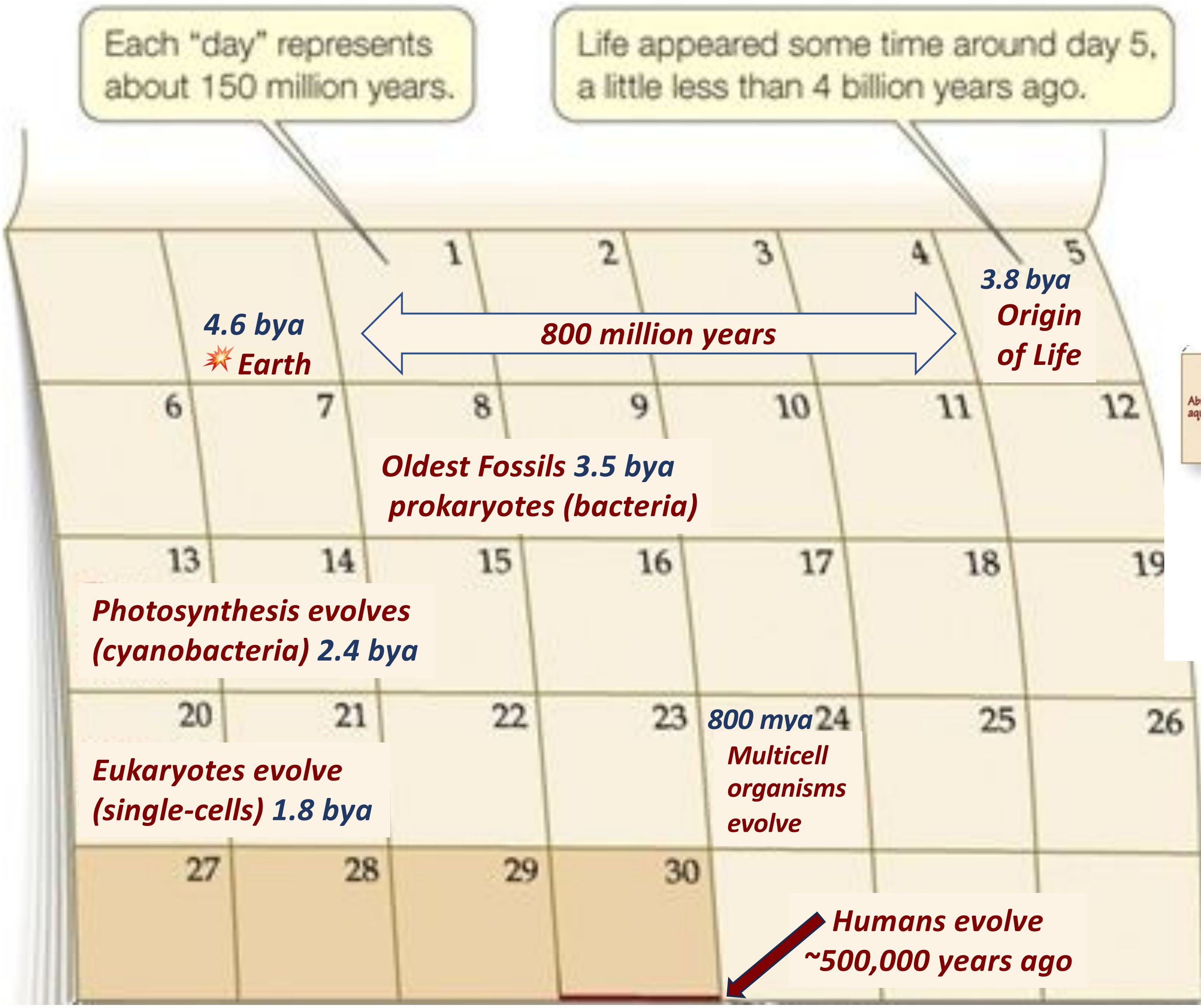
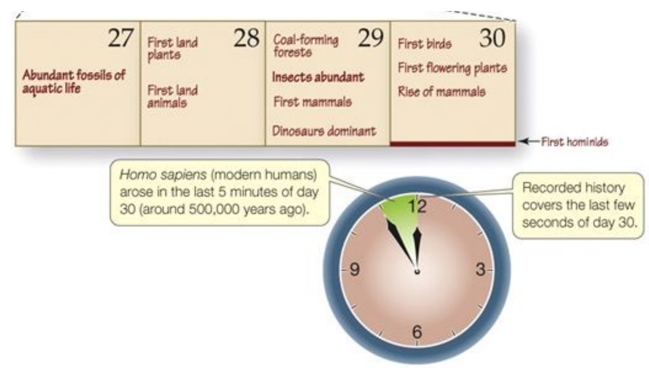
Lecture 1 : Origins

Origins of Life

timescale is vast

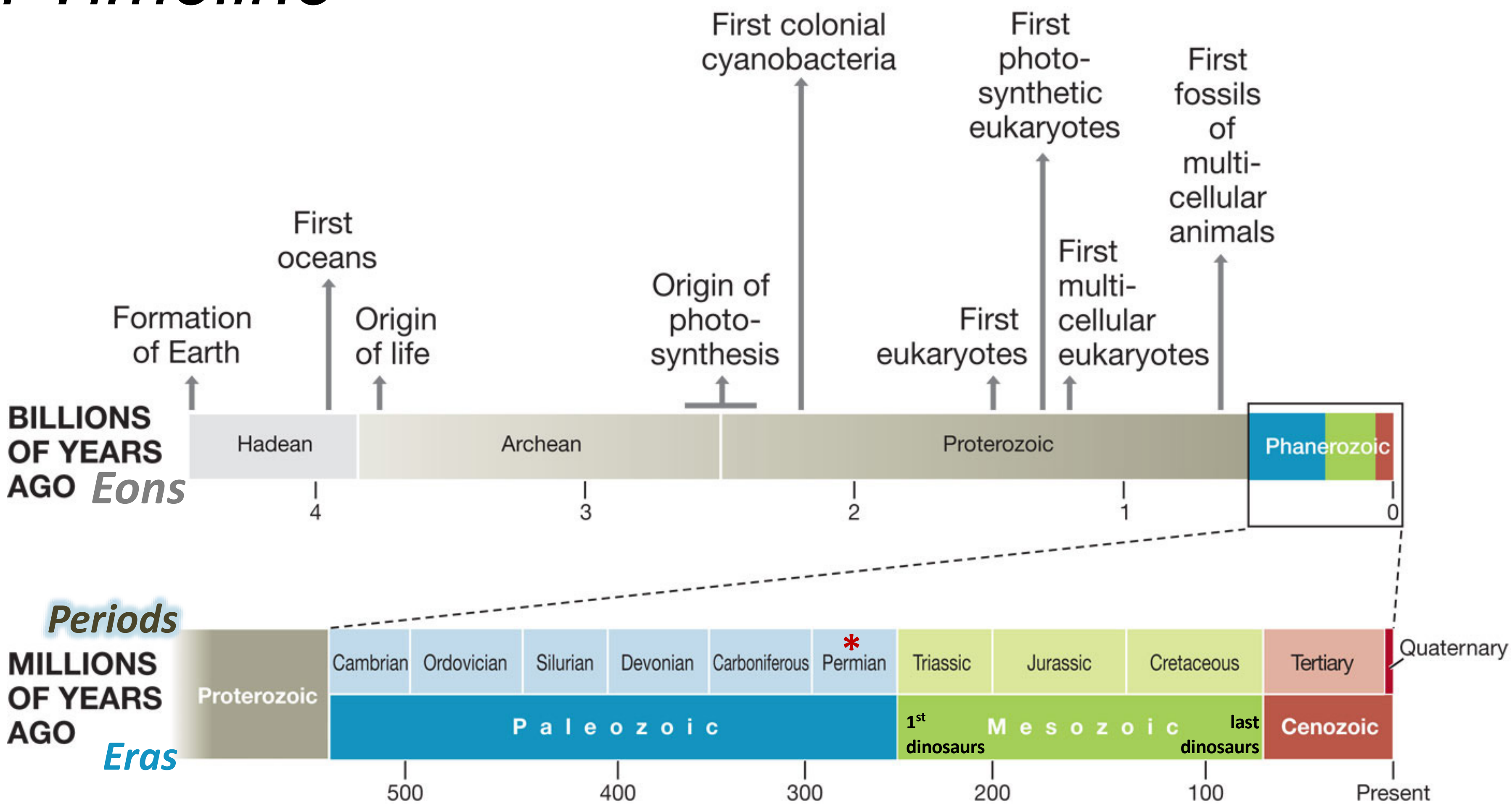
*bya = **billion** years ago*





Chapter 1, Figure 1.1

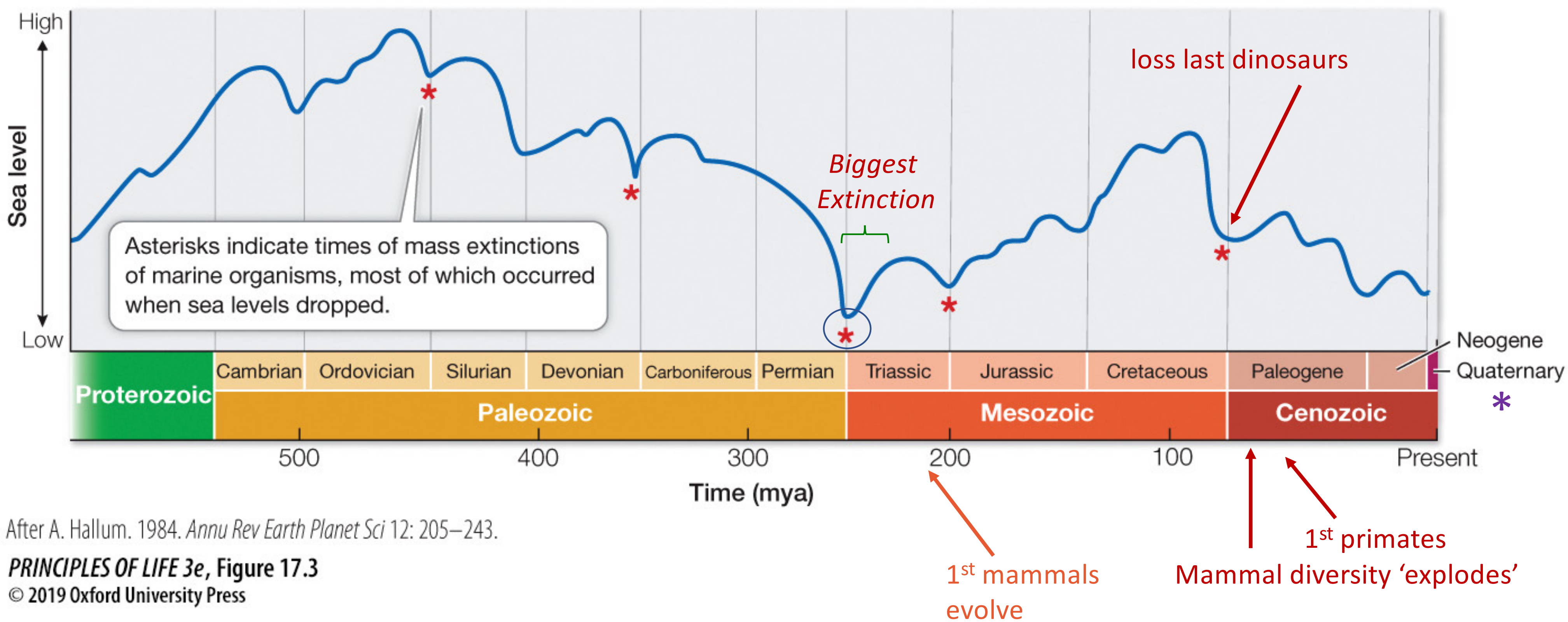
Earth Timeline



***PRINCIPLES OF LIFE 2e*, Figure 18.10**

3rd Ed. (3e) 17.3, p.402-6, 410-11

History - Five Mass Extinctions: Look for Correlations in Data ....

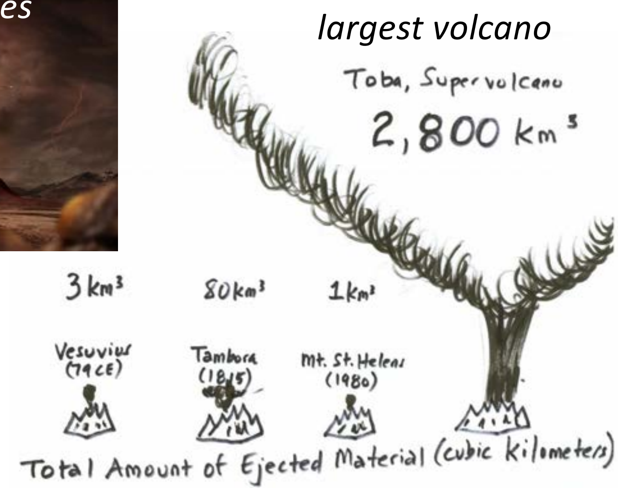


After A. Hallum. 1984. *Annu Rev Earth Planet Sci* 12: 205–243.

PRINCIPLES OF LIFE 3e, Figure 17.3

Possible 6th Extinction *now*: high *rate* of CO_2 increase, warming atmosphere

Known Causes of Extinctions



Very OLD Earth was harsh: no O_2, *hot* – 1st life extremophiles! Photosynthesizers brought oxygen, atmosphere, water, mild temps ... Evolution and lifeform diversification ... And then:
5 Exinctions ...

1. huge **glaciers**, **sea levels** plummet, kills ~ 85% of all species
2. **not clear**, kills ~ 75% of all species, mostly marine.
3. large **asteroid** & **volcanic** explosion lava burns coal layer that **warms** Earth, increases $\mathbf{CO_2}$, kills > 95% of all species, the Great Dying.
4. massive **volcanos** cause high CO2/methane/sufur, and **soot** blocks sun
5. huge **asteroid** hits Mexico Yucatan, **debris** block out sun, volcanoes in India, kills 78% of all species, including dinosaurs. ☹

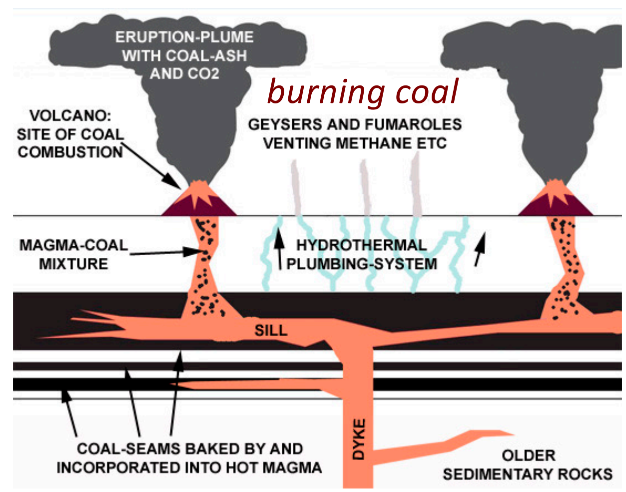


TABLE 18.1 Earth's Geological History *(Part 2)*

Eon	Era	Period	Onset	Major Events in the History of Life
Phanerozoic (~0.5 billion years long)	Cenozoic	Quaternary (Q)	2.6 mya	Humans evolve; many large mammals become extinct * ?
		Tertiary (T)	65.5 mya	Diversification of birds, mammals, flowering plants, and insects
	Mesozoic	Cretaceous (K)	145.5 mya	Dinosaurs continue to diversify; mass extinction at end of period (~76% of species lost) *
		Jurassic (J)	201.6 mya	Diverse dinosaurs; radiation of ray-finned fishes; first fossils of flowering plants
		Triassic (Tr)	251.0 mya	Early dinosaurs; first mammals; marine invertebrates diversify; mass extinction at end of period (~65% of species lost) *
	Paleozoic	* Permian (P)	299 mya	Reptiles diversify; giant amphibians and flying insects present; mass extinction at end of period (~96% of species lost)
		Carboniferous (C)	359 mya	Extensive fern/horsetail/giant club moss forests; first reptiles; insects diversify
		Devonian (D)	416 mya	Jawed fishes diversify; first insects and amphibians; mass extinction at end of period (~75% of marine species lost) *
		Silurian (S)	444 mya	Jawless fishes diversify; first jawed fishes; plants and animals colonize land
		Ordovician (O)	488 mya	Mass extinction at end of period (~75% of species lost) *
		Cambrian (Ꞓ)	542 mya	Rapid diversification of multicellular animals; diverse photosynthetic protists
Proterozoic	Collectively called the Precambrian (~4 billion years long)		2.5 bya	Origin of photosynthesis, multicellular organisms, and eukaryotes
Archean			3.8 bya	Origin of life; prokaryotes flourish
Hadean			4.5–4.6 bya	Life not yet present

Note: mya, million years ago; bya, billion years ago.

***PRINCIPLES OF LIFE 2e*, Table 18.1 (Part 2)** 2019, 3rd Ed. *(3e)* Table 17.1

Humans Evolve
Diversity 'Explosion'
- *birds, mammals, plants, insects*

Dinosaurs Expand/Abound
1st Flowering Plants
1st Mammals
1st Dinosaurs

****Mass Extinction – The Biggest***
Giant plants & animals
Lush Vegetation
1st Reptiles
1st Amphibians
1st Insects
1st Fish
Organisms Colonize LAND
1st Multicell Animals

1st Multicellular Plants
1st Eukaryote Photosynthesis
1st Eukaryotes
1st Photosynthesizers
1st Prokaryotes
No evidence of Life

TABLE 18.1 Earth's Geological History *(Part 1)*

Eon	Era	Period	Onset	Major Physical Changes on Earth
Phanerozoic (~0.5 billion years long)	Cenozoic	Quaternary (Q)	2.6 mya	Cold/dry climate; repeated glaciations
		Tertiary (T)	65.5 mya	Continents near current positions; climate cools
	Mesozoic	Cretaceous (K)	145.5 mya	Laurasian continents attached to one another; Gondwana begins to drift apart; meteorite strikes near current Yucatán Peninsula at end of period
		Jurassic (J)	201.6 mya	Two large continents form: Laurasia (north) and Gondwana (south); climate warm
		Triassic (Tr)	251.0 mya	Pangaea begins to drift apart; hot/humid climate
	Paleozoic	* Permian (P)	299 mya	Extensive lowland swamps; O_2 levels 50% higher than present; by end of period continents aggregate to form Pangaea, and O_2 levels drop rapidly
		Carboniferous (C)	359 mya	Climate cools; marked latitudinal climate gradients
		Devonian (D)	416 mya	Continents collide at end of period; one or more giant meteorites probably strike Earth
		Silurian (S)	444 mya	Sea levels rise; two large land masses emerge; hot/humid climate
		Ordovician (O)	488 mya	Massive glaciation; sea level drops 50 meters
		Cambrian (Є)	542 mya	Atmospheric O_2 levels approach current levels
Proterozoic	Collectively called the Precambrian (~4 billion years long)		2.5 bya	Atmospheric O_2 levels increase from negligible to about 18%; "snowball Earth" from about 750 to 580 mya
Archean			3.8 bya	Earth accumulates more atmosphere (still almost no O_2); meteorite impacts greatly reduced
Hadean			4.5–4.6 bya	Formation of Earth; cooling of Earth's surface; atmosphere contains almost no free O_2; oceans form; Earth under almost continuous bombardment from meteorites

Note: mya, million years ago; bya, billion years ago.

***PRINCIPLES OF LIFE 2e*, Table 18.1 (Part 1)**

Fossil Fuels: *coal, oil, gas* are remains of organisms from *Carboniferous* period.

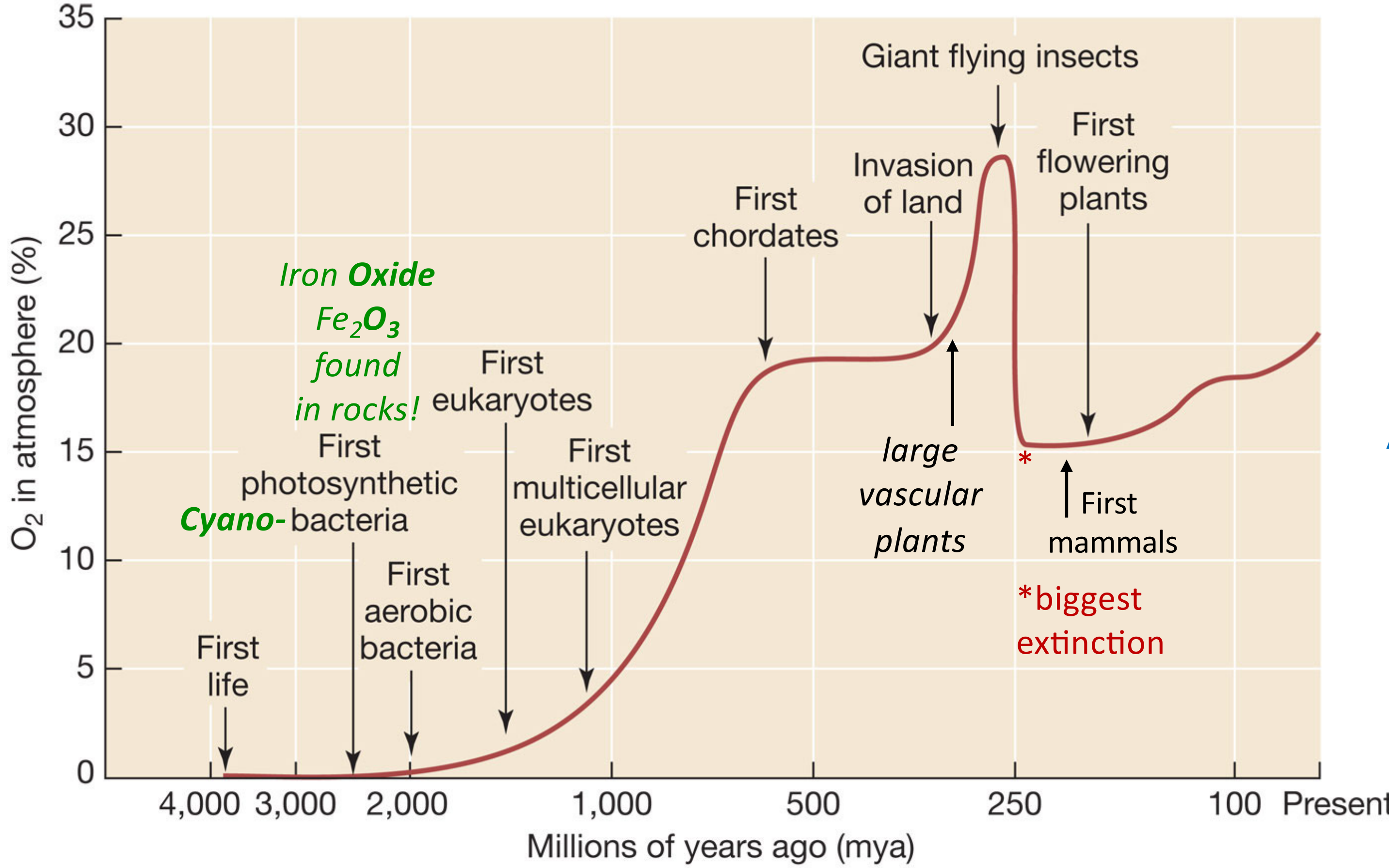
... the biggest extinction*

Lush, dense, tropical, swampy giant organisms thrive.

New life forms evolve
Air & water chemistry +O_2
Photosynthesis arises.

Hot, dry, anoxic/anaerobic

Atmospheric Oxygen Concentrations Change Over Time



PRINCIPLES OF LIFE 2e, Figure 18.7

Organisms' Size

↑

Accumulating $[O_2]$ in water & air

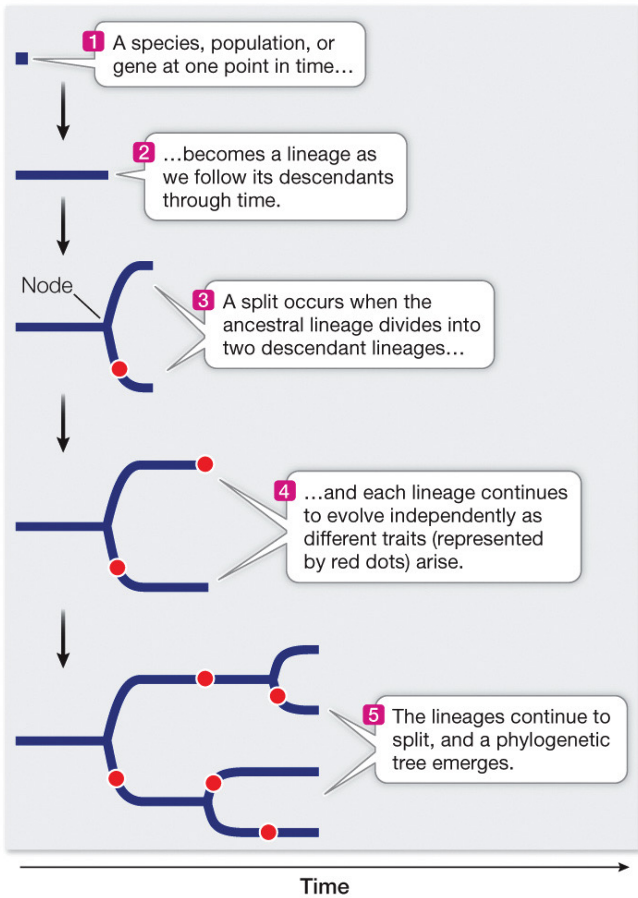
O_2 in Water & Air

↑

Photosynthesizers

Lecture 2 : Phylogeny

Components of a Phylogenetic Tree



PRINCIPLES OF LIFE 3e, Figure 14.1

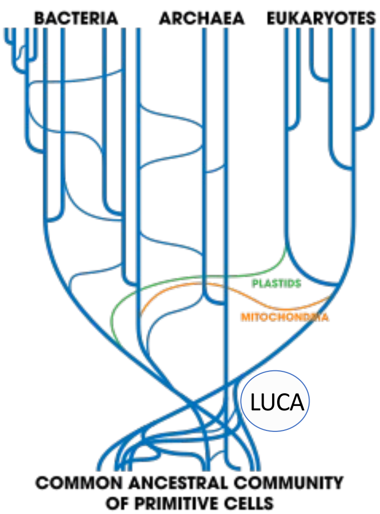
Phylogeny: study evolutionary relationships

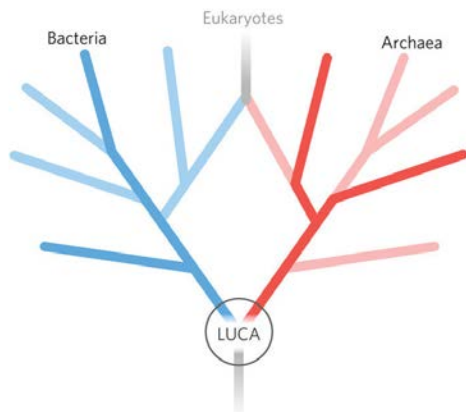
Phylogenetic tree: graphical representation of the evolutionary relationships with some reference of evolutionary distance (time).

