1. Molecular & Cellular Biology
1.1 Chemical Composition of Organisms
1.2 Cells
1.3 Enzymes
1.4 Energy Transformations

Light energy

Water

Carbon Dioxide CO₂

Oxygen O₂

Sugars
1.5 Cell Division
1.6 Chemical Nature of the Gene
1.1 Chemical Composition of Organisms
Chemistry of Biology

1.1.1 Reactions & Bonds

1.1.2 Properties of Water

1.1.3 Organic Molecules

1.1.4 Origin of Life
1.1.1 Reactions & Bonds

- matter & elements
- atoms
- types of bonds
- chemical reactions
- energy
1.1.2 Properties of Water

• what makes water special
• acids & bases
• the pH scale
1.1.3 Organic Molecules

- what makes a molecule organic
- carbohydrates
- lipids
- proteins
- nucleic acids
1.1.4 Origin of Life

• when & where did living things first appear
• what were the first living things
• how did life evolve from simple to complex
• evidence for current hypotheses
1.1.1 Simple Chemical Reactions and Bonds
Matter & Elements

Matter: anything that takes up space & has mass, made of elements
  • rocks
  • gases
  • kittens

Elements: cannot be broken down to other substances
  • Carbon
  • Oxygen
  • Hydrogen
Elements

Atom: smallest unit of matter w/ element’s properties

Each element has unique atoms, composed of three types of subatomic particles
  • neutrons (0)
  • protons (+)
  • electrons (-)
An Atom
Elements

Compound: 2+ different elements combined in fixed ratio
  • table salt (NaCl)

Molecule: 2+ same or different elements combined in fixed ratio
  • oxygen gas
Electrons

Electrons found orbiting in *shells*

Valence shell: outermost shell, “valence electrons”

Only valence electrons interact w/ other atoms

Atoms most reactive if valence shell incomplete
Chemical Bonds

Attractions that keep atoms close together

Protons & electrons attract like magnets
Chemical Bonds - Covalent

Sharing pair of electrons, strong bonds

1. nonpolar: sharing is equal
2. polar: sharing is unequal, creates partial charges (poles)
Chemical Bonds- Ionic

One atom (anion) steals electron, other atom (cation) loses electron, strong bonds
Chemical Bonds- Hydrogen

Form between poles of H and O in water molecules, weak bonds
Chemical Reactions

Make and break chemical bonds

Reactants “react” together, start of reaction

Products are “produced,” end of reaction

\[ A + B \leftrightarrow C \]
Energy

1\textsuperscript{st} Law of Thermodynamics: energy cannot be created or destroyed

2\textsuperscript{nd} Law of Thermodynamics: reactions tend to increase disorder (make energy less available for cells)

Endothermic reactions take energy

Exothermic reactions release energy
1.1.2 Properties of Water
Properties of Water

All 3 states

Solid less dense than liquid

Adhesion, cohesion, & surface tension

Universal solvent

High specific heat

Evaporative cooling
**Acids & Bases**

**Acids:** dissolve in water & increase relative H\(^+\) ion concentration in the solution

\[\text{HCl} \leftrightarrow \text{H}^+ + \text{Cl}^-\]

**Bases:** dissolve in water & decrease the H\(^+\) ion concentration in the solution

\[\text{NH}_3 + \text{H}^+ \leftrightarrow \text{NH}_4^+\]
Acids & Bases

pH scale shows relative amount of $H^+$ ion concentration
- smaller # means more acidic
- larger # means more basic
- 7 is neutral

Buffers can be added to bring pH to 7
The pH Scale
1.1.3 Chemical Structure of Organic Molecules
Any molecule containing carbon is called “organic”

Can contain other molecules—oxygen, hydrogen, nitrogen...

Made of building blocks called monomers

Many monomers linked together form polymer (whole molecule)
Organic Molecules

4 Classes:

1. carbohydrates
2. lipids
3. proteins
4. nucleic acids
Carbohydrates

Made only of carbon, oxygen, and hydrogen

Monomer name: monosaccharide, example is glucose

Polymer name: polysaccharide, example is starch
Lipids

Grouped together b/c of hydrophobic properties

Common lipids:
- waxes - water barrier
- fats - energy storage
- phospholipids - cell membranes
- steroids - hormones
Proteins

Monomer name: amino acid

Polymer name: polypeptide (protein)

Peptide bond: holds amino acids together

Many functions:
• most enzymes
• defense- antibodies
• muscle- fibers
Nucleic Acids

Monomer name: nucleotide

Two types:
1. deoxyribonucleic acid (DNA)
2. ribonucleic acid (RNA)

Primary function: information storage
Nucleotides

Nucleotides are made of:

1. 1 Nitrogen base
   - adenine (A)
   - thymine (T, only in DNA)
   - uracil (U, only in RNA)
   - cytosine (C)
   - guanine (G)

2. 1 Sugar (deoxyribose or ribose)

3. 1 Phosphate group
Nucleotides
Nucleic Acids

Sugar-phosphate “backbone” forms

Nucleotides paired (called a base pair), so that DNA or RNA strands are complimentary

- A-T or A-U
- C-G

Base pairs joined in center by hydrogen bonds
Nucleic Acids
1.1.4 Origin of Life
When and Where

Fossils suggest life evolved 3.5 million years ago

Bacteria & similar organisms

Likely places:
- deep sea vents
- hot springs
- tide pools
From Simple to Complex

Evolution of life happened in steps, each building on those previous

1. simple organic molecules
2. some molecules able to replicate
3. membranes, cell division
4. metabolism
First Living Things

Many lines of evidence of common ancestry
• cell membranes
• metabolism
• DNA
• fossils

Tree of life has patterns of evolution from simple to complex.
1.2 Cells
The smallest units of life

1.2.1 Structure & Function of Cell Organelles

1.2.2 Properties of Cell Membranes

1.2.3 Comparison of Prokaryotic & Eukaryotic Cells
Structure & Function of Cell
Organelles

- cell basics
- cytoplasm & cell membrane
- nucleus
- ribosomes
- endoplasmic reticulum
- Golgi apparatus
- mitochondria & chloroplasts
- cytoskeleton
- cell wall
Properties of Cell Membranes

- membrane basics
- selective permeability
- transport basics
- passive transport
- active transport
Comparison of Prokaryotic & Eukaryotic Cells

- cells basics
- prokaryotic cell characteristics
- eukaryotic cell characteristics
1.2.1 Structure & Function of Cell Organelles
Cells

Smallest collection of matter that be alive

All organisms made of one or more cells
  • single-celled
  • multicellular
Cytoplasm & Cell Membrane

Cytoplasm: jelly-like substance in which all organelles are suspended

Cell membrane: lipid layer surrounding cell
Nucleus

“Command center”

Stores, protects most of DNA

Nucleolus makes RNA & ribosomes
Ribosomes

Protein factories - use DNA instructions to make proteins

Made of RNA & proteins
Endoplasmic Reticulum

Functions:

• makes lipids
• detox
• makes secretory proteins & membrane
Golgi Apparatus

Functions: receiving, sorting, modifying, and shipping center for ER products
Mitochondria & Chloroplasts

Both have:
- their own DNA & ribosomes
- double-membrane
- somewhat autonomous

Mitochondria: site of cell respiration (converts food to energy molecules)

Chloroplasts: site of photosynthesis (converts sunlight into food)
Cytoskeleton

Support scaffolding for cells

Duties:
  • cell shape, muscle movement, highways, organizing cytoplasm, locomotion

