Insects dominate animal diversity

Most types of organisms probably have not been discovered/described

Organismal diversity is not evenly distributed across the planet

Organismal diversity is associated with other features of the earth (latitude, precipitation, seasonality, etc.) (environment changes a lot across the globe)

Organisms are distributed differently in different environments

Organismal diversity has changed over time

Earth is old

Over that time the physical layout has changed

Continents lie on “plates” that have drifted over time

Life is influenced by other aspects of the physical environment that have changed over time

Over time life has been influenced by the change in the physical environment

Life is getting more complex, but complexity is not a goal of evolution

Cambrian Explosion

There was a lot of new types of organisms

Was it caused by changing environments? Changing ecological interactions? Other?

The Cambrian is the boundary between the Proterozoic (older) and the Paleozoic era

Biodiversity

A balance between species formation (speciation) and species lost (extinction)

There is a background rate of extinction but occasionally there are upheavals of that rate (spikes in extinctions)

Permian extinction

Wiped out a lot of life

Unclear cause, comet impact? Volcanoes? Changing atmosphere? Other? Combination?

K-T extinction

Marks the end of the Mesozoic era

Believed that the reason for this extinction was a giant object smashing into the earth knocking up lots of dust.

Led to the blossoming of mammals

Quaternary extinction

There were lots of large mammal species in north America but that disappeared

Potential causes: climate change (glaciers moving back allowing for grass lands)? Human predation (people moved into north America from Asia)? Disease (did people migrating here lead to disease being brought over)?

This extinction was mostly in north America but also spread down into south America

How do we describe the diversity of life?

There can be diversity within a species

There can be similarities between different species

Biological species concept: animals are the same species if they can breed and their offspring can also breed

In this model, gene flow defines species

When it doesn’t work

It doesn’t work if we don’t know if gene flow is occurring (like in the fossil record)

It doesn’t work on organisms that reproduce asexually because species are defined with gene flow

Morphological species concept

Based on structural features (bones, claws, etc.)

Ecological species concept

How they interact with others and their habitat

Mechanisms of evolution

* Before Darwin, people looked into nature to try to understand god
  + William Paley, Natural Theology (1802)
    - Something looks designed? Someone must have designed it.
    - His example was walking seeing a watch and thinking that it looks like it was designed to tell time, and was probably designed by a person
  + Lamark’s hypothesis of evolution (1744-1829)
    - Species evolve through use and disuse of body parts and the inheritance of acquired characteristics (giraffe stretches its neck to reach higher leaves and passes a longer neck onto its offspring)
    - Has been discredited but is coming back a little with epigenetics
  + Charles Darwin (1809-1882)
    - Observed organisms and natural phenomena and he collected a lot of specimen
    - At the Galapagos islands he saw a whole variety of birds and was thinking about how science could explain biodiversity
    - He knew about William Paley’s ideas and knew about artificial selection and was learning about how old the world is (people thought that the earth was thousands of years old)
      * He appreciated deep time (world was old)
    - Thomas Malthus, principal of population
      * Had the idea that with massive population growth, there would be massive competition for resources and there would be many people who would lose that competition
      * Charles Darwin applied that idea to animals
    - His natural selection (how he understands what farmers did (artificial selection) applies to nature)
      * Observation 1: members of a population often vary in their inherited traits
      * Observation 2: all species can produce more offspring than the environment can support, and many of these offspring fail to survive and reproduce (based off Thomas Malthus)
        + Inference 1: individuals whose inherited traits give them a higher probability of surviving and reproducing in a given environment tend to leave more offspring than other individuals (higher “fitness”) (based on observations 1&2)
        + Inference 2: this unequal ability of individuals to survive and/or reproduce will lead to (select for) the accumulation of “favorable” traits in the population over generation (over long periods of time, this process can lead to change in form and function of organisms) (based on observations 1&2)
        + These lead to individuals being really good as either surviving or reproducing (see sharks vs peacocks)

Induced variation (artificial selection)

* People select individuals and breed them together to try to get specific traits
  + Like how kale, brussels sprouts, cabbage, broccoli, kohlrabi are all from the same plant with various parts exaggerated