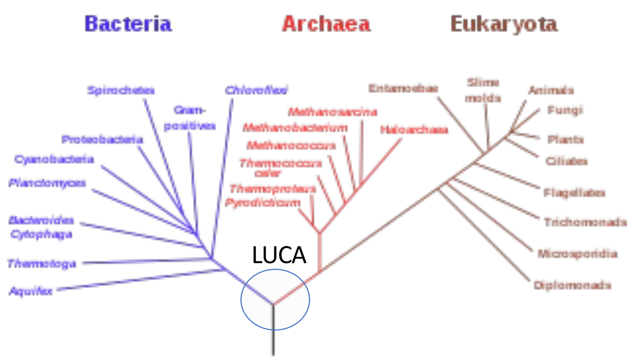
Node: point in a phylogenetic tree representing **an *averaged* ancestral state – but not a single organism.** Many very similar species populations live at any given time, with variants even within those populations. ***Internal*** nodes represent an ancestral population common to organisms on two different branches of a tree. ***Terminal*** nodes are at the outermost points on the branches of the tree - they represent the organisms studied or relevant in that tree, for which data exist.

Branch: Evolutionary connections between organisms in a tree. Organisms along the same branch share some type of feature or trait.

Three “Domains” of Life – for Now ... today





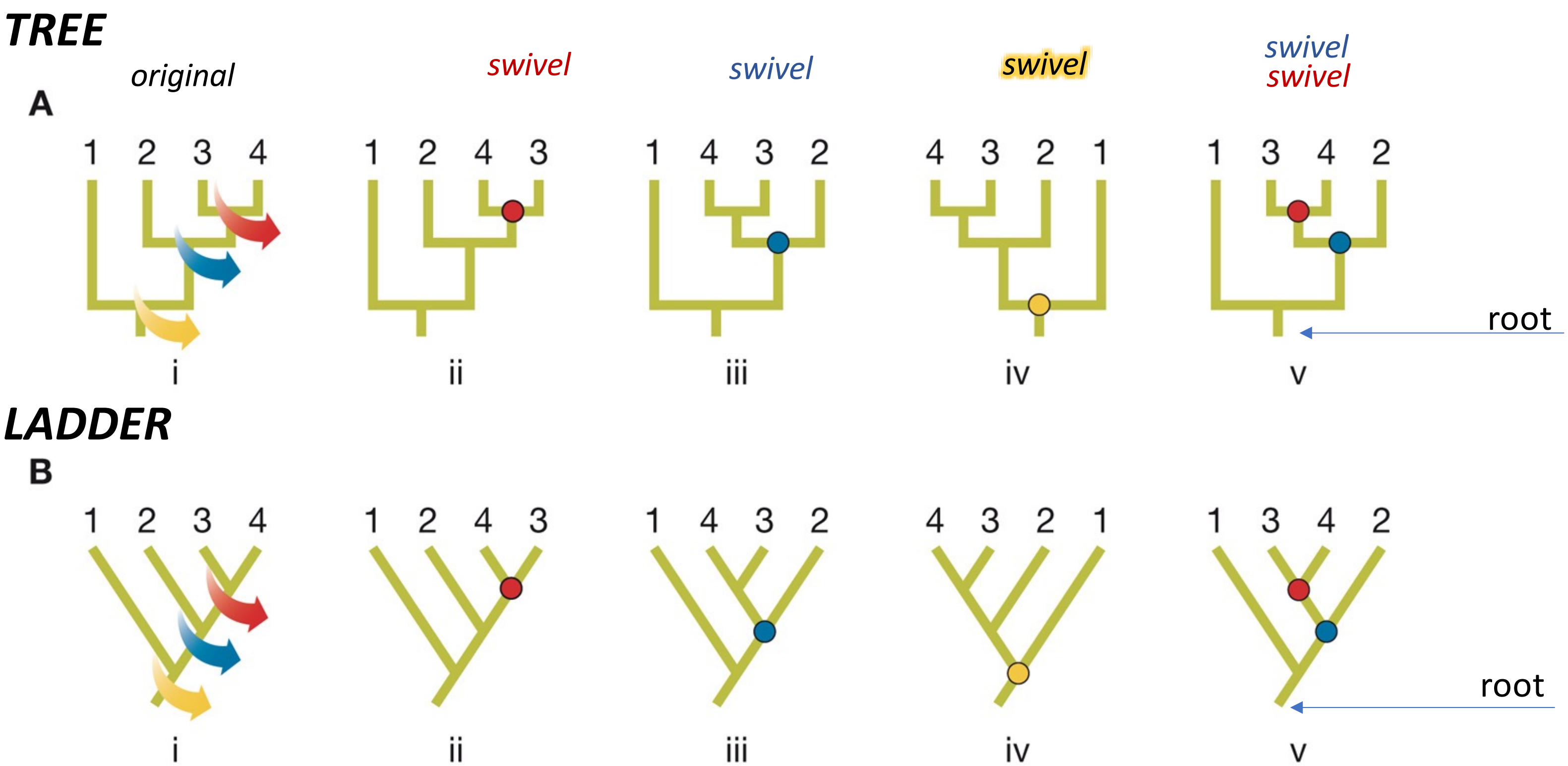


LUCA=
***L**AST **U**NIVERSAL **C**OMMON **A**NCESTOR(S)*

LUCA = is NOT one single species; likely a *group* of similar organisms: an *Ancestral Population*

Relationships can be drawn as TREEs or LADDERs:

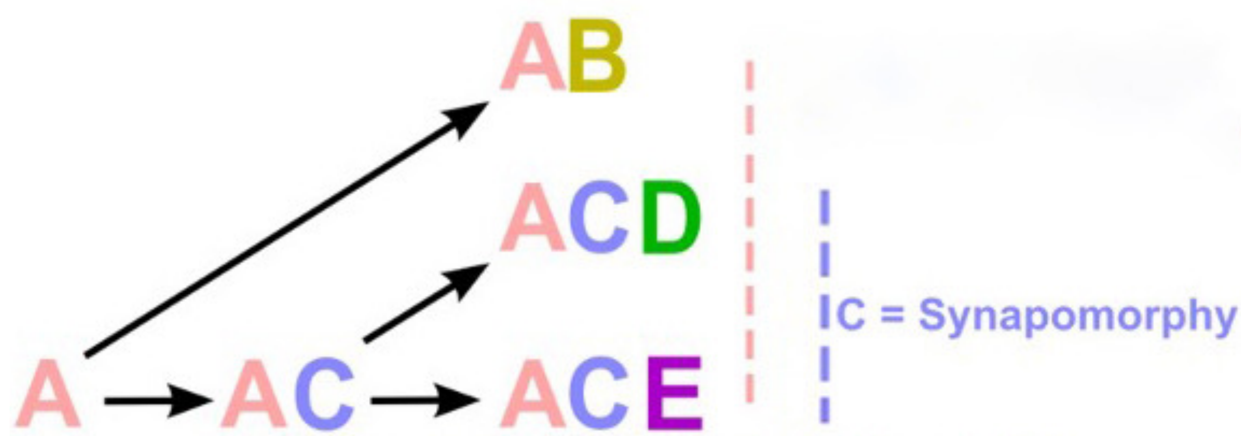
#1 is outgroup *in all of these* A and B.

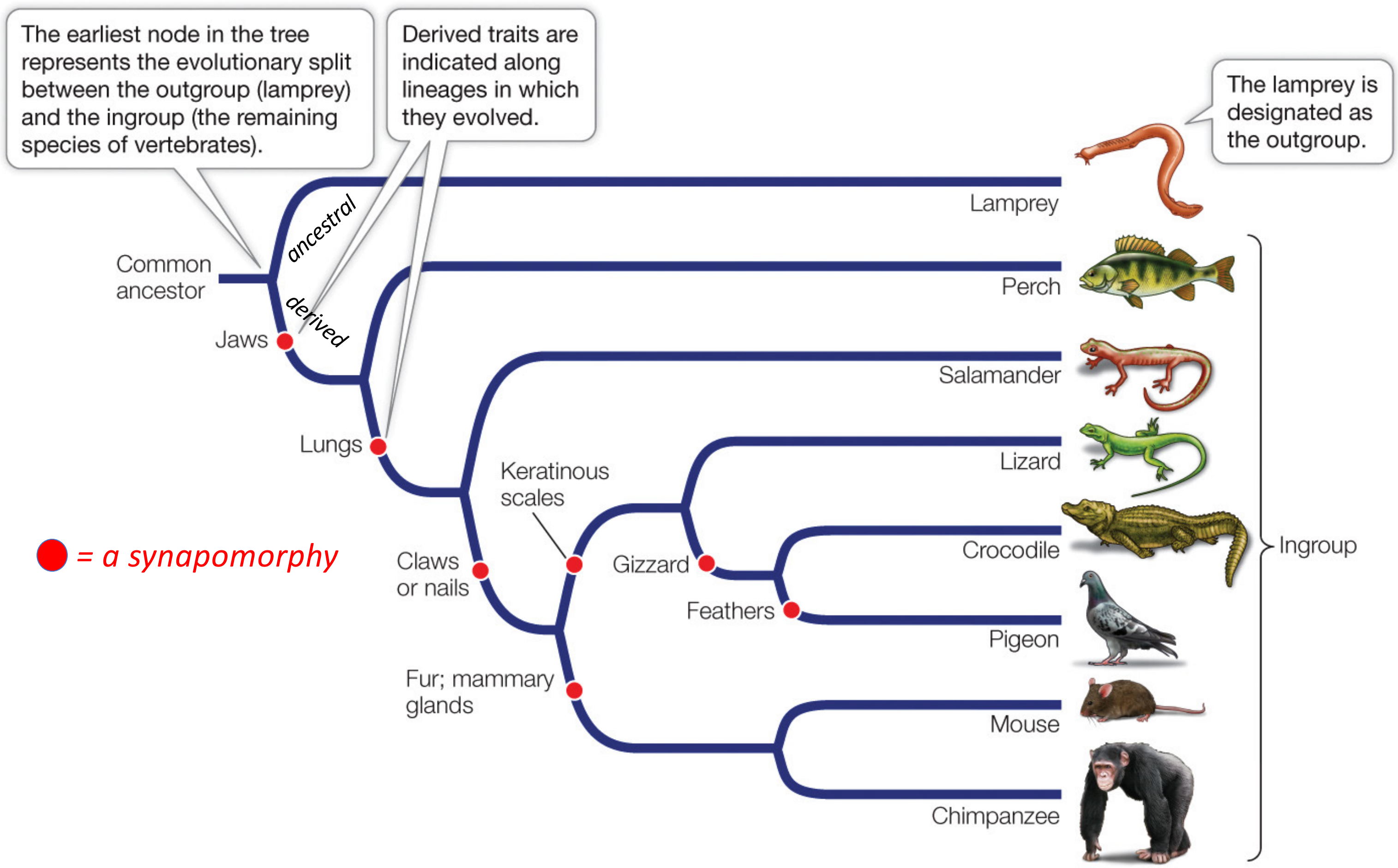


Definition: *Synapomorphy*

Trait present in a common ancestor and *shared* exclusively by its descendants.

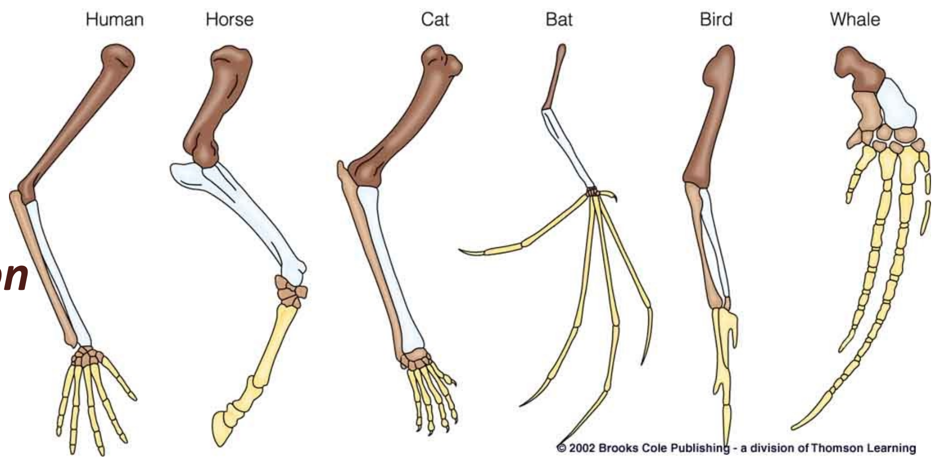
Trait *evidence of shared ancestry*.



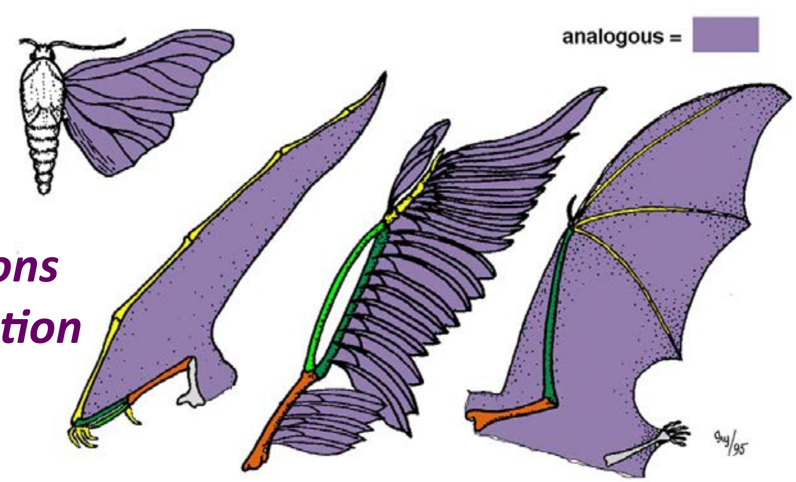


PRINCIPLES OF LIFE 3e, Figure 14.5

<u>Homology:</u> Bones.
Evolved
from common ancestor
structures related
may change via selection

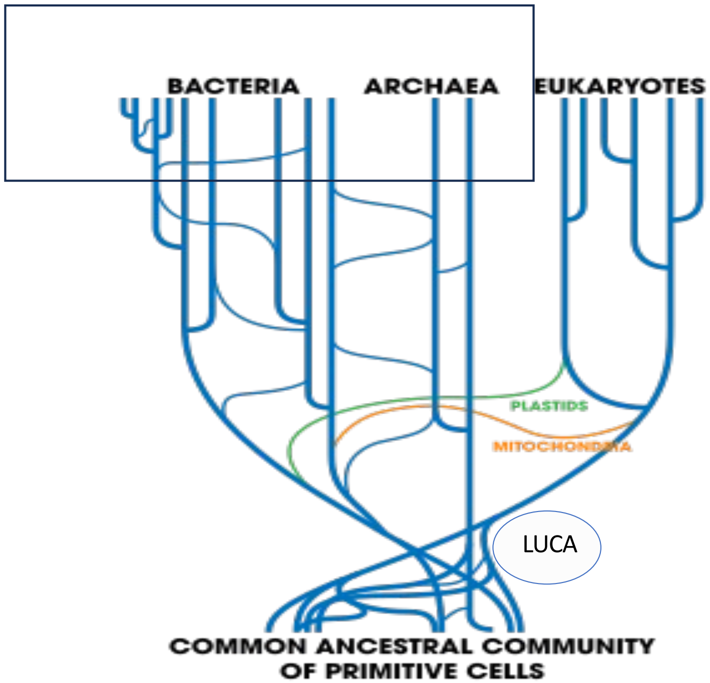


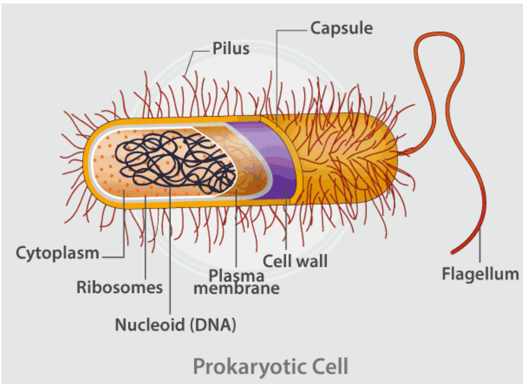
<u>Analogy:</u> Flight.
Evolved independently
not from a common ancestor
structures not directly related,
occur from independent selections
Selected for advantageous function
= flight

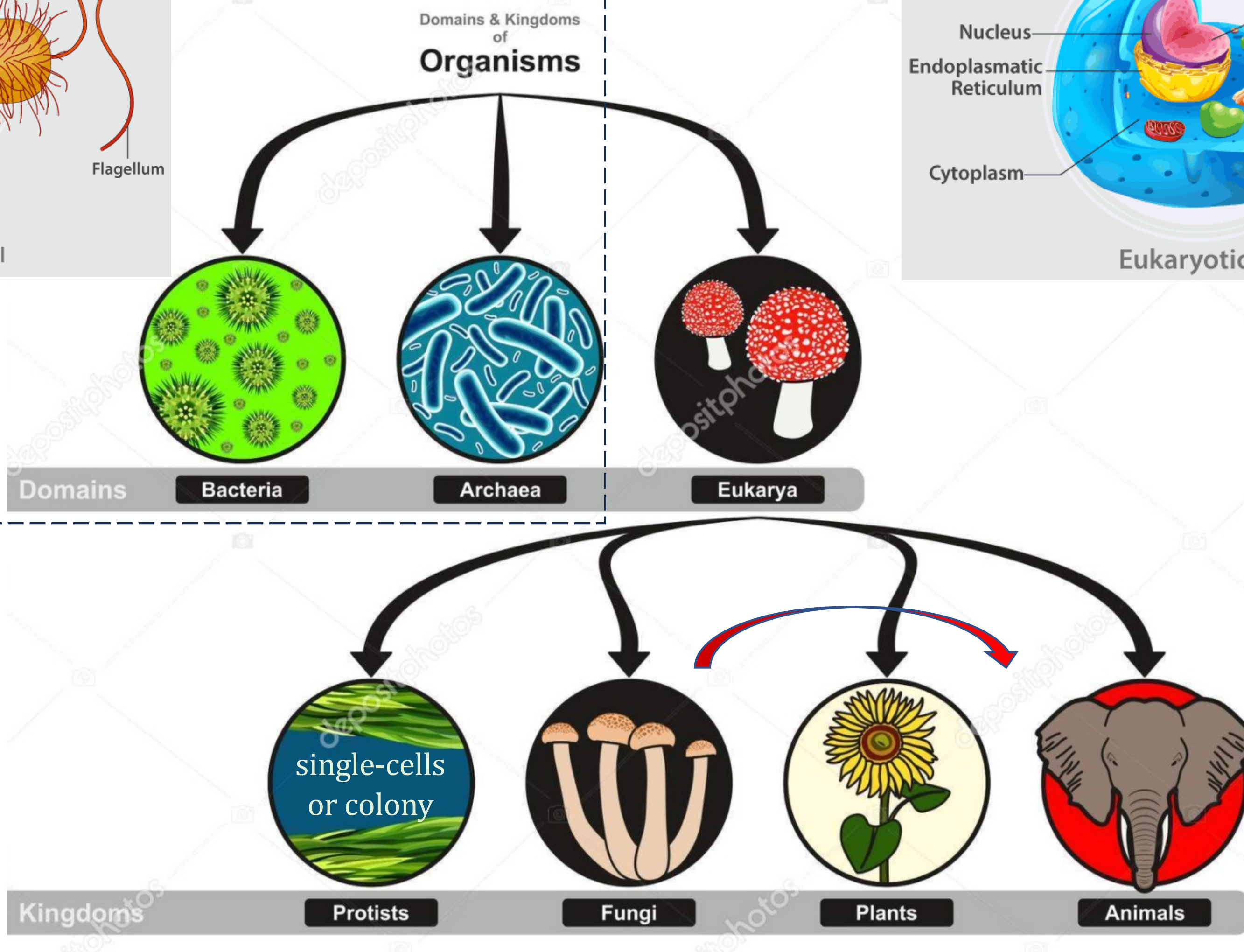


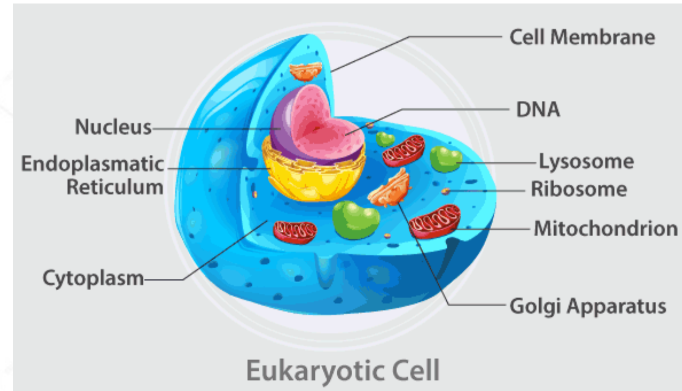
http://www.ncbi.nlm.nih.gov/pmc/articles/PMC2736124/

Lecture 3 : Prokaryotes



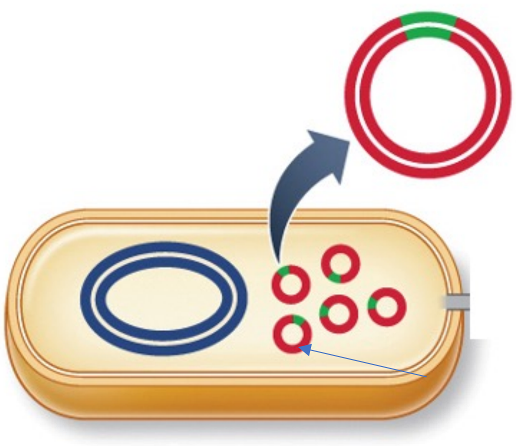

Capsule
Pilus
Cytoplasm
Cell wall
Ribosomes
Plasma membrane
Flagellum
Nucleoid (DNA)
Prokaryotic Cell


Domains & Kingdoms of
Organisms
Domains
Bacteria
Archaea
Eukarya
single-cells or colony
Kingdoms
Protists
Fungi
Plants
Animals

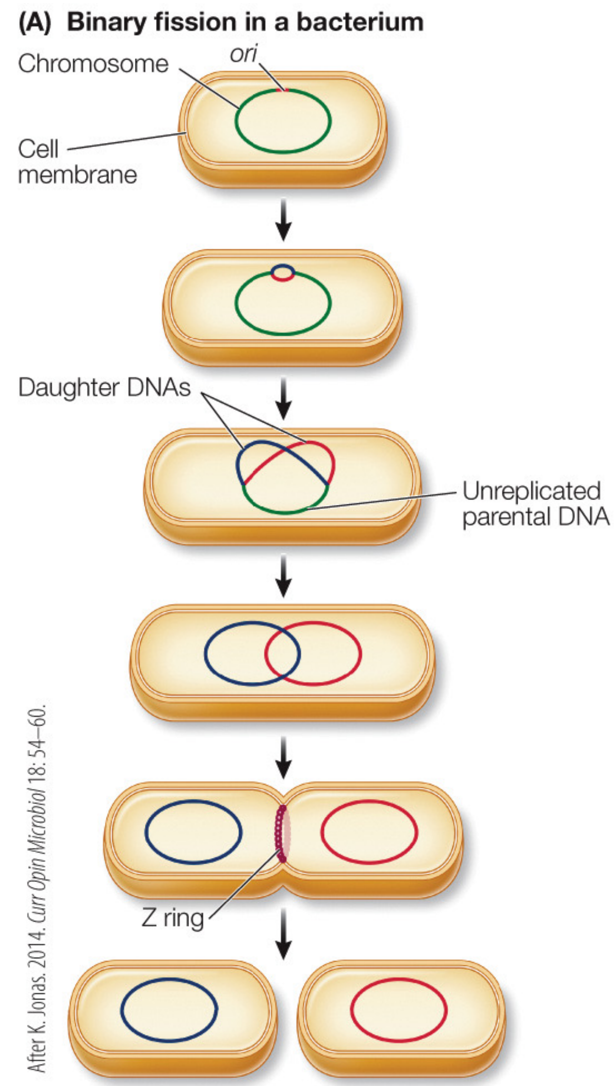

Cell Membrane
DNA
Nucleus
Endoplasmatic Reticulum
Lysosome
Ribosome
Mitochondrion
Cytoplasm
Golgi Apparatus
Eukaryotic Cell

Prokaryotes: Bacteria and Archaea

- genome is ***not*** in a nucleus (no organelles)
- have a single **circular dsDNA** DNA genome
- replicate by **binary fission**, ***not*** *mitosis*, not the classic cell cycle.
- are **haploid** (ONE copy each gene)
- carry **plasmids** (independent tiny circles of DNA)

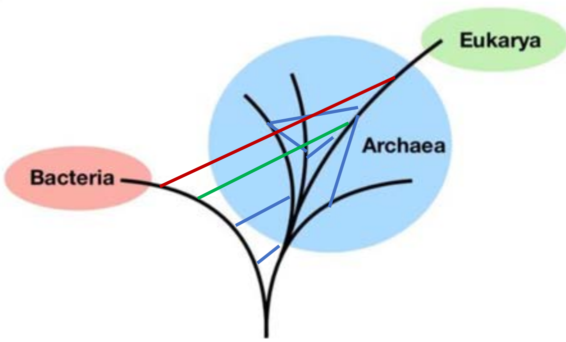


Plasmids are tiny circular independently-replicating bits of dsDNA. Plasmids are easily transmitted between different bacteria, "mobile" via conjucation. Plasmids often **carry** antibiotic-resistance genes which can make the pathogenic bacteria hard to kill.