Centrosomes: organizes some of cytoskeleton, & cell division
Cell Wall

Found in plants, fungi, bacteria

Rigid, structural support

Common components:
  • cellulose
  • pectin
  • chitin
1.2.2 Properties of Cell Membranes
Membranes

Boundary b/w inside of cell & surroundings

Selectively permeable

Phospholipid bilayer w/ proteins, other lipids, hybrid molecules
Selective Permeability

Membranes regulate cell traffic by only allowing some things to pass freely, transporting others, preventing still others.
Membrane Transport

Passive transport: diffusion across membrane; no energy required; sometimes need “doorway” protein (which is in membrane)

Active transport: movement across membrane requiring energy and “doorway” protein
Passive Transport: Diffusion

Movement of molecules from higher to lower concentrations
- each molecule moves randomly
- no energy required; spontaneous
Passive Transport: Osmosis

Diffusion of water across membrane from higher to lower concentrations
Passive Transport: Facilitated Diffusion

Diffusion w/ help of “doorway” proteins- very specific
Active Transport

Requires energy and “doorway” protein

Useful for moving molecules against their concentration gradients
Active Transport: Bulk Transport

Large molecules can’t pass through membrane
• Exocytosis: leaving the cell through vesicles
• Endocytosis: entering cell through vesicles
1.2.3 Comparison of Prokaryotic and Eukaryotic Cells
Cells

Two types of cells:
1. Prokaryotic
2. Eukaryotic

All living things are either prokaryotes or eukaryotes
Prokaryotic Cells

Bacteria & Archaea

Most ancestral living things

Like all cells, they have:
  • cell membrane
  • cytoplasm

Unlike eukaryotic cells, they have:
  • no nucleus
  • no organelles
Prokaryotic Cells

All prokaryotes are unicellular

Some have a cell wall and/or locomotor structures

Most abundant living things on planet

Some helpful (gut), some harmful (infection)

Many shapes, all very small
Lyme disease bacteria
Eukaryotes

Animals, plants, fungi, protozoans, etc.

Evolved from prokaryotes

Like all cells, they have:
  • cell membrane
  • cytoplasm
Eukaryotes

Unlike prokaryotes, they all have:

- internal organelles like nucleus, mitochondria, etc.
- DNA in nucleus

Some have:

- cell walls
- locomotor structures

Unlike prokaryotes, they can be uni- or multicellular
Eukaryotes
1.3 Enzymes
Enzymes

1.3.1- Enzyme-Substrate Complex

1.3.2- Roles of Coenzymes

1.3.3- Inorganic Cofactors

1.3.4- Inhibition & Regulation
Enzyme-Substrate Complex
- activation energy
- enzymes as catalysts
- substrates & active sites
Roles of Coenzymes

- cofactors
- coenzymes
Inorganic Cofactors

- cofactors & coenzymes
- examples of inorganic cofactors
Inhibition & Regulation
- molecular inhibitors
- environmental inhibition
- regulation
- methods of regulation
1.3.1 Enzyme- Substrate Complex
Any reaction has an initial energy barrier, called *activation energy* \((E_a)\)

- before new bonding can occur, existing chemical bonds must be broken
- rate of reactions determined by \(E_a\)
Enzymes are proteins that act as catalysts, which make reactions happen faster by lowering $E_a$ (without being changed/used themselves).

Example: lactase and lactose
Enzymes

The molecule an enzyme interacts with is called a \textit{substrate}.

An enzyme’s \textit{active site} is the location where it interacts with the substrate.

Enzyme and substrate fit together like hand in glove, forming an enzyme-substrate complex.
Enzymes

Some enzymes break substrates into smaller pieces

Other enzymes join two substrates together into one molecule
1.3.2 Roles of Coenzymes
Coenzymes

Some enzymes need help from other molecules called cofactors

Cofactors can be inorganic (metals) or organic (coenzymes)

These bind to the enzyme’s active site and help form the enzyme-substrate complex
Coenzymes

Commonly vitamins (Ex: coenzyme Q$_{10}$, Vitamin B$_6$)

Two types:
  • Cosubstrates are detachable
  • Prosthetic groups are permanent
1.3.3 Inorganic Cofactors
Inorganic Cofactors

• Cofactors are non-protein molecules that are necessary for some enzymes to function properly

• Organic cofactors are called *coenzymes* (see module 1.3.2)
Cofactors

- Inorganic cofactors are usually metal ions
  - Fe$^{2+}$
  - Mn$^{2+}$
  - Zn$^{2+}$ (Ex: with alcohol dehydrogenase, below)
1.3.4 Inhibition & Regulation
Inhibition

• Inhibitors: molecules that compete with substrates for enzymes’ active sites
  • Sit in the active site, blocking it so enzyme & substrate cannot interact
  • Attach to enzyme outside active site, but change shape of active site so it doesn’t work

• Example: a2-antiplasmin (below) stops enzymes from dissolving blood clots, helpful for treating bleeding disorders like hemophilia
Inhibition

• Enzyme activity is also inhibited when the shape of the enzyme active site is changed by the environment, causing it to stop working
  • temperature
  • pH

• Denaturation: change in enzyme shape that makes it stop working
Regulation

• Regulation: when a cell controls the action of its own enzymes

• Two common methods of enzyme regulation:

  • 1. product of reaction inhibits enzyme
      • reaction slows as product increases
      • Example: production of energy molecule ATP decreases as its concentration increases
Regulation

• Two common methods of enzyme regulation:
  • 2. regulator molecules control shape of enzyme active site
    • causes it to fit with substrate or not, depending on what cell needs
    • Example: oxygen is regulator of hemoglobin, changing active site shape when it’s attached
1.4 Energy Transformations
Energy Transformations

1.4.1- Cellular Respiration

1.4.2- Photosynthesis

\[ 6\text{CO}_2 + 6\text{H}_2\text{O} \xrightarrow{\text{Chlorophyll}} \text{C}_6\text{H}_{12}\text{O}_6 + 6\text{O}_2 \]
Cellular Respiration

- overview
- glycolysis
- aerobic respiration
  - pyruvate oxidation
  - citric acid cycle
  - electron transport chain
- anaerobic respiration
Photosynthesis

• overview
• light reactions
• dark reactions
1.4.1 Cellular Respiration
Cellular Respiration

Cells convert ‘food’ (glucose, below) into energy molecule ATP in all organisms.

ATP used any time energy needed in organism.

