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## 44 Animal Sensory Systems

### 44.1 How Do Sensory Organs Convey Information to the Brain?

- ▷ **Transduction:** conversion of an external stimulus to an internal signal in the form of action potentials along sensory neurons.
  - Requires a sensory receptor:
    1. *Mechanoreceptor*: respond to changes in pressure.
    2. *Photoreceptors*: respond to particular wavelengths of light.
    3. *Chemoreceptors*: detect specific molecules.
    4. *Thermoreceptors*: respond to changes in temperature.
    5. *Nociceptors*: sense harmful stimuli such as tissue injury.
    6. *Electroreceptors*: detect electric fields.
    7. *Magnetoreceptors*: detect magnetic fields.
  - Frequency of action potential firing rate can indicate the intensity of the stimulus.
- ▷ **Transmission:** the process of sending the signal to the central nervous system.

### 44.2 Mechanoreception: Sensing Pressure Changes

- ▷ **Statocyst:** an fluid filled organ that grabs use to help sense pressure created by gravity.
- ▷ Direct physical pressure causes ion channels to open and close, creating voltage gated action potentials.
- ▷ **The Mammalian Ear:**
  - *Outer ear*: collects incoming pressure waves and funnels them into tube known as the ear canal, which leads to the **tympanic membrane**, or eardrum.

- *Middle ear*: contains three tiny bones that the eardrum passes vibrations to in order to amplify sound. One of the bones, called **stapes**, vibrates against a membrane called the **oval window**, which separates the middle ear from the inner ear.
- *Inner ear*: the oval window oscillates in response to vibrations which generates waves in a chamber known as the **cochlea**. These waves are pressure inputs the hair cells respond to.
- ▷ Hair cells, forming rows that sit in the middle chamber, are embedded in a tissue that sits atop the **basilar membrane**. In addition, the hair cells' stereocilia touch another smaller surface called the **tectorial membrane**.
- ▷ This sandwiching of hair cells produce very specific responses to various frequencies, allowing us to distinguish between them.
- ▷ **Lateral line system**: a mechanoreceptor organ that most fish and larval amphibians use. Consists of embedded gel-like domed structures called cupulae that lay inside canals along the length of the body.

### 44.3 Photoreception: Sensing Light

- ▷ **The Insect Eye:**
  - **Compound eyes**: eyes composed of hundreds of thousands of light-sensing columns called **ommatidia**.
  - Each ommatidium has lens that focuses light into a smaller number of receptor cells—usually four.
- ▷ **The Vertebrate Eye:**
  - **Simple eye**: a structure with a single lens that focuses incoming light onto a layer of many receptor cells.
  - **Structure of the Vertebrate Eye:**
    - *white of the eye*: outermost layer of the eye that consists of tough rind of white tissue called the *sclera*.
    - *Cornea*: a transparent sheet of connective tissue on the front of the

sclera.

- *Iris*: pigmented, round muscle just inside the cornea that can contract or expand to control the amount of light entering the eye.
- *Pupil*: hole in the center of the iris.
- *Lens*: works with the cornea to focus incoming light.
- *Retina*: a layer of photoreceptors and several layers of neurons.
  - The photoreceptors are held in place by the pigmented epithelium.
  - photoreceptors synapse with an intermediate layer of connecting neurons called **bipolar cells**.
  - Bipolar cells synapse with neurons called **ganglion cells**, which form the innermost layer of the retina.
  - The axons of the ganglion cells project to the brain via optic nerve.
  - Photoreceptors come in two distinct types:
    - **Rods**: sensitive to dim light but not to color.
    - **Cones**: sensitive to different wavelengths of light, but not dim light.
  - **Opsin**: a transparent membrane protein that associates with a molecule of pigment in the **retinal**.
  - **Rhodopsin**: a two molecule complex similar to opsin in rod cells.

#### 44.4 Chemoreception: Sensing Chemicals

- ▷ Chemoreception occurs when chemicals bind to chemoreceptors, initiating action potentials in sensory neurons.
- ▷ **Gustation**: the sense of taste.
- ▷ **Olfaction**: sense of smell.
- ▷ **Taste buds**: clustered structures containing about 100 spindle shaped taste cells that make synapses with sensory neurons.
- ▷ *Salty*: due to sodium ions dissolved in food.