Horizontal Gene Transfers

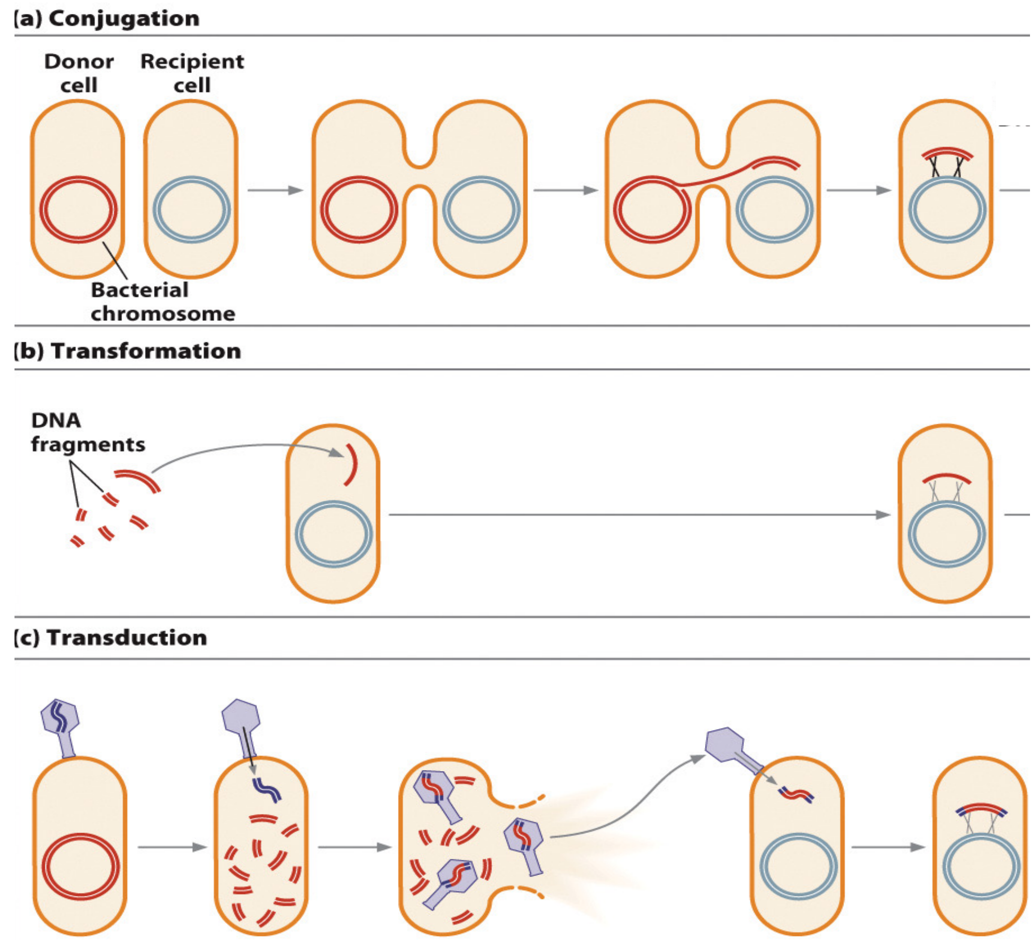
or 'Lateral' Gene Transfers



Three ways prokaryotes swap genes:

1. <u>Conjugation</u> "*bacterial sex*" via plasmids
2. <u>Transformation</u> take uptake external DNA bits
3. <u>Transduction</u> phage virus-mediated transfer of genomic bits

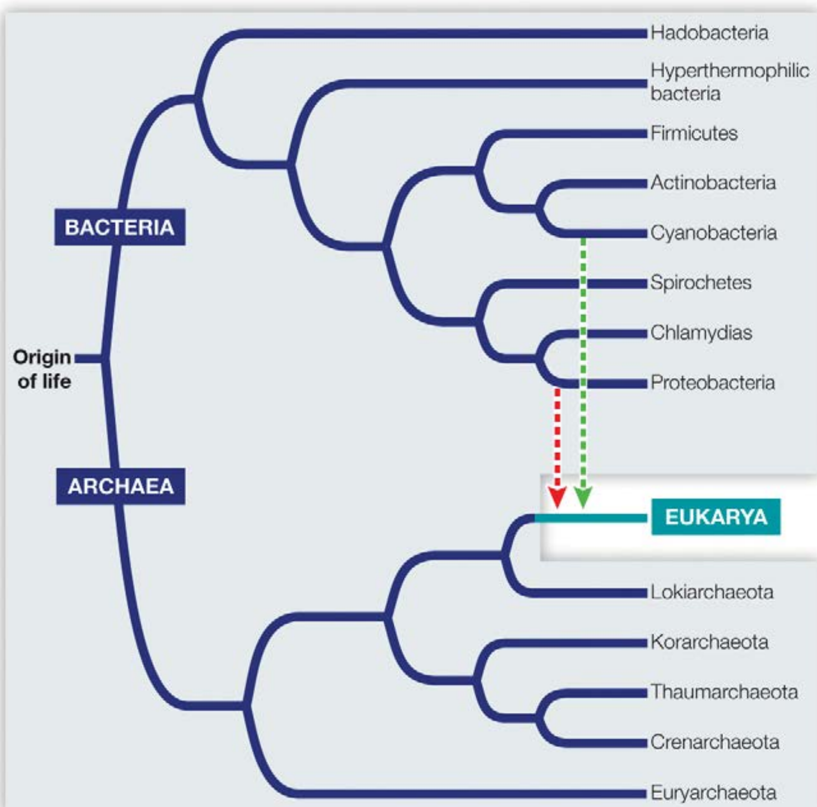
Three ways prokaryotes swap genes:



Endosymbiosis

origin of single-cell eukaryotes

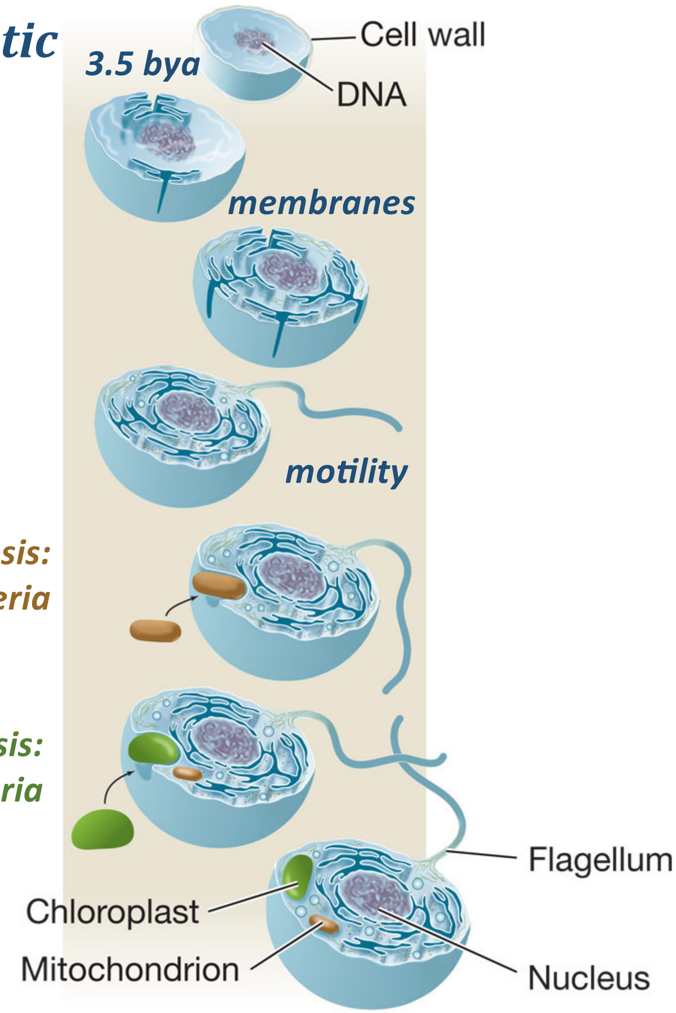
*hot, dry lifeless**



PRINCIPLES OF LIFE 3e, Figure 18.1

*Hypothesis: Theia/Earth water/collision

Theory: Prokaryotic Archaea Cells …



Eukaryotic cells

LIFE 10e, Figure 27.1

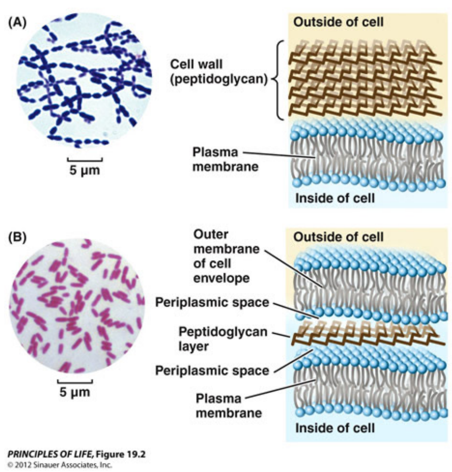
Prokaryotic vs. Eukaryotic

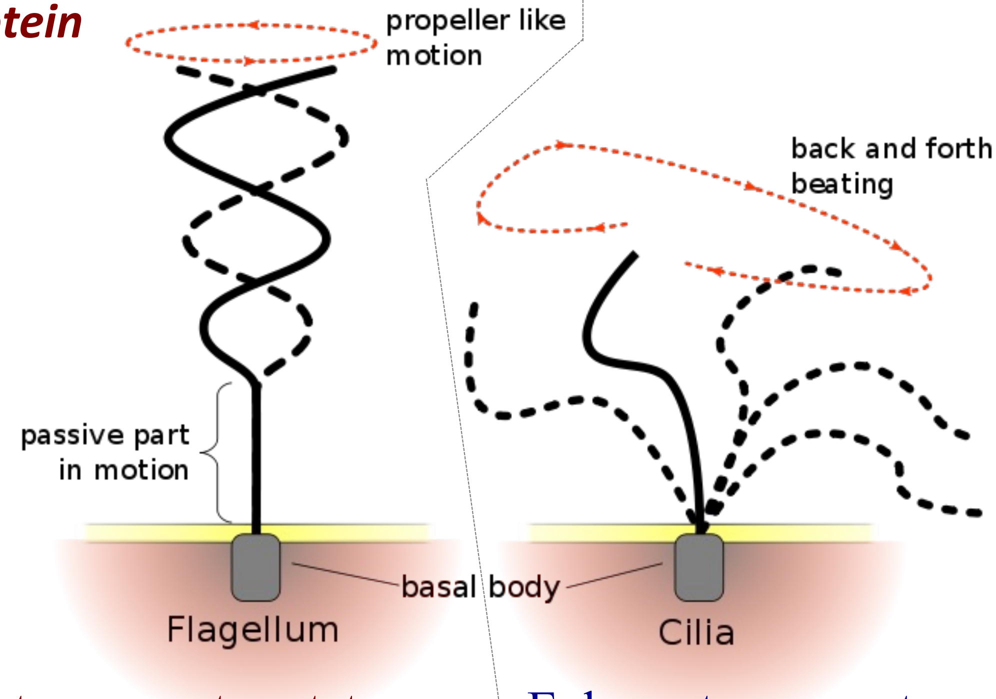
different proteins & different motions

Prokaryote:

Flagellin protein

polymers

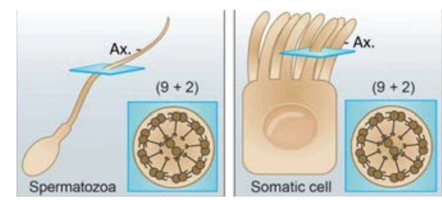


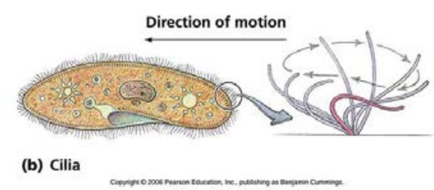


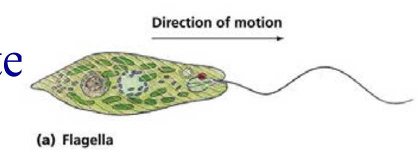
Eukaryote:

Tubulin dimers

9 by 2 microtubules





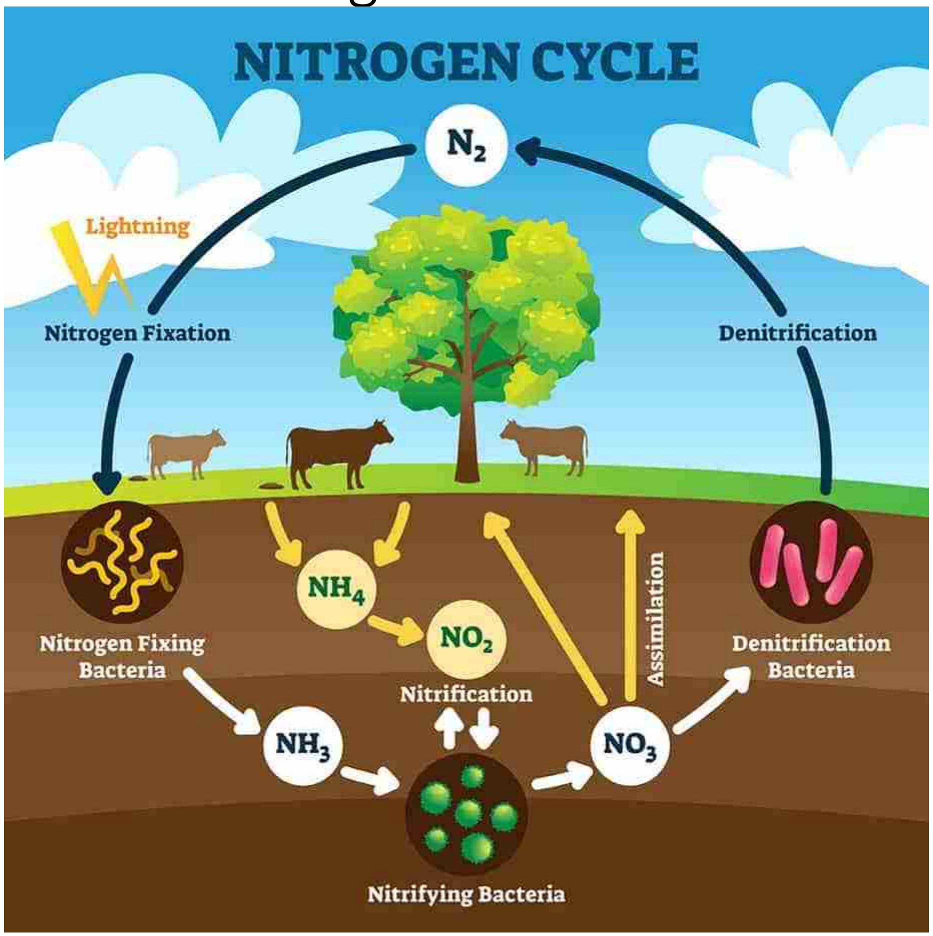


Prokaryote energy to rotate:
Proton H+ Gradient

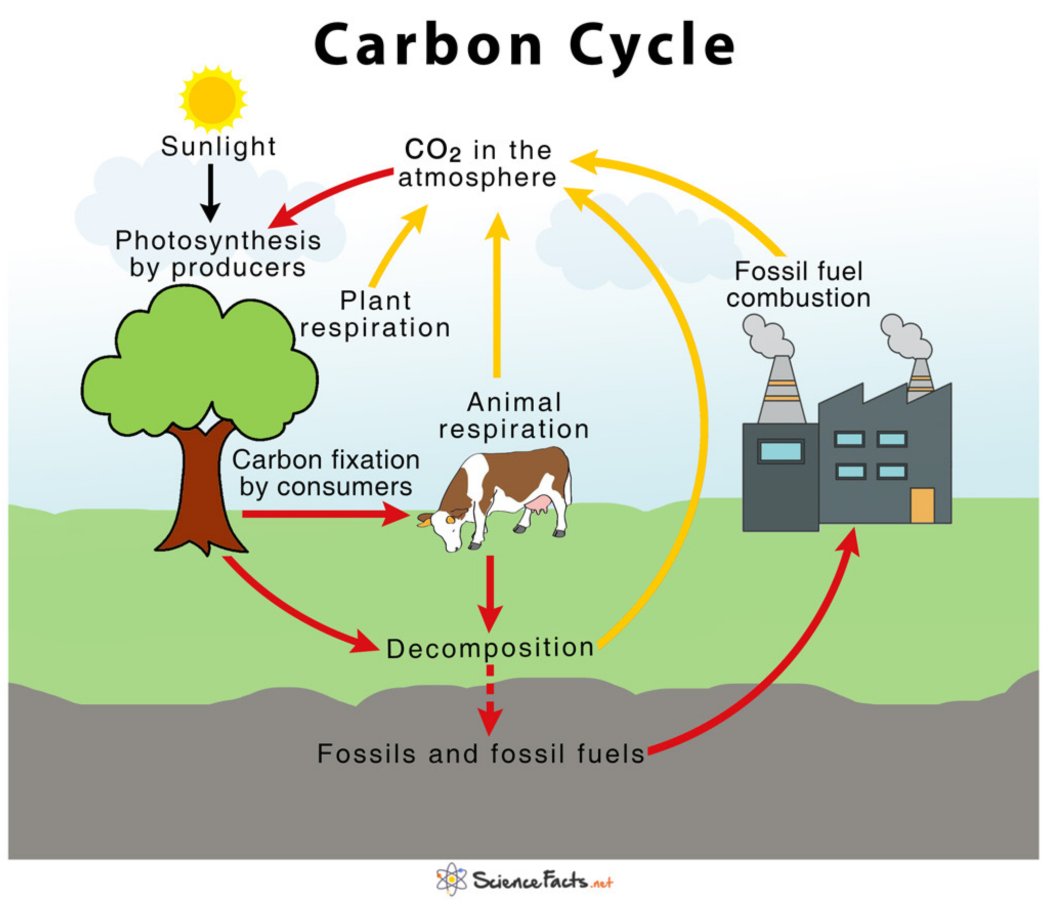
Eukaryote energy to rotate
ATP hydrolysis

CYANOBACTERIA

Nitrogen Fixation



Carbon Fixation



Archaea are often *Extremophiles*

Many can live in hot salty environments

Yellowstone National Park, Wyoming
Grand Prismatic hot spring
Water temperature: 160ºF (71ºC)

Koch's Postulates

Helicobacter pylori

* Estimated <<1% of ***all*** Bacterial are pathogens

How to Identify a PATHOGEN … →

Marshall and Warren set out to satisfy Koch's postulates:

Test 1

The microorganism must be present in every case of the disease.

Results: Biopsies from the stomachs of many patients revealed that the bacterium was always present if the stomach was inflamed or ulcerated.

Test 2

The microorganism must be cultured from a sick host.

Results: The bacterium was isolated from biopsy material and eventually grown in culture media in the laboratory.

Test 3

The isolated and cultured bacteria must be able to induce the disease.

Results: Marshall was examined and found to be free of bacteria and inflammation in his stomach. After drinking a pure culture of the bacterium, he developed stomach inflammation (gastritis).

Test 4

The bacteria must be recoverable from newly infected individuals.

Results: Biopsy of Marshall's stomach 2 weeks after he ingested the bacteria revealed the presence of the bacterium, now christened *Helicobacter pylori*, in the inflamed tissue.

Conclusion

Antibiotic treatment eliminated the bacteria and the inflammation in Marshall's stomach. The experiment was repeated on healthy volunteers, and many patients with gastric ulcers were cured with antibiotics. Thus Marshall and Warren demonstrated that the stomach inflammation leading to ulcers is caused by *H. pylori* infections in the stomach.

After B. J. Marshall and J. R. Warren. 1983. *The Lancet* 321: 1273–1275; B. J. Marshall et al. 1985. *Med J Aust* 142: 436–439.

PRINCIPLES OF LIFE 3e, Figure 18.21

Lecture 4 : Microbial Eukaryotes

‘Protists’

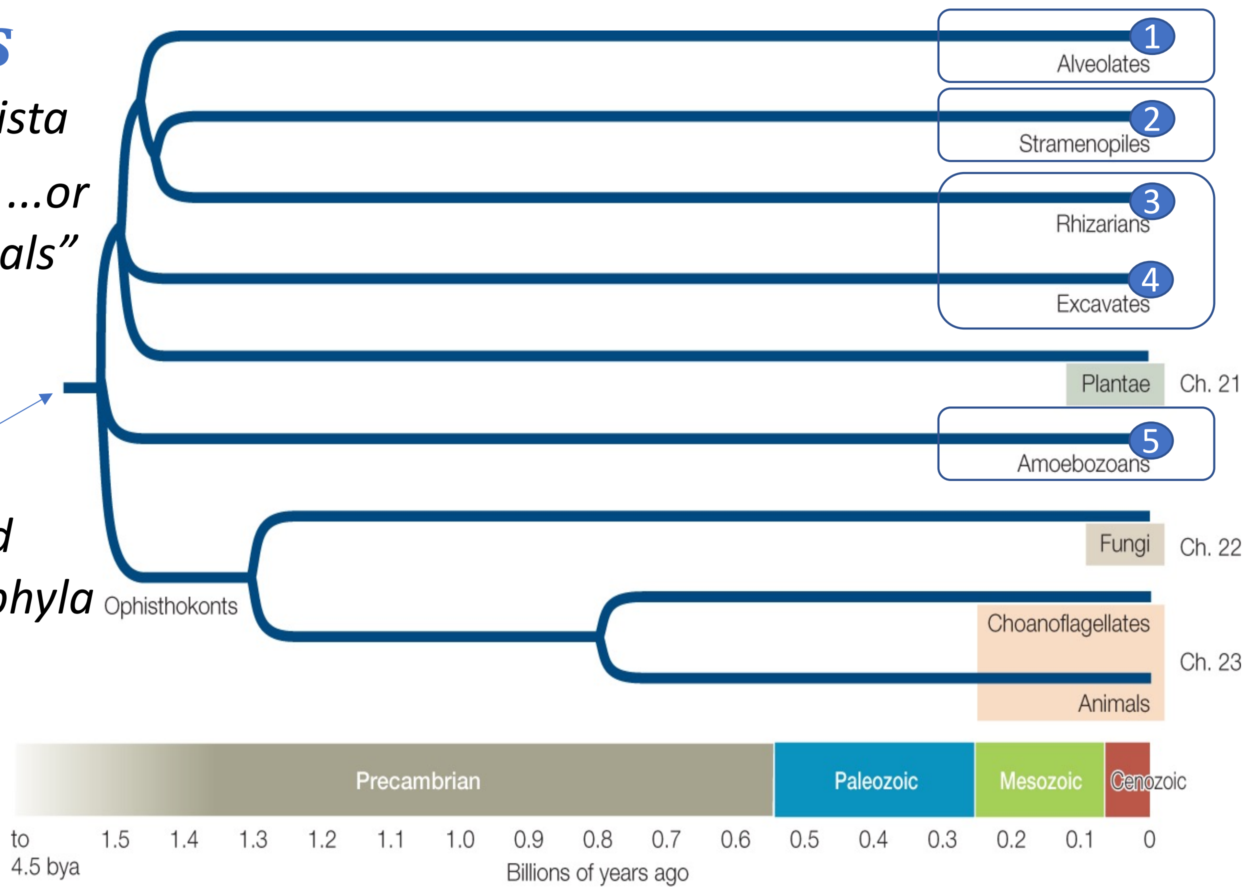
Microbial *Eukaryotes*

Retired name: Protists; phylum Protista

*"a mix of eukaryotic unicellular life" ...or "stuff that is **not** plants, fungi, animals"*

- *mostly* single-cells (few multi-cell)
- eukaryotic cells
- diverse!

Polyphyletic, go back to LUCA to find common shared traits among all 5 phyla



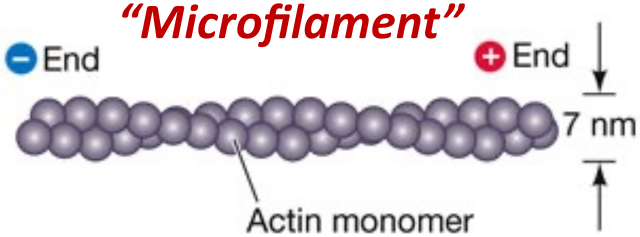
Know these organisms: Dinoflagellates vs. Diatoms, Plasmodium vs. Paramecium, Rhizaria, N.fowleri, Trypanosomes, Euglena, True Amoebas.

For each organism, know the interesting, unique traits or behaviors, how it interacts/lives its niche

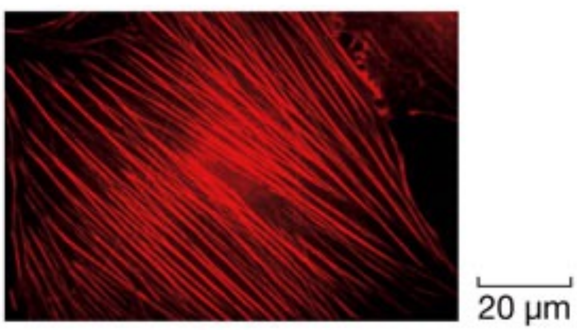
Actin Cytoskeleton enables ***<u>Eukaryotic</u>*** MOVEMENT

ACTIN … 1st in Amoebozoans!

