BROAD PATTERNS OF EVOLUTION

Evolution occurs at the population level, evolutionary impact of natural selection is seen in how a population changes over time.

THE EVOLUTION OF POPULATIONS

evolution	changes in allele frequency
allele frequency	(all add up to 1)
population	group individuals of the same species that live in the same area & interbreed to produce fertile offspring
genetic variation	differences in genen composition
sources of genetic variation	*sexual reproduction*
	mutation (change in nucleotide sequence)
	point mutations (single nucleotide change) ex. sickle-cell
	delete, disrupt, duplicate, rearrange loci

genetic variation is required for evolution, but does not guarantee a population will

CHANGE IN ALLELE FREQUENCY

	effect on allele frequency	causes
genetic drift	unpredictable fluctuation of alleles, reduces genetic variation, can limit natural selection	founder effect, pop. bottleneck
founder effect	few individuals isolated, diff. allele frequencies in small founder pop.	chance

CHANGE IN ALLELE FREQUENCY (cont)

bottleneck effect	reduced genetic variation and increased frequency of harmful alleles	sudden environmental change

3 mechanisms change allele frequency = genetic drift, gene flow, natural selection (consistent adaptive evolution)

SEXUAL SELECTION

what is it?	individuals w certain characteristics are more likely to find mates
sexual dimorphism	marked differences between sexes (ex. pavo real)
intrasexual selection	selection within same sex for mates
intersexual selection	one sex is choosy with mates

sexual selection is natural selection for mating success

NATURAL SELECTION MODES

directional	conditions favor individuals at one end of the phenotypic range
disruptive	conditions favor individuals at both extremes of phenotypic range
stabilizing	conditions favor intermediate variants

natural selection ***consistently*** *causes adaptive evolution by acting on phenotypes*

Hardy-Weinberg Principle: Equilibrium Population

condition	consequence if condition is not kept
1. **no mutations**	gene pool is modified
2. **random mating	inbreeding = no random mixing of gametes, genotype frequencies change

Hardy-Weinberg Principle: Equilibrium Population (cont)

3. **no natural selection**	allele frequencies change
4. **very large pop. size**	in small pop. allele frequencies change by chance (*genetic drift*)
5. **no gene flow**	gene flow can alter allele frequencies

CAUSES OF EVOLUTION

Causes of Evolution

Process	Consequence
Mutation	Creates new alleles; increases variability
Gene flow	Increases similarity of different populations
Genetic drift	Causes random change of allele frequencies; can eliminate alleles
Nonrandom mating	Changes genotype frequencies, but not allele frequencies
Natural and sexual selection	Increases frequency of favored alleles; produces adaptations

DEFINITION OF SPECIES

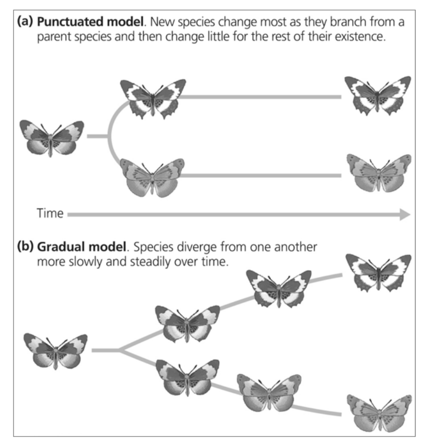
concept	defines species by
biological	reproductive compatability
reproductive isolation → new species	gene flow between populations holds gene pool together, species pop. resemble each other
limitations	*gene flow between morphologically & ecologically distinct species (ex. grolar bear)*
morphological	structural features
ecological	ecological niche, interactions w nonliving and living environment

based on potential to interbreed, not physical similarity

THE ORIGIN OF SPECIES

speciation	one species splits into two or more species
speciation rates	range from 4,000 y to 40 million y (avg. 6.5 my)
allopatric	geographically isolated populations
	population -gene flow interrupted→ subpopulation
	mutation, genetic drift, natural selection, reproductive isolation
reproductive isolation	can't breed bc of differences
behavioral isolation	prezygotic barrier, specific mates
sympatric	population (no geographic barrier)→ new species
	reproductive barrier, reduced gene flow
	polyploidy, habitat differentiation, sexual selection
polyploidy	extra chromosomes
	auto: same species *allo*: diff species
habitat differentiation	new ecological niches
sexual selection	female selecting mates
microevolution (speciation)	many speciations, extinctions → macroevolution

