

BIOLOGY

Cells	Genetics	Ecology
<u>Structure</u> Macromolecules Organelles Membranes <u>Function</u> Photosynthesis Respiration <u>Cycle</u> Mitosis Meiosis	<u>Heredity</u> Mendel Non Mendel <u>Genetics</u> Replication Expression Regulation <u>Evolution</u> Natural Selection Phylogeny Speciation	<u>Ecology</u> Community Population Ethology <u>Systematics</u> Viruses Archaea Bacteria Protists Plants Fungi Animals

Plants	Animals	Neuroscience
<u>Structure</u> Organs Tissues Cells <u>Function</u> Growth Transport Nutrition Reproduction Behaviour	<u>Structure</u> Homeostasis <u>Systems</u> Endocrine Digestive Circulatory Respiratory Excretory Reproductive Immune	<u>Structure</u> Nervous Cognition Neurons <u>Senses</u> Hearing Vision Taste Smell Muscles Skeleton

MACROMOLECULES

macromolecules		
macromolecules	building blocks of life	polymer chains of monomers
	synthesis dehydration	break down hydrolysis
carbohydrates	hydrocarbon chains and rings	energy store and structure
	glycosidic linkage structure	determines function
lipids	non-polar glycerol 3 fatty acids	energy store and hormones
	trans double bonds no kinks	steroids four fused rings
	polar phosphate 2 fatty acids	phospholipid cell membranes
nucleic acids	sugar phosphate nitrogen base	genetic code for heredity
	purines double ring <i>A G</i>	pyrimidines single ring <i>C T U</i>
proteins	polymers of amino acids	control of biological functions
	structure determines function	folding by bond interactions
	central carbon 20 side chains	peptide bonds for polypeptides
	1° amino acid sequence	2° non sidechain <i>H</i> bonds
	3° side chain all types bonds	4° multiple subunits hemoglobin

enzymes		
enzymes	protein catalysts for reactions	heat denatures structure function
	reagent substrate binds enzyme	at active site form complex
regulation	activator binds allosteric site	change enzyme shape activates
	inhibitor prevent enzyme	competitive or non competitive
	cofactor supports enzyme	cooperation feedback mechanism
kinetics	$v = \frac{v_{max}a}{K_M + a}$	Michaelis-Menten
	$\frac{1}{v} = \frac{K_M}{v_{max}} \cdot \frac{1}{a} + \frac{1}{v_{max}}$	Lineweaver-Burk

ORGANELLES

cells		
cells	endosymbiosis of prokaryotes	mitochondria chloroplast
	into more complex eukaryotes	with organelles and nucleus
organelles	nucleus holds genetic material	with instructions for proteins
	ribosomes synthesize proteins	with instructions from nucleus
	chloroplasts store energy	convert sunlight to carbohydrates
	mitochondria produce energy	convert carbohydrates to ATP
	vacuoles store and transport	plant central vacuole for liquids

endomembrane		
endomembrane	internal membrane network	from nucleus to outside
	synthesize macromolecules	store transport and recycle
components	smooth ER makes lipids	rough ER makes phospholipids
	cisternae sacs store	vesicle sacs transport
	Golgi apparatus	hosts and directs vesicles
	lysosomes breakdown	recycle macromolecules
	peroxisomes detoxify toxins	inside livers and kidney

cytoskeleton		
cytoskeleton	fibers network through cell	cell shape organelle movement
	microtubule hollow rods	for organelle movement
	microfilament solid rods	for cell division and muscles
	intermediate filaments	coiled cables for cell shape

MEMBRANES

plasma membrane		
plasma membrane	phospholipid bilayer	with selective permeability
	polar head non polar tail	like dissolves like fat soluble
fluid mosaic model	fluidity by fatty acid saturation	cholesterol reduces fluidity
	mosaic of embedded proteins	for transport and communication
inter cellular junctions	connect cells to each other	allow inter cellular transfer
	plants plasmodesmata	direct cytoplasmic exchange
	animals gap junction direct	tight leaks desmosomes staple

transport		
passive	diffusion random net movement	down concentration gradient
	facilitated selective permeability	protein support channel carrier
osmoregulation	moving down gradients	of water potential energy
	$\Psi = \Psi_p + \Psi_s$	solute and pressure potential
	$\Psi_p = 0$ air $\Psi_p \neq 0$ cell wall	$\Psi_s = -iCRT$ zero pure water
active	use energy counter diffusion	against concentration gradient
	primary transport uses ATP	secondary uses primary gradient
bulk	transport in quantity	large or many molecules
	endocytosis membrane pinch	pinocytosis fluids phagocytosis

communication		
communication	reception receptor of ligand	G-protein kinases ion channels
	transduction conduct signal	multiple points of regulation
	response by nucleus	make proteins change behaviour

PHOTOSYNTHESIS

photosynthesis		
photosynthesis	convert light into sugar	thylakoid discs membrane
	light reaction light to ATP	dark reaction ATP to glucose
	$\text{photons} + 6\text{H}_2\text{O} + 6\text{CO}_2 \rightarrow 6\text{O}_2 + \text{C}_6\text{H}_{12}\text{O}_6$	

light		
light	use light energy	to make ATP NADPH
	electron flow carrying energy	down transport chain
	$\text{photons} + \text{H}_2\text{O} \rightarrow \text{O}_2 + \text{ATP} + \text{NADPH}$	
linear	at photosystem II	light energize e^- to acceptor
	at cytochrome complex	hydrogen gradient make ATP
	at photosystem I	terminal carrier make NADPH
cyclic	if NADP+ not available	as terminal carrier
	back to cytochrome complex	more ATP to balance NADPH

dark		
dark	ATP NADPH make glucose	at stroma chloroplast interior
	$\text{CO}_2 + \text{ATP} + \text{NADPH} + \text{H}_2 \rightarrow \text{C}_6\text{H}_{12}\text{O}_6$	
Calvin	five carbon ribulose	is used and regenerated
	rubisco enzyme fixes carbon	$\text{CO}_2 \rightarrow 6\text{C} \rightarrow \text{G3P} \rightarrow \text{glucose}$
hot climates	separate carbon dioxide capture	from rest of Calvin cycle
	CAM plants temporal separate	C4 plants spatial separate