"Microfilament"

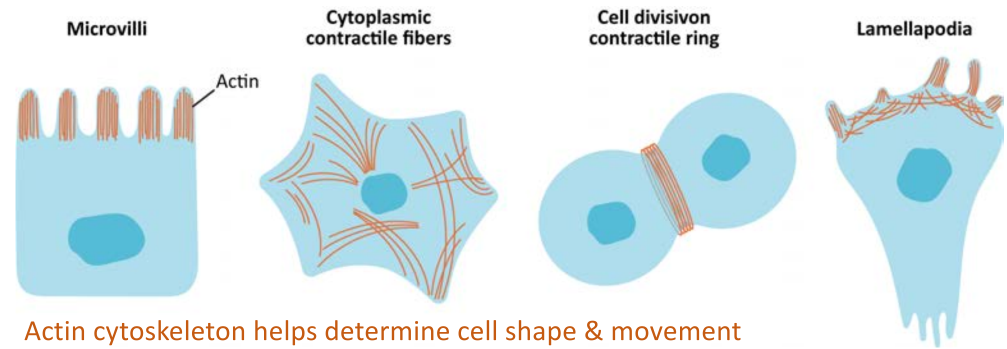


[Video of Amoeba Movement]



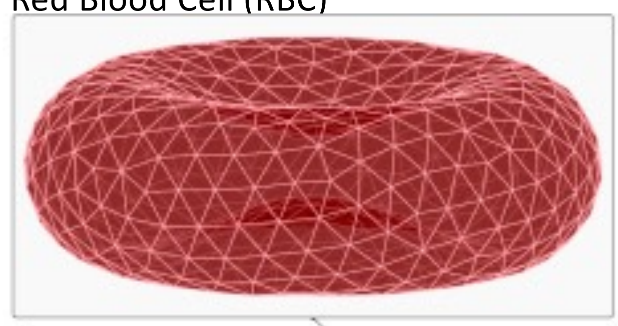
(A) Microfilaments

'Dynamic instability'



Actin cytoskeleton helps determine cell shape & movement

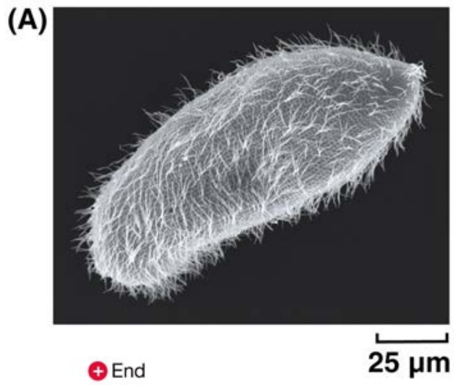
Red Blood Cell (RBC)



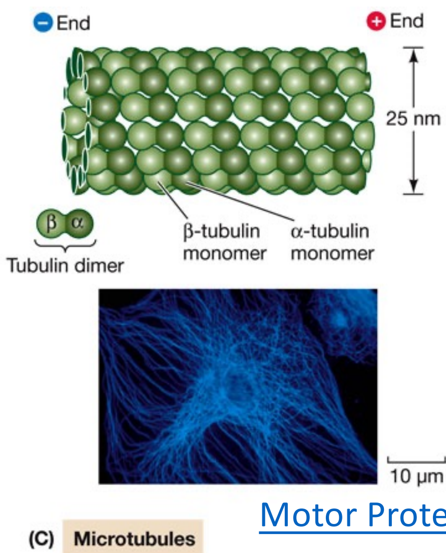
Vertebrate RBCs have ACTIN cytoskeleton network, keeps classic wildtype RBC shape.

Flagella & Cilia: Microtubule Cytoskeleton in *Eukaryotic* MOVEMENT

TUBULIN protein ... Ciliates and Flagellates !!!



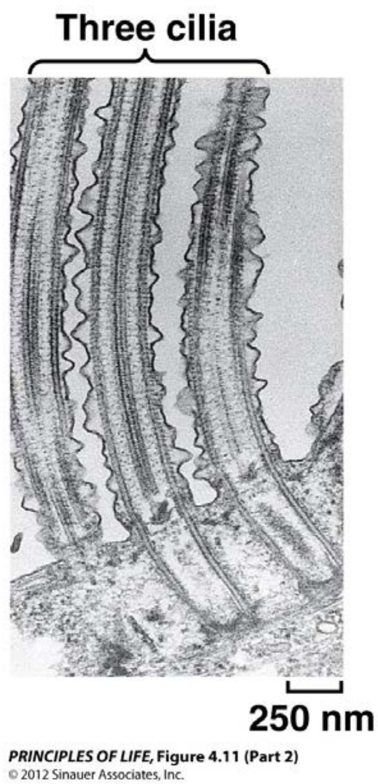
"Microtubule"



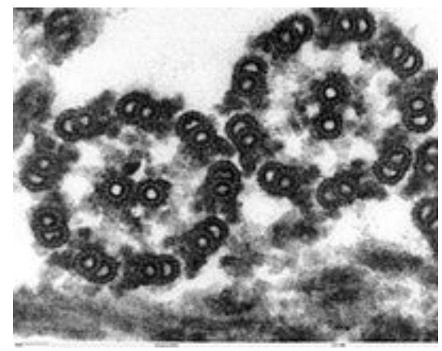
Motor Proteins (Dynein)

move macromolecules

Cilia



Sperm Movement via single flagellum



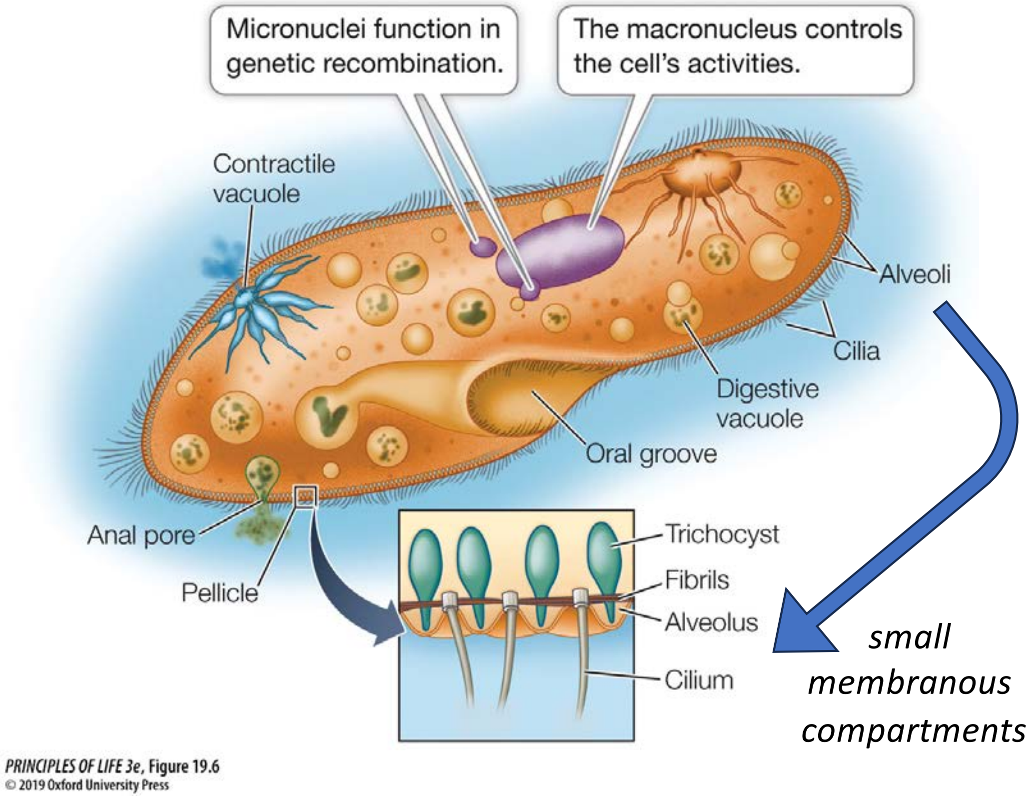
Cross section
2 sperm tails
9-by-2
configuration

Flagella

Chlamydomonas

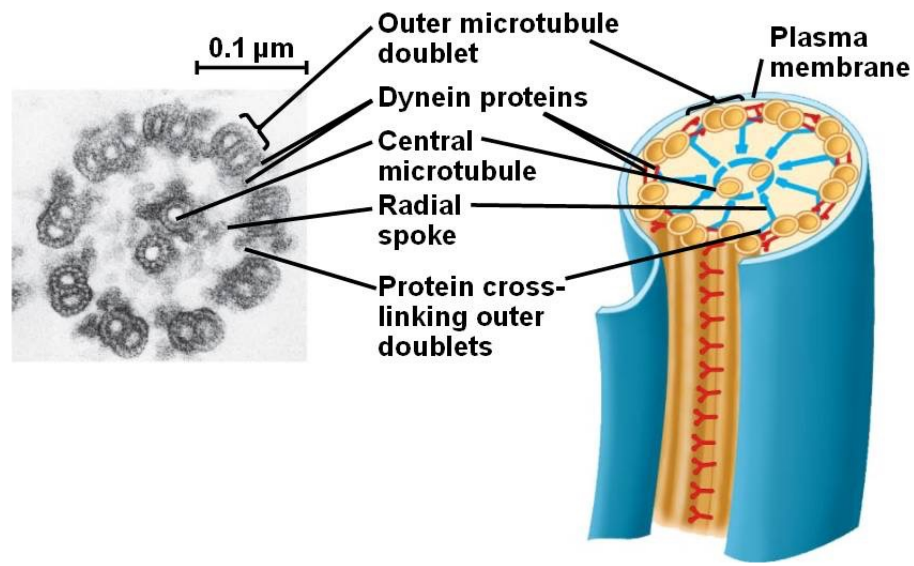
Eukaryote
unicellular
photosynthetic
Has 2 flagella!

A Ciliate: *Paramecium*



Weapons: Trichocyst captures prey
Contractile Vacuole regulates water pressure

Cilia
(multiple, tiny Eukaryotic flagella)
for motility



Flagella & Ciliates move protists using Tubulin & Dynein Proteins

Lecture 5 : Viruses

Viruses Have Evolved Many Times

For every known living cell ... There is at least one virus!

Difficult to create a general phylogeny

a. genomes are very small

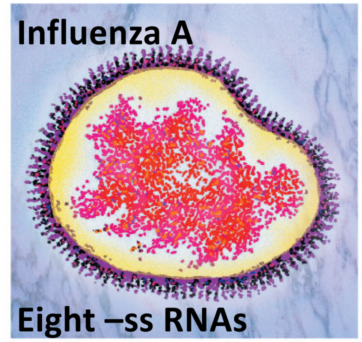
b. genes are highly diverse.

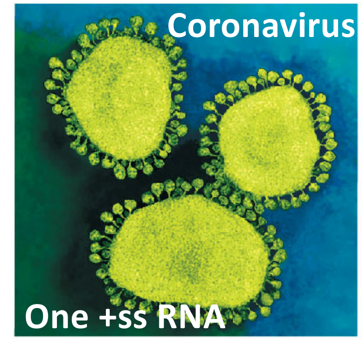
c. strain: rapid mutation/evolution

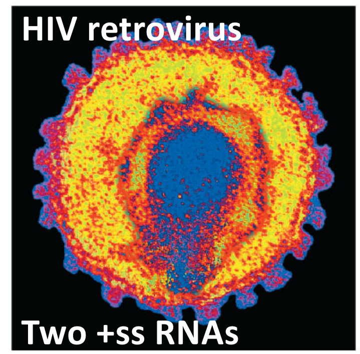
d. no known fossils

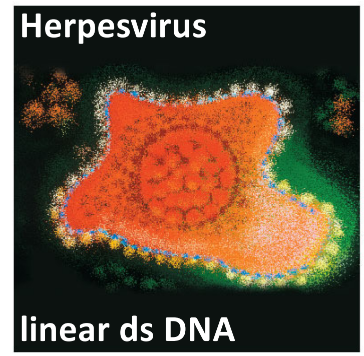
Know these viruses shown:

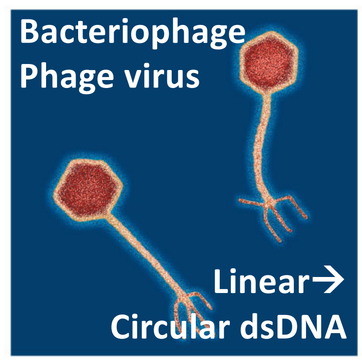
Type of genome, what cells they infect, how they replicate, what is unique about them

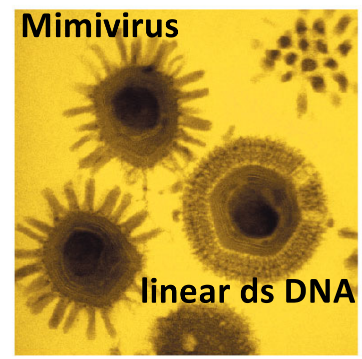




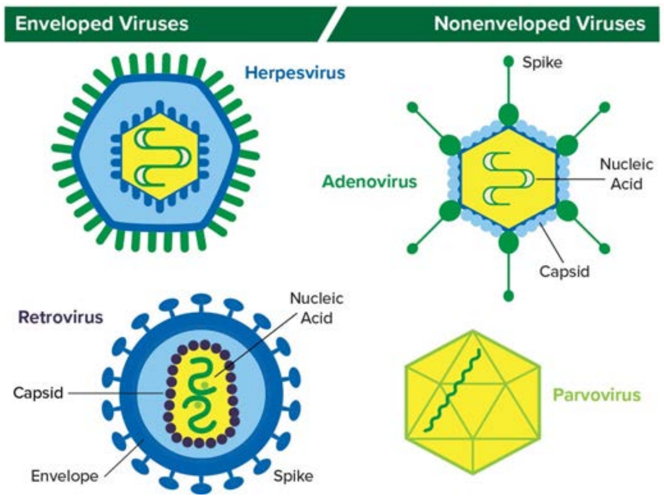


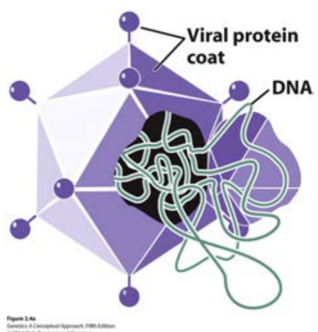






Viruses





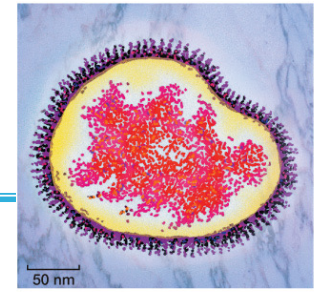
- ***Capsid***: outer protein coat surrounding nucleic acid
- ***Enveloped virus***: a lipid membrane outer coating (from host). Envelope required for their infectivity / cell binding. "Hides" virions from immune system. Susceptible to detergents. ex: Influenza (flu)
- ***Non-enveloped virus:*** out capsid only. Do not have, do not need, envelopes. "Naked." More hearty, resistant to detergents. ex: Rhinoviruses (common cold)

Know these differences. Which is easier to kill by washing hands? Which type infect human cells.

https://bioprocessintl.com/downstream-processing/viral-clearance/detection-and-clearance-of-viruses-in-the-biopharmaceutical-industry/

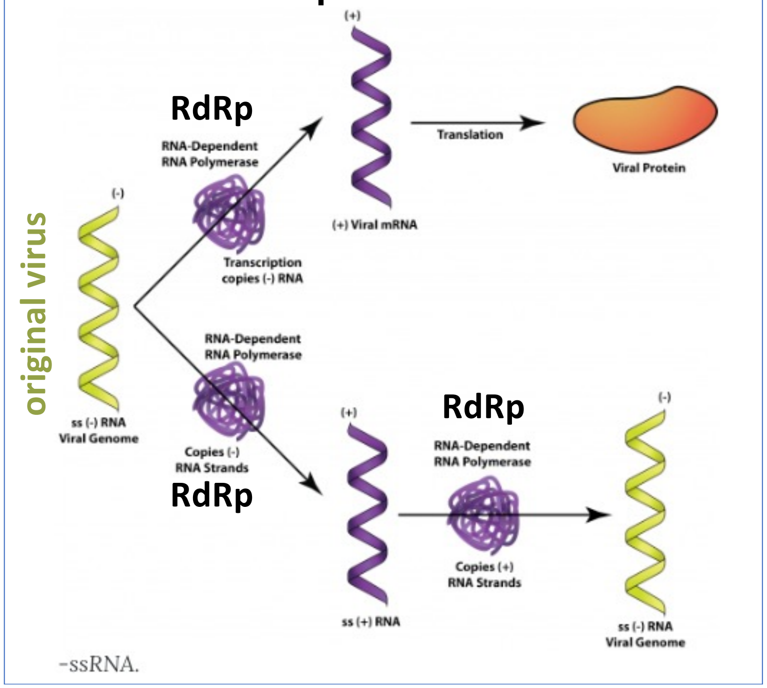
Influenza:

- **Enveloped**
- Genome: 8 single stranded mRNAs (-**ssRNAs**)
- mRNAs re-assort in host → genetic diversity
- needs **viral RdRp (**RNA-dependent RNA polymerase)
- Influenza strains A, B, C,sD
- Influenza A infects most hosts:
  - bird, pigs, humans
- ”Flu” epidemics are influenza A
  - H = hemagglutinin, 18 variations!
  - N = neuraminidase, 11 variations



A negative-sense single-strand RNA virus: The influenza A virus. This virus is responsible for seasonal influenza epidemics in humans. Surface view.

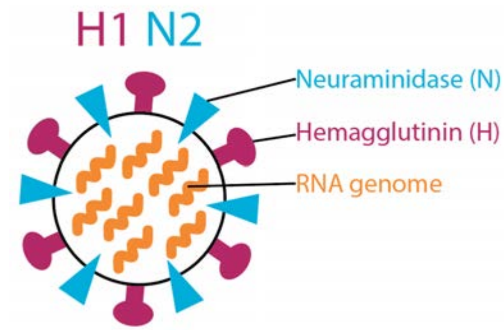
-ssRNA virus Replication:

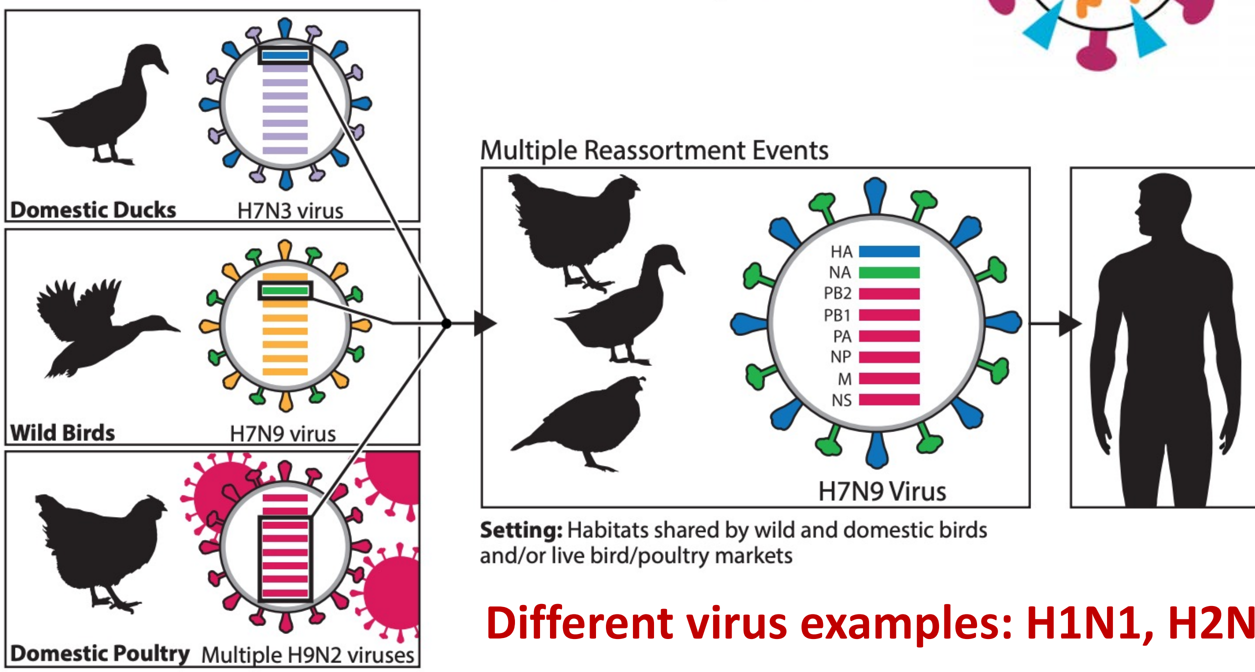


https://www.mdpi.com/1999-4915/11/2/122/htm

Influenza A Viruses: ‘the flu'

- Types of H and N proteins define virulence.
- **Hemagglutinin** (H) binds virus to cells to **infect**
- **Neuraminidase** (N) helps virus escape to **spread**
- ***Influenza genome: eight (8) mRNAs ‘Re-assort’ !!!***

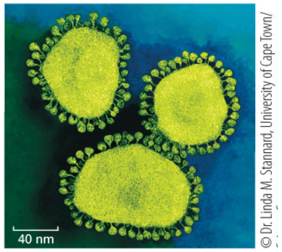




Different virus examples: H1N1, H2N3, H7N9

Coronaviruses:

Single +ssRNA genomev'sense' strand, mRNA-like, ready to translate into viral protein(s). Enveloped



A positive-sense single-strand RNA virus: Coronavirus of a type thought to be responsible for severe acute respiratory syndrome (SARS). Surface view.

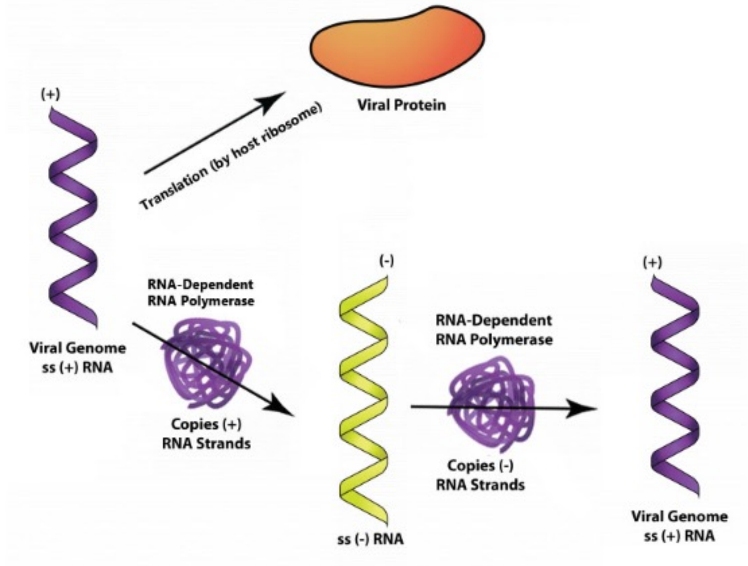
Other Enveloped +ssRNA viruses:

- ***Hepatitis C***
- ***Rubella (of the MMR vaccine)***
- ***SARS1 (SARS-CoV-1)***
- ***MERS and ...***
- ***COVID-19 (SARS2 = SARS-CoV-2)***

NON-Enveloped +ssRNA

- **mosaic viruses**
- **common cold (rhinoviruses)**
- **polio**

+ssRNA virus Replication:

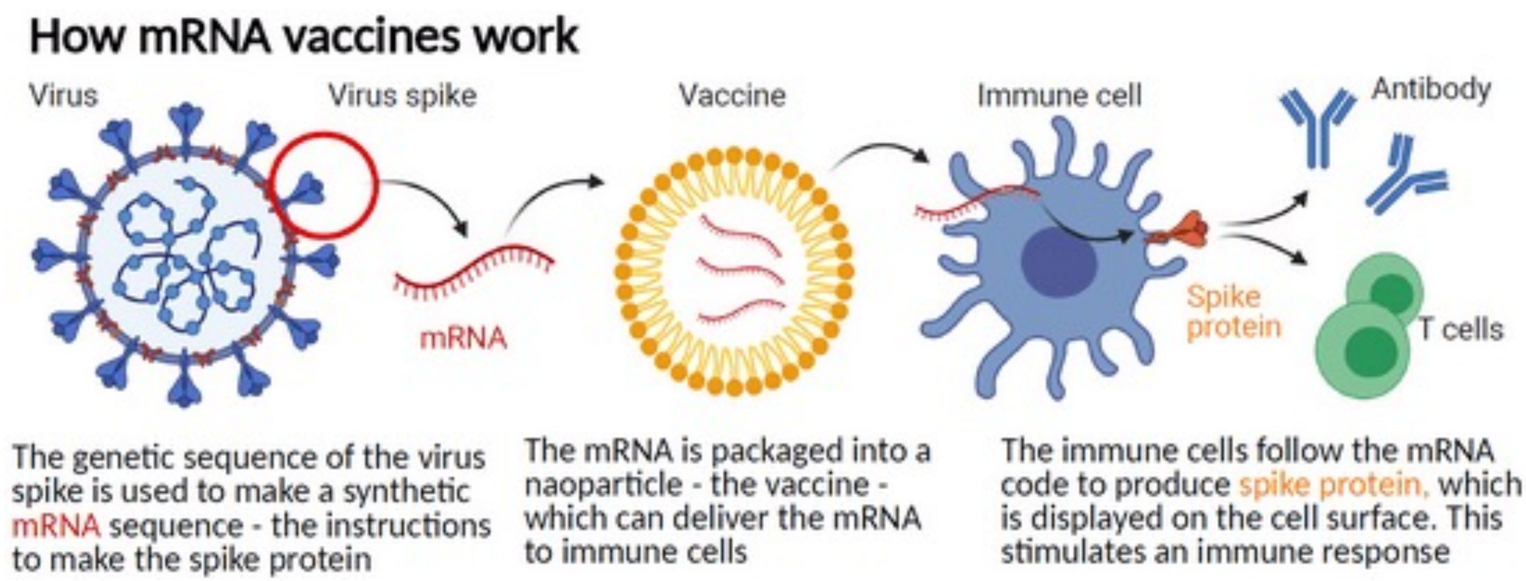


Baltimore Scheme for Viral Classification

COVID19: Immunize with
mRNA encoding Spike (S) Protein

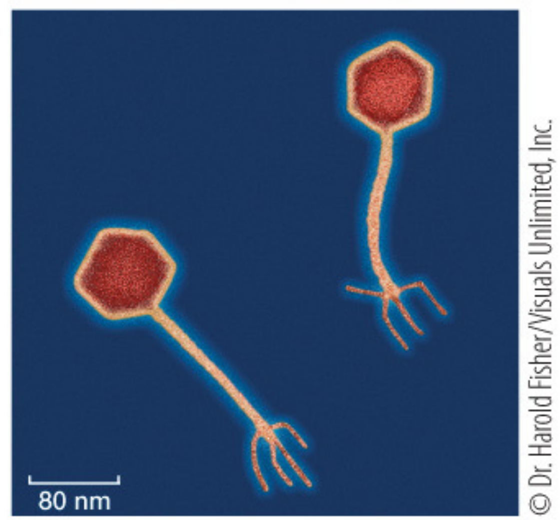
Your cells translates mRNA→ **S protein**

Immune system makes antibodies against **S protein**



dsDNA Bacteriophages infect Prokaryotes

- **Non-Enveloped, protein capsid head**
- Bacteriophage discovered during WWI to treat bacterial infections, including dysentery, cholera, and bubonic plague ([**phage therapy**]). Infect, they either burst the cells or integrate into host cell genome, to kill later.
- Phage therapy mostly replaced by antibiotics in 1930s - 1940s. But since then ...
- Antibiotic resistance arises due to *variation in populations* of bacteria. Drug-resistant bacteria grow and dominate bacterial populations.
- As bacterial populations evolve resistance, phage therapy is once again an area of research. An advantage of phages over drugs: bacteriophages also *evolve!*
- NIAID Phage Video

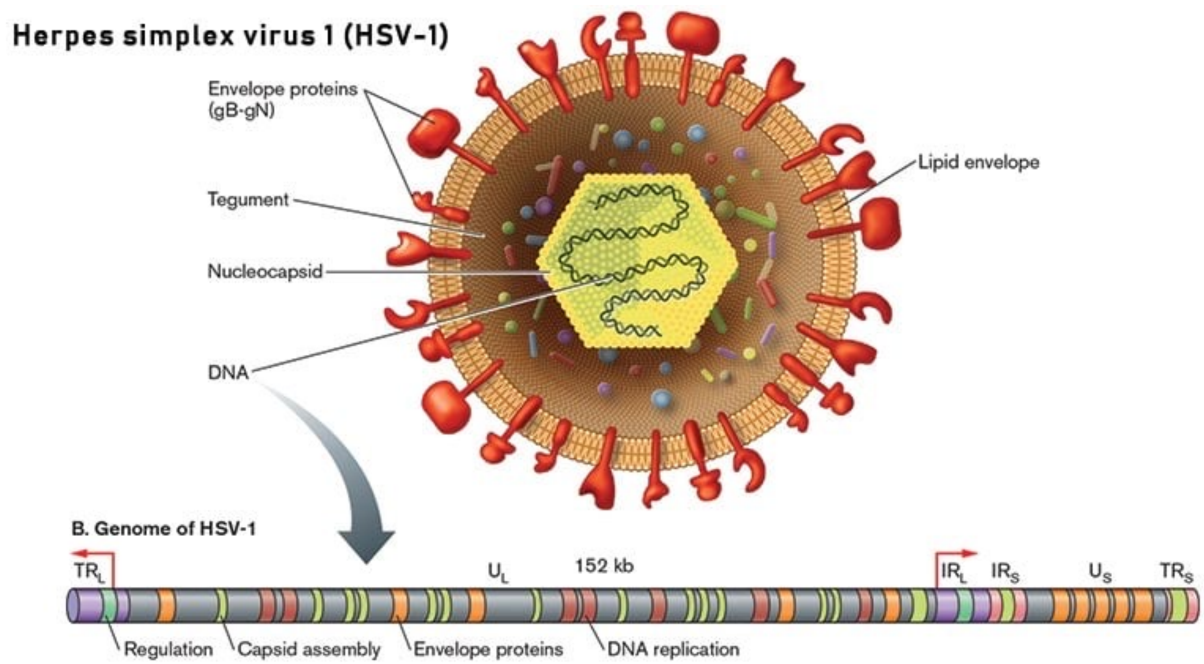


A double-strand DNA virus: Bacteriophage T4. Viruses that infect bacteria are referred to as bacteriophage (or simply phage). T4 attaches leglike fibers to the outside of its host cell and injects its DNA into the cytoplasm through its "tail" (pink structure in this rendition).

