

Science (see Unit 2 & Unit 6 on d2l)

Scientific method

- Observe patterns
- Develop hypotheses
- Derive predictions of hypotheses
- Design & implement study to test hypotheses
- Analyze & interpret results
- Reject hypothesis, redefine hypothesis, or continue to test if results support it.

Types of scientific studies

- Correlative--observe statistical relations among variables without manipulation
- Experiment--manipulate system & observe response
 - Independent variables, dependent variables, control & treatment groups
 - Blind & double-blind experiments

Good science--balance, logic, verifiability or falsifiability, repeatability, consistency

Scientific consensus

Study design--random sampling to avoid bias

Statistics & plotting data

Scientific method in practice

- Grant review & funding
- Peer review & publication--authors, reviewers, editors
- Conference presentations & posters
- Further research by scientific community
- Paradigms & scientific revolutions

Scientific theories & historical evidence

Matter

Subatomic particles, elements, atoms, periodic table, isotopes, compounds

Electrons & energy, chemical bonds

Ionic bonds, covalent bonds, hydrogen bonds

Chemical reactions

Life

Distinguishing characteristics of living organisms

- Growth, development, reproduction
- Need energy & materials, metabolism, cellular respiration
- Composed of cells
- Organization
- Adaptation
- Genes

Biological hierarchy

Cell, tissue, organ, organ system, organism (individual)

Ecological hierarchy

Organism (individual), population, community, ecosystem, landscape, biome, biosphere

Biochemistry

Molecular shape & biological function

Properties of water

High heat capacity, high heat of vaporization

Polar solvent

Cohesion & adhesion

Expands on freezing

Hydrogen & hydroxide ion concentration, pH, acids, bases, buffers

Carbon and organic molecules

Monomers & polymers

Carbohydrates, lipids, proteins, nucleic acids

Dehydration synthesis & hydrolysis

Metabolism

Catabolism (for example, hydrolysis)

Anabolism (for example, dehydration synthesis)

Cell structure & function

Cytoplasm

Organelles

Nucleus

Genes in DNA

Envelope (2 membranes), DNA replication & RNA transcription

Mitochondria

2 membranes, cellular respiration, abundant in muscle cells

Matrix, intermembrane space, cristae

Chloroplasts

2 membranes, photosynthesis, abundant in leaves

Ribosomes

No membranes, 2 subunits composed of RNA & protein, translation

Endoplasmic Reticulum

One membrane surrounding lumen

Lipid bilayer synthesis, transport to membranes

Rough ER (with ribosomes)

Smooth ER (no ribosomes)

Golgi apparatus

Stack of membrane-bound "pancakes"

Staging area for ER products

Lysosomes--1 membrane, intracellular digestion

Peroxisomes

1 membrane, oxidation of toxins by peroxide, abundant in protective cells

Vesicular transport--ER, transport vesicles, Golgi apparatus, secretory vesicles

Cell membranes

Phospholipid bilayer with embedded proteins

Hydrophilic & hydrophobic ends of phospholipids

Hold cytoplasm in cell, flexible shape

Selective transport across membranes

Facilitated diffusion, active transport, bulk transport

Cell walls--Found in plants, algae, bacteria; Rigid, made of carbohydrates

Energy & life

Conservation laws & thermodynamics

Conservation of matter

Conservation of energy (1st law of thermodynamics)

Forms of energy--kinetic, potential, heat, electromagnetic radiation, etc.

Second law of thermodynamics

Entropy (disorder) increases in closed systems.

Transition among forms of energy results in a loss of useful energy.

Products of photosynthesis are reactants of cellular respiration and vice-versa.

ATP, NADH, NADPH

Photosynthesis

Photoautotrophs use solar radiation to build organic molecules that store energy.

Plants, algae, cyanobacteria

Photosynthesis requires energy input from light.

Carbon dioxide and water are used to build food molecules, releasing oxygen.

Glucose is the primary food molecule produced by photosynthesis.

Light-dependent reaction, photosynthetic electron transport, light-independent reaction

Cellular respiration

Cellular respiration releases stored energy for use in metabolic reactions.

Food molecules are burned with oxygen to yield carbon dioxide and water.

Glycolysis & fermentation (metabolic cascades, roles of enzymes)

Citric acid cycle, electron transport chain, oxidative (chemiosmotic) phosphorylation

Reproduction

Cellular reproduction

Somatic

Cell cycle

Interphase

G₁, S, G₂

Mitosis (separation of replicate chromatids in preparation for cytokinesis)

Spindle fibers, centromeres

Prophase, metaphase, anaphase, telophase

Ploidy of daughter cells is same as ploidy of parent cell.

Cancer

Normal cell activity

Contact inhibition, apoptosis, differentiation, etc.