RESPIRATION

respiration		
respiration	convert sugar into ATP	inner mitochondrial membrane
	glycolysis split glucose	Krebs spin to make ATP
	$C_6H_{12}O_6 + 6O_2 \rightarrow 6CO_2 + 6H_2O + 30ATP$	

glycolysis		
glycolysis	split glucose into pyruvate	net gain $2ATP$ $2NADH$
	historical process in cytoplasm	after glucose diffuse inside
$C_6H_{12}O_6 + 2ATP \rightarrow 2 \text{ pyruvate} + 4ATP + 2NADH$		
anaerobic	no oxygen inefficient	reset glycolysis restore NAD^+
	pyruvate not oxygen	as terminal carrier
	plants alcohol fermentation	ethanol and carbon dioxide
	animals lactic acid fermentation	lactate and no carbon dioxide

aerobic		
aerobic	oxygen available efficient	strip apart pyruvate for $28ATP$
	$2 \text{ pyruvate} + 6O_2 \rightarrow 6CO_2 + 6H_2O + 28ATP$	
pyruvate oxidation	coenzyme A joins pyruvate	$2C$ acetyl-coA complex
	brings into mitochondria	release CO_2 makes $NADH$
Krebs	four carbon oxaloacetate	is used and regenerated
	successively remove carbon	make ATP $FADH_2$ $NADH$
oxidative phosphorylation	$NADH$ $FADH_2$ electron carriers	transport chain to oxygen
	active transport of hydrogen	hydrogen gradient make ATP

MITOSIS

mitosis		
mitosis	eukaryote cell replication	prokaryote binary fission
	large interphase	gap 1 synthesis gap 2
	small mitotic phase	mitosis and cytokinesis

mitotic phase		
prophase	chromatin to chromosomes	sister chromatids tied centromere
	centrioles at centrosomes	make microtubules
prometaphase	nuclear membrane disintegrates	centrosomes move to cell sides
	kinetochore spindles	grab chromosomes
metaphase	chromosomes aligned	on metaphase plate
anaphase	chromosomes pulled apart	nonkinetochore elongate cell
telophase	nuclear membrane forms	chromosomes unravel chromatin
cytokinesis	cells split at cleavage furrow	plant cells new cell wall

regulation		
regulation	ensure DNA errors	do not get replicated
	checkpoints at G1 G2 M	if fail repair else apoptosis
	cyclin concentration buildup	cyclin-CDK complex allow pass
	external regulation	quorum sensing anchorage detect
cancer	loss of cell cycle control	unrestricted proliferation
	proto oncogene normal division	oncogene uncontrolled growth
	tumor suppressor inhibit division	mutated suppressor uncontrolled
	tumor group of cancer cells	metastasis spread through blood

MEIOSIS

meiosis		
meiosis	mixing parent genes	for genetic diversity
	each contributes one haploid set	fertilize for diploid zygote
	meiosis I two haploid daughters	double genetic material
	meiosis II four haploid daughters	through mitosis separation

meiosis I		
prophase I	chromatin to chromosomes	homolog pairs form tetrad
	crossover at overlap tips	exchange genetic material
metaphase I	tetrads lineup metaphase plate	independent assortment
	daughter haploids	random mix of grandparents
anaphase I	tetrads separate homolog pairs	chromatic pairs remain intact
	daughter get one haploid pair	get half of parent chromosomes

disorders		
aneuploidy	abnormal number chromosomes	either one or three
	due to nondisjunction	failed anaphase separation
crossover	lack of crossover	increases nondisjunction rate
	faulty crossover	translocation lose segment
examples	monosomy X	Turner
	trisomy 21	Down

MENDEL

Mendel		
dominance	inherited traits of pea plants	observe three laws
	for heterozygous fertilization	dominant gene is expressed
	as shown in monohybrid cross	$TT \times tt \rightarrow Tt$
segregation	one parent pass one allele	through haploid gametes
	second generation (1 : 2 : 1)	$Tt \times Tt \rightarrow TT, Tt, tt$
independent assortment	alleles do not affect each other	during metaphase tetrad lineup
	dihybrid cross (9 : 3 : 3 : 1)	$AaBb \times AaBb \rightarrow AABB...aabb$

inheritance		
inheritance	inheritance that follows	the three Mendelian laws
	Punnett square one generation	pedigree multiple generations
dominant disease	parents are affected	offspring may not be
	most diseases not dominant	Huntington dwarfism
recessive disease	parents are not affected	but offspring may be affected
	parents are disease carriers	unexpressed recessive alleles

recessive disorders		
sickle-cell disease	hemoglobin mutation	sickle-shaped red blood cells
	carry less oxygen but have	increased malaria resistance
cystic fibrosis	most common	lethal genetic disease
	intracellular chlorine ions	cell absorb water lung infection