Linear dsDNA circularizes
In host cell →
"Rolling Circle Replication"

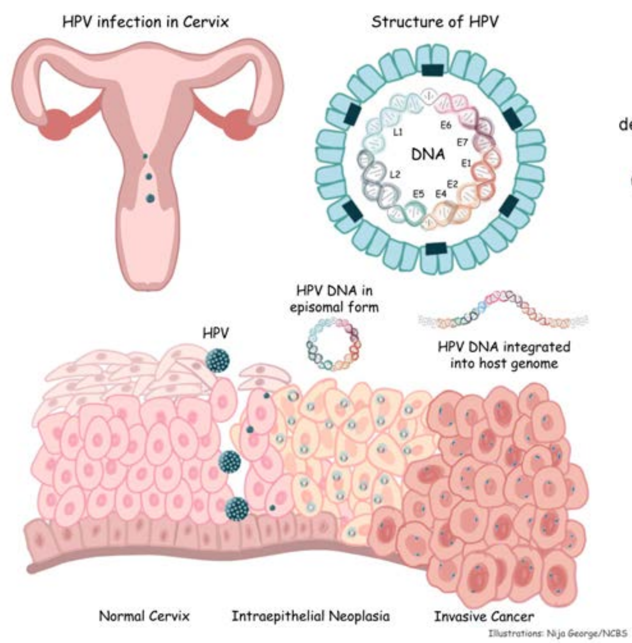
dsDNA HSV – herpes simplex virus

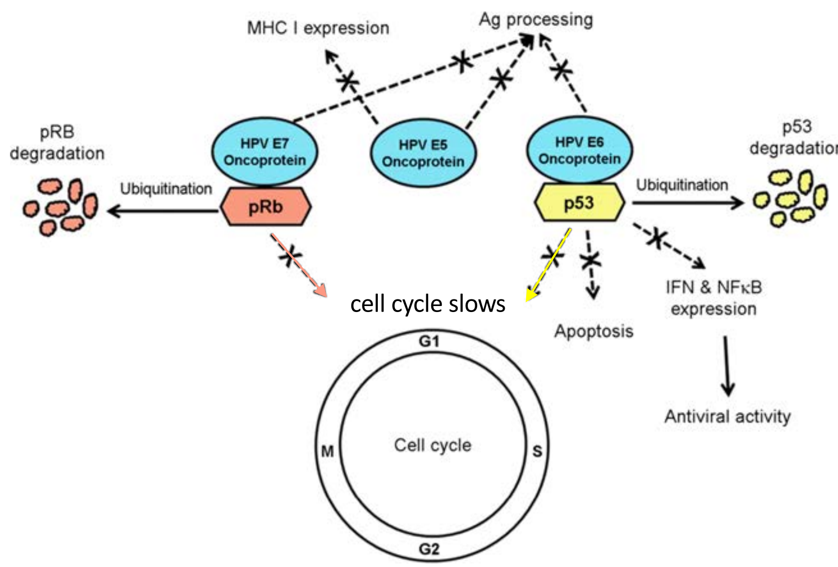
HSV-1 (usually) oral
HSV-2 (usually) sexually transmitted
Enveloped, linear genome, circularizes when dormant.
Does not integrate into cell genome - does not cause mutations/cancers.



dsDNA HPV– human papilloma virus

- Enveloped, circular genome
- Integrates into cell's genome
- Causes cervical cancer:
- Proteins E6, E7 degrade "tumor suppressing" proteins





pRb and p53 normally ***slow*** cell growth!
HPV **E7** inhibits pRb, HPV E6 inhibits p53
→ Cells grow out of control → Cancer. ☹

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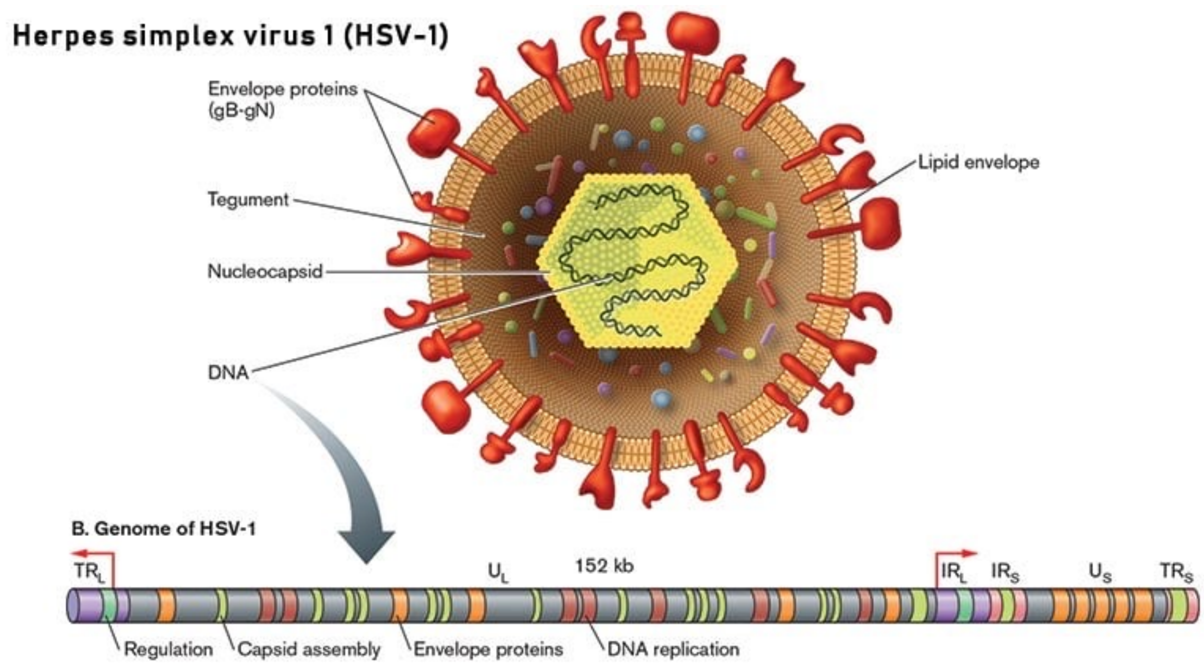

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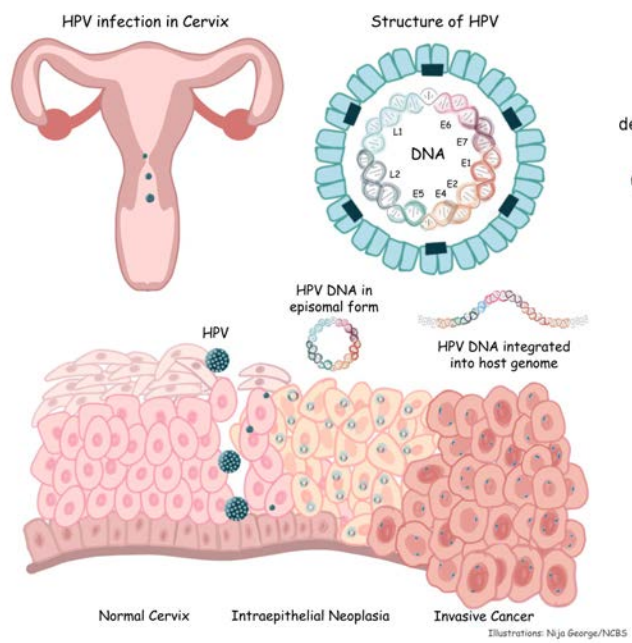
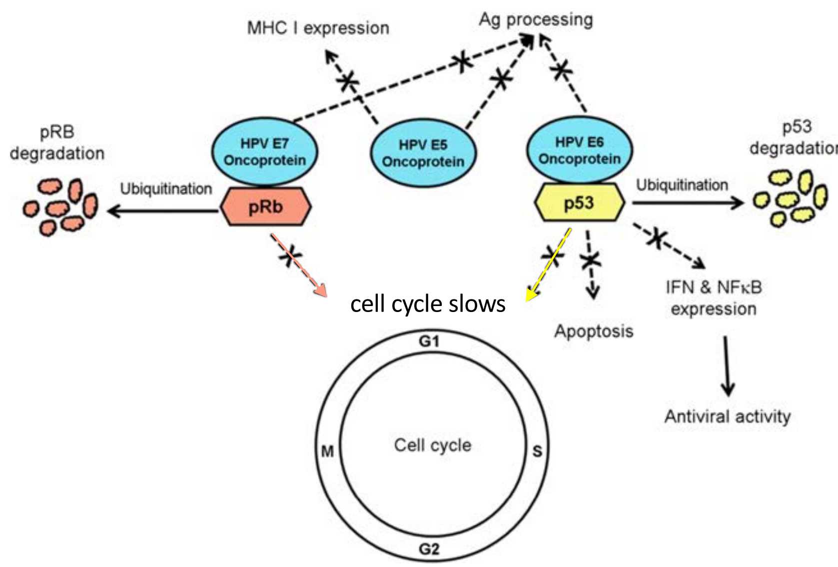
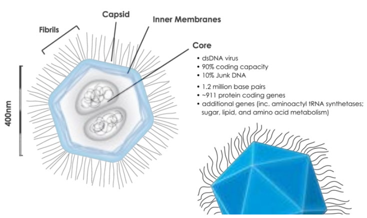


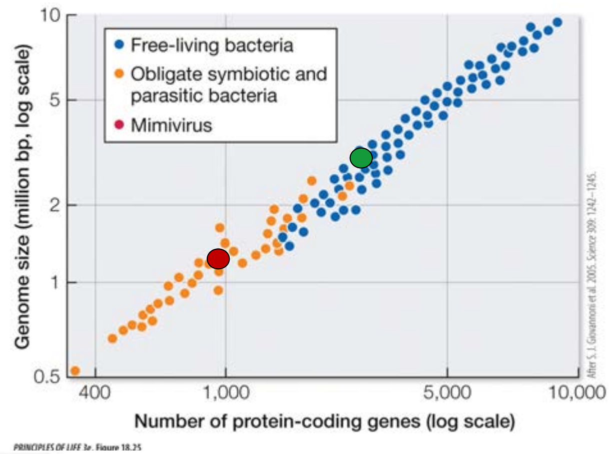


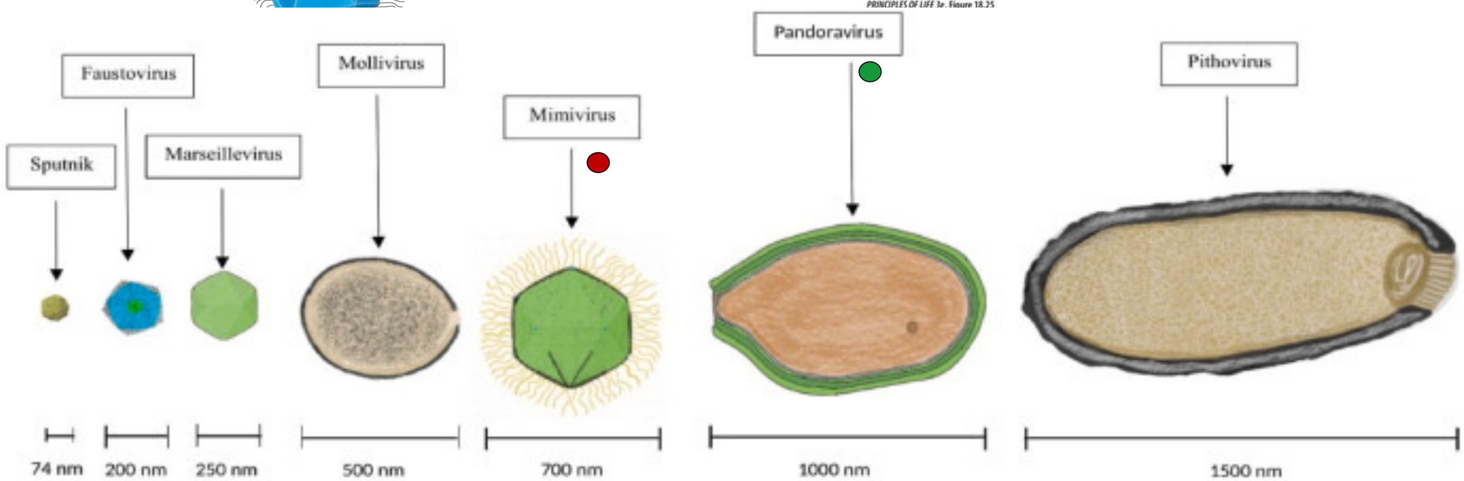
pRb and p53 normally ***slow*** cell growth!
HPV **E7** inhibits pRb, HPV E6 inhibits p53
→ Cells grow out of control → Cancer. ☹

Giant dsDNA virus:

Mimivirus is dsDNA big virus
A. polyphaga infects ***amoeba*** microbial eukaryotes
up to 1.2 million bp genome
Nucleocytoviricota
Nucleocytoplasmic Large DNA Viruses
(NCLDVs) up to 2.5 million bp genome



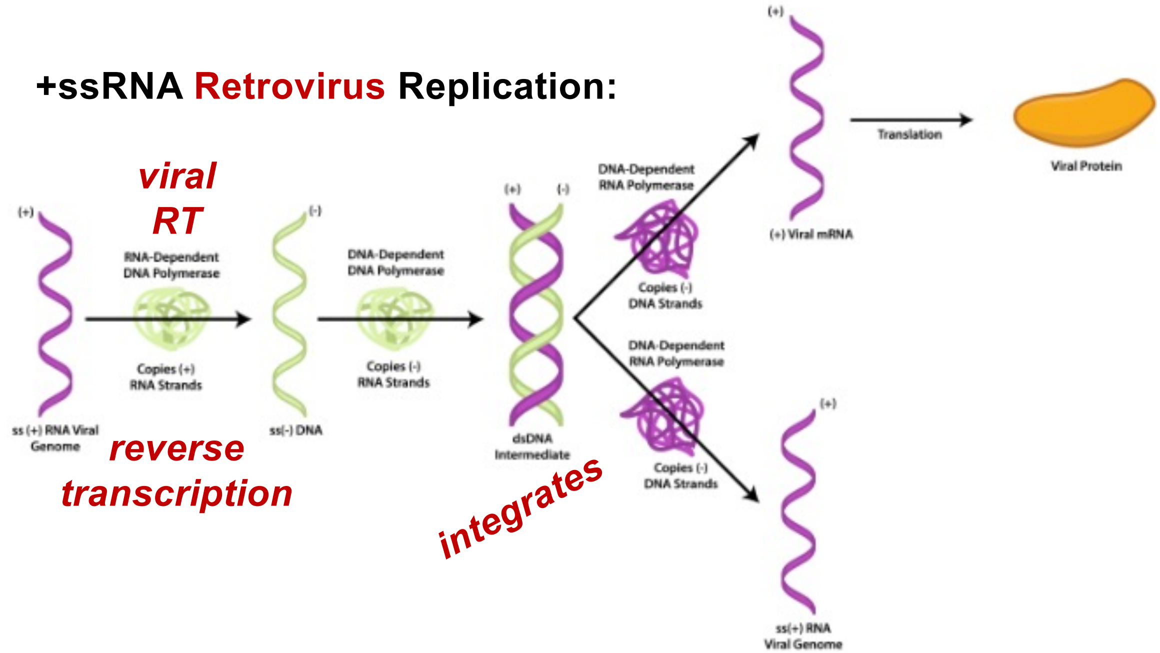




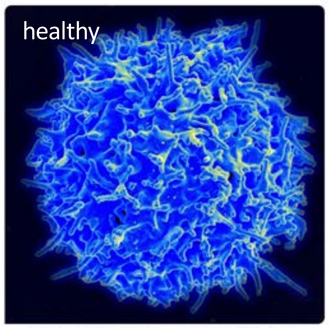
Retroviruses

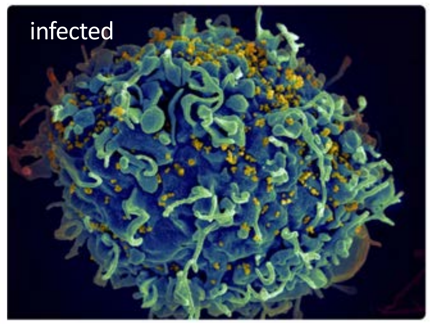
- +ssRNA viruses, infect ***only*** vertebrates, **enveloped**
- has **viral *Reverse Transcriptase*** enzyme ***(=RT)***
- **Reverse dogma: RNA → back to DNA**
- ***integrates*** into the host genome
- *DIFFICULT TO GET RID OF!* Example: HIV
- 8% of human genome is remnants of ancient retrovirus

+ssRNA Retrovirus Replication:

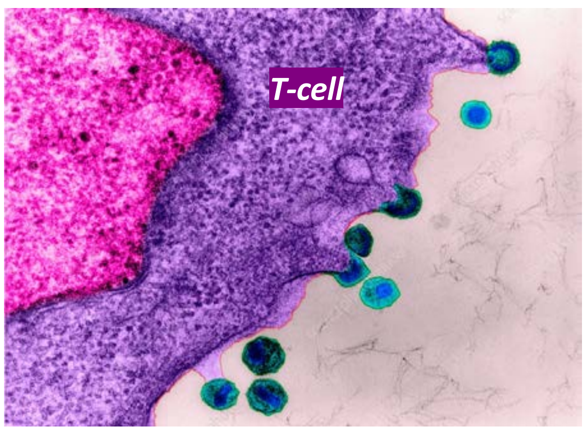


HIV retrovirus infects CD4+ *(helper)* T-cells, binds their CCR5 receptors



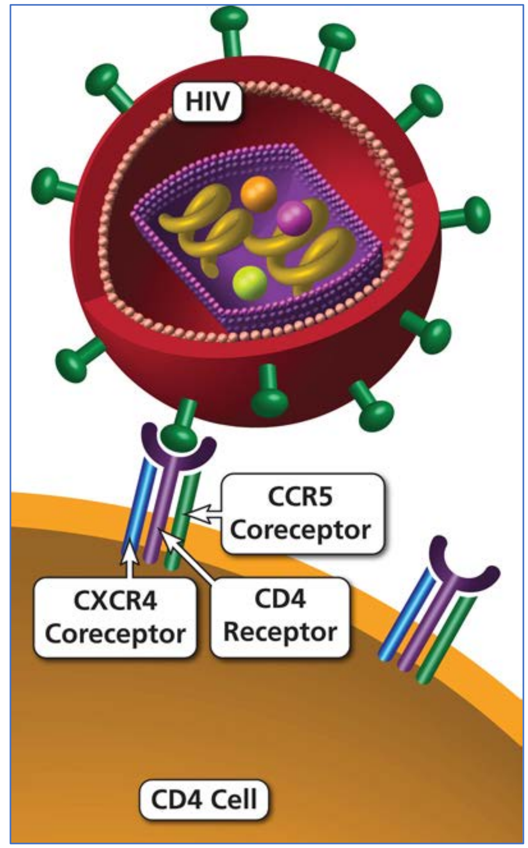


National Institute of Allergy and Infectious Diseases (NIAID)



virus "buds" taking with it lipid membrane envelope

Image: Denis Kunkel, https://www.sciencephoto.com/contributor/dkn/

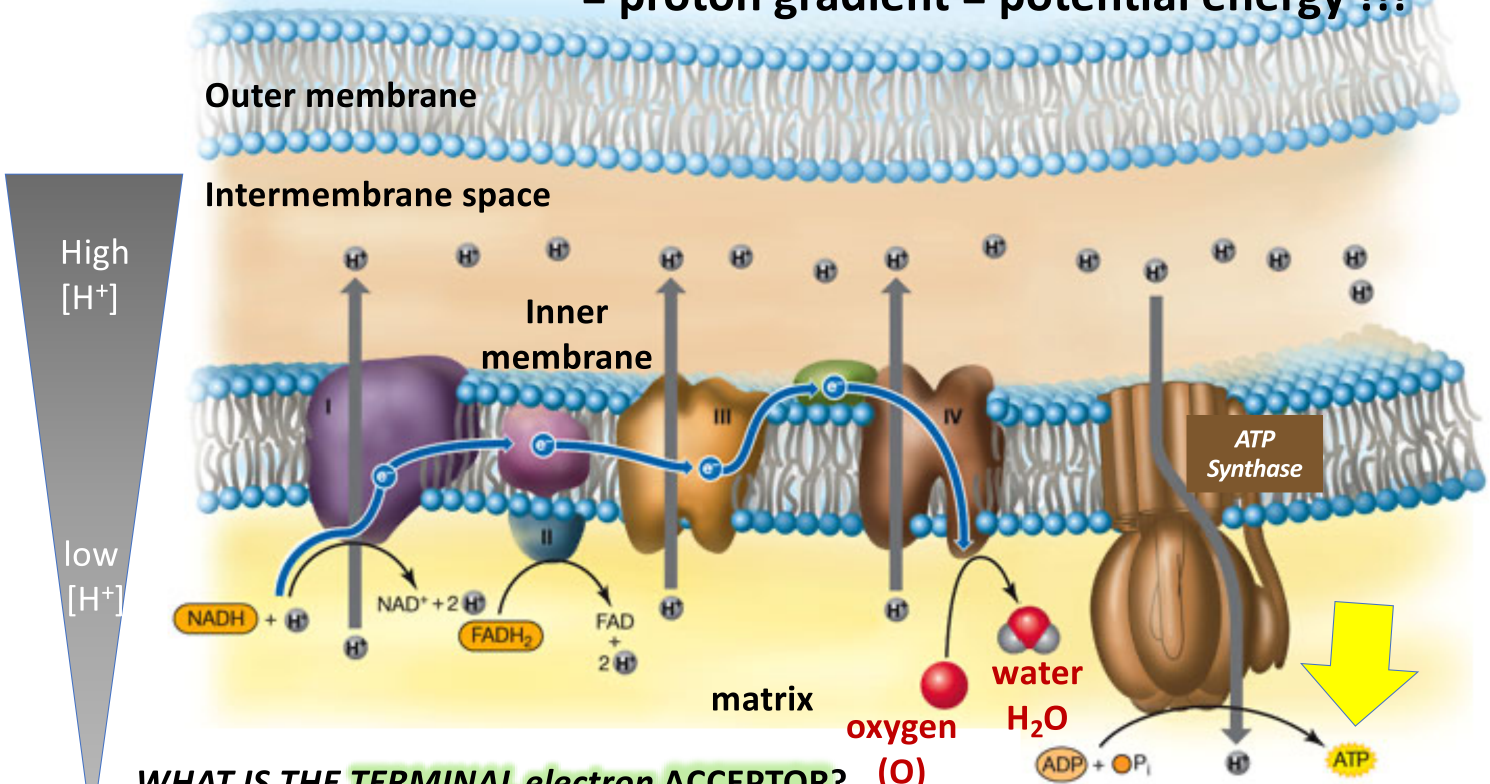


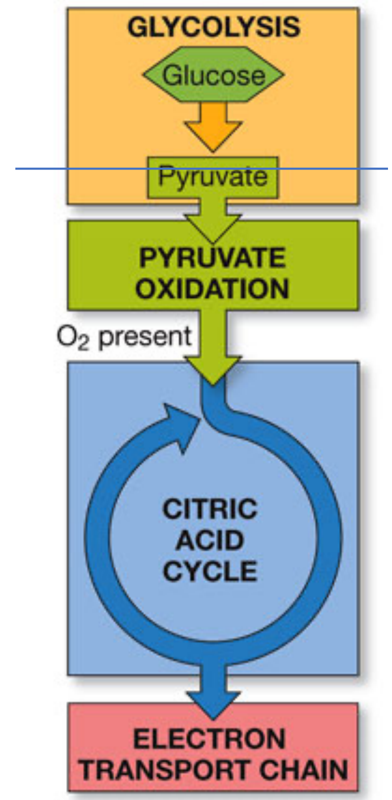
Lecture 6 : Photosynthesis

Mitochondria

Oxidative phosphorylation →makes **ATP**

electron transfers drive H^+s across the inner membrane
= proton gradient = potential energy !!!