- ▷ *Sourness*: due to presence of protons.
- ▷ *Umami*: due to monosodium glutamate.
- ▷ **Odorants**: airborne molecules.
- ▷ **Olfactory bulb**: part of the brain where olfactory signals are processed and interpreted.
- ▷ **Pheromone**: a chemical that is secreted into the environment that affects the behavior or physiology of animals.

## 44.5 Other Sensory Systems

- ▷ Thermoreceptors are located in the central nervous system and also commonly found skin and other outer surfaces of animals.
- ▷ *nociceptor*: senses extreme temperatures as well as other painful stimuli produced by chemicals, excessive pressure, and tissue damage.
- ▷ **Ampullae of Lorenzini**: tiny pores scattered across a shark's head contain structures that are responsible for their electroreception. Sharks can detect electrical potentials as small as a nanovolt.
- ▷ *Electrogenic fishes* have specialized organs near their tails that generate electric fields stronger than those of regular nerves or muscles.
- ▷ *Magnetoreception*: seen in many organisms, including fungi, invertebrates, and all other vertebrate classes.

## 45 Animal Movement

### 45.1 How Do Muscles Contract?

- ▷ **Muscle fiber:** a muscle fiber is a long, thin muscle cell.
- ▷ Within each muscle cell are many threadlike, contractile structures called **myofibrils**.
- ▷ Myofibrils often look striped or striated due to alternating light and dark units called **sarcomeres**, which repeat along the length of a myofibril.
- ▷ The question of how muscles contract simplifies to how sarcomeres shorten.
- ▷ **Thin filaments** are composed of actin.
- ▷ **Thick filaments** are composed of myosin.
- ▷ **Sliding-filament model:** filaments slide past one another during contraction, with the sarcomere shorting with no change between the lengths of thick and thin filaments themselves.
- ▷ ATP is required for myosin to release from actin once the two molecules have bound to each other.
- ▷ **Tropomyosin** and **Troponin** work together to block the myosin binding sites on actin. When the sites are blocked, the myosin-actin interaction cannot occur, relaxing the muscle.

### 45.2 Muscle Tissues

- ▷ **Smooth Muscle:**
  - Unbranched.
  - Tapered at each end.
  - Often organized into thin sheets.
  - Lack sarcomeres, which gave them their smooth appearance.
  - Relatively small and have a single nucleus.

- Essential for the lungs blood vessels, digestive system, urinary bladder, and reproductive system.

- Involuntary

▷ **Cardiac Muscle:**

- Makes up walls of the heart.
- Contain sarcomeres and is striated.
- Unique branch structure.
- Directly connected end to end via specialized regions called intercalated discs which are critical to the flow of electrical signals and coordination of the heartbeat.
- Involuntary

▷ **Skeletal Muscle:**

- Exceptionally long, unbranched muscle fibers.
- Multinucleate
- Contains sarcomeres
- Voluntary
- Force depends on:
  - relative proportion of different fiber types.
  - organization of fibers within the muscle.
  - how the muscle is used.

▷ **Skeletal Muscle Fiber Types:**

- **Slow muscle fibers:**
  - oxidative.
  - appear red, due to high concentration of myoglobin.
  - myosin hydrolyzes ATP at a slow rate, causing slow contraction.
  - slow to fatigue due to many mitochondria and aerobic respiration.



- **Fast muscle fibers:**

- glycolytic.
- appear white, due to low myoglobin concentration.
- myosin hydrolyzes ATP at a rapid rate.
- fast to fatigue due to primarily relying on glycolysis.

- **Intermediate muscle fibers:**

- combination of both fast and slow.

## 46 Chemical Signals in Animals

### 46.1 Cell-to-Cell Signaling

- ▷ **Autocrine Signals:** signals that affect the same cell that releases them.
- ▷ **Paracrine Signals:** diffuse locally and act on target cells near the source cell.
- ▷ **Endocrine Signals:** hormones carried to distinct cells by blood or other body fluids and released by discrete organs called glands.
- ▷ **Neural Signals**, or neurotransmitters, act on other neurons.
- ▷ **Neuroendocrine Signals:** hormones released by neurons that act on distant cells.
- ▷ Many hormones can act as multiple signal types.
- ▷ All three types of signaling pathway—endocrine, neuron-daocrine, and neuroendocrine-to-endocrine—are regulated by negative feedback, or feedback inhibition.