Two types:
  • Aerobic (with oxygen)
  • Anaerobic (without oxygen)
Cellular Respiration

- Glycolysis
- Aerobic Respiration
- Pyruvate Oxidation
- Citric Acid Cycle
- Electron Transport Chain
- Anerobic Respiration
  - Lactic Acid Fermentation
  - Alcoholic Fermentation
Glycolysis

Glycolysis is first step in all organisms, whether doing aerobic or anaerobic respiration

• same in all organisms
• glucose split and used to make 2 molecules of pyruvate and 2 net ATPs
• Pyruvate (below) goes to Pyruvate Oxidation pathway
Aerobic Respiration: Pyruvate Oxidation

Pyruvate converted to Acetyl CoA (below), then goes to Citric Acid cycle
Aerobic Respiration: Citric Acid Cycle

Acetyl CoA converted into different molecules, a little ATP produced (below), other molecules produced that are used in electron transport chain
Aerobic Respiration: Electron Transport Chain

Electrons and molecules from the citric acid cycle help in the production of ATP

Makes the most ATP of all respiration pathways: about 32
Anaerobic Respiration

Conversion of pyruvate (from glycolysis) to ATP without oxygen

1. Lactic acid fermentation: lactic acid is byproduct (causes muscle burn after hard exercise)
2. Alcoholic fermentation: ethanol is byproduct (important for alcoholic drinks)

Produces very little ATP
1.4.2 Photosynthesis
Photosynthesis Overview

Converts energy from sunlight into glucose that is used in cellular respiration to form ATP
6CO₂ + 6H₂O $\xrightarrow{\text{Light energy}}$ C₆H₁₂O₆ + 6O₂
Photosynthesis

Two processes:
1. Light reactions harvest sunlight
2. Dark reactions make glucose
**Light Reactions Overview**

Take place in thylakoid membrane

1. Capture/use light as energy source
2. Produce ATP & other molecules for dark reactions
3. Produce \( \text{O}_2 \) as byproduct
Dark Reactions

Take place in stroma
• Use ATP from light reactions
• Use CO₂ from air
• Make molecules used in light reactions
• Produce glucose that is used in cellular respiration
1.5 Cell Division
Cell Division

1.5.1- Structure of Chromosomes

1.5.2- Mitosis, Meiosis, Cytokinesis
Structure of Chromosomes

• what are chromosomes?
• chromosome terminology
• homologous chromosomes
• ploidy
• karyotypes
Mitosis, Meiosis, Cytokinesis

- cell cycle
- stages of mitosis
- stages of meiosis
1.5.1 Structure of Chromosomes
Chromatin: How DNA exists most of the time, unwound like a pile of yarn

Chromosome: DNA wound up, only happens right before mitosis

- DNA wound around proteins called histones
- each group of histones w/ DNA is called a nucleosome
Chromosome Terms

Sister chromatids: copies of each other, made before mitosis

Centromere: visible constriction, holds chromatids together
Homologous chromosomes

- have genes coding for the same characteristics, in the same locations (loci)
- roughly the same size and shape
- pair up before mitosis
Homologous Chromosomes

Alleles: variations of the same gene, found on homologous chromosomes.

Example: in a gene coding for hair color, one allele for black hair, another for blonde hair
Ploidy

Denotes number of copies of genes/ chromosomes in organism, abbreviated as a number and the letter “n”

- Haploid: 1n, having 1 copy of each gene
- Diploid: 2n, having 2 copies of each gene
Ploidy

From the moment of fertilization, humans are 2n

Only our sperm & eggs are haploid (1n)
Karyotype

Karyotype: picture of chromosomes

For humans, $2n=46$

Sex chromosomes are #23
1.5.1 Structure of Chromosomes
Chromosomes

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Karyotype

Karyotype: picture of chromosomes

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1.5.2 Mitosis, Meiosis, Cytokinesis
Cell Cycle

Interphase: 90% of cell’s life, DNA is copied
- $G_1$
- $S$
- $G_2$

Mitotic Phase: Parent cell splits into 2 identical daughter cells
Mitotic Phase

Mitosis (PMAT)
1. Prophase - chromosomes condense
2. Metaphase - chromosomes align on metaphase plate
3. Anaphase - chromosomes pulled to poles
4. Telophase - chromosomes decondense

Cytokinesis: parent cell splits into 2 identical daughter cells (2n)
Mitotic Phase
Meiosis

Forms 4 unique 1n cells, sperm in testes & eggs in ovaries

2 Parts:
   1. Meiosis I
   2. Meiosis II
Meiosis
Meiosis I

Stages in same order, do the same things as in mitosis w/ one difference

- Prophase I
- Metaphase I
- Anaphase I
- Telophase I
- Cytokinesis

Important difference: crossing over occurs during Prophase I, new combinations result
Meiosis I
Meiosis II

Same as in mitosis & Meiosis I, but chromosomes have been through crossing over

End product is four haploid cells, instead of the 2 that result from mitosis & Meiosis I
Meiosis II

Prophase II

Metaphase II

Anaphase II

Telophase II

Cytokinesis
1.6 Chemical Nature of the Gene
Genes

1.6.1 - Watson-Crick Model of Nucleic Acids
1.6.2 - DNA Replication
1.6.3 - Mutations
1.6.4 - Control of Protein Synthesis
1.6.5 - Structural & Regulatory Genes
1.6.6 - Transformation
1.6.7 - Viruses
Watson-Crick Model of Nucleic Acids

- discoveries before Watson & Crick
- the Watson-Crick model
DNA Replication

- DNA as blueprint
- each strand a template
- process
- end product
Mutations

• what are they
• causes
• types

Siamese  Persian  Russian Blue  Manx
Control of Protein Synthesis

- genes & protein synthesis
- transcription
- translation
Structural & Regulatory Genes

- types of genes/ proteins
- structural genes/ proteins
- regulatory genes/ proteins
Transformation

- bacterial genes
- transduction
- transformation
Viruses

- are they alive
- structure
- how they work
1.6.1 Watson-Crick Model of Nucleic Acids
Discoveries Before Watson & Crick

Friedrich Miescher (1860s): discovered phosphate-rich chemicals in white blood cell nuclei
Discoveries Before Watson & Crick

Frederick Griffith (1920s): some kind of molecule transformed pneumonia bacteria from harmless to lethal
Discoveries Before Watson & Crick

Avery, MacLeod, McCarty (1940s): DNA was the transforming molecule
Discoveries Before Watson & Crick

Chase & Hershey (1950s): DNA (not proteins) the genetic material
Discoveries Before Watson & Crick

Erwin Chargaff (1950s): A=T and C=G
Discoveries Before Watson & Crick

Rosalind Franklin (1950s): X-ray crystallography showed helical structure
Watson-Crick model of nucleic acids

James Watson & Francis Crick (1950s): A-T bond was the same length as the C-G bond, leading to double-helix

Watson & Crick published their model in 1953
1.6.2 DNA Replication
The Blueprint

DNA is the “blueprint” for everything cells make and do

Before mitosis, a cell must copy DNA, so each daughter cell gets an identical copy

DNA replication- making the copy
The base pairing rule (A=T and C=G) means each DNA strand can be a template for a new strand.
The Process

Steps:

1. The enzyme *helicase* breaks bonds b/w nucleotides on the two DNA strands, unwinding the double helix.

2. The enzyme *DNA polymerase* reads the sequence of nucleotides on one DNA strand (*template strand*).

3. Polymerase builds a new strand by matching nucleotides to those on template strand.
When polymerase is finished, two identical double helices have been formed.
1.6.3 Mutations
Mutations

Ultimate source of new genes

Can be beneficial or detrimental

Called genetic disorder if detrimental (i.e. sickle-cell disease)
Mutations

Siamese

Persian

Russian Blue

Manx
Causes

1. Accidents during replication or transcription
2. Exposure to carcinogens (like radiation)
1. **Substitutions:** when the wrong nucleotide is used (i.e. A instead of C)

2. **Frameshifts:** an extra nucleotide added or essential one deleted
1.6.4 Control of Protein Synthesis
Genes & Protein Synthesis

Gene: segment of DNA that is blueprint for specific protein

Genes control protein synthesis

Two stages:
1. Transcription
2. Translation
Transcription

Gene copied from DNA into RNA format (U instead of T)

mRNA- messenger RNA, takes message to cytoplasm for translation
Translation

Sets of 3 nucleotides on mRNA form *codons*, which are complimentary to sets of *anticodons* on transfer RNA (tRNA)

tRNA carries amino acids from cytoplasm to ribosomes
Translation

Ribosomes match anticodons to codons

Attached amino acids are joined to form proteins
1.6.5 Structural & Regulatory Genes
Two Types of Proteins

Genes code for production of two types of proteins:

1. Structural
2. Regulatory
Structural Genes

Structural genes code for structural proteins, which form things like:

• organs
• cell walls
• cytoskeleton
Regulatory genes code for regulatory proteins which do things like:

- regulate growth
- control development
- start or stop transcription of certain genes
1.6.6 Transformation
Bacterial Genes

Remember that bacteria are prokaryotes, no nucleus

DNA can be changed more easily, one reason why they can become resistant to medication quickly

1. Transduction
2. Transformation
Transduction

A virus can put genes from one bacterium into another
Transformation

Bacteria can incorporate bits of DNA from environment into their own genes.
1.6.7 Viruses
Are They Alive?