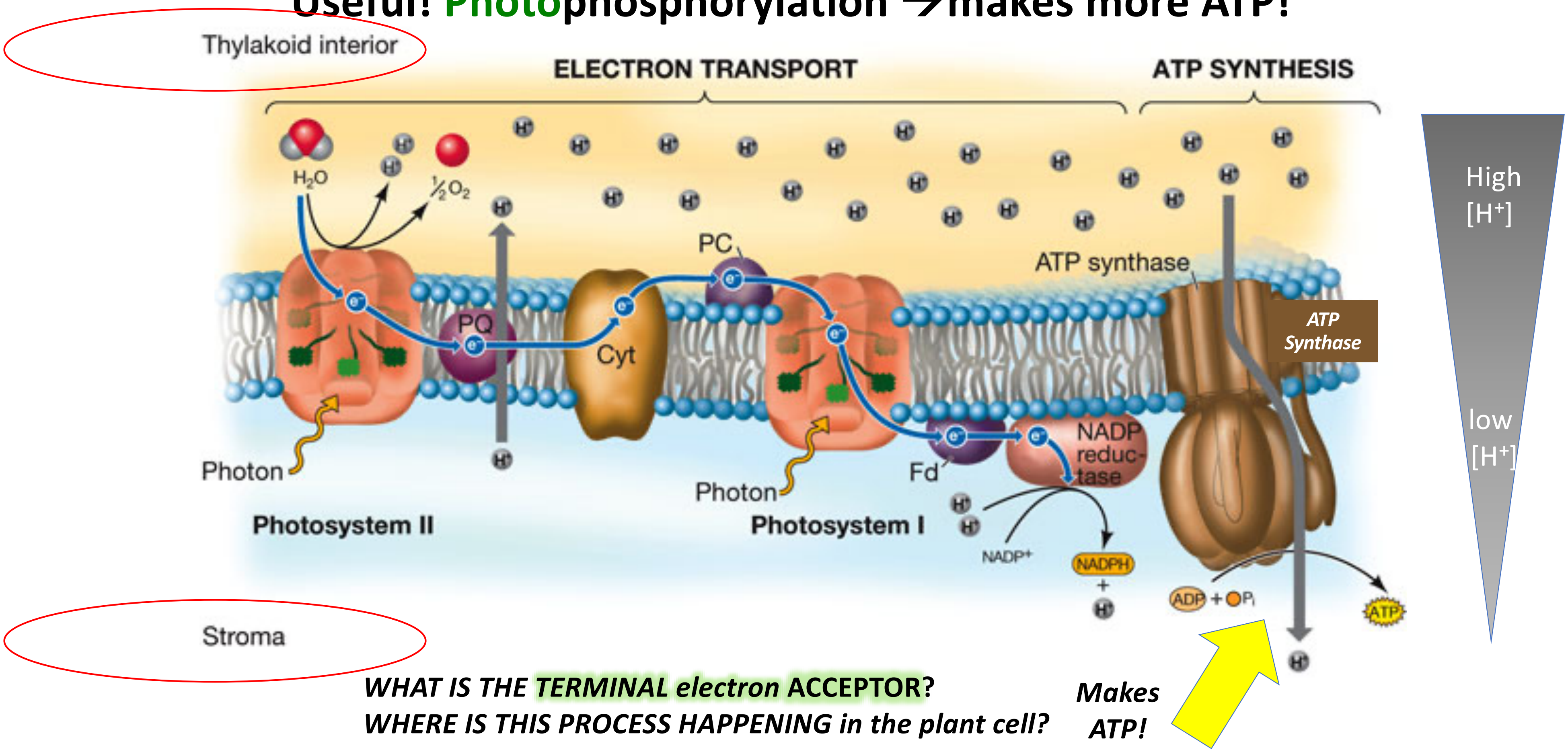


WHAT IS THE TERMINAL electron ACCEPTOR?
WHERE IS THIS PROCESS HAPPENING in the plant cell?

Chloroplasts

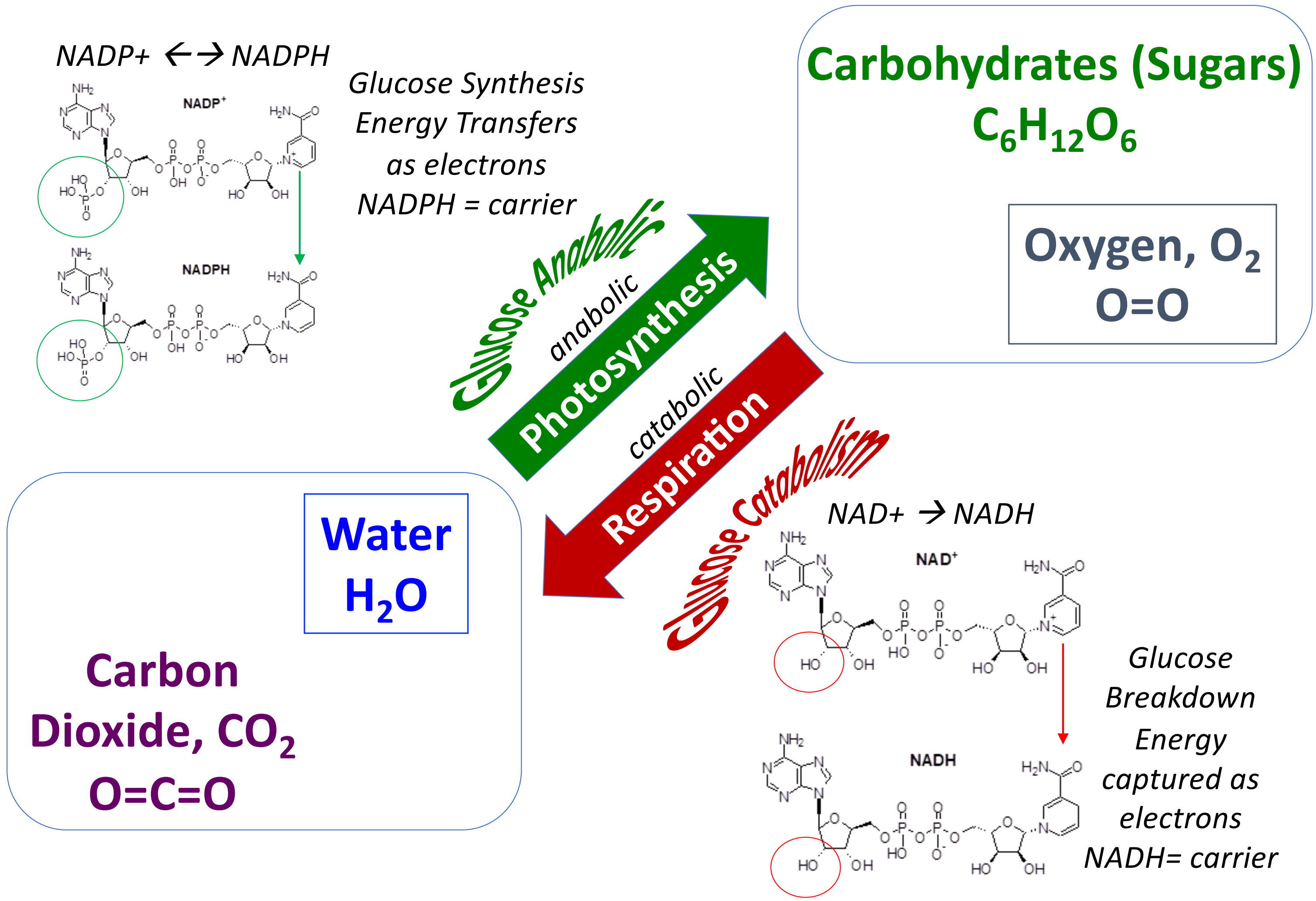
Light Reactions Generate a Proton (H+) *Gradient*

Useful! Photophosphorylation →makes more ATP!



WHAT IS THE TERMINAL electron ACCEPTOR?
WHERE IS THIS PROCESS HAPPENING in the plant cell?

Metabolism: Build-N-Break BONDS

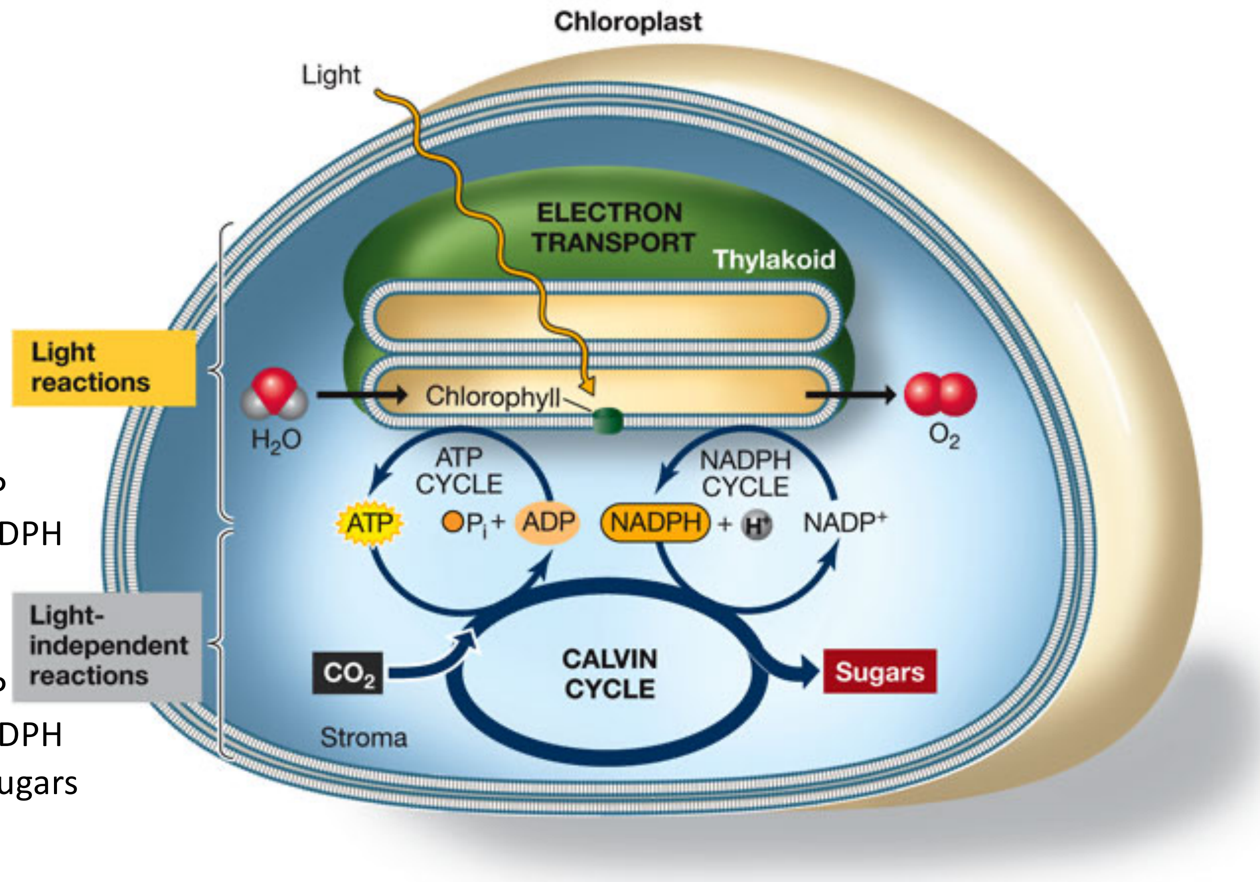


Photosynthesis has TWO Sets of Reactions

* Notice the crosstalk via Energy Molecules: ATP, NADPH

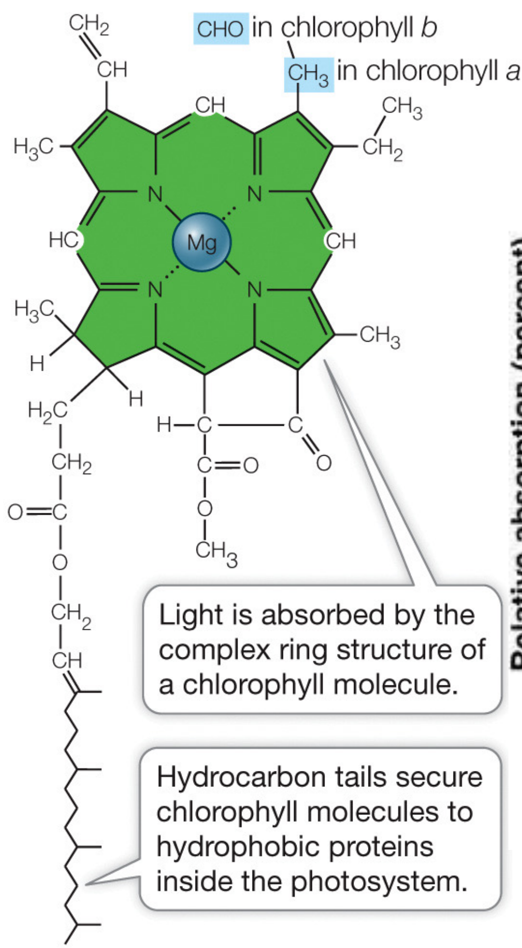
Uses Light
Makes O_2
Makes ATP
Makes NADPH

Uses ATP
Uses NADPH
Makes Sugars



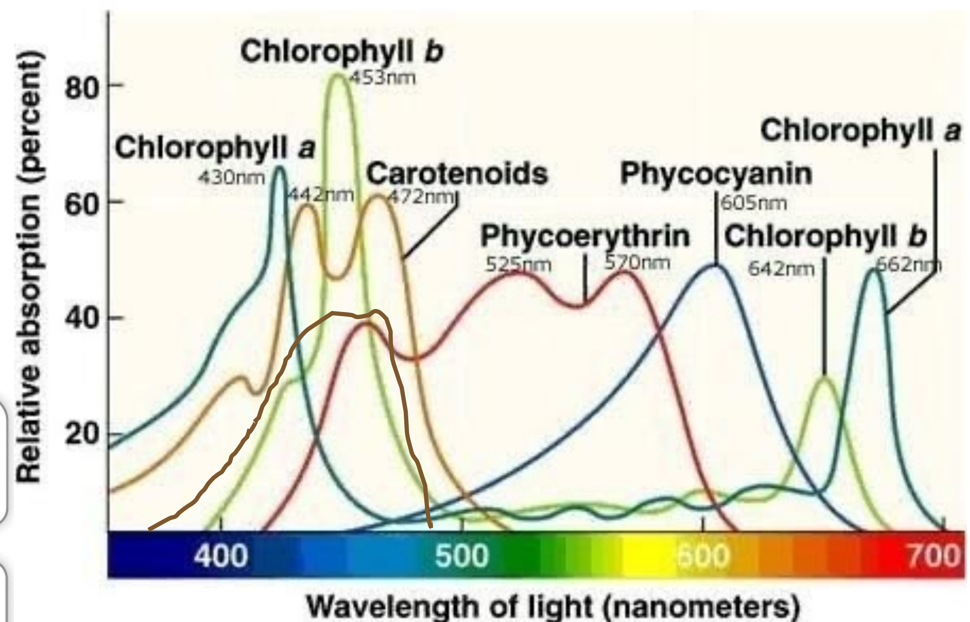
LIFE 8e, Figure 8.3

Example: Clorophyll b, Chl



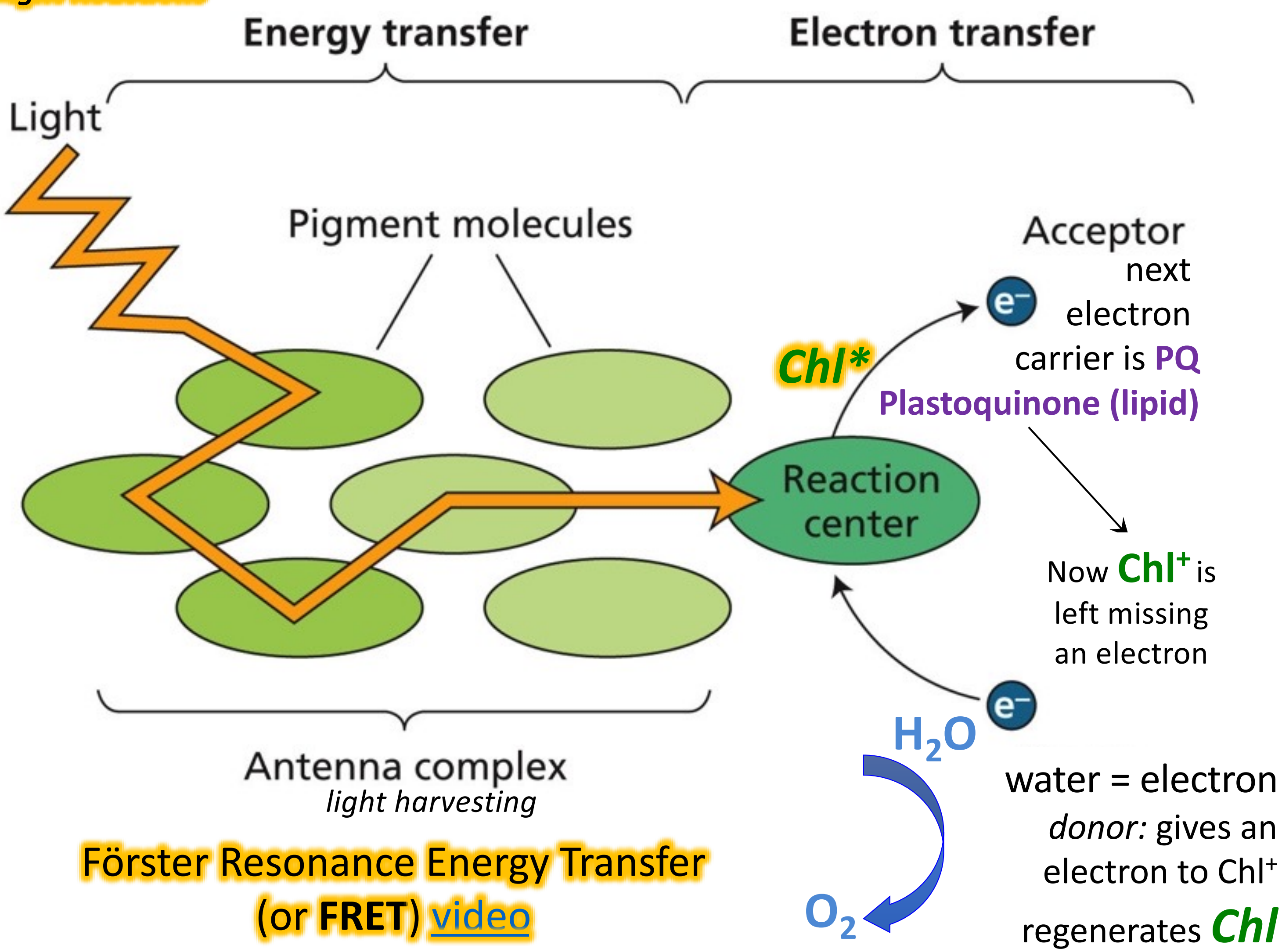
PRINCIPLES OF LIFE 3e, Figure 5.19

Light Reactions: Pigment molecules ***ABSORB*** light



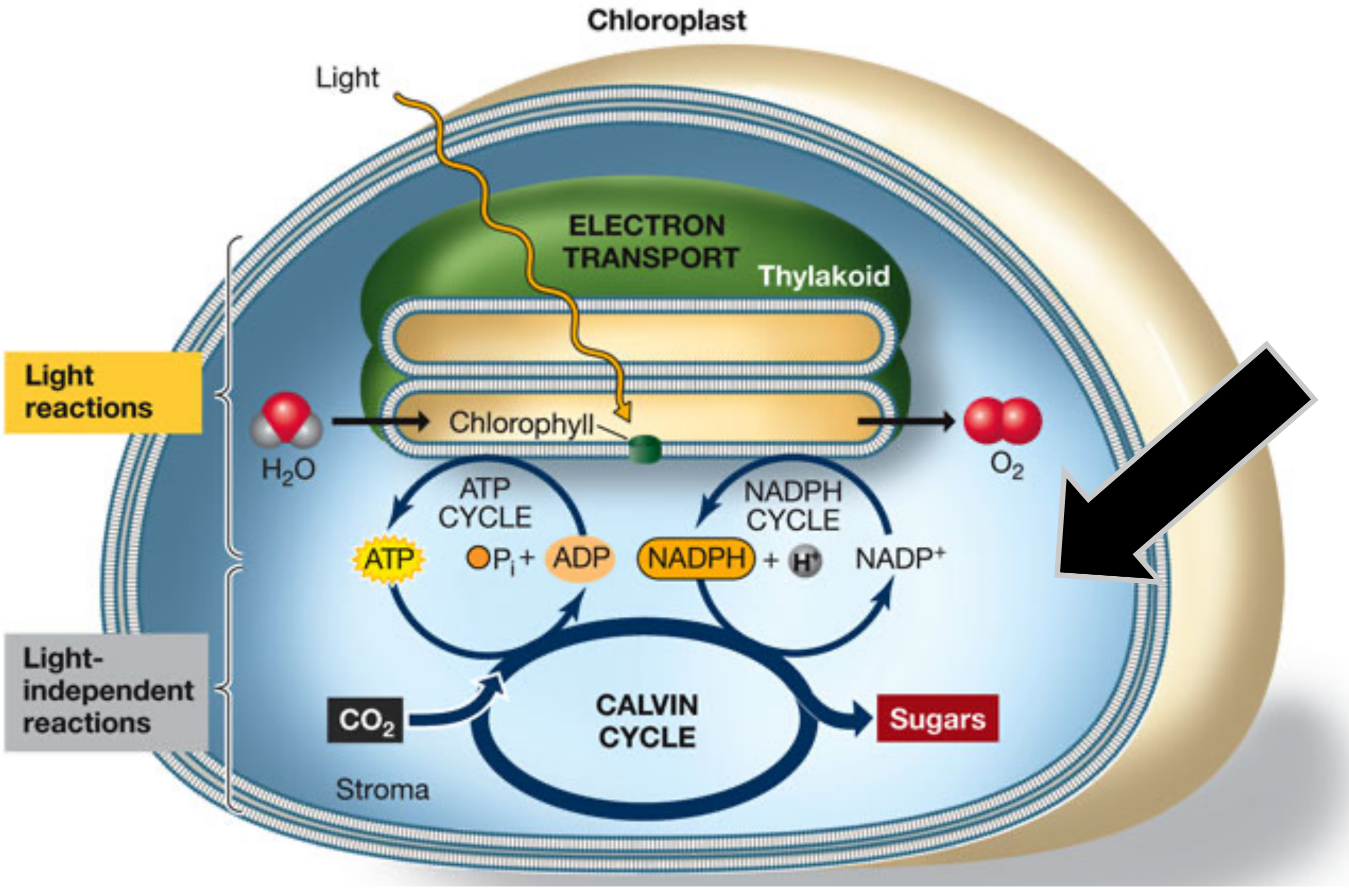
What pigments dominate in GREEN algae?
What pigments dominate in RED algae?
What pigments dominate in BROWN algae?

Light Reactions

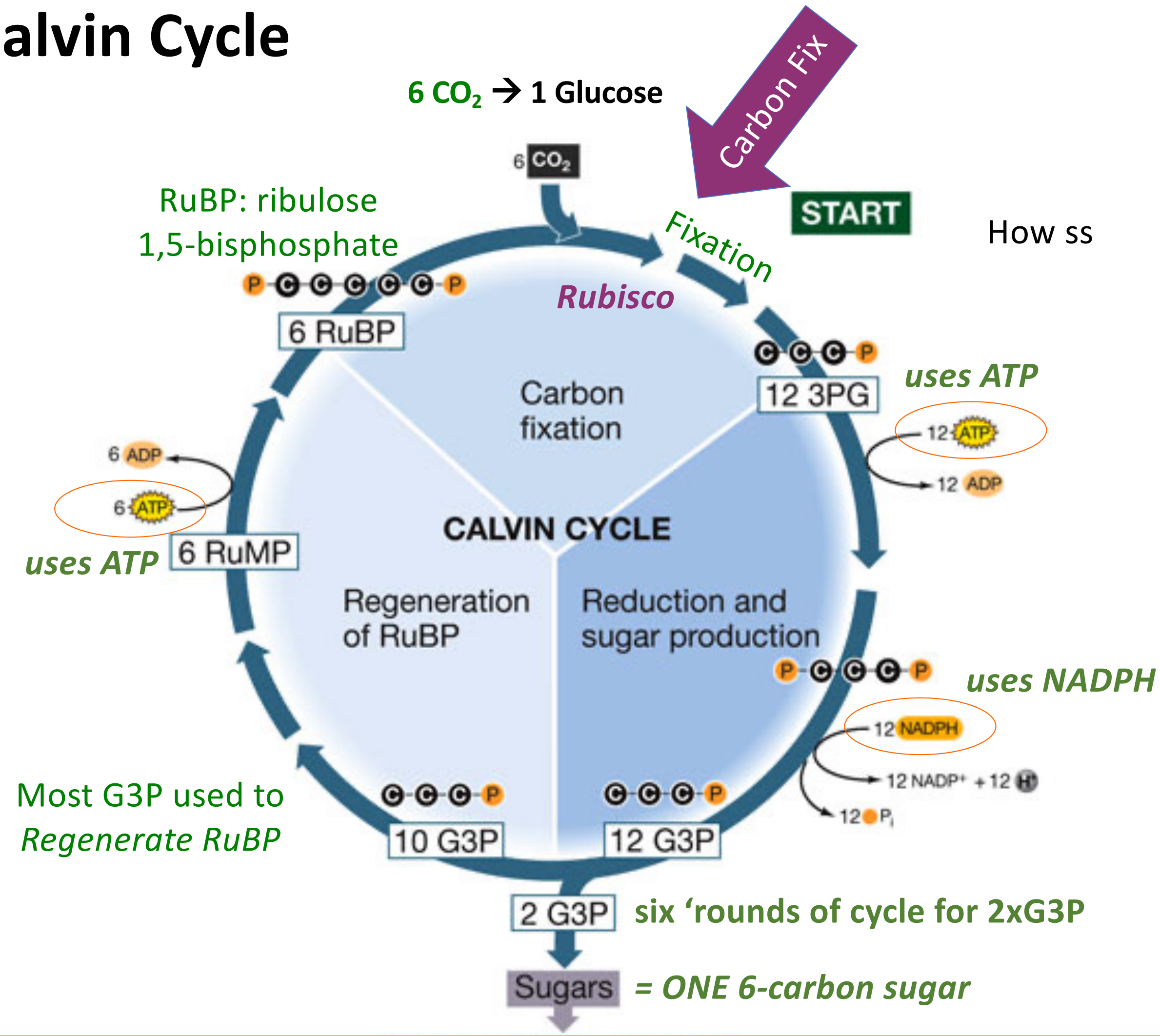


Förster Resonance Energy Transfer (or **FRET**) video

The light-*independent* reactions take place in the stroma – Calvin Cycle!