Cancer cell activity

Abnormal nucleus, disorganized, metastasis, angiogenesis

Cancer treatment

Gametic (germ line)

Gametogenesis--spermatogenesis & oogenesis

Meiosis (segregation of homologous chromosomes into haploid gametes)

Meiosis I (reduction division)

Prophase I, metaphase I, anaphase I, telophase I

Ploidy is reduced from diploid to haploid.

Independent assortment of genes on different chromosomes

Meiosis II

Metaphase II, anaphase II, telophase II

Parent cells and daughter cells are haploid.

Organismal reproduction (see Units 5 & 7 on d21)

Asexual

Cloning

Binary fission

Budding

Ameiotic parthenogenesis

Haplodiploidy

Meiotic parthenogenesis

Sexual--dioecy (separate sexes), monoecy (hermaphroditism)

Sexual life cycle

Meiosis, ovum, sperm, fertilization, zygote, embryo, development

Costs to individual

Half of all alleles thrown away during meiosis.

Half of offspring (males) can't produce eggs.

Advantage for population

Increased variability, so sexual populations can adapt to changes

Sex determination in *Drosophila*, mammals, & reptiles

Maternal physiological investment

Ovipary

Ovovivipary

Vivipary--example: placental mammals

Genetics

Genetic analysis (transmission genetics)

Mendelian genetics

Alleles, genes, genome, genotype, phenotype, dominance relations

Pea genes--plant height, seed color, seed shape

Monohybrid & dihybrid crosses, homozygous & heterozygous

P, F₁, F₂, Punnett square, genotypic & phenotypic ratios

Segregation & independent assortment

Chromosomes

Autosomal genes--autosomes have homologues

Sex-linked genes--homogametic (XX) & heterogametic (XY) sexes

Linked genes

Human inheritance

Pedigree analysis (male squares, female circles)

Autosomal recessive disorders--Tay-Sachs disease, cystic fibrosis

Autosomal dominant disorders--Huntington's chorea

X-linked recessive disorders--hemophilia

Polymorphism--PTC tasting, blood groups

Incomplete dominance--sickle-cell anemia

Sex-influenced traits

Codominance (A & B blood types)

Multiple alleles (ABO gene locus)

Genetic counseling

Molecular genetics

DNA structure

Nucleotide--phosphate, deoxyribose, nitrogenous base

Double helix of 2 antiparallel strands

Phosphodiester backbones, complementarity

DNA function

Replication--Template strand, leading strand, lagging strand, Okazaki fragment

Enzymes: Helicase, RNA polymerase, DNA polymerase, DNA ligase

Transcription--synthesis of complementary RNA strand from gene in DNA

RNA structure

Single-stranded, ribose, uracil instead of thymine

RNA function--transcription, etc

Translation (protein synthesis)

Ribosome, ribosomal RNA, messenger RNA, transfer RNA, polypeptide

Causes & consequences of mutations

Gene regulation

Regulatory proteins, DNA binding sites, promoter, lactose operon in *E. coli*

Biotechnology--Cloning genes & organisms, genetic engineering

Recombinant DNA--complementarity & DNA-binding proteins, endonucleases

Splicing, vector, replication, amplification, clone, donor, recipient, PCR

Sources of genes to clone--genomic DNA, cDNA, synthesized oligonucleotides

Applications of genetic engineering

Research, protein synthesis, agriculture, medicine, forensics, sequencing

Ethical, legal, environmental, & social questions

Evolution

Lamarck, Lyell, Malthus, Darwin, Wallace

Darwin

Voyage on HMS Beagle, Galapagos

Natural selection & adaptation

Population growth & limits to growth

Competition & heritable variation

Differential fitness (survival & reproduction)

Gradual adaptation

Reproductive barriers & speciation

Evidence for evolution

Fossil record, evolutionary trends

Carbon dating

Homologous & vestigial structures

"Ontogeny recapitulates phylogeny." --Haeckel

Genetics

Experiments (such as lizards introduced to a new island)

Microevolution

Population genetics

Gene pool

Hardy-Weinberg equilibrium

Forces that change allele frequencies

Mutation, genetic drift, nonrandom mating, migration, selection (natural, sexual)

Measuring genetic variation

Macroevolution

Allopatric & sympatric speciation

Hybridization & extinction

Adaptive radiation (diversification)

Gradualism, punctuated equilibrium

Mass extinction

Levels of selection--genic, individual, kin, group, species

Biological diversity

Taxonomy--domain, kingdom, phylum, class, order, family, genus, species

Noncellular quasi-organisms--Viruses, viroids, prions, plasmids

Prokaryotes

Unicellular, no nucleus or membrane-bound organelles

Binary fission, conjugation, plasmids, recombination

Aerobic or anaerobic, heterotrophic or autotrophic

Autotrophic prokaryotes--photoautotrophs, chemoautotrophs

Symbiosis--Mutualistic, commensalistic, or parasitic

Domain Bacteria--Gram-staining, shell shape, biochemical characteristics

Domain Archaea

Biochemical characteristics distinguish Domains Bacteria, Archaea, & Eukarya.