Scientists disagree
- have their own DNA or RNA
- can only reproduce in host cells
- no metabolism

A single virus: particle or virion
Structure

Much smaller than smallest bacteria

All are composed of:
  • Capsule
  • DNA or RNA

Some have enzymes, attachment structures
Rabies
A viral “infection” involves:
1. A virus invades a living cell (host)
2. Takes control of DNA replication, sometimes transcription & translation
3. Gets host cell to make more of itself

Some viruses program the host’s immune system to stop working or attack itself
2. Organismal Biology
Structure & Function in Plants

1- Plant Organs
2- Water & Mineral Acquisition
3- Food Translocation & Storage
Plant Reproduction & Development

1- Alternation of Generations
2- Gamete Formation & Fertilization
3- Growth & Development
4- Tropisms & Photoperiodicity
Structure & Function in Animals

1- Major Systems
2- Homeostatic Mechanisms
3- Hormones in Homeostasis & Reproduction
Animal Reproduction & Development

1- Gamete Formation & Fertilization
2- Cleavage, Gastrulation, Germ Layers, Organ System Differentiation
3- Experimental Analysis of Vertebrate Development
4- Extraembryonic Membranes
5- Formation & Function of Mammalian Placenta
6- Blood Circulation in the Human Embryo
Principles of Heredity

1- Mendelian Inheritance
2- Chromosomal Basis of Inheritance
3- Linkage
4- Polygenic Inheritance
2.1 Structure & Function in Plants
Plant Structure & Function

2.1.1- Plant Organs
2.1.2- Water & Mineral Acquisition and Transport
2.1.3- Food Translocation & Storage
2.1.1 Plant Organs

• shoots
• leaves
• flowers
• fruits
• roots
2.1.2

Water & Mineral Acquisition and Transport

- vascular plants
- vascular tissues
- transport
2.1.3

Food Translocation & Storage
  • phloem
  • sugar movement
  • food storage
2.1.1 Plant Organs
Major Plant Organs

Shoots
Leaves
Flowers
Fruits
Roots
Shoot System

Usually above-ground part of plants

Sometimes has leaves, flowers, fruits

Gathers light & CO\textsubscript{2} for photosynthesis
Leaves

Gather light for photosynthesis

Sometimes modified or absent
Flowers

Only present in angiosperms

Attract pollinators, release pollen
Fruits

Mature reproductive organ

Contain seeds, sometimes tasty flesh
Roots

Absorb water & nutrients from soil

Below-ground organs

Sometimes store energy, water
2.1.2 Water & Mineral Acquisition and Transport
Vascular Plants

Non-vascular plants: no transport tissues; small & inconspicuous

Vascular Plants: plants that have transport vessels for water, sugars, & minerals; most conspicuous plants
- grasses
- trees
- cacti
- herbs...
Vascular Tissues

Specifically for transport

Xylem: transports water & minerals
Transport

Water & minerals diffuse into root cells

Cohesion-tension pulls water & minerals up through plant as water vapor is lost
2.1.3 Food Translocation & Storage
Phloem

“Food” is sugars made via photosynthesis

Phloem: food transport tissues, shuttle sugars from leaves to rest of plant
Sugar Movement

Sugars build up in phloem, water diffuses in, sugar solution (sap) pushed throughout the plant
Food Storage

Some plants store carbohydrates as starch in stems or roots
- potatoes
- beets
- turnips
2.2 Plant Reproduction & Development
Plant Reproduction & Development

2.2.1- Alternation of Generations
2.2.2- Gamete Formation & Fertilization
2.2.3- Growth & Development
2.2.4- Tropisms & Photoperiodicity
2.2.1

Alternation of Generations
• alternation of phases
• diploid & haploid phases
2.2.2 Gamete Formation & Fertilization

- plant gametes
- plant sperm
- plant eggs
- fertilization in plants
2.2.3

Growth & Development

• plant hormones
• auxins
• cytokinins
• gibberellins
• abscisic acid
• ethylene
2.2.4

Tropisms & Photoperiodicity

- tropisms
- phototropism
- gravitropism
- thigmotropism
- photoperiodicity
2.2.1 Alternation of Generations
Alternation of Phases

The plant’s life cycle is an alternation of haploid and diploid phases

Both phases can undergo mitosis

Sporophyte dominant in most plants, but depends on species
Diploid & Haploid Phases

Sporophyte (ex: pine tree): diploid phase, produces spores via meiosis, which grow into gametophytes via mitosis

Gametophyte (ex: inside pine cones): haploid phase, produces gametes via mitosis, which fuse to form new diploid individual (a sporophyte)
2.2.2 Gamete Formation & Fertilization
Plant Gametes

Gametes in plants are named like gametes in animals:

- male gamete: sperm
- female gamete: egg
- zygote: fused sperm & egg (fertilized egg)
- embryo: growing zygote (more than a few cells)
Plant Sperm

Formed by male gametophyte

Produced in large numbers, leave to join eggs

Transmittal depends on species:
- swimming in plants from wet areas
- non-swimming & packaged inside pollen grains in other plants
Plant Eggs

Formed by female gametophyte

Produced in small numbers, larger

Transmittal uncommon (they stay put)
Fertilization in Plants

Similar to fertilization in animals- male & female gametes fuse to form zygote

In seed plants (ex: pines, roses) sperm must grow through female plant tissue to reach ovaries w/ eggs

In seedless plants (ex: mosses, liverworts) it’s simpler
2.2.3 Growth & Development
Plant Hormones

Function similarly to animal hormones, transported in vascular system

Control most aspects of growth & development

Often several interact
Auxins

Promote shoot elongation

Produced mostly in shoot tips; transported only from tip to base of shoot
Cytokinins

Stimulate cytokinesis

Produced in actively growing tissue: roots, embryos, fruits
Gibberellins

Affect cell division & elongation, fruit growth, seed germination

Young roots & leaves major sites of production
Abscisic Acid

Slows growth, often antagonizing actions of growth hormones

Ratio of ABA to growth hormones determines whether growth occurs
Ethylene

Produced in response to stresses...
• drought
• flood
• injury

And as part of normal life cycle
• fruit ripening
• programmed cell death
2.2.4 Tropisms & Photoperiodicity
Tropism

Any growth response that results in plants growing towards or away from stimuli
Phototropism

Response to light

Positive: plant organs grow toward light, most often seen in shoots

Negative: plant organs grow away from light, most often seen in roots
Gravitropism