SPECIATION MODELS



punctuated = rapid speciation gradual = slow speciation

REPRODUCTIVE ISOLATION

reproductive barriers	depend on environmental & genetic factors	
Prezygotic Barriers	*prevent mating between species*	
	geographical	physical barrier (rivers, mountains)
	habitat/ecological	same area, diff habitats
	temporal	diff breeding times
	behavioral	unique courtship rituals
	mechanical	morphological diff
	gametic	cannot fertilize
Postzygotic Barriers	*prevent a viable, fertile hybrid*	

REPRODUCTIVE ISOLATION (cont)

	reduced hybrid viability	poor development/survival
	reduced hybrid fertility	fertile hybrid
	hybrid breakdown	infertile 2nd gen
Hybrid Zones	diff species mate, incomplete reproductive barriers	
	*novel genetic variation outcomes =**	
reinforcement	hybrids cease	← hybrids less fit
fusion	two species fuse	← weakened rep. barriers
stability	continued hybrids	← hybrids equally fit

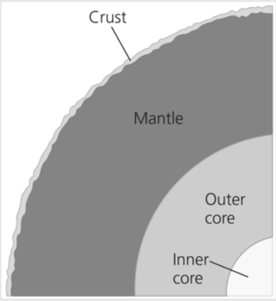
biological barriers that impede fertile offspring

THE GEOLOGIC RECORD

Table 23.1 The Geologic Record

Eon	Era	Period	Epoch	Age (Millions of Years Ago)
Phanerozoic	Cenozoic	Quaternary	Holocene	0.01
			Pleistocene	2.6
		Neogene	Pliocene	5.3
			Miocene	23
		Paleogene	Oligocene	33.9
			Eocene	56
			Paleocene	66
	Mesozoic	Cretaceous		145
		Jurassic		201
		Triassic		252
	Paleozoic	Permian		299
		Carboniferous		359
		Devonian		419
		Silurian		444
		Ordovician		485
		Cambrian		541
Proterozoic		Ediacaran		635
				2,500
Archaean				4,000
Hadean				Approx. 4,600

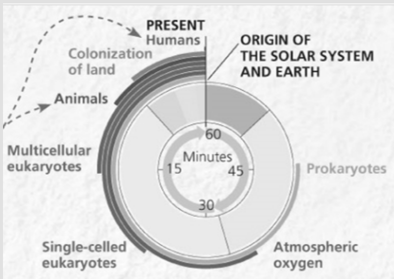
TECTONIC PLATES THEORY



continents are part of plates of Earth's crust, floating on hot mantle

3 occasions (1 billion, 600 million, and 250 million years ago) when most of the landmasses of earth came together to form a supercontinent

HISTORY OF EARTH



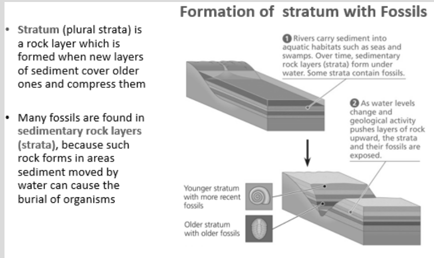
FOSSILS

fossils are the traces of ancient life, naturally preserved, but an incomplete chronicle of evolution

macroevolution	evolution above the species level, *interspecific variation*
microevolution	evolutionary change in allele frequencies in a population over generations, *intraspecific variation*

favor species that existed for a long time, were abundant/widespread, had hard shells, skeletons