### 46.2 How do Hormones Act on Target Cells?

- ▷ There are three chemical classes of hormones:
  - Peptides are polypeptides.
  - Amino acid derivatives.
  - Steroids.
- ▷ Steroids and thyroid hormones cross plasma membranes much more readily than other types of hormones.
- ▷ **Cyclic AMP (cAMP):** the key ingredient in the activation of phosphorylase, which catalyzes a reaction that cleaves glucose molecules off glycogen.
- ▷ **Signal transduction cascade** can allow the binding of just a single molecule of epinephrine may trigger the release of millions or even billions of glucose molecules.

- ▷ Most steroid and thyroid hormones act by inducing a change in gene expression.

### 46.3 What do Hormones Do?

- ▷ Hormones coordinate the activities of cells in three arenas:
  - development, growth, and reproduction.
  - response to environmental challenges.
  - maintenance of homeostasis.
- ▷ A single hormone may affect a wide array of cells and tissues and induce a variety of responses.
- ▷ **Xenoestrogens:** foreign chemicals that bind to estrogen receptors and induce estrogen like effects.
- ▷ Cortisol triggers the long-term response to stressors by inducing changes that conserve glucose for use by the brain.
- ▷ Glucocorticoids make amino acids available for glucose synthesis by promoting the degradation of contractile proteins in muscle. The resulting loss of muscle mass may cause severe weakness.

### 46.4 How is the Production of Hormones Regulated?

- ▷ In many cases, hormone production is directly or indirectly controlled by the nervous system, where the release of a hormone is regulated by hormones from the anterior pituitary.
- ▷ Hormone-secreting cells in the anterior pituitary are regulated by hormones released by the hypothalamus.
- ▷ Glucocorticoids accomplish feedback inhibition—they suppress their own production.
- ▷ *Cushing's disease:* the result when feedback inhibition fails.

## **49 An Introduction to Ecology**

### **49.1 The Levels of ecological study**

- ▷ Organisms: study of the morphological, physiological, and behavioral adaptations that allow individuals to live in a particular area
- ▷ Populations: focus on the number and distribution of individuals in a population and their change over time.
- ▷ Communities: focus on predation, parasitism, and competition, or explore how communities respond to fires, floods, and other disturbances.
- ▷ Ecosystems: study of all the organisms in a particular region along with nonliving components.
- ▷ Biosphere: the sum of all terrestrial and aquatic ecosystems.

### **49.2 What Determines the Distribution and Abundance of Organisms?**

- ▷ For each species, a unique combination of abiotic and biotic factors determines where individuals live and the size of populations
- ▷ Understanding historical events, such as the movement of entire continents, is important to interpreting current patterns of species distributions
- ▷ Abiotic and biotic factors often interact to produce a different effect on species distributions than either type of factor would have on its own.

### **49.3 Abiotic Factors**

- ▷ Air circulation cells such as Hadley cells create bands of wet and dry habitats, and the tilt of Earth's axis causes seasonality in the amount of sunlight that non-equatorial regions receive.
- ▷ The presence of mountains can create local areas of wet or dry habitats, and proximity to an ocean and the direction of ocean currents moderates temperatures in certain terrestrial habitats.

## 49.4 Global Climate Patterns

- ▷ The major terrestrial biomes include tropical wet forest, subtropical desert, temperate grassland, temperate forest, boreal forest, and arctic tundra.

## 49.5 Terrestrial Biomes

## 49.6 Aquatic Biomes

- ▷ **Intertidal zone:** consists of a rocky shoreline, sandy beach, or mud flat that is exposed to the air at low tide but submerged at high tide.
- ▷ **Neritic zone:** extends from the intertidal zone to depths of about 200 m. Its outermost edge is defined by the end of the continental shelf
- ▷ **Oceanic zone:** the deepwater region beyond the continental shelf.
- ▷ **Benthic zone:** bottom of the ocean at all depths.
- ▷ **Photic zone:** intertidal and sunlit regions of the neritic, oceanic, and benthic zones
- ▷ **Aphotic zone:** Areas that do not receive sunlight.