Response to gravity

Roots display positive gravitropism

Shoots display negative gravitropism

Response occurs as soon as seed germinates & organs grow in appropriate direction no matter how seed is oriented when it lands
Thigmotropism

Response to touch

Comes in several forms

• trees in windy habitats grow short & thick
• plants that use objects for climbing
• plants that close when touched
Photoperiodicity

Physiological response to relative lengths of night & day

Affects growth & development
  • time of year for growing
  • time of year for flowering
2.3 Structure & Function in Animals
Structure & Function in Animals

1- Major Systems
2- Homeostatic Mechanisms
3- Hormones in Homeostasis & Reproduction
Major Systems

- the animal body
- digestive
- respiratory
- circulatory
- musculoskeletal
- nervous
- excretory
- immune
Homeostatic Mechanisms

• homeostasis
• homeostatic components
• feedback mechanisms
• thermoregulation
Hormones in Homeostasis & Reproduction

- endocrine system
- what is a hormone?
- endocrine glands
- hormones as signals
- hormones in reproduction
2.3.1 Major Systems
The Animal Body

Highly complex “machine” with numerous processes occurring simultaneously & systems cooperating to maintain life

Mostly controlled by hormones, but affected by environment
Digestive System

Processes ingested food & drink
Respiratory System

Responsible for intake of essential gases, release of waste gases
Circulatory System

Moves gases, nutrients, hormones throughout body
Musculoskeletal System

Muscles & skeleton work together to provide support, stability, movement
Nervous System

Passes messages between brain & body
Excretory System

Filters wastes & excess water from blood, releases outside body
Immune/ Lymphatic System

Defense against invaders (bacteria, viruses, parasites...)

2.3.2 Homeostatic Mechanisms
Homeostasis

“Steady state,” refers to maintenance of internal balance

Examples:
- temperature
- ion concentration
- blood oxygen
- blood glucose
Homeostasis

Set point: animal maintains a variable at or near a particular value

Stimulus: fluctuations in a variable

Sensor: detects stimuli & sends signal to control center

Control center: generates output that triggers a physiological response to stimulus

Hormones are chemicals used as signals, important for homeostasis
Homeostasis

Relies largely on negative feedback cycles, which reduce stimulus

“Negative” feedback because stimulus results in events that decrease it
Example:

1. human body temperature set point= 98.6°F
2. exercise produces heat that raises your body temperature (stimulus)
3. nervous system (sensor) sends message to control center (brain)
4. brain causes body to sweat (response)
5. Cooling from sweat decreases body temperature & sweating stops
Thermoregulation

Endothermy: internal temperature regulation through heat generated by metabolism; mammals, birds

Ectothermy: internal temperature regulated by external environment; amphibians, reptiles, most fish, most invertebrates
2.3.3 Hormones in Homeostasis & Reproduction
Endocrine System

Regulates body’s ‘set points’- temperature, heart rate, metabolism

Triggers important physiological events- puberty, reproduction

Facilitates cell to cell communication- glucose uptake, antihistamine release
Hormone

A chemical secreted by an endocrine gland/organ into the blood for transport

Affects growth, metabolism, development, homeostasis
Endocrine Gland

A ductless gland or single cell that secretes a hormone, which travels through blood

Hormone targets the cells or organs that have receptors for the hormone
In response to the lower concentration of glucose, the pancreas stops secreting insulin.

Food is consumed and digested, causing blood level glucose to rise.

In response to higher glucose levels, the pancreas secretes insulin into the blood.

In response to higher insulin levels, glucose is transported into cells and liver cells store glucose as glycogen. As a result, glucose levels drop.
Hormones as Signals

Once released by the control center (usually the brain), hormones work as signals in one of two ways:

1. diffuse into cells’ cytoplasm and join w/ receptor protein, which causes a response
2. join w/ receptor protein in cell membranes, which causes a response
Hormones in Reproduction

Hormones responsible for sexual maturation & cycling:

- development of gonads, which also release hormones
- development of sperm & eggs
- release of eggs
- development of embryos after fertilization
- contractions during labor or egg-laying
- lactation and other maternal behavior
2.4 Animal Reproduction & Development
Animal Reproduction & Development

1- Gamete Formation & Fertilization
2- Cleavage, Gastrulation, Germ Layers, Organ System Differentiation
3- Experimental Analysis of Vertebrate Development
4- Extraembryonic Membranes
5- Formation & Function of Mammalian Placenta
6- Blood Circulation in Human Embryo
Gamete Formation & Fertilization

- reproduction
- gametogenesis
- spermatogenesis
- oogenesis
- fertilization
Cleavage, Gastrulation, Germ Layers, Organ System Differentiation

- the zygote
- cleavage
- developmental stages
- germ layers
Experimental Analysis of Vertebrate Development

- Model Organisms
- Zebrafish
- Frogs
- Chicks
- Mice
- Fish in Space!
Extraembryonic Membranes

- extraembryonic membranes
- chorion
- amnion
- allantois
- yolk sac membrane
Formation & Function of Mammalian Placenta

- placental formation
- placental function
Blood Circulation in the Human Embryo

- embryonic blood vessels
- exchange with mother
2.4.1 Gamete Formation & Fertilization
Reproduction

Reproduction is complicated for multicellular organisms

Two processes involved

1. gametogenesis
2. fertilization
Gametogenesis

“Making gametes”
• sperm
• eggs
Spermatogenesis

Formation of sperm

Occurs in spermatogonia - cells in testes

1. Primary spermatocytes (2n) formed
2. Secondary spermatocytes (1n) formed from primary, via Meiosis I
3. Sperm cells (1n) formed from secondary spermatocytes via Meiosis II
Spermatogonium → Mitosis → Meiosis I → Secondary spermatocyte → Meiosis II → Sperm
Oogenesis

Formation of eggs

Occurs in oogonia—cells in ovaries

1. Primary oocyte (2n) present in ovaries from birth
2. Secondary oocytes (1n) formed from primary, via Meiosis 1; polar body also formed
3. Egg cells and polar bodies (1n) formed from secondary oocytes via Meiosis II
4. Polar bodies recycled
Meiosis I

2n Oogonium

Mitosis

2n Primary oocyte
Meiosis I

1n Polar body

Secondary oocyte

1n Meiosis II

1n Fertilized Egg
Fertilization

Sperm and egg join to form zygote
2.4.2 Cleavage, Gastrulation, Germ Layers, Organ System Differentiation
The Zygote

All sexually-reproducing multicellular organisms start life as a zygote (fertilized egg)
Cleavage

Zygote divides several times via mitosis, without changing size
Developmental Stages

1. Morula- solid ball of cells
2. Blastula- hollow sphere of cells
3. Gastrula (gastrulation)- hollow sphere of cells w/ tube through center that forms digestive canal
1. Zygote
2. Cleavage
3. Eight-cell stage
4. Cleavage
5. Blastula cross section
6. Gastrulation
7. Blastopore
8. Gastrula cross section
Germ Layers

Layers of tissue in developing organism

1. Endoderm - inside, forms alimentary canal
2. Mesoderm - in middle, forms muscles, bones, circulatory system, reproductive system
3. Ectoderm - outside, forms skin, nervous system
2.4.3 Experimental Analysis of Vertebrate Development
Model Organisms

Model organisms are used to learn about generalities in vertebrate development

The majority of what we know about development has come from these models
Zebrafish

Zebrafish embryos have been used to explore:

• effects of inhibitors
• effects of alcohol
• stages of development
Frogs

Frog embryos have been used to investigate:

- blastula formation
- causes of two-headedness
- control of spinal formation
Chicks

Chicken embryos are used to learn about:
  • formation of limbs  
  • signaling molecules
Mice

Study of mouse embryos have helped us understand:
  • toe formation & separation
  • cell fate determinants
Fish in Space!