NON MENDEL

non Mendel		
non Mendel	inheritance of traits	that do not follow Mendel
	Morgan fruit flies eye color	alleles are genes on chromosome
linked	genes on same chromosome	more likely inherited together
	unlinked combinations can	still recombine after crossover
	map units recombine frequency	proportional to physical distance
	use $AaBb \times aabb$	to determine frequency
sex linked	genes on sex chromosome	traits appear in one gender
	X linked three alleles $Y X^A X^a$	recessive more likely males
	Bar body only one X is active	in any one cell tortoiseshell cats
X linked recessive	color blindness	humans for red and green colors
	hemophilia clotting protein	cannot stop bleeding
	Duchenne muscular dystrophy	muscles weaken die young

others		
incomplete dominance	both traits are recessive	result is mix snapdragon pink
codominance	both traits are dominant	result is both blood type AB
non nuclear inheritance	through mitochondrial DNA	always inherit from mother
phenotype plasticity	environment affects expression	nutrition height temp gender
pleiotropy	one gene affects	multiple traits
polygenic inheritance	multiple genes affect same trait	continuous spectrum like height
epistasis	expression of one gene	affects expression of another
relatedness	probability of shared genes	derived from family tree paths
	Hamilton cost benefit analysis	$rB > C$ by diversity of genes

REPLICATION

replication		
replication	duplicate genetic material	during mitotic synthesis phase
	takes place inside nucleus	using semiconservative model

process		
helicase	unwind DNA at replication fork	origin site of replication
topoisomerase	break swivel rejoin ahead fork	relieve strain of unwinding
primase	short initial RNA primer	to anchor replication
polymerase	builds DNA in 5' to 3' direction	using complimentary base pairs
leading strand	made continuously 5' to 3'	on both front and back forks
lagging strand	discontinuous Okazaki fragments	ligase links the chunks
telomeres	polymerase needs space	additional useless bits at end

control		
repairs	polymerase proofreads	if it makes mistakes
	mismatch repair	other enzymes fix single error
	nucleotide excision	nuclease replaces whole segment
chromatin	histone stick ball protein	positive holds negative DNA
	nucleosome string of beads	wrap around sets of 8 histones
	euchromatin loose packing	ready for expression
	heterochromatin tight packing	not available for expression

EXPRESSION

expression		
expression	use DNA to make proteins	DNA to RNA to proteins
	RNA single strand copy DNA	work as messengers and carriers

transcription		
transcription	use DNA to make RNA	with chromatin inside nucleus
initiation	helicase unwind DNA	at promoter staging area
elongation	polymerase build RNA 5' to 3'	multiple simultaneous no primer
termination	detach and release	as pre mRNA
splicing	remove non coding introns	keep exons add cap and tail

translation		
translation	use RNA to make protein	at ribosome outside nucleus
	condon of three nucleotides	specify which amino acid
	transfer RNA with anti codon	brings correct amino acid
initiation	ribosome attaches to mRNA	read start codon AUG
elocation	build polypeptide at three sites	sites Attach Polypeptide Exit
termination	reads stop UGA UAA UAG	polypeptide folds into protein

REGULATION

regulation		
regulation	control DNA expression	different times multiple points
pre transcription	epigenetic regulation	chromatin wrapping availability
	operons in prokaryotes	transcription factors eukaryotes
post transcription	splicing arrangement	alternative exon sequences
	telomere cell life spans	RNAi mark for destruction
post translation	activation of proteins	controlled by enzymes
	ubiquitin mark proteins	slated for destruction

operons		
operons	activate or disable expression	inducible or repressible types
	promoter is staging area	where polymerase attaches
	operator is part of promotor	to block or allow access
regulation	repressor binds operator	prevent access and transcription
	inducer removes repressor	allows access and transcription
lac	inducible regulation	by lactose enzyme
	when lactose is present	make enzyme for breakdown
trp	repressible regulation	by tryptophan enzyme
	when tryptophan is present	stops making more

MUTATIONS

mutations		
mutations	error in genetic code	permanent propagation if DNA
	single error base substitutions	or sequence rearrangement errors
substitutions	silent error same amino acid	results in same protein
	missense different amino acid	possibly different protein
	nonsense stop codon	terminates protein synthesis
rearrangements	frameshift insertion deletion	changes entire sequence
	duplication and inversion	translocation break and rejoin

genetic variation		
variation	mitosis uncaught error	mutation is propagated
	meiosis crossover	translocation rearrangements
	meiosis independent assortment	2^{23} permutations
	fertilization random pairing	$2^{23} \cdot 2^{23}$ combinations

biotechnology		
technology	manipulate the genetic code	emulate nature hijack organisms
	copy genes insert in bacteria	natural replication factory
	edit genes bacterial defense	CRISPR cut repair replace
	clone genes undifferentiated	plants totipotent animal stems
polymerase chain reaction	mass produce via replication	unwind target elongate
hybridization	stain to match complementary	fluorescent strand detect pair
gel electrophoresis	separate target segments	fingerprinting total uniques
blotting	separate and stain to search	southern DNA northern RNA

NATURAL SELECTION

natural selection		
evolution	change of species	over long time
	Darwin finches	descent with modification
observations	over production	more than can survive
	genetic variation	vary in heritable traits
inferences	struggle for existence	compete limited resources
	differential survival	preferred traits reproduce
natural selection	environment	determines favoured traits
	favourable traits	accumulate over time
	survival of the fittest	environments keep changing
types	abiotic non living forest fires	biotic living predator prey
	sexual intra inter dimorphism	artificial selective breeding
direction	continuous traits range values	directional stabilizing disruptive
	balancing left right mouth	heterozygote carrier advantage

evidence		
fossils	incremental species change	extinct intermediate species
	absolute dating isotopes	relative dating rock layers
anatomy	living fossils similarities	marine mammals leg bones
	homologous common ancestor	now different functions
	analogous different ancestor	now same functions
molecular	same macromolecules	same organelles
	all carbon based	majority shared genes
experimental	induced change	London peppered moth
	domestication cats dogs	artificial selection