## 53 Ecosystems and Global Ecology

### 53.1 How Does Energy Flow through Ecosystems

- ▷ **Primary producer:** a autotroph that allows energy to enter into ecosystems.
- ▷ **autotroph:** an organism that can synthesize it's own food from inorganic sources.
- ▷ **Gross Primary Productivity (GPP):** total amount of chemical energy produced in a given area and time period.
- ▷ **Net primary productivity (NPP):** energy that is invested by primary producers in building new tissue of offspring.
- ▷  $NPP = GPP - R$ .  $R$  = energy used in cellular respiration or lost.
- ▷ Only 0.8% of solar radiation is captured by plants.
- ▷ It's estimated that 45% of GPP to NPP and the other 55% was used for either cellular respiration or lost to the environment.

#### 53.1.1 What Happens to the Biomass of Autotrophs?

- ▷ **Primary consumers** eat living organisms, secondary eat primary, tertiary eat secondary, and so on.
- ▷ **Decomposers:** or detritivores, obtain energy from the remains of other organisms or waste products.
- ▷ **Trophic:** the level at which organisms obtain energy from the same source.

#### 53.1.2 Energy Transfer between Trophic Levels

- ▷ All ecosystems share a pattern: the total biomass produced each year declines from lower trophic levels up to the higher levels.
- ▷ Productivity is measured in  $g/m^2/year$
- ▷ Efficiency is a fraction of biomass transferred from one level to the next.
- ▷ Biomass production at each trophic level varies, but generally efficiency is only about 10%.

- ▷ Large mammals are more efficient at producing biomass than small mammals due to less heat loss.
- ▷ Biomass production is more efficient in ectotherms than endotherms, since they primarily rely on heat gained rather than oxidizing sugars.
- ▷ **Biomagnification**: molecules that increase in concentration at higher trophic levels.

### 53.1.3 Global Patterns in Productivity

- ▷ Productivity is limited by anything that limits the rate of photosynthesis.
- ▷ NPP on land is much higher than it is in oceans.
- ▷ Wet tropics have the highest net productivity.
- ▷ Excluding deserts, NPP declines as you move away from the equator due to availability of sunlight and decreasing temperature.
- ▷ Marine productivity is highest along coastlines, due to increased nutrients from rivers and process called upwelling.
- ▷ Tropical wet and dry forests cover less than 5% but account for over 30% of NPP.
- ▷ In aquatic ecosystems, the most productive are algal beds, coral reefs, wetlands, and estuaries.
- ▷ It's estimated that humans are preventing of appropriating 24% of potential NPP.

## 53.2 How Do Nutrients Cycle through Ecosystems?

### 53.2.1 Nutrient Cycling within Ecosystems

- ▷ **Biogeochemical cycle**: The path an element takes as it moves from abiotic systems, through biotic, and back.
- ▷ **Soil organic matter**: the carbon-containing compounds that microscopic decomposers release.
- ▷ **Humus**: result of when detritus becomes completely decayed.

- ▷ the decomposition of detritus is the limiting factor in the overall rate of the biogeochemical cycle.
- ▷ Decomposition is affected by: abiotic conditions such as oxygen availability, temperature and precipitation; quality of nutrient source for the fungi, bacteria, and archaea; abundance and diversity of detritivores present.
- ▷ Nutrients can be lost from one ecosystem and exported to another.
- ▷ Exported nutrients must be replaced by imports if ecosystems are to function.
- ▷ Mechanisms of nutrient replacement: ions from rocks are released due to weathering; wind or water transport; carbon via photosynthesis; nitrogen via nitrogen-fixing.
- ▷ Vegetation lowers the rate of nutrient export.

### **53.2.2 Global Biogeochemical Cycles**

- ▷ Human effects on the water cycle: asphalt and concrete limiting water absorption to deep soil; grasslands and forest converted to agricultural fields resulting in lost water in roots, more water off, and less percolates into groundwater; human consumption outpacing recharge rate.
- ▷ Human effects on the nitrogen cycle: cultivation of nitrogen fixing crops; industrially produced fertilizers, burning of fossil fuels.
- ▷ Consequences of increased nitrogen: algal blooms in aquatic ecosystems, removing oxygen from the area; short term production increase at cost of diversity and long term productivity; acid rain, climate change, depletion of ozone layer.
- ▷ Humans have more than doubled the rate of nitrogen fixation.
- ▷ Humans have quadrupled the amount of phosphorus entering the global biogeochemical system.