Extremophiles

Eukaryotes--nucleus & membrane bound organelles, endosymbiosis

Protists, Fungi, Plants, Animals

Kingdom Protista--Unicellular or multicellular, classification by mode of nutrition

Algae--chlorophyll a, photosynthesis

Diatoms--unicellular, with cell wall

Phylum Rhodophyta (red algae)

Phylum Chlorophyta (green algae)

Flagellates

Diatoms & dinoflagellates are important marine producers

Protists with pseudopods

Ciliates

Slime molds

Phylum Oomycota (water molds)

Kingdom Plantae

Evolution and diversity

Relationship with green algae

Alternation of generations, spores, gametes, zygote

Forests of the Carboniferous Era, fossil fuels

Human uses of plants

Bryophytes (non-vascular plants)

Gametophyte and sporophyte

Phylum Anthocerothyta (hornworts)

Phylum Hepatophyta (liverworts)

Phylum Bryophyta (mosses)

Moss life cycle, antheridia and archegonia

Vascular plants

Xylem and phloem

Stomata--gas exchange, guard cells, photosynthesis, transpiration

Dominant sporophyte

Seedless vascular plants

Phylum Lycophyta (club mosses)

Phylum Sphenophyta (horsetails)

Phylum Psilotophyta (whisk ferns)

Phylum Pterophyta (ferns)

Fern life cycle, fronds

Seed plants

Pollen grain and female gametophyte, pollination, seed

Dioecy and monoecy

Gymnosperms

Phylum Coniferophyta (cone-bearing plants)

Phylum Cycadophyta (cycads)

Phylum Ginkgophyta (ginkgo tree)

Phylum Gnetophyta

Angiosperms (flowering plants)

Phylum Anthophyta

Monocots and dicots, cotyledons

Flower parts

Pollinators, pollen tube

Structure and organization (roots, shoots, meristem); Nutrition & transportation; Hormones

Kingdom Fungi--Multicellular or unicellular

Saprophytic decomposers, hyphae, nutrient cycling

Spores, sexual and asexual reproduction

Phylum Zygomycota

Phylum Ascomycota

Phylum Basidiomycota

Fungal symbioses--lichens, mycorrhizae

Kingdom Animalia--Multicellular, invertebrate vs vertebrate, protostome vs deuterostome

Phylum Porifera--sponges

Mostly marine, radially symmetrical or asymmetrical, sessile adults

Maintain internal water currents to obtain food, ostia & osculum

No nervous system or sensory organs, spongocoel

Phylum Cnidaria--jellyfish, corals, sea anemones, etc.

Radially symmetrical

Tissue level of organization, saclike body plan, tentacles, nerve net, mouth

Aquatic, mostly marine, muscles for locomotion, polyp & medusa

Phylum Platyhelminthes--flatworms

Bilateral symmetry, head, organ-system level of organization, free-living or parasitic

Anterior ganglia for "brain", sensory organs

Planarian--free-living

Sac-like digestive system, ventral mouth, pharynx, intestine, eyespots & auricles

Class Cestoda (tapeworms)--endoparasitic

Phylum Nematoda--roundworms

Found everywhere--aquatic, terrestrial, parasitic

Tube-within-a-tube (complete) digestive system: mouth, pharynx, intestine, rectum, anus

Phylum Annelida--segmented worms (marine worms, earthworms, leeches, etc.)

Segmentation, somites, cerebral ganglia for brain, complete digestive system

Nephridia (kidneys) in each segment remove waste from blood

Phylum Mollusca--snails, slugs, clams, mussels, squid, octopi, etc.

Spiral cleavage, unsegmented, organ systems, shell, foot

Phylum Arthropoda

Diversity & abundance, somites, jointed appendages, metamorphosis

Horseshoe crabs, spiders, scorpions, crustaceans, insects, centipedes, millipedes, etc.

Beneficial (pollinators) & harmful insects

Phylum Echinodermata--sea stars, brittle stars, sand dollars, sea urchins, etc.

Radial cleavage, spiny skin, water vascular system, bilateral larvae, radial adults

Phylum Chordata

Notochord, dorsal hollow nerve cord, pharyngeal gill slits, postanal tail

Tunicates, lancelets, vertebrates

Subphylum Vertebrata--vertebrates

Fishes--hagfishes, lampreys, cartilaginous fishes, bony fishes

Tetrapods--early tetrapods, colonization of land, fins become legs, lung

Amphibians--water for reproduction, ectothermic, gills as larvae

Reptiles--amniotic eggs, ectothermic, lungs, direct development

Birds--amniotic eggs, endothermic, 2-cycle lungs, dinosaurs & feathers

Mammals--Hair, endothermic, glands in skin, placentals are viviparous

Opossums, moles, bats, humans, rabbits, rodents, dogs, deer, etc.