The medaka, and Asian relative of the zebrafish, is being used to study the effects of low gravity on vertebrate embryo development.
2.4.4 Extraembryonic Membranes
Extraembryonic Membranes

Membranes outside the embryo, surrounding embryo during development
Chorion

Regulates water, gases, nutrients, wastes
  • In egg-layers, in contact with inner shell surface
  • In others, in contact with uterus
Amnion

Fluid-filled sac around embryo
- cushioning
- temperature regulation

[Diagram showing Amnion components]
- Amniotic cavity (filled with amniotic fluid)
- Albumen
- Yolk
- Yolk sac
- Amnion
- Embryo
- Allantois
- Chorion
Allantois

Comes from developing digestive tract, gas & nutrient exchange
• becomes umbilical cord in non-egg layers
• waste storage in egg-layers
Yolk Sac Membrane

Comes from developing digestive tract, encloses yolk sac that stores nutrients

- becomes part of umbilical cord in non-egg layers
- larger in non-egg layers
2.4.5 Formation & Function of Mammalian Placenta
Placental Formation

Formed from outer cells of embryo and inner cells of uterus

Connection between mother & embryo
Placental Function

Function: transfer nutrients, water, wastes between mother & embryo
2.4.6 Blood Circulation in Human Embryo
Human embryos develop their own blood vessels
Embryo’s blood vessels next to mothers, and molecules exchanged via diffusion:
• from mother to embryo- nutrients, water, oxygen
• from embryo to mother- carbon dioxide & waste
2.5 Principles of Heredity
Principles of Heredity

1- Mendelian Inheritance
2- Chromosomal Basis of Inheritance
3- Linkage
4- Polygenic Inheritance
Mendelian Inheritance

- Gregor Mendel
- terminology
Chromosomal Basis of Inheritance

- Mendel’s Laws
- probability
- Punnett square
Linkage

- Non-Mendelian genetics
- sex linkage
- cat coat color
- other Linkage
Polygenic Inheritance

- multiple genes
- disease
2.5.1 Mendelian Inheritance
Gregor Mendel

Inheritance: characteristics passed from one generation to another, in form of genes

Mendel: Austrian monk who studied pea plant inheritance ~1865

First to quantify genetic tests
Mendel’s ideas still accurate for simple systems

Mendel coined several terms still used:

1. **Allele**: alternate form of gene, everyone has 2 alleles for each gene, represented by a letter (R, r)
2. **Homozygous**: two copies of same allele (RR or rr)
3. **Heterozygous**: one copy of each allele (Rr)
4. Dominant allele: always expressed when present, shown by capital letter (R, G, N)
5. Recessive allele: masked when dominant allele present, shown by lowercase letter (r, g, n)
Terminology

6. **Genotype**: alleles carried by individual
7. **Phenotype**: appearance of individual
8. **Cross**: sexual reproduction between different individuals
9. Character: a feature, like hair color or plant height
10. Trait: the genotype or phenotype of an individual for a given character (red hair or dwarf plants)
2.5.2 Chromosomal Basis of Inheritance
Mendel’s Laws

Law of Independent Assortment: Every possible combination of alleles is equally likely for each gamete
Mendel’s Laws

Law of Segregation: Paired genes separate and randomly recombine in gametes, so offspring have an equal likelihood of inheriting either
If independent assortment is occurring, laws of probability predict genotypes of offspring from crosses.

Parental generation (P): the parents of a cross b/w two individuals

First Filial generation (F₁): offspring of P

Second Filial generation (F₂): offspring from cross b/w two F₁ individuals
Punnett Square

Method of predicting offspring genotypes, using probability

Use gametes possible from each parent to see predicted offspring genotypes & phenotype ratios

P: Yy x Yy
F₁: ¼ YY, ½ Yy, ¼ yy
2.5.3 Linkage
Non-Mendelian Genetics

Since Mendel’s time, we’ve discovered that his Law of Independent Assortment isn’t always true.

- Some genes only on sex chromosomes
- Some genes always inherited together
Sex Linkage

Sex-linked genes: those located on either sex chromosome

Y-linked genes usually harmless because so small
Sex Linkage

X-linked genes are responsible for several human genetic conditions

- color-blindness in men
- Duschene muscular dystrophy in men
- hemophilia
Cat Coat Color

Tortoiseshell coat coloration the result of X-linked genes

- genes for orange and black coat color are both on the X chromosome
- males (Xy) express the color on their one X
- females (XX) express both colors, causing tortoise-shell patterning if black & orange
- only males with XXy genotype can be tortoiseshell or calico
Other Linkage

Linkage: autosomal genes inherited together during meiosis if close together

As distance between genes increases, likelihood of linkage decreases
2.5.4 Polygenic Inheritance
Polygenic inheritance: two or more genes affect the same phenotypic character

- Human height
- Human eye & skin color
Polygenic traits hard to predict, but can contribute to many illnesses
  - diabetes
  - heart disease
  - hypertension
3. Population Biology
Principles of Ecology

1- Energy Flow & Productivity in Ecosystems
2- Biogeochemical Cycles
3- Population Growth & Regulation
4- Community Structure, Growth, Regulation
5- Habitat
6- Concept of Niche
7- Island Biogeography
8- Evolutionary Ecology
Principles of Evolution

1- History of Evolutionary Concepts
2- Concepts of Natural Selection
3- Adaptive Radiation
4- Major Features of Plant & Animal Evolution
5- Concepts of Homology & Analogy
6- Convergence, Extinction, Balanced Polymorphisms, Genetic Drift
7- Classification of Living Organisms
8- Evolutionary History of Humans
Principles of Behavior

1- Stereotyped, Learned Social Behavior
2- Societies
Social Biology

1- Human Population Growth
2- Human Intervention in Natural World
3- Biomedical Progress
3.1 Principles of Ecology
Principles of Ecology

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8- Evolutionary Ecology
Energy Flow & Productivity in Ecosystems

- Energy Flow
- Trophic Levels
- Trophic Categories
- Ecological Roles
- Transfer of Energy
Biogeochemical Cycles

- Introduction
- Water
- Carbon
- Nitrogen
- Phosphorous
Population Growth & Regulation

- Introduction
- Limiting Biotic Factors
- Limiting Abiotic Factors
- Density
- Demography & Growth
Community Structure, Growth, Regulation

- Introduction
- Competition
- Symbiosis
- Succession
Habitat

- Definition & examples
Concept of Niche

• Definition & examples
Island Biogeography

- Introduction
- Dispersal
- Species Diversity
- Immigration & Extinction
- Area Effects
- Distance Effects
- Age Effects
Evolutionary Ecology

- Introduction & Example
- Interactions
- One-way Interactions
- Reciprocal Interactions
3.1.1 Energy Flow & Productivity in Ecosystems
Energy Cycle

Also ‘Food Chain’ and ‘Food Web’
- represent flow of energy (matter)
- show how energy enters & leaves
Trophic Levels

Producers: make energy accessible to ecosystems via photosynthesis

Consumers: eat producers or other consumers
Trophic Categories

Autotrophs: self-feeders, producers, make food molecules from sun

Heterotrophs: other-feeders, consumers, get food molecules from eating other
Ecological Roles

Herbivores: eat plants

Carnivores: eat animals

Omnivores: eat plants & animals
Transfer of Energy

Very inefficient due to heat loss

Each higher level gets 10% of previous

Transfer of Energy

1J

10J

100J

1000J
3.1.2 Biogeochemical Cycles
Biogeochemical Cycle?