FOSSIL FORMATION



FOSSIL DATING

relative age determined by rock strata sequence

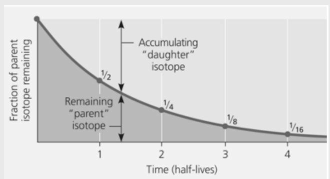
younger stratum has more recent fossils	older stratum has older fossils

absolute age determine through radiometric dating

radioactive "parent" isotope decays to "daughter" isotope at a constant rate

half-life	known time required for half parent isotope to decay

RADIOMETRIC DATING



If the half-life of carbon-14 is about 5,730 years, then a fossil that has 1/8th the normal proportion of carbon-14 to carbon-12 should be about how many years old? **5730 Years X 3= 17190 years**

CREATIONS ACCORDING TO FOSSILS

earliest **prokaryote** fossils (ARCHAEAN EON)	form *stromatolites* dating back 3.5 BYA, sole inhabitants for 1.5 BY
increase in **atmospheric oxygen**	2.7 BYA

CREATIONS ACCORDING TO FOSSILS (cont)

cyanobacteria, other photosynthesizers	led to extinction of many
earliest **eukaryote** fossils (PROTEROZOIC EON)	1.8 BYA, gave rise to multicellular organisms
jawed vertebrates (PHANEROZOIC EON)	440 MYA
Cambrain explosion (535-525 mya)	+diversity, unique mammalian features
tetrapods (PALOZOIC ERA)	375 MYA colonized land
mammals	120 MYA, from synapsids

MASS EXTINCTIONS

can be caused by:

Habitat destruction and/or unfavorable environmental change

Biological causes (factors)-Origin of one new species can spell doom for another

Permian Mass Extinction (252mya)	96% marine life when extinct due to intense volcanisms *Paleozoic to Mesozoic era*
Cretaceous Mass Extinction (66mya)	+50% of all marine animals, many terrestrial plants and animals, dinosaurs (except birds) due to meteorite *Mesozoic to Cenozoic era*

5–10 million years for diversity to recover

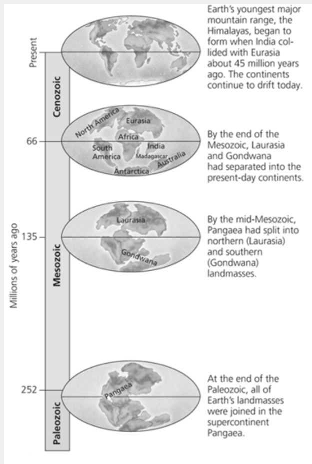
mass extinctions alter ecological communities and remove lineages, forever change the course of evolution and can also pave the way for *adaptive radiations*

ADAPTIVE RADIATION

the evolution of many diversely adapted species from a common ancestor that allows new species to occupy different habitats

may follow:	mass extinctions	ex. mammals after extinction of dinosaurs
	evolution of novel characteristics	ex. rise of photosynthetic organisms
	colonization of new regions	organisms colonize new environments with little competition

CONTINENTAL DRIFT DURING PHANEROZOIC EON



Pangea (250 mya), organisms adapt (speciation) or go extinct

when continents drift can result in *allopatric speciation*

GENETIC MECHANISMS

developmental genes	program development, influence rate, timing, spatial patterns	
heterochrony	evolutionary change in the rate or timing of developmental events	ex. human vs chimpanzee jaw

GENETIC MECHANISMS (cont)

homeotic genes	determine the organization of basic features	
hox genes	a class of homeotic genes, provide positional information during animal development	
evolutionary novelties	changes at the genetic level lead to developmental changes at the phenotypic level	
exaptations	structures that originally played one role but gradually acquired a different role	ex. bird feathers

EUKARYOTES ARE "COMBINATION" ORGANISMS

Table 25.1 Inferred Origins of Key Eukaryotic Features

Feature	Original Source
DNA replication enzymes	Archaeal
Transcription enzymes	Archaeal
Translation enzymes	Mostly archaeal
Cell division apparatus	Mostly archaeal
Endoplasmic reticulum	Archaeal and bacterial
Mitochondrion	Bacterial
Metabolic genes	Mostly bacterial

consequence of endosymbiosis

PROTIST

is any eukaryotic organism that is not an animal, plant, or fungus

first eukaryote was a unicellular protist and most eukaryotes are protists

structural and functional diversity, most are aquatic, most are unicellular

complex at the cellular level, though simple when compared to eukaryotes

PROTIST (cont)