PHYLOGENY

tree of life		
classical	Linnaeus by similarity	morphology predates genetics
	does not distinguish	homology and analogy
phylogenetic	by common ancestry	through genetic analysis
	evolutionary history hypothesis	always a work in progress

phylogenetic tree		
phylogenetic tree	taxon are nodes	common ancestor branches
	basal taxon are earliest	diverging common ancestor
	clade monophyletic grouping	ancestor and descendants
	cladistics use shared traits to	hypothesize phylogenetic tree
	ancestral traits from ancestor	derived traits new to group
	cladogram groups species	with shared derived traits
	test phylogenetic hypothesis	parsimonious fewest changes

genomics		
genomics	genome of species	entire genetic code
	genomic evidence	of evolutionary history
	focus on homology	similar from shared ancestry
homology	orthologous genes	from ancestor in different species
	paralogous genes	from duplication in same species
molecular clock	rate of mutations	roughly constant
	can be used to date	speciation and diseases
gene transfer	primarily vertical	parent to child
	with extensive horizontal	viral between species

SPECIATION

microevolution		
microevolution	change in allele frequency	of regular breed population
	$p + q = 1$	individual allele frequency
	$p^2 + 2pq + q^2 = 1$	two allele combinations
	allele frequency constant	Hardy-Weinberg conditions
conditions	large size	law of large numbers
	no mutations	random allele changes
	no migration	gene flow other populations
	no sexual selection	alleles randomly chosen
	no natural selection	alleles randomly chosen
size	genetic drift	small size chance fluctuations
	founder effect	isolated different composition
	bottleneck effect	sudden decline different mix

speciation		
speciation	how one species splits to two	no longer viable offspring
	reproductive barriers	lead to divergent evolution
	allopatric speciation	geographic separation
	sympatric speciation	same area plants polyploidy
barriers	pre-zygote prevents fertilization	temporal behavioral separation
	post-zygote prevents propagation	reduced viability fertility

COMMUNITY

ecology		
ecology	organism interactions	with hierarchy of environments
	biosphere Earth climate	sunlight air precipitation
biomes	major life zones	terrestrial and aquatic
	terrestrial climate vegetation	with vertical layering
	aquatic sunlight nutrients	with layering and turnover
	distribution of species	dispersal of gametes
	conservation of biodiversity	genetic species and ecosystem
community	species interactions	with each other in ecosystem
	trophic food chain hierarchy	10% energy limits number levels
	each level has organisms	decomposer producer consumer
	regulated by keystone engineers	bottom up or top down
	chemical cycles water nutrients	toxins accumulated magnified
	change is the norm	succession after disturbance
	$1 - \sum \left(\frac{n}{N} \right)^2$	Simon's diversity index
	some disturbance more diverse	more adaptive more resistant

interactions		
competition	(-, -) limited resources	reduces survival reproduction
	exclusion same niche no coexist	partitioning divide niche coexist
exploitation	(+, -) one preys upon other	predation herbivory parasitism
	prey adaptations for survival	camouflage chemical mimicry
mutualism	(+, +) symbiosis	both gain sucker fish shark
commensalism	(+, 0) one gain one unaffected	birds on large herbivores

POPULATION

population		
population	organisms of same species	in local ecosystem and breeds
	density is number per area	direct count or mark recapture
	dispersion across ecosystem	uniform random clumped
	demography age distribution	life table survivorship curves
growth	equilibrium increase decrease	births deaths migration
	$\frac{dN}{dt} = rN$	exponential abundant resources
	$\frac{dN}{dt} = rN \left(\frac{K - N}{K} \right)$	logistic limited carry capacity
limiting factors	density dependent	predation disease competition
	density independent	climate disasters humans
life history	traits that affect	reproductive schedule
	semelparity big bang	<i>r</i> -selected enough resources
	iteroparity repeated small	<i>K</i> -selected near capacity

ethology		
ethology	animal behaviour	in response to stimuli
	proximate cause instinct learning	ultimate cause natural selection
instinct	innate automatic response	sign stimulus behaviour rhythms
learning	changing with experience	cross fostering imprinting
	spatial pine cones locate nest	associative vomit monarch
	cognition crow get water	social chimpanzee crack nuts
natural selection	behaviour to propagate genes	bees genes optimal foraging
	monogamy patternity certainty	altruism kin selection

VIRUSES

systematics		
systematics	classification living organisms	by evolutionary relationships
prokaryotes	archaea extremophiles	bacteria cyano photosynthesis
eukaryotes	plants photosynthesis	fungi absorption decomposition
	animals optional backbone	protists catch all

viruses		
viruses	non living agents	that infect cells
	bind to surface proteins	inject DNA to replicate
structure	capsid protein shell	enclosed genetic material
	optional viral envelope	of stolen host membrane
epidemic	is disease outbreak	pandemic if global
	usually existing virus	expand host type territory

hosts		
bacteria	lysogenic cycle	dormant passive replicate
	lytic cycle	break host release copies
	CRISPR-Cas	adaptive immunity to virus
animals	enveloped viruses	spread by exocytosis
	retrovirus	reverse RNA to DNA
plants	RNA virus	viroid if no protein shell
	transmission	vertical parent horizontal virus