Animal physiology--organization, homeostasis, organ systems

Circulatory system

Moves stuff around--gas exchange, nutrients, immune cells, hormones, platelets

Open & closed circulatory systems

Arteries & veins, capillaries, pulmonary & systemic circuits

Heart--Chambers, valves, arteries leaving heart, veins entering heart

Immune (lymphatic) system

Regulates fluids & fats, produces lymphocytes to fight infection

Bone marrow, thymus, lymph vessels, lymph nodes, tonsils, spleen

Respiratory system

Gas exchange, relation with circulatory system, internal & external respiration

Gills in fish

Mammals--trachea, larynx, bronchi, bronchioles, lungs, alveoli

Hemoglobin in erythrocytes, concentration of gases

Digestive

Nutrition--nutrients and energy

Ingestion, digestion, absorption, assimilation

Mouth, teeth, tongue, pharynx, esophagus, stomach, small intestine, colon

Accessory organs: salivary glands, pancreas, liver

Urogenital system

Excretory (urinary) system--filters blood, removes wastes, regulates solute concentration

Nitrogenous wastes--uric acid, urea

Kidneys, ureters, urinary bladder, urethra

Reproductive system--fertilization & activation, fast & slow block to polyspermy

Internal signaling

Nervous system

Neuron, dendrite, nerve cell body, axon, ganglion, nerve

Electrical impulses--membrane potential, depolarization pulse

Chemical signal--synapse, neurotransmitter, receptor

Central nervous system--brain, spinal cord

Peripheral nervous system--sensory & motor nervous systems

Sensory system

Photoreceptors, mechanoreceptors, chemoreceptors, thermoreceptors, pain

Endocrine system--hormones (chemical messengers that travel systemically)

Positive & negative feedback loops

Hypothalamus & pituitary, gonadotropins & sex hormones

Corticosterone, epinephrine, insulin, glucagon, growth hormone

Musculoskeletal system--functions

Muscular--muscles, tendons, contractions, antagonism, sliding filament model, ATP

Innervation of muscles, calcium in muscle contraction

Skeletal--osteoblasts, osteocytes, types of bone, axial & appendicular skeleton, joints

Calcium & osteoporosis

Integumentary system (skin)

Development--direct or indirect

Zygote--gray crescent, polarity, yolk

Mechanisms of cellular differentiation--cytoplasmic localization, induction

Cleavage, blastulation, gastrulation, neurulation

Animal behavior

Comparative psychology--conditioning (Pavlov's dogs), reinforcement

Ethology--adaptation, instinct (innate behavior) imprinting

Development of behavior--environmental influences, instinct, sensitive periods

Biological aspects of learning

Behavioral ecology

Decision-making

von Frisch's honeybees--foraging, flower recognition, communication

Optimality--optimality, trade-offs, time & energy budgets

Sociobiology--sexual selection, altruism, mating systems, social structure

Evolution of behavior--behavioral genetics, inclusive fitness, ESS

Physiology & behavior

Neurobiology--nervous system, sensory systems, echolocation

Acclimatization, hibernation, migration, biological clocks

Mentality of animals--language & mental representation, intelligence, tool-use, culture

Animal awareness & emotion--self-awareness, consciousness, fear & suffering

Ecology--an organism's relationship to its biotic & abiotic environment (Haeckel)

Factors that affect abundance & spatial distribution of organisms

Physiological ecology--one individual's interaction with environment

Energy budgets, endothermy & ectothermy

Population ecology--A deme (population) is a group of individuals of the same species.

Demographic parameters

Abundance & density

Age structure--relationship to population growth rate

Sex ratio

Population growth rate

Survivorship & reproductive success

Population dynamics & regulation--exponential & logistic growth

Metapopulation dynamics--sources & sinks

Community ecology--A community is a group of individuals of different species.

Species interactions, species diversity, niche & habitat, mimics, keystone species

Ecosystem ecology--biotic & abiotic components

Trophic levels & food webs

Producers (gross & net productivity), consumers, & decomposers

Landscape ecology--adjacent ecosystems interact with each other

Biogeography--biomes determined primarily by climate

Climate determines plant communities

Temperature, precipitation, seasonality in northern & southern hemispheres

Tilt of Earth on axis of rotation, angle of solar incidence

Global circulation model--latitude, climate, & terrestrial biomes

Biomes

Terrestrial

Aquatic--freshwater & marine

Plant communities determine animal communities

Biodiversity conservation--conservation biology, extrinsic & intrinsic valuation of biodiversity

Global warming--effects on biodiversity