The Calvin Cycle



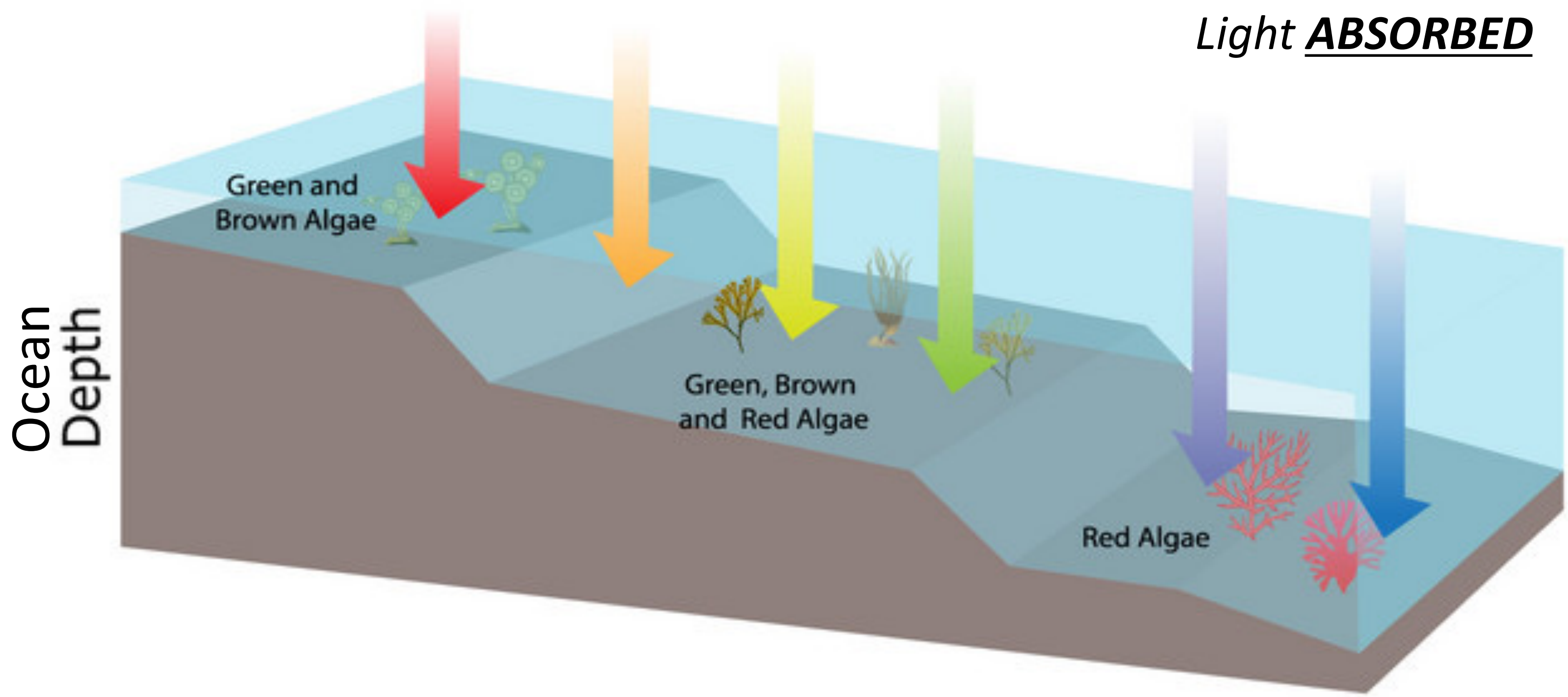
RuBP + CO_2 + ATP + NADPH → 2 x Glyceraldehyde 3-Phosphate(G3P) = 1 Sugar

	Photosynthesis	Cellular Respiration
Takes place in which organisms: bacteria, plants, and/or animals?		
Takes place in which organelle in eukaryotic organisms?		
What is the purpose of this metabolic pathway?		
What source of energy drives this metabolic process?		
What is the initial electron donor to the electron transport chain?		
What is the final electron acceptor in the electron transport chain?		
What are the final products from the electron transport chain?		
Which type of electron transport is involved? cyclic and/or non-cyclic?		
What electron carriers are involved?		
Is ATP synthesized? How?		
What "cycle" is used in this metabolic pathway? What happens during the cycle?		

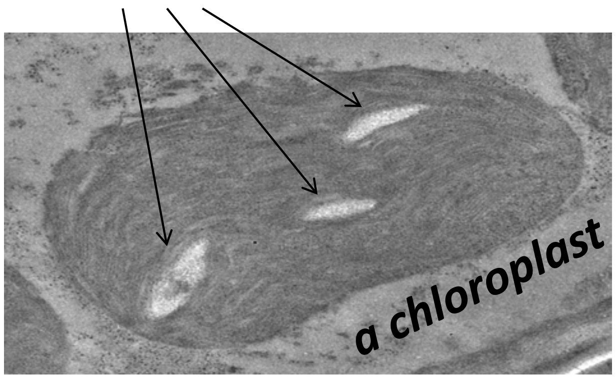
Lecture 7 : Plants

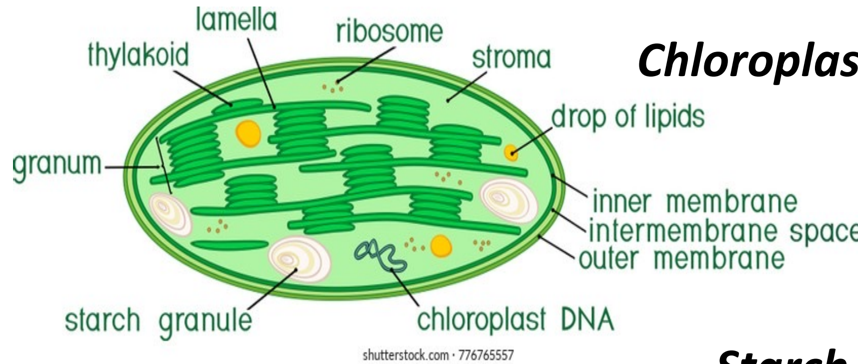
aquatic to wetland-non-vascular
to dryland-vascular

Aquatic Photosynthesizers: ***Green, Brown, Red algae***



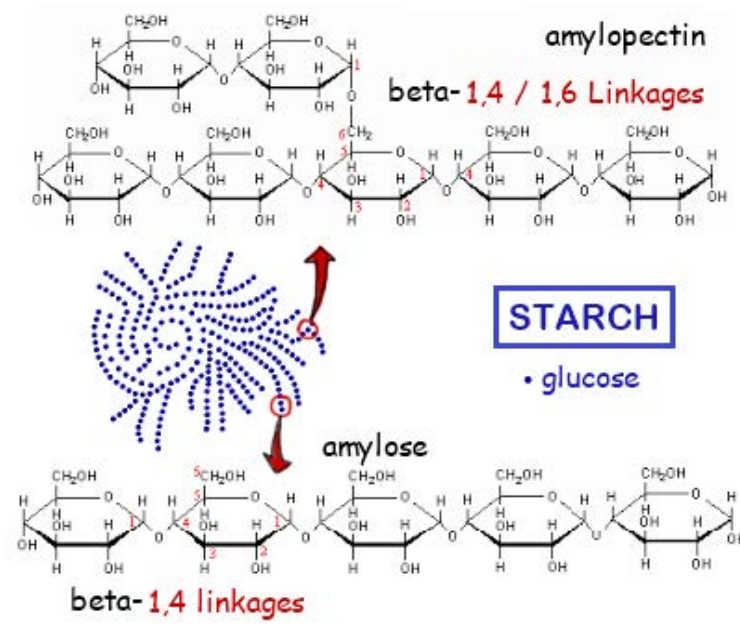
Starch *Granules* in the Chloroplast … Unique to GREEN Algae/Plants:



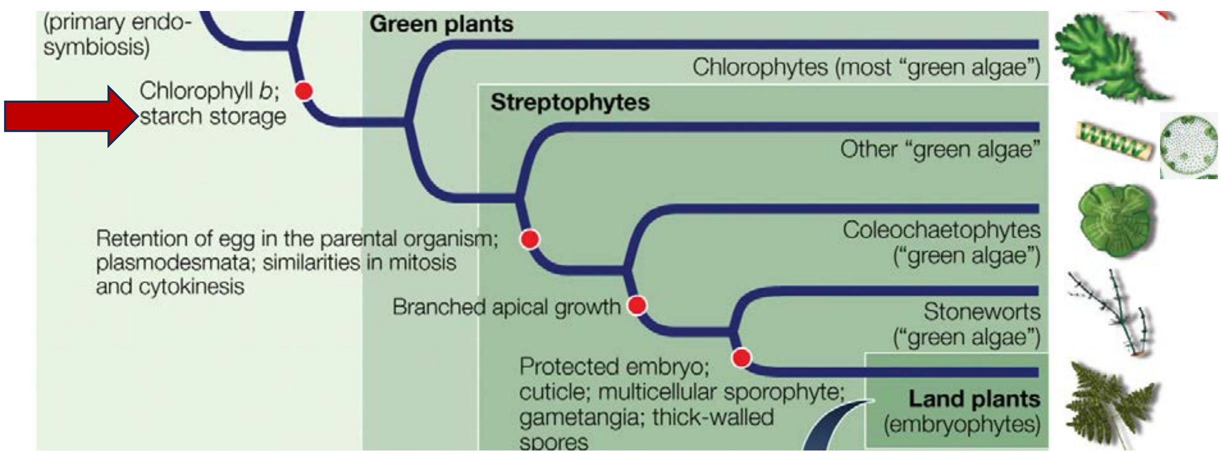


Chloroplasts store starch

Starch = glucose chains



<u>GREEN</u> Algae/Plants: synapomorphy traits



NON-Vascular Plants

need

WET HABITATS

The liverwort *Marchantia polymorpha*

peat moss bog

Hornwort (*Anthocerophyta*)

Polytrichum gametophytes (moss)

Mosses :

leafy, green <u>gametophytes</u> (n) dominate.

brown, *dependent* <u>sporophytes</u> (2n) dependent.

Shimamura M, Yamaguchi T, Deguchi H.
Airborne sperm of Conocephalum conicum (Conocephalaceae)
J Plant Res. 2008 Jan;121(1):69-71.

http://www.tolweb.org/

RHIZOIDS of the *MOSSES*

Example: Physcomitrella patens

NONvascular – Rhizoids

Filamentous outgrowth of root hairs on the underside of the thallus in some lower plants, especially mosses and liverworts, serving both to anchor the plant and (in terrestrial forms) to conduct water.

Vascular – Rhizomes

Underground system of stem that sends out roots and shoots. Bamboo, ferns, etc.

Vascular – Mycorrhizae

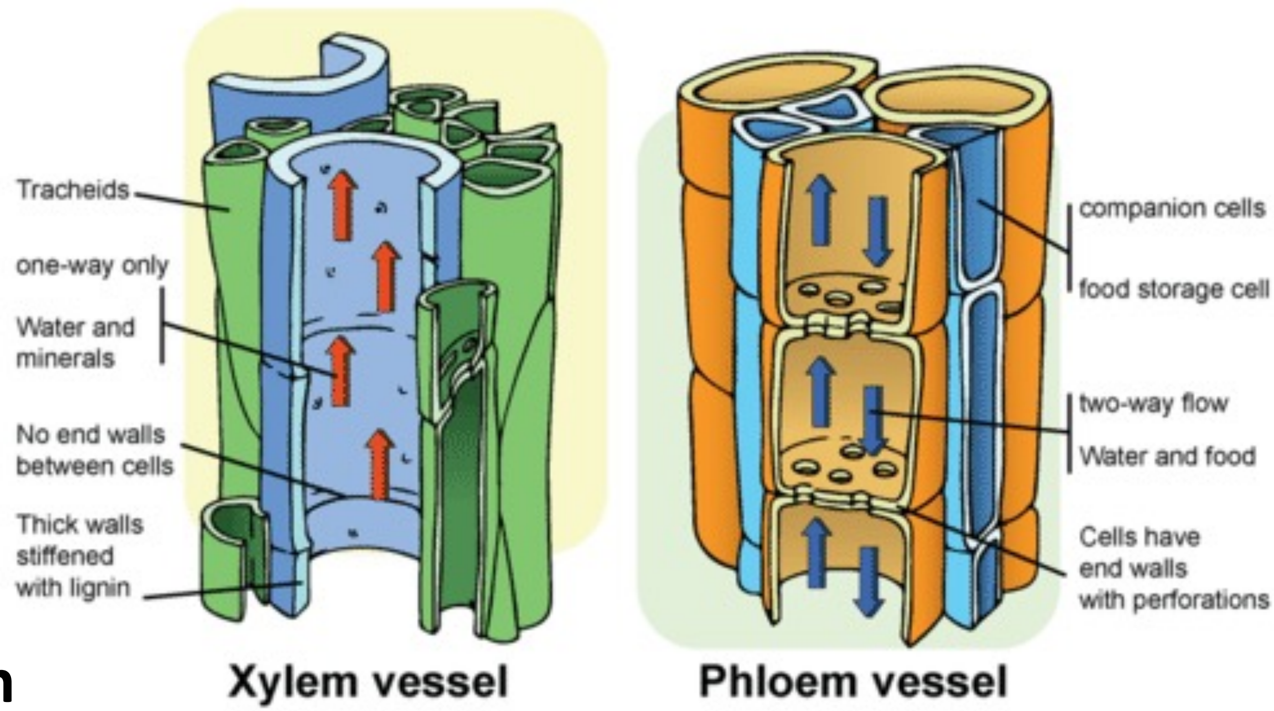
Fungal partner of a **mutualistic** association between vascular **plant** roots and their **symbiotic fungi** … 1^{st} evolved ~460 mya

Sakakibara, et al., 2003

True “Vascular” Plants

Textbook Ch. 23, p. 583-583 (3[rd])

Xylem: ‘Roots to Shoots’



Complex Fluid System

Distinguishes vascular from non-vascular plants

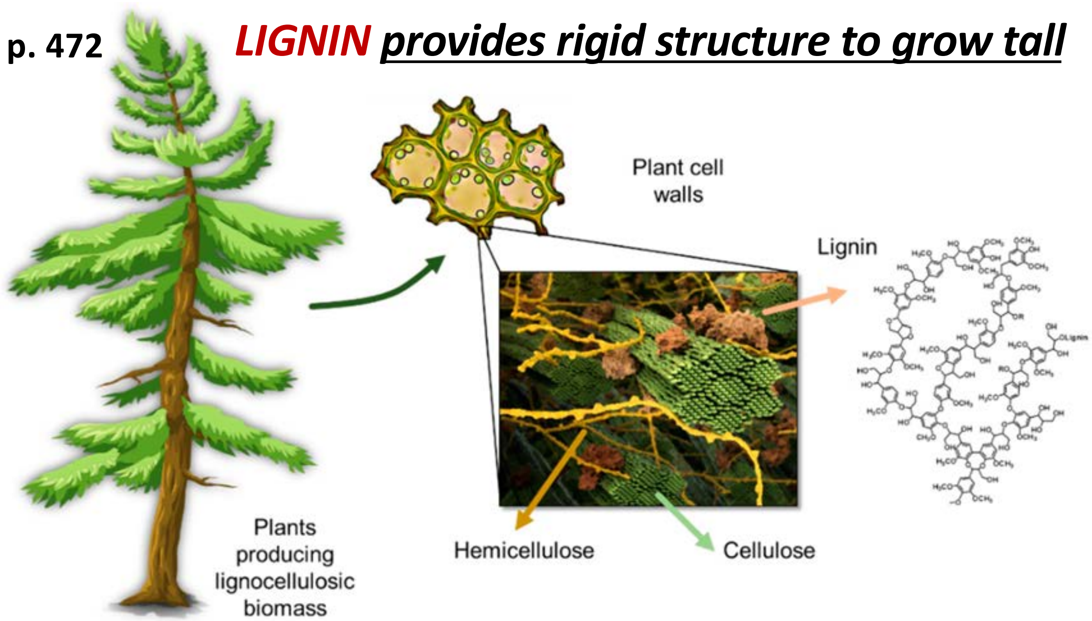
tracheid cells around *vessel* tubes
dead, rigid w/lignin

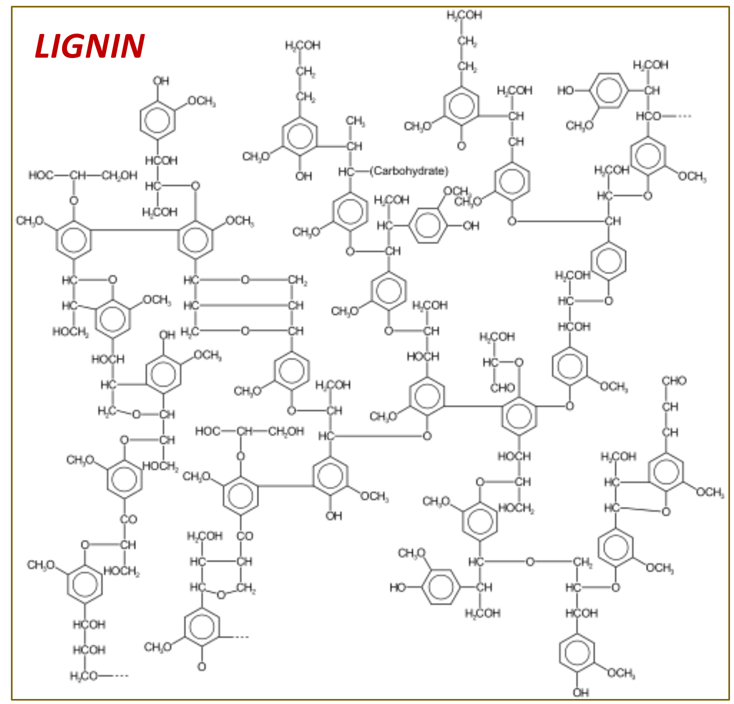
sieve tube-like cells surrounded by ***companion cells***
live cellular structures

Vascular plants' *LIGNIN* <u>*in the cell walls*</u> provides structural support, allowing **taller** growth. **Think: wood, bark. *Taller plants can intercept more sunlight and disperse spores more effectively.***

See p. 472

***LIGNIN* <u>*provides rigid structure to grow tall*</u>**





Gymnosperms-
Vascular land plants

- *1st True vascularity begins:*
  - *Xylem has tracheids but no vessel elements*
  - *Phloem with sieve cells, not companion cells*
- *unisex cones, 'naked' seeds*
- *no flower/fruit ... POLLENATED by WIND*

Example: ginkgos

Example: conifers

Ch. 20, p. 480-481 (3rd)

ADAPTATION

NON-vascular plants live in wetter habitats. Only some have stomata ...

Stomata

Pores in the Cuticle

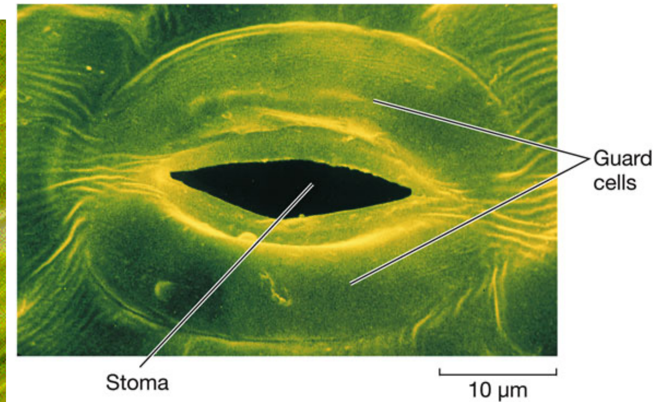
***help conserve H_2O.**

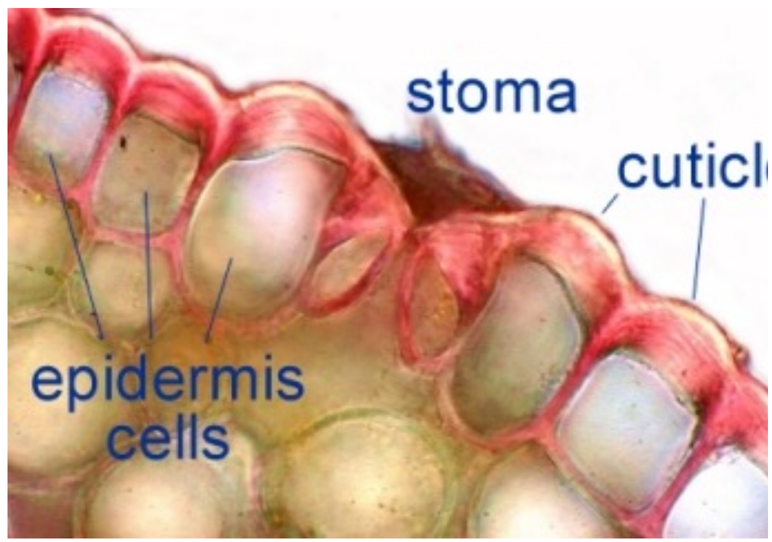
Vascular plants can live in drier habitats. ALL have stomata

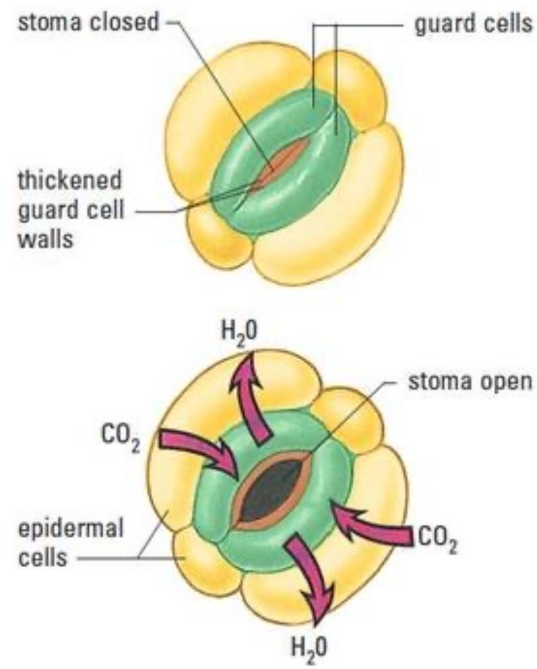
Waxy Cuticle

***conserves water**

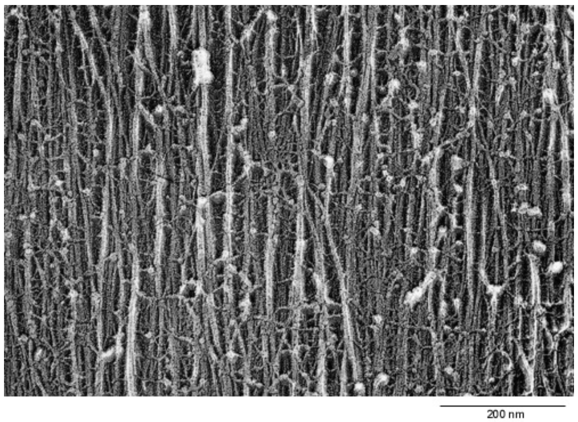
All land plants have cuticles, non-vascular + vascular