PROKARYOTES

prokaryotes		
prokaryotes	single celled organisms	massive diversity of being
	shape spherical rod spiral	cell wall hypotonic not burst
archaea vs bacteria	peptidoglycan	bacteria yes archaea no
	introns	bacteria no archaea some
	histones	bacteria no archaea some
	RNA polymerase	bacteria one archaea several
	start amino acid	bacteria formyl-methionine
bacteria	quick staining classification	cell wall peptidoglycan
	Gram positive	thick seeped dye purple stain
	Gram negative	double membrane blocked blue

diversity		
genetic	main circular chromosome	independent circular plasmids
	rapid reproduction	fast evolution via mutations
transfer	conjugation	pilus mating bridge
	transformation	pickup from environment
	transduction	viral capsule with donor gene
metabolic	carbon source	autotroph air heterotroph sugars
	photoautotroph plants	chemoheterotroph fungi animals
respiratory	oxygen	aerobe require anaerobe poison
	nitrogen	fix atmosphere to ammonia
lineage	gram-positive	mostly pathogens
	proteobacteria	source of mitochondria
	cyanobacteria	source of chloroplasts

EUKARYOTES

eukaryotes		
eukaryotes	more complex organisms	most are single celled
	organized by supergroups	phylogenetic hypothesis
	excavata feeding groove	SAR shells photosynthesis
	archaeplastida algae plants	unikonta fungi animals
algae vs plants	algae are aquatic protists	green algae evolved to plants
	red green brown algae	multicellular photosynthesis
	green brown algae cell walls	green algae have chloroplasts
	charophytes with sporopollenin	prevent dry out migrate to land

plants		
plants	photosynthetic eukaryotes	alternation of generations
	walled spores sporopollenin	meristems continuous division
non vascular	ground hugging mosses	dominant gametophyte
	bryophyte moss with sprouts	dependent sporophyte
	rhizoids anchor no absorb	sperm swim need water
seedless vascular	ferns dominant sporophyte	zombie gametophyte
	vascular tissue allows	transport and support
	roots anchor absorb	leaves photosynthesis
seed plants	dominant sporophytes	microscopic gametophytes
	multicellular spores	for distance and time
	gymnosperms naked seeds	pine cones
	angiosperms protected seeds	flowers and fruits

fungi		
fungi	decompose by absorption	dominant haploid form
	hyphae chitin cell walls	prevent hypotonic bursting
	septa divide hyphae cells	large pores for organelles
coenocytic	no septa divisions	continuous cytoplasm lots nuclei
	repeated cell division	with no cytokinesis
mycorrhizae	symbiosis with plants	trade minerals for sugar
	vital for all vascular plants	wrap roots or insert into cells
asexual reproduction	quickly conquer food source	leave food grows mold
	haploids reproduce by mitosis	or by pinching bud cells
sexual reproduction	when encounter partner	meet and join by pheromones
	plasmogamy cytoplasm union	delayed union of nuclei
	karyogamy fertilize zygote	meiosis restores haploids

animals		
animals	no photosynthesis	dominant diploid form
	radial symmetry	direct environmental exchange
	bilateral symmetry	internal homeostasis
classification	metazoa sponges	eumetazoa true animals
	bilateria bilateral symmetry	deuterostomia development
	chordata with notochords	vertebrates with backbone
	mammals are vertebrates	with jaws limbs eggs hair milk
mammals	monotremes	egg laying platypus
	marsupials	pouches kangaroos
	eutherians	placenta mouse humans

GROWTH

structure		
organs	root system below	anchor absorb store
	shoot system stem leaves	photosynthesis reproduce store
tissues	continuous through plant	dermal vascular ground
cells	parenchyma cells	stem cells and storage
	collenchyma live support	sclerenchyma dead support
	sieve tube live sugar transport	tracheids dead water transport

growth		
growth	indeterminate growth	continuous through life
	primary growth length	secondary growth thickness

primary		
roots	apical meristem behind cap	divide elongate differentiate
	vascular central cylinder	monocot ring eudicot star
	ground filler to epidermis	short distance transport
shoots	apital meristem in bud	dominates axillary lateral
	dermal waxy layer water loss	ground support storage
	vascular xylem in phloem out	monocot scattered eudicot ring
leaves	dermal water loss	gas exchange stomata guard
	ground photosyn mesophyll	eudicot mesophyll layers
	vascular gas exchange	bundle sheath regulate

secondary		
secondary	growth in thickness	eudicot woody plants
	primary creates cambium	secondary expands cambium
vascular cambium	expand vascular flow	secondary xylem phloem
	ruptures dermal layer	parenchyma make cork cambium
cork cambium	outer layer protection	makes external periderm
	cycle continues	with new cork cambium

layers		
heartwood	oldest secondary xylem	resin hardened no transport
	growth ring demarcation	recent cells are larger
sapwood	youngest secondary xylem	transports water
	radial vascular rays	connect xylem phloem
bark	secondary phloem	transports sugar
	periderm suberin waxed	lenticels slits gas exchange

development		
development	how organisms form	from individual cells
	ABC hypothesis	three genes control flowers
growth	asymmetric cell division	stem to stem and guard
	economic expansion vacuoles	orientated expansion microfibrils
morphogenesis	spatial arrangement	by two hypotheses
	position determines	plants laser destroy cells
	genetics determines	animals Hox changes pattern
differentiation	specialization of cells	during developmental periods
	cell to cell communication	regulate gene expression
	plant root cell hairs	by how many neighbours