## 54 Biodiversity and Conservation Biology

### 54.1 What is Biodiversity?

#### 54.1.1 Biodiversity Can Be Measured and Analyzed at Several Levels

- ▷ **Genetic diversity:** total genetic information contained within all individuals or a population and measured as the number and relative frequencies of all genes in a group.
- ▷ **Species richness:** how many species are in an area.
- ▷ **Species diversity:** both species richness and evenness, of relative abundance of each species.
- ▷ **DNA barcoding:** use of well characterized gene sequences to distinguish species.
- ▷ **Ecosystem diversity:** a measure of horizontal diversity by trophic species richness and vertical diversity by number of trophic levels, plus complex factors with the nonliving environment.
- ▷ **Ecosystem function:** the sum of biological and chemical processes that are characteristic of a given ecosystem.
- ▷ Primary production, nitrogen cycling, decomposition, and carbon storage emerge from the sum of the feeding, growing, moving, respiring, excreting, and decomposing processes.

#### 54.1.2 Where is Biodiversity Highest?

- ▷ Patterns of biodiversity are usually measured by dividing geographic area into grids of cells and mapping the biodiversity within each cell.
- ▷ **Endemic species:** species found in a particular area and nowhere else.
- ▷ Areas with geographical variation tend to have higher biodiversity.
- ▷ Tropical rainforests are estimated to contain at least 50% of all species, with coral reefs being the most aquatic species rich environment.
- ▷ **Biodiversity hotspot:** areas in urgent need of conservation action.

## 54.2 Threats to Biodiversity

- ▷ Habitat loss is the most important factor in the decline of species in terrestrial environments.
- ▷ Overexploitation is the dominant problem for marine species, and pollution for freshwater species.
- ▷ Invasive species, native species interactions, and other natural events are additional threats to all environments.

### 54.2.1 Habitat Destruction

- ▷ human causes: burning, logging, damming, dredging, filling in of estuaries and wetlands, plowing, grazing livestock, mining, and various infrastructure development.
- ▷ Deforestation of natural areas is the greatest threat.
- ▷ **Habitat degradation**: a reduction in quality of habitat.
- ▷ **Habitat fragmentation**: a pattern of degradation resulting from the dividing of habitats into smaller isolated fragments.
- ▷ Fragmentation particularly hurts top predators, resulting in trophic cascades due many complex food web interactions and results in often unpredictable consequences.
- ▷ Smaller populations have higher chances to be exterminated by catastrophic events.
- ▷ Absence of gene flow results in inbreeding depression.
- ▷ **Overexploitation**: unsustainable removal of organisms for human consumption.

### 54.2.2 Estimating the Probability that a Population or Species Will Go Extinct

- ▷ A population is considered viable if the prediction probability of survival for at least 100 years is 95%+.

- ▷ Predictions are made with data from age-specific survivorship and fecundity.
- ▷ geographic structure.
- ▷ rate and severity of habitat disturbance.

### 54.3 Benefits of Biodiversity

- ▷ Biodiversity increases productivity.
- ▷ Diverse assemblages of plant species make more efficient use of sunlight, water, and nutrients.
- ▷ *Facilitation*: some species provide nutrients or other benefits that also make the environment better for other vital species.
- ▷ Higher chance of producing extremely productive species.
- ▷ **Resistance**: measure of the extent a community remains unchanged by a disturbance.
- ▷ **Resilience**: measure of how quickly a community recovers following a disturbance.
- ▷ **Bioprospecting**: exploration of bacteria, archaea, protists, plants, fungi, and animals as novel sources of drugs or ingredients in consumer products.

## 50 Behavior Ecology

- ▷ **Behavioral ecology:** a focus a subset of organismal ecology— the behavioral adaptations that have evolved in response to ecological selection pressures.

### 50.1 Introduction to Behavioral Ecology

- ▷ **Proximate causation:** explains how actions occur in terms of genetic, neurological, hormonal, and skeletal–muscular mechanisms involved.
- ▷ **Ultimate causation:** explains why actions occur, based on their evolutionary consequences and history.
- ▷ **Fixed action patterns (FAPs):** highly inflexible behavior patterns.