Bio: living things
Geo: sediments/ rocks
Chemical: molecules
Cycles: circular movement

Circular movement of molecules through an ecosystem’s living and non-living things
The Nitrogen Cycle

Nitrogen gas in atmosphere ($N_2$)

- Denitrification by bacteria
- Nitrification by bacteria to $NO_3^-$
- Nitrification by bacteria to $NO_2^-$
- Nitrogenous wastes in soil
- Freshwater
- Terrestrial food webs
- Marine food webs
- Fertilizers
- Runoff
- Denitrification by bacteria to $N_2$
- Nitrification by bacteria to $NO_3^-$, $NO_2^-$
- Nitrogenous sediments fall to ocean floor

Ammonification by bacteria and fungi to $NH_4^+$
3.1.3 Population Growth & Regulation
What is it?

Study of groups of organisms of one species living together (population)
- limiting factors
- birth rate
- death rate
- growth rate
Limiting Biotic Factors

- Dispersal: movement away from center
- Competition
- Predators
- Lack of prey/food
- Parasites
Limiting Abiotic Factors

- Climate
- Landscape
- Soil
- Water salinity
- Sunlight
Density

Density: # individuals per unit area

Density-dependent regulators:
  • competition
  • predation
  • disease
Density

Density-independent regulators:
  • climate
  • disturbance (fire, flood, etc.)
  • pollution
Demography & Growth

Demography: vital statistics like birth & death rate, age at maturity

Growth rate: how fast is population getting larger or smaller? Rate of growth \( (r) \) equals births \( (b) \) minus deaths \( (m) \)
\[
    r = b - m
\]
3.1.4 Community Structure, Growth, Regulation
What is it?

Study of interactions among different species in the same area
  • competition
  • predation
  • symbiosis
  • succession
Competition

More than one species in community attempts to use the same limited resource
Competitive Exclusion Principle: no two species can occupy the same niche indefinitely; one will be a better competitor, other will go extinct locally.

Niche partitioning allows coexistence.
Symbiosis

Close interaction b/w two species
1. Mutualism: both benefit
2. Commensalism: one benefits, other neutral
3. Parasitism: one benefits, other harmed
Succession

Process through which community recovers from disturbance

1. Primary: no soil
   (ex: lava flows, glacial moraine)
2. Secondary: soil present
   (ex: abandoned fields)
3.1.5 Habitat
Habitat

Species’ physical location, including all biotic & abiotic factors it needs to survive

- pond
- forest
- river
- grassland
3.1.6 Concept of Niche
Ecological Niche

Species’ role in community
  • time of day/ year
  • parts of habitat
  • prey size
  • temperature
  • trophic level
3.1.7 Island Biogeography
Biogeography

Study of distribution of organisms in space, historically & currently
Island Biogeography

Biogeography specific to islands & their species
- dispersal
- species diversity
  - area effects
  - distance effects
  - age effects
Dispersal

Species reach islands by dispersal methods
  • flying
  • blown by wind
  • floating on water
Species Diversity

Number of species on island determined by:
• immigration & extinction rates
• size
• distance
• age
Immigration & Extinction

As diversity increases, immigration rate decreases and extinction rate increases
Area Effects

Diversity highest on larger islands
Distance Effects

Diversity highest on near islands
Age Effects

Diversity is highest on older islands
3.1.8 Evolutionary Ecology
What is it?

Study evolution of interactions between & among species and with their environment

- competitors
- mutualists
- predators
- prey
- pathogens
Example: Research on the origin of the mutualism b/w termites and protozoa
Interactions

Two types studied:
1. with physical environment
2. with other species
   a. one-way
   b. reciprocal
One-way Interactions

One species affects another, but not vice versa
  • commensalism
Reciprocal Interactions

Two species affect each other

- predator-prey
- parasite-host
- competitors
3.2 Principles of Evolution
Principles of Evolution

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History of Evolutionary Concepts

- Evolution
- Carolus Linnaeus
- Lamarck
Concepts of Natural Selection

- Darwinian Concept
- Modern Synthesis
Adaptive Radiation

- Adaptations
- Species
- Resource Partitioning
Major Features of Plant & Animal Evolution

- Plant Evolution
- Animal Evolution
- Explosions
Concepts of Homology & Analogy

• Homology
• Analogy
Convergence, Extinction, Balanced Polymorphisms, Genetic Drift

- Convergence
- Extinction
- Balanced Polymorphisms
- Genetic Drift
Classification of Living Organisms

• Taxonomy
• Taxa
• The Domain
• Classification of Domestic Cat
• Eukaryote Kingdoms
• Animal Phyla
Evolutionary History of Humans

- Order Primates
- Great Apes
- Hominid Fossils
- Location
3.2.1 History of Evolutionary Concepts
Evolution

Genetic change in a population over time
Carolus Linnaeus

Invented binomial nomenclature

Wrote about origins & relationships b/w organisms (1700s)
Lamarck

Proposed that organisms acquire traits throughout lifespan & pass these on (proven false)
3.2.2 Concepts of Natural Selection
Natural Selection is driving force behind evolution

- more offspring produced than can survive
- variation in characteristics among individuals of population
- some individuals better competitors
- these have more offspring
- frequency of characteristic increases in population
- population smallest unit that can evolve
Modern Synthesis

Darwin’s theory still supported, but we know more details now:

- characteristics result from genes
- variations in characteristics result from alleles
- evolution can take thousands of years
3.2.3 Adaptive Radiation
Adaptations

Inherited characteristics that provide survival/ reproductive advantages

• speed
• camouflage
• armour
• hearing
Species

Population of interbreeding individuals, common gene pool, viable offspring, don’t interbreed w/ other populations

A new species forms when two populations no longer interbreed
Resource Partitioning

Decreases competition b/w species by utilizing more specialized niches

Adaptive radiation occurs as result of resource partitioning:
  • alleles that allow individuals to use resources differently are adaptive
  • over time, many new species evolve as result of benefits of using new niches
3.2.4 Major Features of Plant & Animal Evolution
Plant Evolution

Endosymbiont Theory explains evolution of autotrophs from heterotrophs

Early plants were aquatic, asexual

Movement to land accompanied by adaptations for water storage, increased gravitational pull
Plant Evolution

Separate sexes allowed for greater genetic diversity

First land plants didn’t have seeds

Evolution of seeds allowed colonization of more habitats

Evolution of flowers allowed animal attraction for pollination & seed dispersal
First animals were aquatic, unicellular, soft-bodied

Multicellularity & hard structures appeared (spicules, exoskeletons)

Invertebrates first on land

Animal Evolution
Fish were first with backbones

Adaptations for conserving water & dealing with higher gravitational pull appeared with land colonization
Explosions

Cambrian explosion: rapid increase in multicellular organisms

- aquatic plants appeared
- most major animal phyla appeared
- new niches evident: active hunting, burrowing into sediment, making branching burrows
3.2.5 Concepts of Homology & Analogy
Homology

Similar structures resulting from common ancestry, could have different functions.
Analogy

Similar structures resulting from common function but not common ancestry
3.2.6 Convergence, Extinction, Balanced Polymorphism, Genetic Drift
Convergence