TRANSPORT

transport		
transport	coordination between	short and long distances
	short passive active diffusion	long pressure gradient bulk flow
regions	protoplast inside cell	symplast cell membranes
	apoplast cell to cell wall	ideal hypotonic push cell wall

water		
water	water and solutes	from root to leaves
	short distance root to xylem	long distance up xylem
short distance	root hair absorption	selective permeability
	Casparian strip block apoplast	force endodermis filter
long distance	root pressure positive push	active ions passive water
	minor source	guttation not dew
	transpiration negative pull	evaporation lower pressure
	major source	regulate by stomata opening
	xerophytes desert plants	reduce water loss

sugar		
sugar	phloem sap sugars	leaf to whole plant
	sugar source to sugar sink	either up or down
source to vascular	symplast or apoplast	mesophyll to sieve tube
	active or cotransport	with proton gradient
bulk flow	positive pressure by gradient	if not enough remove sinks
vascular to sink	sugar passive diffusion	water follow by osmosis

NUTRITION

nutrition		
soil	water nutrition from soil	topsoil is most fertile
	loam equal sand silt clay	mix water air organic inorganic
	organic humus prevent packing	retains water reservoir minerals
minerals	soil particles negative	negative ions runoff
	cations enter soil solution	when displaced by protons
	capacity depends on	cation sites and soil pH
classification	plants require minerals	life cycle and reproduction
	classify by hydroponic culture	symptoms by parts and age
	macronutrients require lots	nitrogen affects yield most
	micronutrients require trace	sodium for CAM C4 plants

adaptations		
mutualisms	vital for plant nutrition	trade minerals for sugar
	nitrifying bacteria	adds nitrate to soil
	nitrogen fixing bacteria	invited into legume roots
	mycorrhizae fungi	wrap roots or insert into cells
epiphytes	plant grows on other	anchor not sustenance
	water minerals from rain	orchids staghorn ferns
parasitic	plant grows in other	anchor and sustenance
	haustoria roots penetrate host	mistletoe dodder indian pipe
carnivorous	supplement photosynthesis	minerals from insects
	dissolve with enzymes	pitcher flytraps sundew

REPRODUCTION

sexual		
sexual	flower unique structure	four concentric whorls
	sepals protect floral bud	petals attract pollinators
	stamens male gametophyte	carpels female gametophyte
fertilization	uneven meiosis triple mitosis	no cytokinesis embryo 8 nuclei
	pollen tube double fertilization	zygote and triploid endosperm
	zygote asymmetric mitosis	makes seed leaf cotyledons
	monocot endosperm energy	eudicot cotyledon energy
germination	environmental trigger	imbibition water uptake
	monocot single cotyledon	eudicot cotyledon pair rise up
	vegetative growth continuous	flowering environmental trigger
fruits	flower wither if no fertilize	fruit protect seed aid dispersal
	ovary walls become pericarp	thickened dry or fleshy wall

asexual		
asexual	clone of a single parent	fragmentation or seeds
	no pollination required	lots resources rapid expand
sexual	avoid self fertilization	spatial temporal structural
	genetic self recognition	similar to immune system
cloning	vegetative propagation	totipotent stem cell mitosis
	shoot cutting	wound develops roots
	grafting	combine close individuals

BEHAVIOUR

behaviour		
behaviour	response to stimuli	light gravity time infection
	animals with movement	plants by altering growth
hormones	broader than animals	plants no circulatory system
	auxin stem elongation	produced at shoot tips
	cytokinins enhance growth	produced at roots
	gibberellins cell division	germination foolish rice
	abscisic acid slow growth	dormancy
	ethylene stress response	triple response avoid obstacle

stimuli		
light	etiolation grow in darkness	focus elongate out of soil
	blue cryptochrome receptors	phototropism toward light
	red phytochrome receptors	red and far red competition
time	circadian rhythm	internal clock reset by light
	photoperiodism flowering	seasons dark period vs critical
gravity	gravitropism response	roots towards stem against
	statoliths to cell bottom	trigger asymmetric auxin
touch	thigmotropism response	vine climb what reaches
	thigmomorphogenesis	propagated rapid change
stresses	dry wet salt heat cold freeze	stomata ethylene fluidity
	herbivory multiple levels	molecular chemicals population
pathogens	innate immune system	no animal adaptive immunity
	associated molecular patterns	recognize flagellin protein
	effector triggered immunity	local isolation systemic alarm

ENDOCRINE

structure		
structure	adaptation to environment	through form and function
	large internal surface systems	deliver resources to all cells
tissues	epithelial protective barrier	connective hold in place
	muscle for movement	nervous for signals
coordination	endocrine and nervous	stimulus processing
	endocrine gradual whole body	nervous immediate response

homeostasis		
homeostasis	maintain steady internal	in changing environment
	requires control system	with negative feedback
regulation	ectothermic	heat from environment
	endothermic	heat from metabolism
mechanisms	insulation reduce exchange	circulatory control exchange
	evaporation cooling	behaviour orient body

endocrine		
endocrine	regulate development	via feedback and cascades
	endocrine glands with cells	get stimuli send hormones
	also indirect coordination	neuroendocrine tropic hormones
hormones	local regulators diffusion	autocrine self paracrine local
	water soluble polypeptides	fat soluble steroids
	either soluble amines	different response pathways