nutritional diversity:	*photoautotroph* = producers (photosynthetic) use energy from light (or inorganic chemicals) to convert CO_2 to organic compounds
	heterotroph = consumers
	parasites =
	mixotroph =
photosynthetic protists	*main producers in aquatic community* biomass of photosynthetic protists is limited by the availability of nitrogen, phosphorus, or iron diatoms, dinoflagelletes, multicellular algae, others *blooms* dramatic increase in abundance
symbiotic protists	some are parasites that harm their hosts ex. photosynthetic dinoflagellets provide food for coral reefs ex. wood-digesting protists break down cellulose in the guts of termites

effect on human health

trypanosoma = excavate that causes sleeping sickness
apicomplexans = alveolate parasites
ex. plasmodium - causes malaria

ORIGINS OF COMPLEX MULTICELLULARITY

multicellular colonies	collections of connected cells, little to no differentiation, can be simple or complex

Multicellular organisms with differentiated cells likely originated from multiple different ancestors

1. origin of cyanobacteria
2. origin of mitochondria
3. origin of plastid (chloroplast)
4. origin of multicellular eukaryotes
5. origin of fungal-plant symbioses

EUKARYOTE SUPERGROUPS

Excavata (unicellular protists)

> ‣**diplomonads**;**parabasalids** —
> lack plastids, cannot do photosynthesis, reduced mitochondria, mostly anaerobic
> ‣**euglenozoans**—
> most have 2 flagella, diverse, inclue predatory heterotrphs, photoautotrophs, parasites
> *ex. trypanosoma - parasitic infection that causes sleeping sickness*

SAR (**S**tramenopiles, **A**lveolates, **R**hizarians)
includes most important photosynthetic organisms)

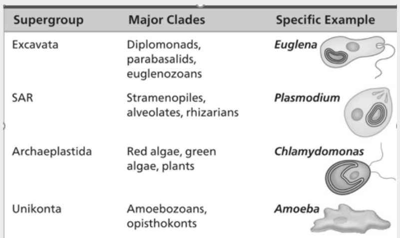
> ‣**diatoms** — diverse photosynthetic unicellular algae
> can affect
> ‣**brown algae (seaweed)** — largest & most complex, multicellular, mostly marine
> *brown due to carotenoids in plastid*
> anchored by *holdfast*, stem-like *stipe* supporting leaflike *blades*

EUKARYOTE SUPERGROUPS (cont)

Archaeplastids

> ‣**red algae** — 2nd largest, mostly multicellular, can absorb green & blue light
> *red due to phycoerythrin pigment*
> ‣**green algae**— very similar to land plants, some are unicellular
> ↪**chlorophytes** — marine, terrestrial, mostly freshwater, multicellular, unicellular (free or symbiotic)
> ↪**charophytes** — most closely related to land plants
> ‣ **plants**
> chloroplasts of land plants *cyanobacteria ➟ green algae ➟ land plants*

EUKARYOTE SUPERGROUPS



Supergroup	Major Clades	Specific Example
Excavata	Diplomonads, parabasalids, euglenozoans	*Euglena*
SAR	Stramenopiles, alveolates, rhizarians	*Plasmodium*
Archaeplastida	Red algae, green algae, plants	*Chlamydomonas*
Unikonta	Amoebozoans, opisthokonts	*Amoeba*

DIVERSITIFICATION OF EUKARYOTES

eukaryotes

	a) plants b) animals c) fungi, molds, mushrooms, yeast d) protists
early eukaryotes	date back *2.7 billion years ago* unicellular, with nucleus, membrane, cytoskeleton, varied size & shape
diverse eukaryotes	1.8 billion years ago novel biological features evolved: multicellularity, sexual life cycles, eukaryotic photosynthesis

DIVERSITIFICATION OF EUKARYOTES (cont)

large eukaryotes	635-541 million years ago (Ediacaran period) *soft-bodied* organisms *hard-bodied* organisms 535-525 mya (Cambrian explosion)