Convergent evolution: unrelated species evolve similar characteristics due to similar environments
Extinction

When a species disappears from planet forever

Permian extinction (250mya): 96% species lost
Polymorphism: genetic diversity within a species for a particular trait

Balanced Polymorphism: natural selection tends to keep number of forms stable; when one is scarce, its fitness increases
Genetic Drift

Random change in allele frequency for a particular trait in a single population

Ex: Storm randomly causes death of most squirrels carrying alleles for light coat color
3.2.7 Classification of Living Organisms
Taxonomy

Organizes living things into groups based on appearance, genetics, evolutionary history

Carolus Linnaeus invented binomial nomenclature, using genus & species “Scientific name” *Borrelia burgdorferi*
Taxa

Taxon: level of classification of living things

Kingdom
Phylum
Class
Order
Family
Genus
Species
The Domain

Recent addition to taxonomy

3 Domains, encompass all other taxa
- Archaea
- Eubacteria
- Eukaryota
Classification of Domestic Cat

Domain: Eukarya (eukaryotes)
Kingdom: Animalia (heterotrophs)
Phylum: Chordata (backbones)
Class: Mammalia (milk)
Order: Carnivora (meat)
Family: Felidae (hypercarnivore, claws)
Genus: *Felis* (small)
Species: *catus* (domesticated)

Scientific Name: *Felis catus*
Eukaryote Kingdoms

1. Animalia - animals
2. Plantae - plants
3. Monera - fungi
4. Protista - unicellular, animal-like or plant-like
Animal Phyla

1. Porifera- sponges
2. Cnidaria- jellies
3. Platyhelminthes- flatworms
4. Nematoda- roundworms
5. Mollusca- clams, snails, squid
6. Annelida- earthworms
7. Arthropoda- crabs, insects, spiders
8. Echinodermata- starfish, sea urchins
9. Chordata- fish, mammals, birds, reptiles, amphibians
3.2.8 Evolutionary History of Humans
Order Primates

Prosimians: lemurs, lorises

More recent:
- tarsiers
- new world monkeys
- old world monkeys
- apes- gorilla, chimpanzee, orangutan, human
Great Apes

Humans, gorillas, chimpanzees, bonobos, and orangutans have recent common ancestor

First true hominids 4.5mya, larger brains & bipedal locomotion
Hominid Fossils

1. *Australopithecus afarensis* (Lucy) - 4.5mya, head smaller, long arms
2. *Homo erectus* - first from same genus, 1.8mya, head larger, facial features
3. First *Homo sapiens* (Cro-Magnon Man) - 100,000 years ago, looked like us
Location

Oldest human fossils from Africa

Fossils suggest we evolved in Africa 100,000 years ago, migrated throughout Europe, Asia, the Americas

Crossed Bering Land Bridge into North America, then to Central & South America
3.3 Principles of Behavior
Principles of Behavior

1- Stereotyped, Learned Social Behavior
2- Societies
Stereotyped, Learned Social Behavior

- Stereotyped Behaviors
- Fixed Action Patterns
- Learned Behaviors
- Conditioning
- Habituation
- Imprinting
Societies

- Society
- Insect Societies
- Primate Societies
3.3.1 Stereotyped, Learned Social Behavior
Stereotyped Behaviors

Instinctive, performed the same way by all individuals of species, in response to a stimulus

1. **taxis** - directional
2. **kinesis** - speed change
3. **reflex** - automatic
   movement of body part
4. **fixed action pattern** - more complex series of behaviors
Fixed Action Pattern (FAP)

Behavior sequence continues, even when stimulus removed
- courtship behaviors
- feeding young
- circadian rhythms
Learned Behaviors

Not instinctive, must be seen & practiced, can be stopped mid-behavior, based on life experience
• conditioning
• habituation
• imprinting
Conditioning

Behavioral response to one stimulus is applied also to different stimulus
  • dogs drool when they smell food
  • ring a bell when food presented
  • dogs eventually drool BOTH when they smell food and hear bell
Habituation

Response decreases with exposure to stimulus if no positive or negative result
- cat cries at night for attention
- you ignore cat, so nothing good or bad happens
- cat eventually stops crying at night
Imprinting

Attachment to another animal or object during critical period (usually shortly after birth/hatching)

- crane hatchlings see a person right after hatching, instead of another crane
- hatchlings imprint on person, following around to learn
3.3.2 Societies
Society

Organization of individuals in population, tasks divided so group works together
Insect Societies

Bees, ants, some wasps
- only queen breeds
- workers are her daughters
- different jobs, depending on age
  - nursery
  - cleaner
  - queen care
  - guard
  - forager
Primate Societies

Built around concept of dominance

- more dominant individuals get best access to mates, resources
- individuals compete for status, often when sexual maturity reached by young
- altruistic behavior common when members related
3.4 Social Biology
Social Biology

1- Human Population Growth
2- Human Intervention in Natural World
3- Biomedical Progress
Human Population Growth

- Human Populations
- Life Span
- Growth Rate
- Demographic Transition
Human Intervention in Natural World

- Human Population Size
- Pollution
- Resource Management
Biomedical Progress

- Nutrition
- Medical Advances
- Treatments
- Other Advances
3.4.1 Human Population Growth
Human Populations

Grow by same means as other populations
  births – deaths = growth

Complex, b/c we reason around resource limitations, technology, think about reproductive behavior
Life Span

Better nutrition & medicine have increased human life span

Infant mortality greatly decreased

Birth rate decreased due to contraception
Growth Rate

Over 7 billion people in 2016

Doubling time decreased

Technology increased food production, but starvation happens due to distribution
Demographic Transition

Theory proposes progressive demographic time periods of human population growth.
Demographic Transition

1- At first, birth & death rates equal, population in equilibrium w/ environment

2- Societal developments of medicine & food production allow birth rate to overtake death rate, population increases rapidly
Demographic Transition

3- Agrarian lifestyles (many children for labor) become less common, children liability in urban society

4- Medical advancement decreases infant mortality, urban populations increase rapidly
Demographic Transition

5- Industrialized countries lower birth rate using contraceptives

6- Increasing population strains environment, resources
3.4.2 Human Intervention in Natural World
Human Population Size

Profound effects on environment
- pollution
- habitat loss
- overharvesting
- introduced species
- climate change
Pollution

Started as result of ignorance during Industrial Revolution

Addition of foreign substances to air, water, soil, etc.

- fertilizers, pesticides, herbicides
- industrial cleaners
- carbon emissions
- trash
Pollution
Resource Management

We’ve had success repairing damaged ecosystems

We’ve learned ways to protect threatened species & ecosystems

“Reduce, reuse, recycle” works
3.4.3 Biomedical Progress
We’ve learned importance of essential nutrients, allowing healthier, longer lives.

Decreases sickness due to malnutrition:
- scurvy
- goiter
- anemia
Medical Advances

Development of antibiotics in 1920s decreased deaths from infection

Vaccines protect from previously lethal diseases (flu, smallpox, rabies, etc.)

Antiviral treatments decrease sickness after viral infection (AIDS)
Treatments

Improvements in managing illness, synthesizing molecules have allowed people to live longer & more comfortably

- heart disease
- osteoporosis
- arthritis
- cancer
- diabetes
Other Advances

Genetically Modified Organisms have increased agricultural output

Use bacteria to make:
  • human insulin
  • vaccines
  • cancer treatments

Investigating stem cells for organ transplantation