DIGESTIVE

digestive		
digestive	preassembled essential nutrients	amino acids and fatty acids
	vitamin organic catalysts	mineral inorganic catalysts
feeding	filter baleen whale	substrate worm on leaf
	fluid mosquito	bulk humans
digestion	compartmentalize avoid self	accessory glands add enzymes
	gastrovascular cavity	in and out same way
	alimentary canal	digestion in stages

stages		
ingestion	oral cavity takes in	tongue mixes to bolus
	salivary glands water salts	amylase dissolve starch
	pharynx splits path	esophagus by peristalsis
digestion	stomach mix to chyme	mechanical and chemical
	gastric juice acidic	pepsin dissolve proteins
	small intestine duodenum	with accessory glands
	pancreas and liver enzymes	dissolve all macromolecules
absorption	small intestine jejunum	large surface area lining
	passive active transport	move nutrients into blood
	hepatic portal vein	blood to liver filter toxins
	fats broken by bile salts	lymph to veins to heart
	large intestine colon	recovers water
adaptations	carnivores incisor teeth	herbivore molar teeth
	coprophagy dung eating	ruminants regurgitate
	large intestine cecum	herbivores microbiome bacteria

TRANSPORT

circulatory		
circulatory	connect exchange surfaces	to all cells for nutrients
	open system interstitial fluid	closed system dedicated blood
	single circuit body to gill	double circuit lung and body
cycle	pulmonary heart arteries lungs	systemic heart arteries body
	atria collect ventricle pump	double beat atria ven body
	pacemaker synchronize pumps	autorhythmic cells periodic
structure	blood cells erythrocytes red	leukocytes white platelets clot
	vessels arteries strong elastic	veins smooth with valves
	capillaries large surface area	lymphatic system recover fluids

respiratory		
respiratory	gas exchange lung blood	large surface area diffusion
	gills ventilation over surface	countercurrent exchange
	tracheal air tube network	direct environmental exchange
	lungs body surface infoldings	alveoli diffusion capillaries
breathing	ventilates lungs	medium over surface
	amphibians positive pressure	birds efficient single direction
	mammals negative pressure	inefficient mix in and out
exchange	coordination with circulatory	oxygen low solubility
	hemoglobin dedicated carriers	cooperability four subunits
	carbon dioxide little in plasma	most in red blood cells
adaptations	diving animals myoglobin	oxygen carriers in muscles
	slow oxygen consumption	anaerobic respiration

EXCRETORY

excretory		
excretory	osmoregulation	solute homeostasis
	waste management	handle toxic ammonia
osmoregulation	sharks do not regulate	maintain urea isotonicity
	freshwater fishes regulate	eject lots dilute urine
	saltwater fishes regulate	eject little concentrated urine
	salmon alternate fresh salt	tardigrades dehydrate dormant
waste management	fishes keep as ammonia	direct environment diffusion
	mammals liver convert urea	eject dissolved in urine
	birds convert to uric acid	insoluble paste no water loss

stages		
filtration	blood to tubules	filtered in stages
	blood pressure pushes filtrate	glomerulus to Bowman capsule
	selective permeability	only small molecules pass
reabsorption	filtrate through nephron	proximal loop of Henle distal
	active sodium reabsorbed	passive water salts reabsorbed
excretion	selective secretion	passive urea ejection
	release filtrate as urine	isoosmotic to inner medulla
water	countercurrent exchange	medulla increasing osmolarity
	countercurrent multiplier	active maintain gradient

REPRODUCTIVE

gestation		
reproduction	asexual no gamete fusion	budding fission parthenogenesis
	sexual fertilized zygote	external aquatic internal care
gametogenesis	sperm from testes	coiled seminiferous tubules
	egg from ovary follicles	ovulation to uterus endometrium
oogenesis	all eggs at birth	suspended at prophase I
	monthly mature at puberty	suspended at metaphase II
cycle	ovarian cycle	follicle matures release oocyte
	uterine cycle	menstrual uterus lining prepared
	ovulation release egg	follicle to corpus luteum
	continue if no fertilization	cycles pause if fertilization

development		
cleavage	rapid cell division	blastula hollow ball
	yolk stored nutrients	affects division pattern
gastrulation	dramatic folding	into three layers
	radial symmetry two	bilateral symmetry three
amniotes	vertebrate adaptations	for terrestrial reproduction
	four membranes	allow aqueous exchange
organogenesis	notochord rod	guides neural plate
	brain and spinal chord	notochord disappears
cell fate	cell migration	cytoskeleton guides to organs
	determination	commit to specialization

IMMUNE

immune		
immune	innate immunity	recognize common molecules
	adaptive immunity	recognize specific pathogens
innate	phagocytes	neutrophils macrophages
	hemocytes	antimicrobial peptides
	specialized cells	dendritic eosinophils killer mast
	inflammation	cytokines histamines
lymphatic	network and organs	interstitial fluids back to blood
	host of white blood cells	from bone marrow stem cells

adaptive		
adaptive	acquired immunity	enhanced future response
	vertebrates only	arsenal of specific receptors
characteristics	diversity	millions of receptors
	self tolerance	test and destroy
	proliferation	effectors and memory
	immunological memory	enhanced future response
components	antigen	recognizable pathogen protein
	antibody	tag and interfere with antigen
activation	antigen presenting cell	macrophage dendritic B cell
	helper T cells	recognize activate responses
humoral response	effector plasma cells	mass produce antibodies
	memory B cells	antibodies for future
cell mediated response	effector cytotoxic T cells	destroy infected cells
	memory T cells	helper cytotoxic for future