ORIGIN OF MITOCHONDRIA & PLASTIDS

plastid	membrane-bound organelle (plants, algae, others) ex. chloroplast
endosymbiont theory	mitochondria and plastids were formerly small bacteria that began living within larger cells
key evidence	•inner membranes are similar (transport proteins) to bacteria plasma membrane •replication is similar to bacteria cell division •have circular DNA like bacteria •transcribe/translate own DNA into proteins •ribosomes more similar to bacterial than eukaryotic

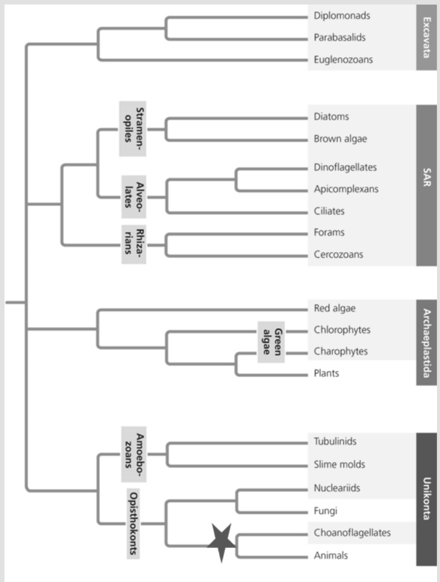
mitochondria come from a single *proteobacterium* ancestor which could do aerobic respiration using O2 to make ATP

plastids come from a single *cyanobacterium* ancestor that could do photsynthesis

ALL eukaryotes have mitochondria, not many have plastids

anaerobic host cells may have benefited from aerobic endosymbionts as oxygen increased in the atmosphere

EUKARYOTIC DIVERSITY (PHYLOGENETIC TREE)



(protists are yellow) \

THE GREENING OF EARTH

+4 billion years ago	Earth was created, lifeless for the first 2 billion years
1.2 billion years ago	cyanobacteria & protists
+470 million years ago	plants colonized land
500 million years ago	plants, fungi, & animals moved to land
385 million years ago	first forests

PLANTS

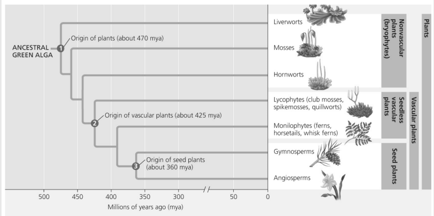
ancestors	red, green, & brown algae multicellular eukaryotes photsynthetic autotrophs cellulose cell walls chlorplasts (chlorophyll a & b) modernly only **charophytes** share most traits w plants
chloroplasts of land plants	cyanobacteria ➞ green algae (charophytes) ➞ land plants
moving to land...	☐ evolution of: **sporopollenin** — protective polymer surrounding charophyte zygotes ➞ dry land ☐ BENEFITs: unfiltered sunlight, plenty CO2, nutrient-rich soil ☐ CHALLENGES: scarcity of water, lack of support against gravity
key traits in plants not found in charophytes	•alternation of generations •multicellular, dependent embryos •walled spores produced in sporangia •apical meristems

PLANTS (cont)

apical meristems	*— localized regions of cell division @ tips of roots & shoots, mitotic division = +mineral & nutrients*
derived traits	•cuticle — waxy coating, prevents water loss •stomata — specialized pores, CO2-O2 exchange

plants affect soil formation, roots stabilize soil and are nutrients when they decay, 50% atmospheric O2

HIGHLIGHTS OF PLANT EVOLUTION



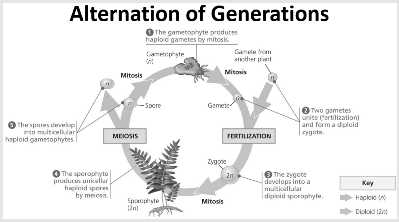
PLANT CLASSIFICATION

vascular plants	vascular tissue for H2O/nutrient transport ‣**xylem**- conducts most H2O/minerals (*tracheids* have lignin = water-conducting cells, provide structural support) ‣**phloem** - tubes of cells, distribute sugars, amino acids, other org. prod ‣lignin = polymer that makes plants rigid, allowing them to grow tall