Natural selection tl;dr

* Natural selection does not create new traits, but edits or selects for traits already present in the population
* The local environment determines which traits will be selected for or selected against
* (missed)

Consequences of this model of natural selection

* Individuals with certain heritable characteristics survive and reproduce at a higher rate than other individuals
* Over time, organisms will acquire traits that better suit them to their environments (adaptations)
* Organisms share ancestors and retain evidence of that relatedness (decent with modification)
  + Organisms have a history, they used to be more related, traits have changed over time
  + Just because one evolved, it does not mean the separate branch went extinct
* Patterns of relatedness can be determined by comparing features that have changed (or not) with evolution
  + The traits used to define the “family tree” (phylogeny) can be features of morphology (appearance)
  + Or of molecular biology like protein structure or DNA sequence (accepted as more accurate than with traits)
  + By combining other evidence (like fossil record, and knowledge about how fast DNA changes) the similarity of DNA between species can be converted from relatedness to time (rough estimate of how long ago they diverged)
* Structures of organisms reflect their evolutionary history (evolution only works on what is already there)
* Individuals do not evolve; populations evolve over time
* Natural selection can only increase or decrease heritable traits that vary in a population
* Adaptations vary with different environments; if the environment change, then the forces of selection will change

Evidence for evolution

* The fossil record
* Homology: similarity (in anatomy or molecular biology) resulting from common ancestry (similar base bone structure in the hand of a person, the leg of a cat, fin of a whale, wing of a bat) (or similarities in the molecular structures of hemoglobin in various animals)
* Comparative embryology: common structures in various species when they are embryos that are not seen when grown
* Biogeography: the geographic distribution of species (how are there marsupials in both Australia and America? The land was connected in the past)
* There is a common biochemical underpinning for all organisms (like DNA, RNA, ATP, etc.)
* Evolution can be directly observed to happen (drug resistance development)

“species” evolve from populations

Evolution: change over time in genetic variability which may or may not be visible as traits

Processes that cause gene frequencies to shift

* Natural selection causes differential success in reproduction and results in certain alleles being passed to the next generation in greater proportions
* Genetic Drift
  + Allele frequencies fluctuate unpredictability from one generation to the next, with a small population, there is a possibility for genetic variation to be lost
    - Potentially by random chance (someone happens to crush all green bugs)
    - Potentially by natural selection (a bird selectively eats all of one bug color)
* Founder Effect/Bottleneck Effect
  + A sudden reduction in population size can cause the gene pool to shrink as the survivors may not represent the original population’s gene pool
    - Can be further impacted by genetic drift if the population does not recover
* Natural selection is the only one of these mechanisms that consistently causes adaptive evolution

How does micro-evolution (evolution of diversity within species) connect with macro-evolution (the evolution of species and higher levels of diversity)

Mechanism for speciation

* Standard model: allopatric speciation
  + Population gets isolated and they evolve new traits over time that prevent them from reproducing with the original population
    - Prezygotic isolation
      * Habitat isolation (live at different places [in trees vs on ground])
      * Temporal isolation (reproduce at different times)
      * Behavioral isolation (different mating rituals)
      * Mechanical barriers (doesn’t fit)
      * Gamete incompatibility (can’t fertilize)
    - Postzygotic
      * Offspring don’t survive (die at birth or not fit for environment)
      * Offspring are not fertile
  + If the two populations happen to interact with each other again, they cannot reproduce and produce viable, fertile offspring.
* Major change during the life cycle can cause an organism to become reproductively active while in a juvenile form (Axolotl)
* Gametes don’t separate properly, and diploids fertilize and create a polyploid organism
  + This is very common around plants, especially ferns and flowering plants
  + The duplicate sets of DNA allow for the development of extra genes as the organism can still survive with the original, healthy gene

Animal from and function

Animal physiology studies balance two principles

* Make the diversity of organisms clear and the ways they adapted to their circumstance
* General principles and mechanism that apply broadly across organisms
  + Common features like streamlining in swimming organisms