### 50.2 What, When, and How to Eat

- ▷ **Optimal foraging:**  $\text{Fitness} \propto \text{Feeding efficiency} \propto \frac{\text{benefits}}{\text{costs}}$

### 50.4 Choosing a Place to Live

- ▷ **Piloting:** the use of familiar landmarks while navigating.
- ▷ **Compass orientation:** movement that is oriented in a specific direction.
- ▷ **Map orientation:** the ability to locate a specific place on Earth's surface.

## 51 Population Ecology

- ▷ **Population ecology:** the study of how and why the number of individuals in a population changes over time and space.
- ▷ **Population thinking:** Understanding variation is key to understanding how populations change through time in their environments.

### 51.1 Distribution and Abundance

- ▷ **Range:** geographic distribution of different species.
- ▷ Two type of factors determine range:
  - *Abiotic:* temperature, rainfall, geographical structures, and ongoing historical processes.
  - *Biotic:* past and current presence of other species.
- ▷ Ranges are dynamic.
- ▷ Dispersion patterns have both proximate and ultimate causes.
- ▷ **Metapopulation:** a population of populations connected by migration.

### 51.2 Demography

- ▷ **Demography:** study of factors that determin the size and structure of populations through time.
- ▷ **Age structure:** how many individuals of each age are alive.
- ▷ **Life table:** Summarizes the probability that an individual will survive and reproduce in any given time interval over the course of its lifetime.
- ▷ **Cohort:** a group of the same age that can followed through time.
- ▷ **Fecundity:** number of female offspring produced by each remale in the population.
- ▷ **Net reproductive rate:** indicates whether the population is increasing or decreasing.

### 51.3 Population Growth

- ▷  $\frac{\Delta N}{\Delta t}$  = Births - Deaths + Immigrants - Emigrants
- ▷ **per capita rate of increase (r)**: birth rate - death rate per individual.
- ▷ **Density independent**: population size does not limit the growth rate.
- ▷ Exponential growth is common colonizing a new habitat or recovery after a disaster.
- ▷ **Carrying capacity, K**: the maximum number of individuals in a population that can be supported in a particular habitat over a sustained period of time.
- ▷ **Logistic population growth**: the decrease in growth rate as a population size approaches the carrying capacity.
- ▷ Density independent factors are usually influenced by abiotic factors.
- ▷ Density dependent factors are usually influenced by biotic factors.

## 52 Community Ecology

### 52.1 Species Interactions

- ▷ **Commensalism:** when one species benefits but the other is unaffected.
- ▷ **Competition:** when individuals use the same resources.
- ▷ **Consumption:** occurs when one organism eats or absorbs nutrients from another.
- ▷ **Mutualism:** when two species interact in a way that confers fitness benefits to both.
- ▷ **Symmetric competition:** when interspecific competition between niches decreases fitness, both persisting in reduced numbers.
- ▷ **Asymmetric competition:** when one species suffers greater fitness decline due to niche competition.
- ▷ **Competitive exclusion principle:** when two species occupy the exact same niche.
- ▷ **Fundamental niche:** total range of environmental conditions a species can tolerate.
- ▷ **Realized niche:** portion of a fundamental niche that a species actually occupies.
- ▷ **Character displacement:** enables a species to exploit different resources, leading to niche differentiation.
- ▷ **Inducible defenses:** physical, chemical, or behavioral defensive traits that are induced in the prey in response to consumers.
- ▷ **Constitutive defense:** present in the absence of consumers.

### 52.2 Community Structure

- ▷ A community structure has four key attributes: total number of species, the sum of interactions between species, relative abundance of those species, and the physical attributes of the community.

- ▷ *Bottom-up*: Sunlight, water, and other abiotic factors determine the abundance of primary producers which have a bottom up effect on the food web.
- ▷ *Top down*: result of keystone species, which have much greater impact on the distribution and abundance of the surrounding species.

### 52.3 Community Dynamics

- ▷ The impact of disturbance is a function of three factors: the type, frequency, and severity.
- ▷ **Disturbance regime**: in most cases disturbances occur with a predictable frequency and severity.
- ▷ **Succession**: the recovery that follows a disturbance.
- ▷ **Pioneering species**: high fecundity, low survivorship. Typically the first species to recover after a disturbance.
- ▷ **Facilitation**: when early-arriving species make conditions more favorable for the arrival of later species.
- ▷ **Tolerance**: existing species do not affect the probability that subsequent species become established.
- ▷ **Inhibition**: when one species inhibits the growth of another.