PLANT CLASSIFICATION (cont)

nonvascular plants	bryophytes lack vascular tissue ‣**rhizoids** - root-like anchor ‣**gametophytes** = larger, live longer than sporophytes ‣mature **sporophyte** fully depends on gametophyte for nutrition ‣limited to moist habitats *•liverworts* *•mosses* *•hornworts*
seedless vascular	✲early vascular plants ‣ **sporophytes** = large/more complex gen. ‣ *gametophyte* & *sporophyte* are independent ‣sperm swims through water to egg (like bryophytes) *•lycophytes (club mosses)* *•monilophytes (ferns)*
seed plants	✲reduced gametophytes, ovules, pollen ‣ **seed**= embryo + food supply + protective coat *•gymnosperms = naked seeds* *•angiosperms = enclosed seeds in ovaries* (flowers & fruits)

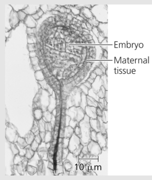
ALTERNATIONS OF GENERATIONS



gametophyte generation is *haploid* and produces *haploid* gametes by mitosis

fusion of sperm+egg creates *diploid* **sphorophyte** and produces *haploid* spores by meiosis

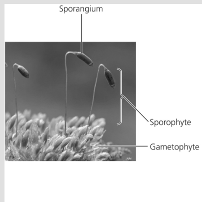
MULTICELLULAR, DEPENDENT EMBRYOS



embryo within female gametophyte tissue, placental transfer cells ➡ nutrients

embryophytes —embryo dependent on parent plant

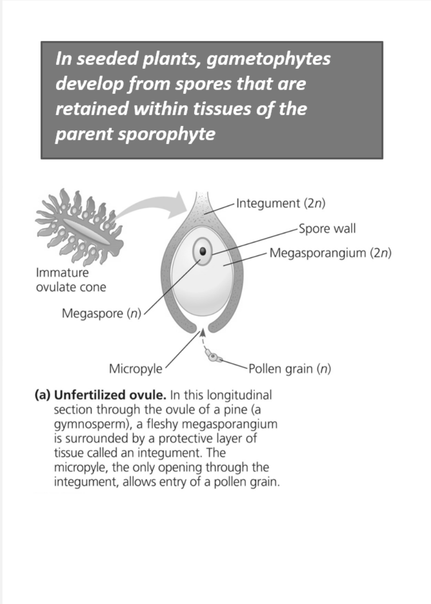
WALLED SPORES PRODCUED IN SPORANGIS



sporangia— multicellular organs that produce spores

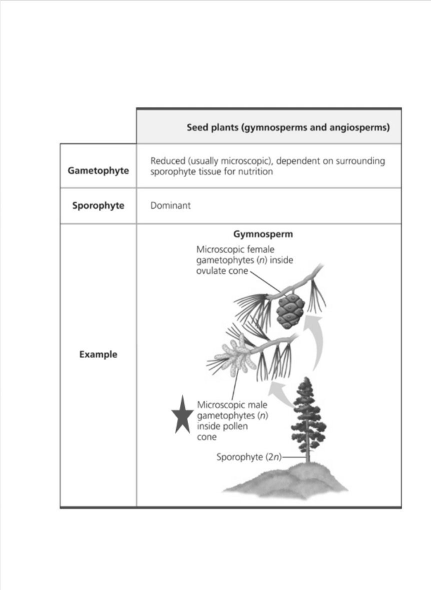
sporopollenin (strong polymer) —in walls, resistant to harsh environments

OVULATE CONE



ovule= *megaspore* (haploid spore → female gametophyte) *+ protective layer*(integument)