Some principles of animal function

* Organisms maintain homeostasis
  + These control systems often overlap (i.e. sweating reduce body temp, sodium content and fluid volume)
  + Physiological variables (like blood pressure) are typically controlled by a complex set of seemingly redundant system
  + Homeostatic regulation can include behavior either individually or as a group
* Animals are not at equilibrium with their environment (i.e. fish have vastly different salt concentrations in their bodies relative to their environment)
  + Maintaining non-equilibrium requires energy and involves regulation by negative feedback
* Physiology can change overtime (like hibernation)

Temperature affects biology

* Chemical reaction rates are sensitive to temperature
* Structures of molecules are sensitive to temperature
* Functions of proteins are sensitive to temperature

Forms of body temperature management

* Homeotherms: regulate relatively constant temperature using metabolism as a source of heat
* Heterotherms: body temperature depends on heat exchange with the environment
* Endotherm: use metabolism to produce their own body heat to regulate body temp
* Ectotherm: have body temperatures determined by heat from the environment, their rate of energy use is determined by the temperature
  + They can still regulate body temperature through behavior
* These are not necessarily separate categories

Organisms vary widely in body size

* Animals of different size may have body forms that are similar or that are different
* Many aspects of biology vary with body size (larger animals have larger limbs)
* Allometry (study of organisms of different sizes) can serve as a basis for comparative analysis
* Metabolic rates for a large animal is greater than that of a small animal
* The metabolic rate per unit body mass decreases with size

Chemical signaling

* Endocrine signaling
  + Into bloodstream
* Paracrine signaling
  + To nearby cells
* Autocrine signaling
  + To itself
* Synaptic signaling
  + Across the synapse
* Neuroendocrine signaling
  + Hormone is released from a neuron to impact other cells
* Pheromones
  + One animal releases chemicals to attract other animals
* Tissues that secrete hormones are called endocrine tissues
* The responding cell is called the target cell, it responds because it has receptors
* Hormones are often classified by chemical structure
  + Steroid hormones (are all lipid like)
  + Peptide hormone
* Hormones generally circulate in the blood at very low concentrations
* Circulating hormone concentration is determined by the balance between hormone release and hormone removal
* Hormone removal is by metabolism in the liver or excretion in the urine
  + Usually part of a negative feedback system
  + Some hormones are released in rhythmic patterns

Mechanisms of hormone action

* Hormones are regulators
  + They stimulate cellular processes, but are not themselves metabolized as part of those processes
* The definition of any tissue as a target for a hormone depends on the presence of specific receptors for that hormone
* Steroids (lipid soluble): steroid receptors are found inside the cell as they can pass through the plasma membrane where they get transported into the nucleus
* Peptides (water soluble): peptide receptors are found on the plasma membrane where they interact and causes a change that leads to a second messenger being released. The second messenger relays the message from the peptide to the targeted region
* A single hormone can have different effects in different target tissues or even the same target tissues because they have
  + Different receptors for the hormone
  + Different second messenger pathways
  + Different cellular response mechanisms
* Hormones can stimulate the release of other hormones
* Hypothalamus and the pituitary gland
  + The hypothalamus releases hormones through the blood stream to the anterior pituitary to get it to release other hormones
  + The hypothalamus uses neurohormones to tell the posterior pituitary (because they are only connected by neurons) to release hormones

Osmoregulation (How body fluids are regulated in the face of changing environment)