NERVOUS

nervous		
nervous	organism command control	immediate stimuli response
	neurons signal management	glia cells for support
central	signal integration	at brain and ganglia
	spinal cord for reflexes	circuit control no brain
peripheral	connect central to body	motor and autonomic
	autonomic involuntary	antagonistic regulation
	sympathetic fight flight	parasympathetic rest digest

brain		
brain	neural tube	from infolding ectoderm
	three bulges	forebrain midbrain hindbrain
regions	forebrain	cerebrum diencephalon
	midbrain	cluster atop brainstem
	hindbrain	cerebellum
cerebrum	two hemispheres	corpus callosum bridge
	cortex perception learning	basal nuclei planning
cerebellum	small helmet	in hindbrain
	movement	hand eye coordination
diencephalon	thalamus	all senses sensory input
	hypothalamus	endocrine control center
	epithalamus	pineal gland melatonin
brainstem	midbrain	integrate some sensory input
	pons medulla	transfer peripheral central
	medulla oblongata	breathing heart digestion

COGNITION

cerebral cortex		
frontal	prefrontal cortex planning	Broca's area forming speech
	motor cortex	mapped muscle output
parietal	sensory association cortex	overall integration
	somatosensory cortex	mapped touch input
temporal	auditory cortex	hearing input
	Wernicke's area	language comprehension
occipital	visual cortex	vision input
	visual association cortex	integration edges to shapes

cognition		
cognition	neural network optimization	connections shape cognition
	embryo keeps quarter	half not arrive half eliminated
	neuronal plasticity	coherent activity strengthened
learning	short term hippocampus	longterm cortex sleep integrate
	longterm potentiation	permanent increase potential

function		
sleep	rest and consolidate	learning and memory
	no receive external stimuli	cycles of shallower sleep
clock	pacemaker for a day	resets with retina sunlight
	suprachiasmatic nucleus	in hypothalamus
emotions	store emotional experiences	recall by similar circumstances
	limbic system amygdala	memory induces autonomic

NEURONS

signal		
resting potential	sodium potassium pump	active transport
	maintain gradient of	separation of charges
polarization	a voltage stimulus	opens ion channels
	change membrane potential	threshold positive feedback
action potential	conduction of	series of action potentials
	pass signal along axon	refractive period no reverse
transmission	signal strength is	rate of action potentials
	change in frequency	only way to encode information

integration		
synapses	gap between neurons	for signal integration
	action potential	releases neurotransmitters
receptor	ligand gated ion channel	open channel create potential
	excitatory increase potential	inhibitory decrease potential
type	ionotropic direct binding	ligand gated ion channel
	metabotropic indirect binding	G protein coupled receptor
integration	summation of inputs	both excitatory inhibitory
	from source terminals	hundreds to thousands
termination	after neurotransmission	reset for next transmission
	deactivate neurotransmitters	reuptake into synaptic vesicles
output	response depends on combo	neurotransmitter and receptor
	many different receptors	for single neurotransmitter
	inhibitory excitatory	ionotropic metabotropic

RECEPTORS

receptors		
receptors	sensory receptor	cell or organ or structure
	different stimuli all result in	action potential on neuron
	signals are distinguished	only by neuron path
	signal intensity encoded as	higher frequency above baseline
perception	integration in brain	generates perceived observation
	amplification strengthen signal	habituation focus on change
classification	mechanoreceptors	physical deformations
	chemoreceptors	molecules internal external
	electromagnetic	light electric magnetic
	thermoreceptors	variety temperature ranges
	pain nociceptors	capsaicin spicy heat

hearing		
hearing	mechano structure deflection	insects hairs fishes gelcaps
	outer auditory channel	to tympanic membrane
	middle three small bones	taps on oval window
	inner pressure cochlea fluid	variety hairs volume pitch

balance		
orientation	vestibule vertical chambers	gelcap otolith bend hairs
	orientation by gravity	linear acceleration by difference
rotation	three semicircular canals	gelcap with hair cells
	three axes angular rotation	spin dizzy stuck gelcaps

SENSES

vision		
vision	photoreceptors detect light	light absorbing visual pigments
	invertebrates eye spots	hide in shade
	insects compound eyes	wide field detect motion
	invertebrates and fishes	move lens change focus
	mammals single lens eyes	change lens shape
eye	through pupil hole in iris	lens focus onto retina
	contrast rods colors cones	neurons with visual pigments
	retina deepest layer first	integration at retina surface
	horizontal cell sharpen	ganglion cell group
	optical nerve to brain	left right fields by both eyes

taste		
taste	chemoreceptors gustation	tastant chemicals in solution
	papillae tongue bumps	lined with taste buds
	taste buds all five receptors	sweet salty sour bitter unami
	salt sodium channel	sour ion channel
	sweet unami G protein	bitter G protein 30 types

smell		
smell	chemoreceptors olfaction	odorant chemicals in air
	nasal cavity receptor cells	cilia in mucus coating
	G protein coupled receptors	bind to odorants
	taste and smell	complex flavour experience

MOTOR

muscles		
muscles	move bones and body	hierarchical organization
	bundle of muscles fibers	single long cell multiple nuclei
	longitudinal microfibrils	repeating sacromere sections
sacromere	basic contractile unit	borders line up
	visible striations	light and dark bands
	thin filaments attach end	thick filaments attach middle
contraction	resting state	thin thick partial overlap
	contraction	filaments slide past each other
	powered by	myosin bind to actin
regulation	tropomyosin binds actin	blocks myosin binding sites
	motor neurons	release binding sites

skeleton		
skeleton	convert muscle contraction	to body movement
	muscles only contract	back forth antagonistic pair
hydrostatic	no skeleton fluid based	muscles change shape
	undulations nematodes	peristalsis earthworms
exoskeletons	hard external skeleton	deposited on surface
	arthropods secrete chitin	muscles in and out molt shell
endoskeletons	hardened internal skeleton	buried in soft tissues
	humans bones and cartilage	fused or joined
locomotion	form suits function	moving through medium
	energy to overcome	gravity and friction