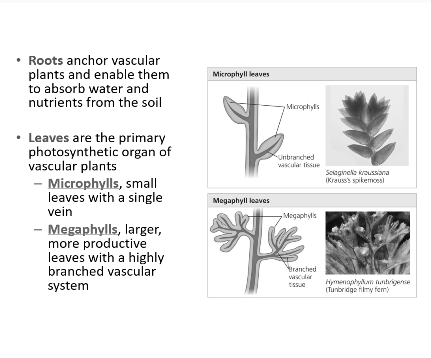
POLLEN CONE



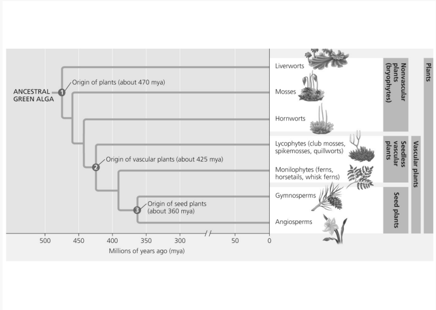
pollen grain = *microspores* (haploid spores → male gametophyte) + *protective wall* (w/ sporopollenin)

**pollination - transfer of pollen to seed plant's ovules

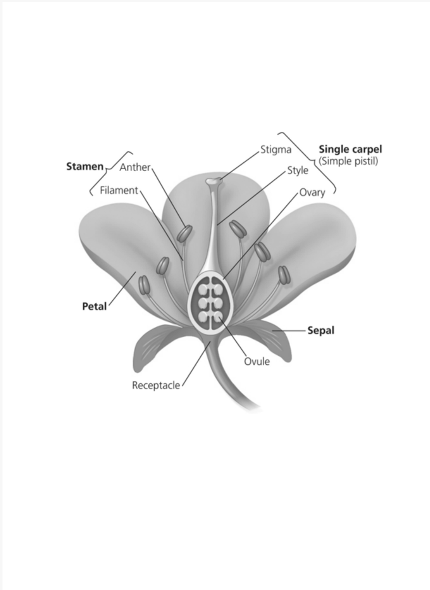
EVOLUTION OF ROOTS & LEAVES



EVOLUTION OF ROOTS & LEAVES



FLOWERS & FRUITS



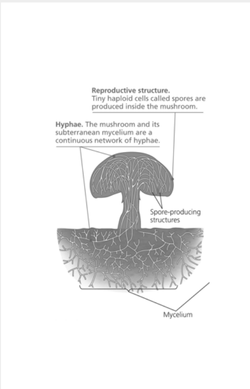
stamen = *filament* (stalk) + *anther* (sac produces pollen)
carpel = ovary (@ base) + style + stigma (where pollen is received)
ovary - 1/+ ovules

FUNGI

oldest fossils	460 million years ago, terrestrial
heterotrophs that feed by absorption	
FEED BY ABSORPTION secrete hydrolytic enzymes to break down complex molecules → small org. comp	
chitin cell walls	
diversification	•mold (multicellular) •yeast (unicellular)
life cycles & reproduction	‣most propagate by producing many spores, sexually or asexually
key role in land plant colonization	symbiotic interactions...

fungi/other decomposers (fungi/bacteria) break down dead organisms and return nutrients to physical environment

FUNGAL ADAPTATIONS TO LAND



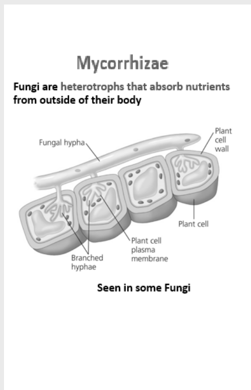
SYMBIOTIC INTERACTIONS

mutualism	benefits BOTH plant + fungi (*endophytes*) inside leaves/other •plant provide nutrition, some endophytes make toxins that deter herbivores/pathogens
parasitism	benefits one, harms other fungi absorb nutrients from host cells
lichen	*photosynthetic microorganism*(algae/cyanobacteria)-*fungus* •fungi benefit from carbs produced by algae/cyanobacteria •microorganism is protected by fungal filaments, gather moisture/nutrients

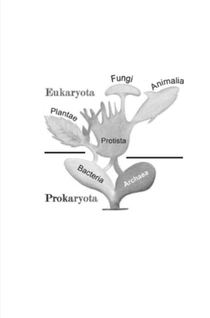
lichens break down surface & promote soil formation so plants can grow, on land 420 mya

mycorrhizae	*plant-fungal* — fungal hyphae transfer nutrients (phosphate/others) to plant earliest land plants *lacked true roots/leaves*

