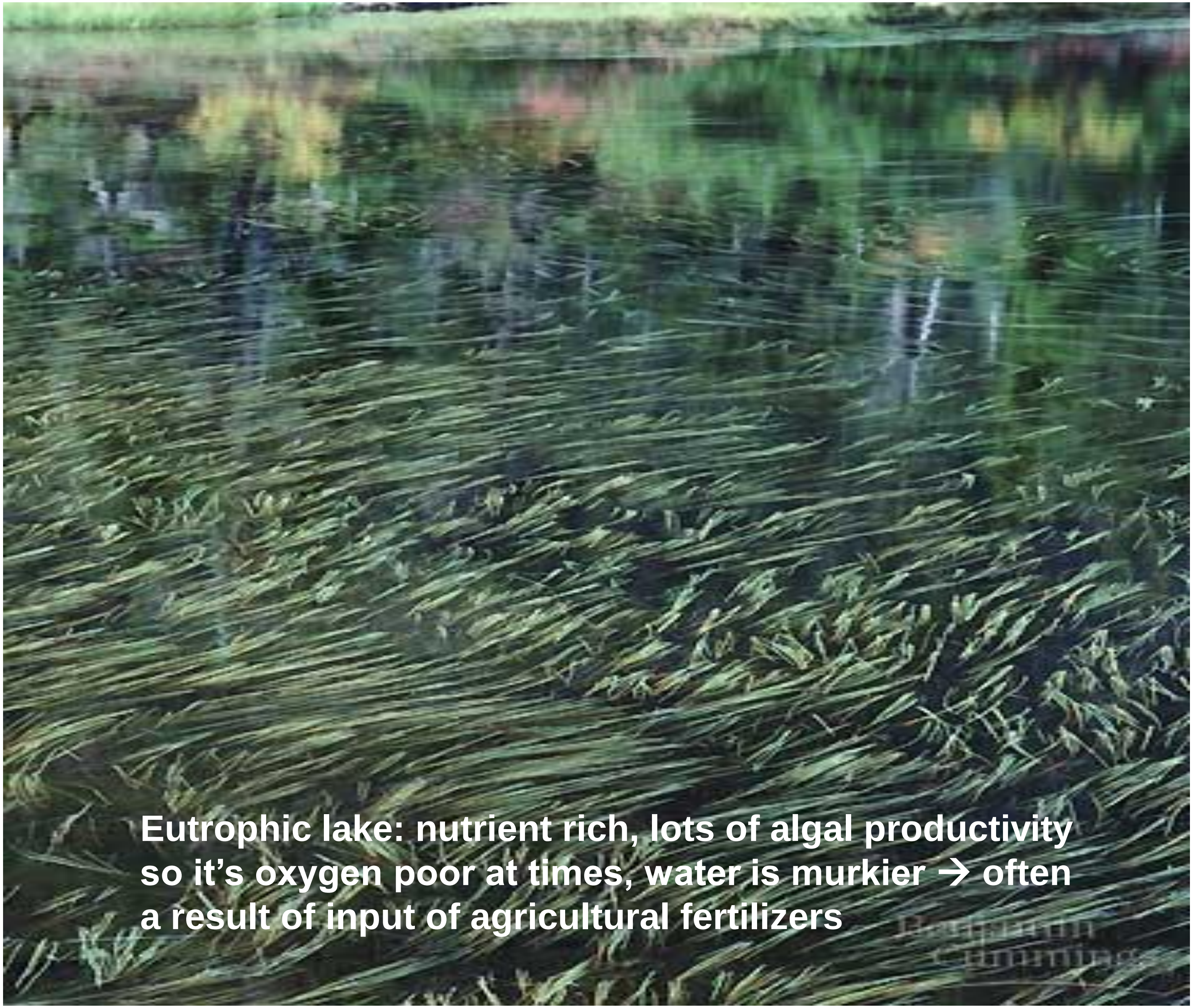
Aquatic Biomes

- **Estuaries**: Boundary between freshwater and salt water.
- Swamps, salt marshes, mangroves lagoons and mouths of rivers.
- Supports a variety of organisms.
- Fish lay their eggs here, and many species of birds migrate here for the winter. This area is flushed out into the sea or ocean not a lot of dead material on the bottom.

Oligotrophic Lake: Nutrient poor, water is clear, oxygen rich; little productivity by algae, relatively deep with little surface area

Productivity of a Water system
Oligotrophic Lake

- **Oligotrophic:** Low productivity.
- Nutrient poor- thus limits the growth of phytoplankton and leaves water clear
- Benthic plants are present in areas where bottom is a few meters below surface and bottom type supports
- DO is high- results from few decomposers demanding oxygen. Entrance of oxygen from atmosphere and mixing provides a sufficient level.



Eutrophic lake: nutrient rich, lots of algal productivity so it’s oxygen poor at times, water is murkier → often a result of input of agricultural fertilizers

Productivity of a Water system
Eutrophic lake

- **Eutrophic :** High productivity ; very fertile.
- available dissolved nutrients- support phytoplankton
- fewer benthic plants due to sediment shading
- If a lake is too fertile this can lead to an unhealthy lake. It chokes off the lake after the algae bloom dies off, due to decomposition. Hardly any oxygen is left over for fish or other organisms.

Rivers and Streams: Organisms need adaptations so that they are not swept away by moving water; heavily affected by man changing the course of flow (E.g. dams and channel-straightening) and by using rivers to dispose of waste.