* Things regulated
  + Cell volume
    - Structural integrity
    - Concentrations of intracellular solutes
  + Body fluid volume
    - Body pressure
    - Concentrations of body solutes
  + Solute concentrations
    - “Ionic strength” surrounding proteins
    - Specific ion gradients
    - Body water volume (especially sodium ions)
* How animals respond to osmotic challenges
  + Osmoconformers: some marine animals don’t regulate their osmolarity and are isosmotic to their surroundings
  + Osmoregulators: expend energy to control the concentrations of their body fluids (even in hyperosmotic and hypoosmotic environments)
* Mechanisms of osmoregulation (mechanisms require a **driving force** and a **pathway**)
  + Filtration
    - The “leakage” of fluid and dissolved solutes out of vessels under pressure
    - Blood pressure (fluid [hydrostatic] pressure) is the driving force and space between cells (like from a puncture wound) is the pathway
    - Kidneys and the lymphatic system are major systems of filtration
  + Evaporation
    - Water vapor pressure difference (driving force) water permeability (path)
    - Animals can adjust the airflow and water permeability of surfaces to adjust evaporation (for cooling)
  + Osmosis
    - Water moves by osmosis towards equilibrium
    - Osmotic pressure (driving force), water permeability across the cell membrane (pathway)
    - Many tissues are exposed to or create osmotic gradients that drive water flow
    - Water permeability across cell membranes is facilitated by proteins called aquaporins
  + Ion transport
    - Driving force: concentration gradient, pathway: cell membrane or space between cells
    - Passive transport: moves ions down their concentration gradient
    - Active transport: requires ATP and moves ions against a concentration gradient
      * Active transport of the sodium-potassium pump leads to the passive transport of sodium into the cell
        + This is used in nerve cells to create electrical signals
* Terminology
  + Molarity: chemical concentration of a particular solute (moles/liter)
  + Osmolarity: total chemical concentration of dissolved solute “particles” (osmoles/liter)
* Overview
  + Concentrations of water and solutes must be maintained within a fairly narrow limit
  + Osmoregulation balances the gains and losses of water and solutes

Digestion and nutrition

Ecosystems are organized around the flow of energy and nutrients

Some animals have highly defined diets, others adjust to changing diets over time

Chemistry and biology of food

* Organisms, and the food they eat, are made of a combination of organic and inorganic molecules
  + Organics include many subcategories such as fiber, lipids, proteins, etc.
  + Inorganics generally include many elements
* Foods differ in nutrient content
  + Creatures in different phases of life may require different amounts of various nutrients
* The ultimate goal of the digestive process is to convert foodstuffs into a form that can be absorbed by the digestive tract
  + The digestive tract may have to convert more complex molecules into simple molecules that can be absorbed
    - This process usually requires the help of enzymes
* Main processes
  + Feeding, mechanical processing & movement, secretion of chemicals that aid digestion, breakdown of food, absorption of nutrients, elimination of undigested material
* Most simply, digestion goes through a tube that may do different things at different parts
* The gut is simply divided into 3 parts
  + The mucous membrane, the smooth muscle (helps move substances along), the connection to the bloodstream
  + Villi: folds at the tissue level
  + Microvilli: tentacle looking stuff that increase surface area at the cell level
* Digestive processes
  + The stomach contains numerous specialized cell types
    - Parietal cells produces HCl (stomach acid) by secreting H+ ions, that come from reacting carbon dioxide and water, and Cl—ions into the stomach lumen
    - Various stimuli (related to feeding and body chemistry) can activate acid secretion
      * These mechanisms can be targeted by drugs (blocking triggers or proton pumps)
  + Enzymes convert macromolecules to their smaller constituents
    - The availability of the necessary enzymes is required for digesting various nutrients
    - Lots of animals rely on digesting cellulose for energy, almost none of them (no mammals) produce cellulase
      * “Ruminants” house cellulose-digesting microorganisms in a complex stomach
      * Many other herbivores (hindgut fermenters) house cellulose-digesting bacteria in the cecum (they have to eat their poop to take advantage of cellulose)
  + Absorption of carbohydrates & proteins
    - Transported across mucosal cells of small intestine by specific membrane transport proteins
      * Usually molecules have to go through cells (transcellular route), but some molecules can go between the cells (paracellular route)
    - The speed at which foods pass through the gut (gut motility) varies with diet and conditions
      * Gut motility affects digestion (the longer the food stayed in the gut, the higher the digestive efficiency)
    - Gut capacity is adjustable
      * A type of groundhog increases its gut size through summer as it consumes a lot of food to store for winter
* Nutrition
  + Energy: 1Cal = 1kcal = 1000cal
    - Typical daily energy expenditure is ≈ 2000 Cal/day
  + Energy values of foods
    - Carbohydrates: ≈4 Cal/g
    - Protein: ≈4-4.5 Cal/g
    - Lipids: ≈9 Cal/g
  + Caloric intake
    - Depends on the amount and composition of foods
      * The mix of carbs, protein, and lipids
      * The digestibility of what you eat (fiber is a carb)
  + Some animals go through seasonal cycles of fattening
    - These animals may be models for how obesity is regulated
  + Some animals go through seasonal cycles of starvation