MYCORRHIZAE

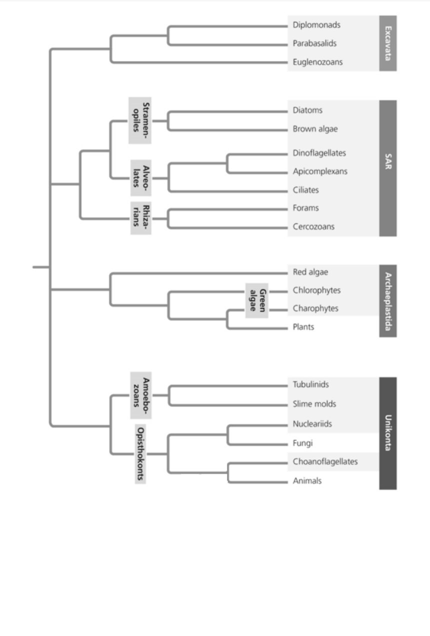


THE RISE OF ANIMAL DIVERSITY



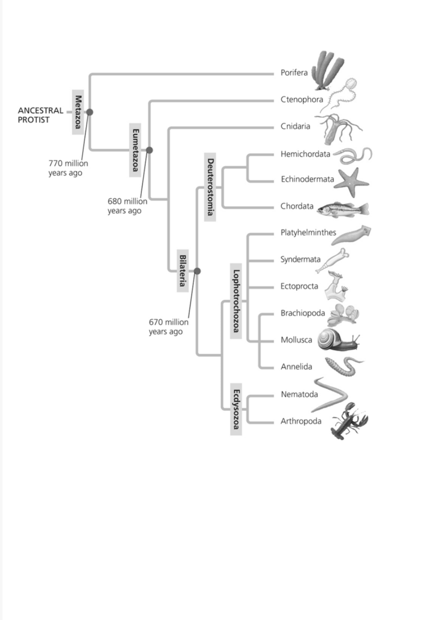
all animals (*metazoa*) share a common ancestor and likely evolve from multiple single-celled eukaryotes (*protist*)

EUKARYOTIC SUPERGROUPS



sponges and choanoflagellates' (protists) similarities = animals evolved from choanoflagellate-like ancestor over 700 millions years ago

DIVERSIFICATION OF ANIMALS



①all animals share a common ancestor
② sponges are sister group to ALL other animals
③eumatozoa = animals with tissues
④ most animal phyla belong to Bilaterian clade
⑤ most animals are invertebrates

EARLY-DIVERGING ANIMAL GROUPS

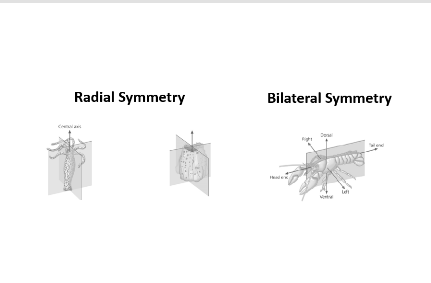
sponges & cnidarians diverged from all other animals early on

sponges (PORIFERA)	•*basal animals* •lack true tissues •filter feeders: capture small particles in water water is drawn through pores into central cavity and flows out through an opening at the top

ANIMALS WITH TISSUES

eumetazoans include cnidarians and all others	*"true animals"* = tissues have symmetrical bodies (radial or bilateral)
•radial symmetry *cnidarians* (jellyfish, anemones)	- single, central axis most animals are sessile{nl}}➢2 embryonic tissue layers →endoderm →ectoderm
•bilateral symmetry	- 2 axes animals that move actively ➢3 germ layers →endoderm →ectoderm →mesoderm
cnidarians	tissues + radial symmetry, blind digestive system, carnivores, lack brain/muscles, nerve net (simplest)
chordata	bilaterians, vertebrates, complete digestive tract
bilateral invertebrates	95% animals

EUMATOZOAN SYMMETRY



BODY CAVITIES

most bilaterians posses a a **body cavity** (*coelom*)	- fluid/air filled space between digestive tract & outer body wall
	cushions organs, acts as hydrostatic skeleton, organs move independently of body wall