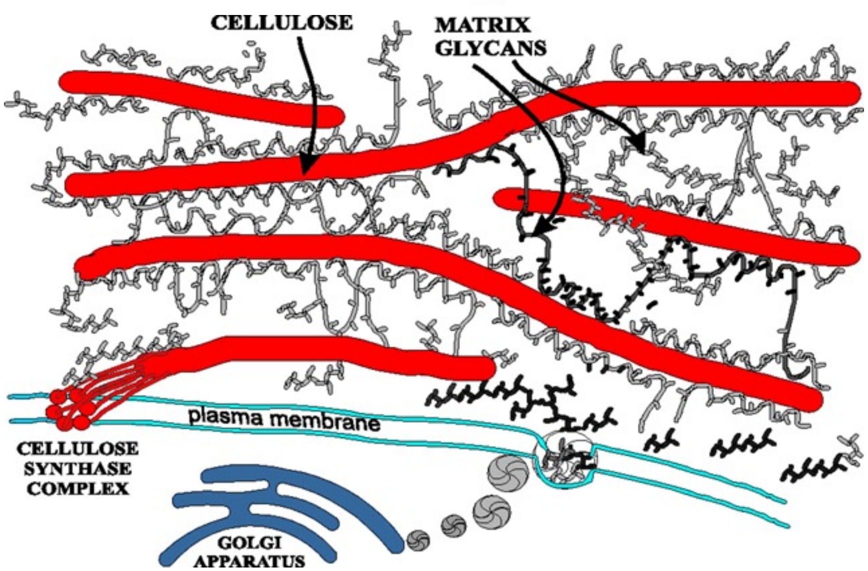


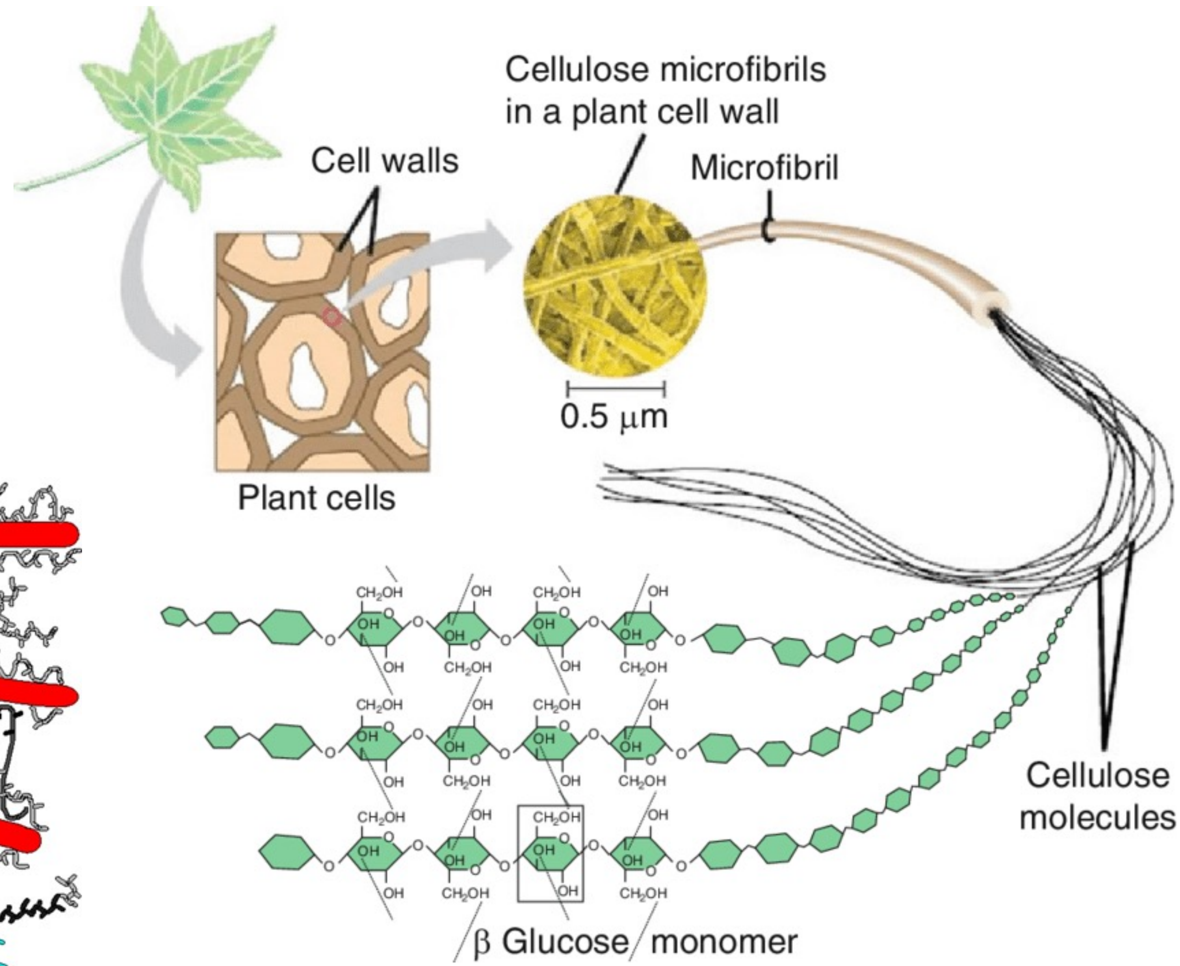




ADAPTATION: A Cell Wall MADE OF CELLULOSE





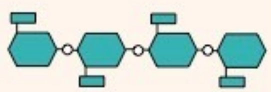
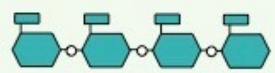
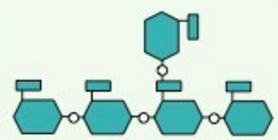
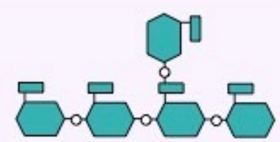
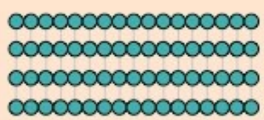
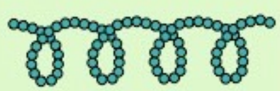
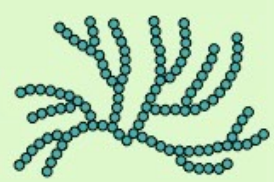
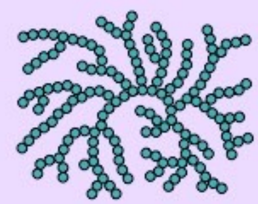


Cellulose is a Glucose Polymer

Yennawar N H et al. PNAS 2006;103:14664-14671

PLANT AND ANIMAL STRUCTURES MADE FROM GLUCOSE:

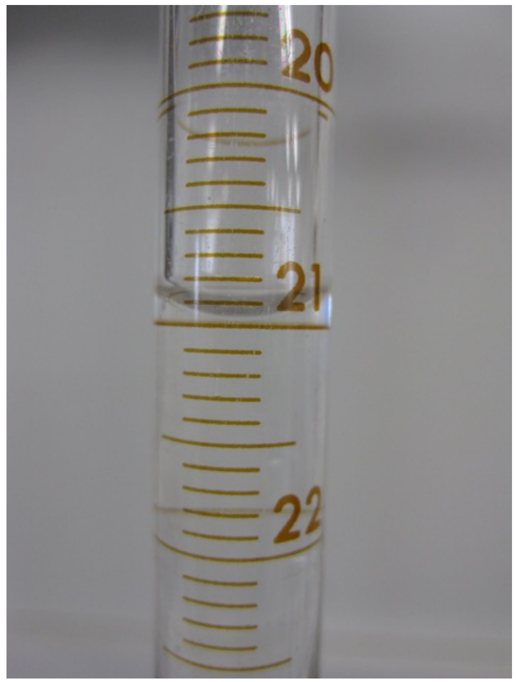
Plants *Animals*

	Cellulose	Starch		Glycogen
		Amylose	Amylopectin	
Source	Plant	Plant	Plant	Animal
Subunit	β-glucose	α-glucose	α-glucose	α-glucose
Bonds	1-4	1-4	1-4 *and* 1-6	1-4 *and* 1-6
Branches	No	No	Yes (~per 20 subunits)	Yes (~per 10 subunits)
Diagram				
Shape				

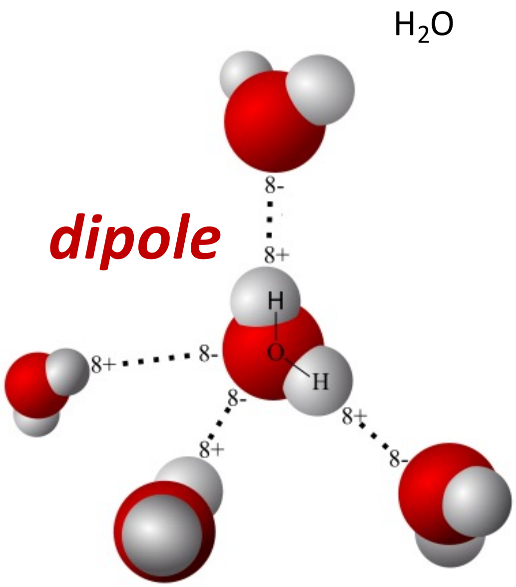
Water Conduction in Vascular Land Plants

cohesion (surface tension)

adhesion

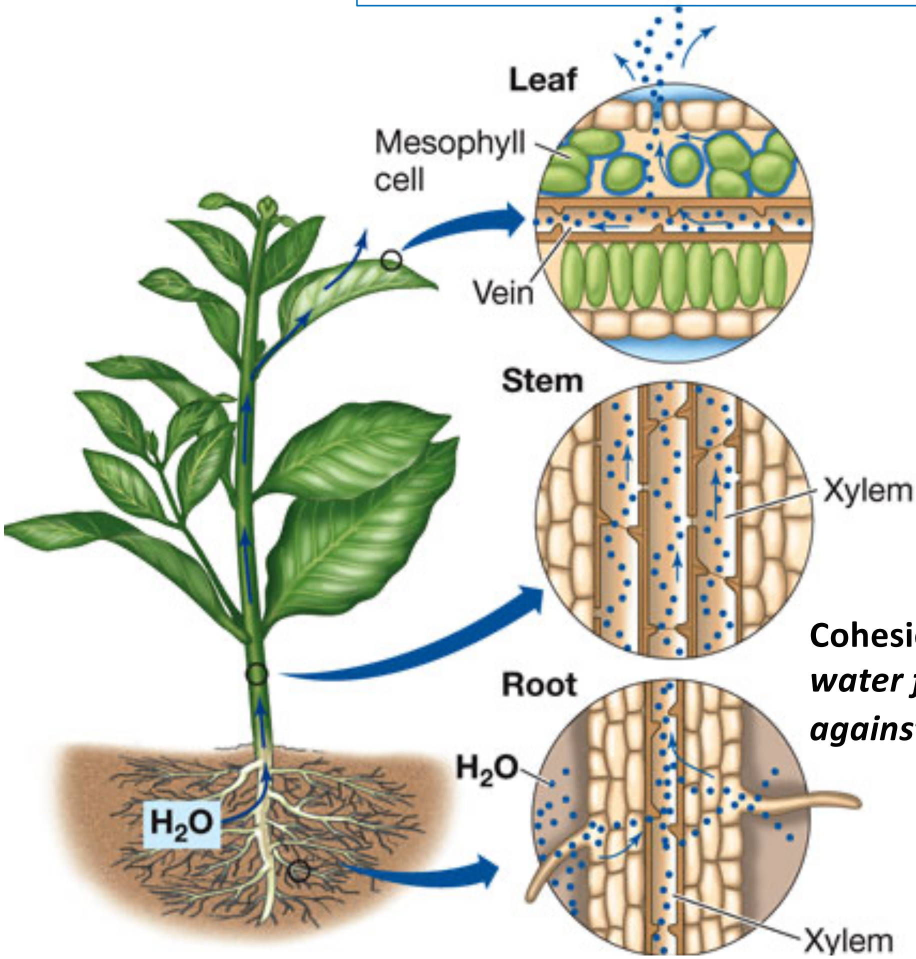


dipole



Transpiration-Cohesion-Tension MECHANISM: WATER CONTROL

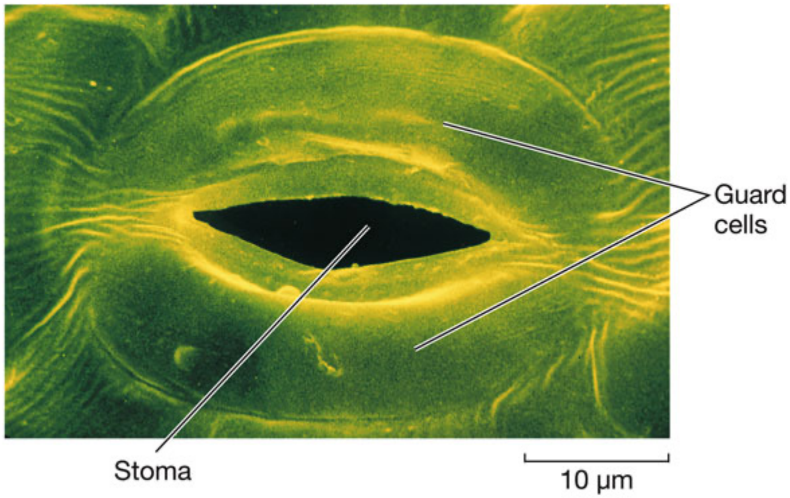
Transpiration … *evaporation pulls water up through the stems*



Cohesion-Tension
water flows up against gravity

Textbook Figure 24.16 (3rd), p. 613

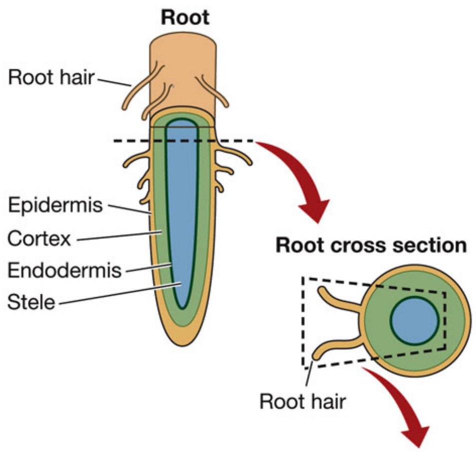
water exits via stomata

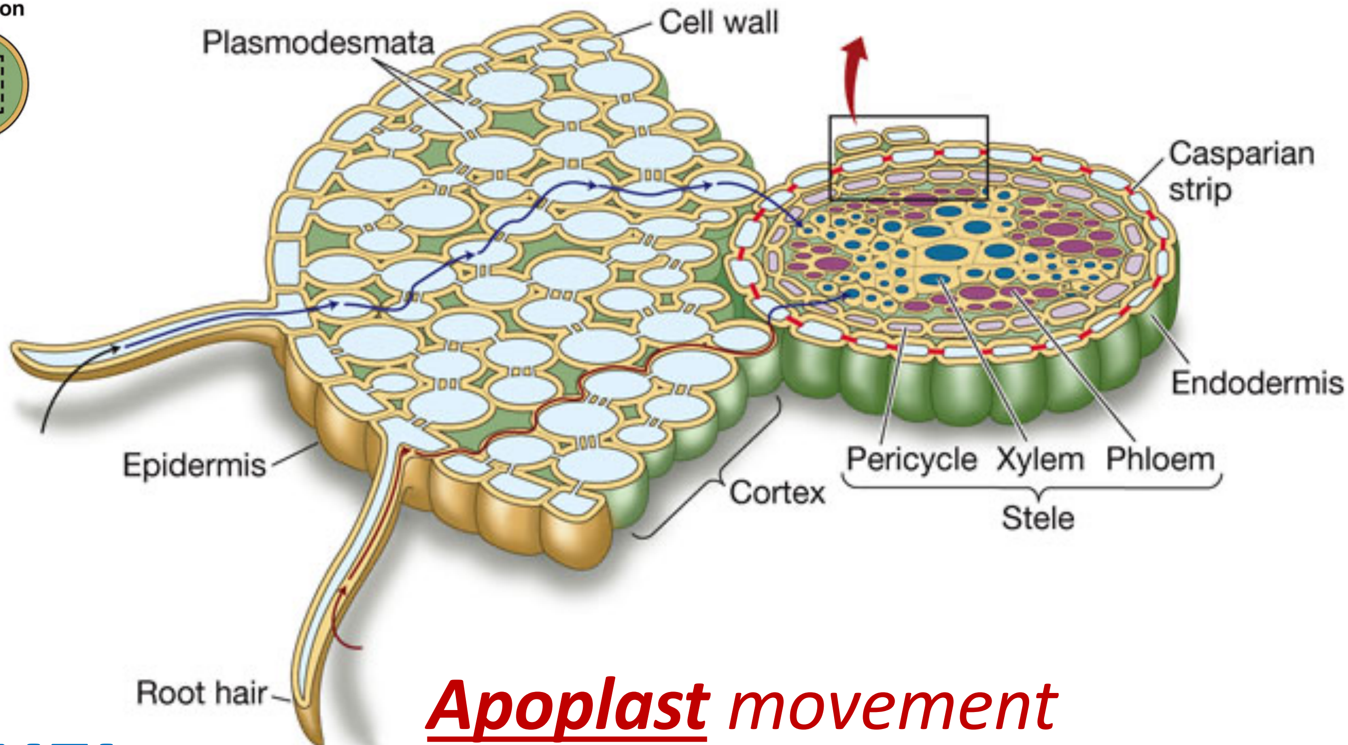


- Rate of water loss is dependent on temperature and humidity
- Too much water loss leads to wilting

Textbook Figure 24.17 (3rd), p. 614

ROOT (hairs) to SHOOT: How does water move into the plant?



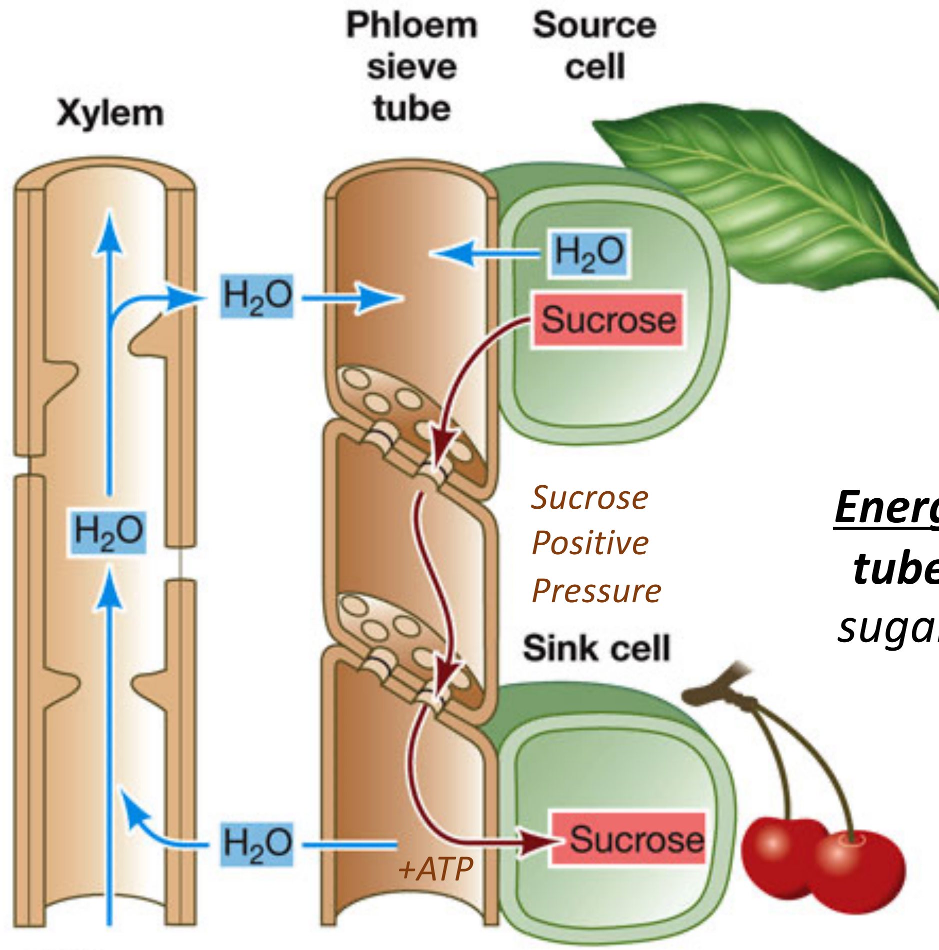


Symplast *movement* ***through cell to cell*** *regulated by* ***PLASMODESMATA***

Apoplast *movement* ***between*** *cells (less regulated)*

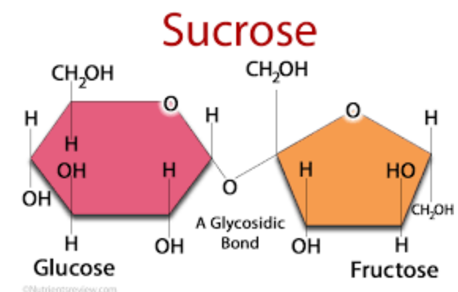
The Pressure Flow Model for Phloem Sap Transport

Water negative pressure



Water positive pressure

Textbook Figure 24.19 (3rd), p. 617

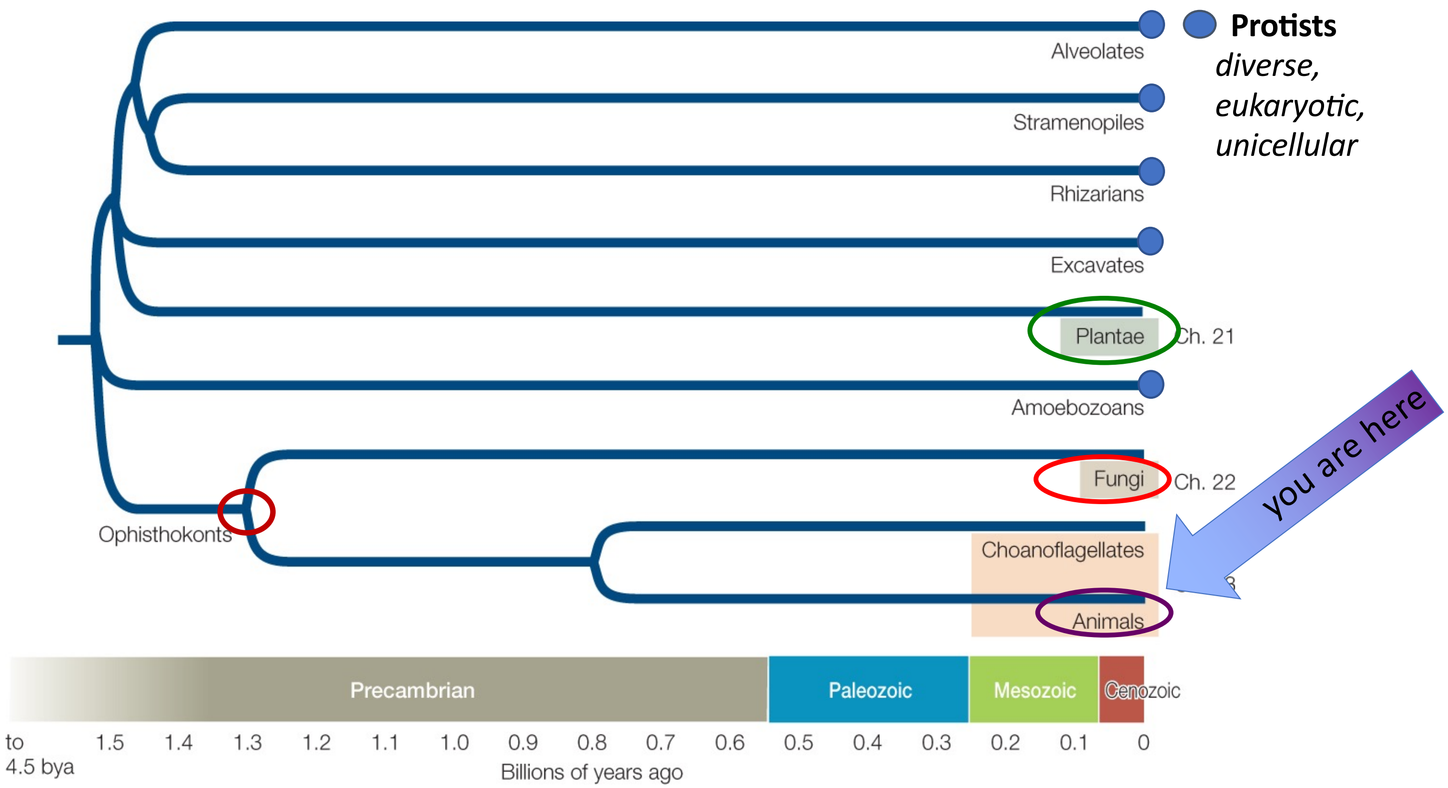


Energy ***stored in 'sink' cells such as fruit, tubers, seeds ...*** ***Active*** *transport of the sugar SUCROSE into a concentrated area requires ATP* ***energy***

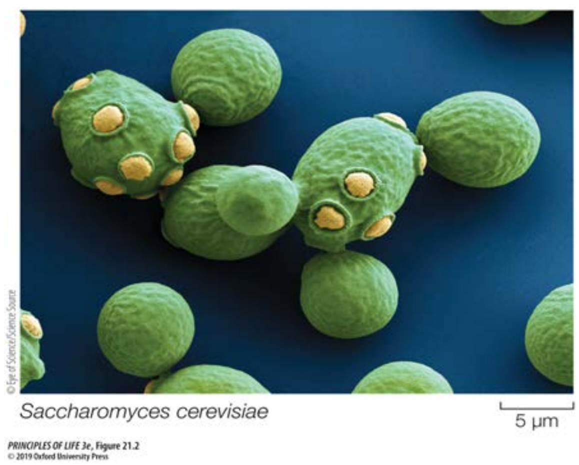
Lecture 8: Fungi

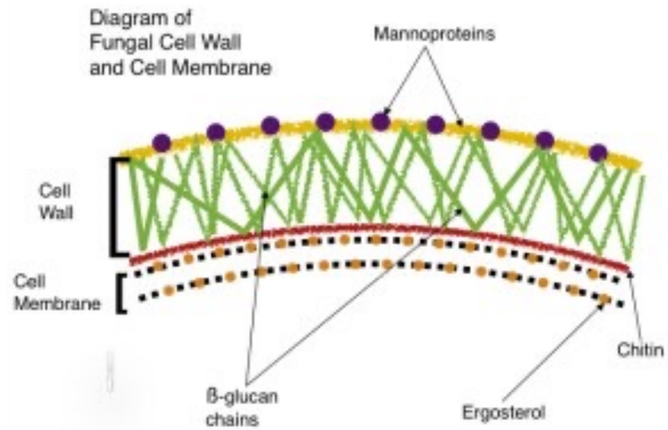
Major Eukaryote Groups

Ophisthokonts – have eukaryotic flagella! (spores or sperms)

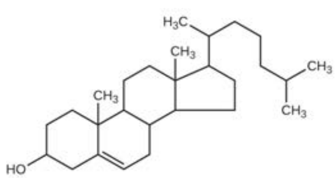


Familiar, Single-Cell Fungus (Yeast: Bread, Beer, Wine)



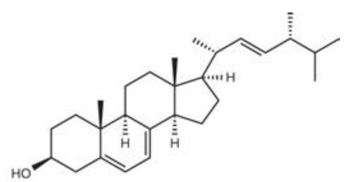


The **cell walls** are strengthened by ***chitin*** polysaccharide (**GLUCOSE!**)



cholesterol

Cholesterol In animal membranes

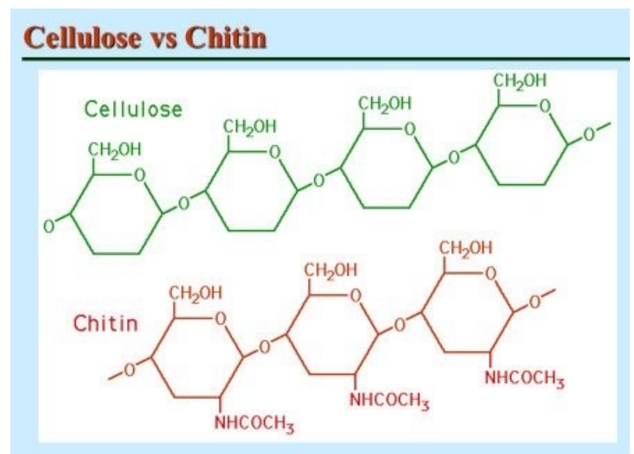


ergosterol

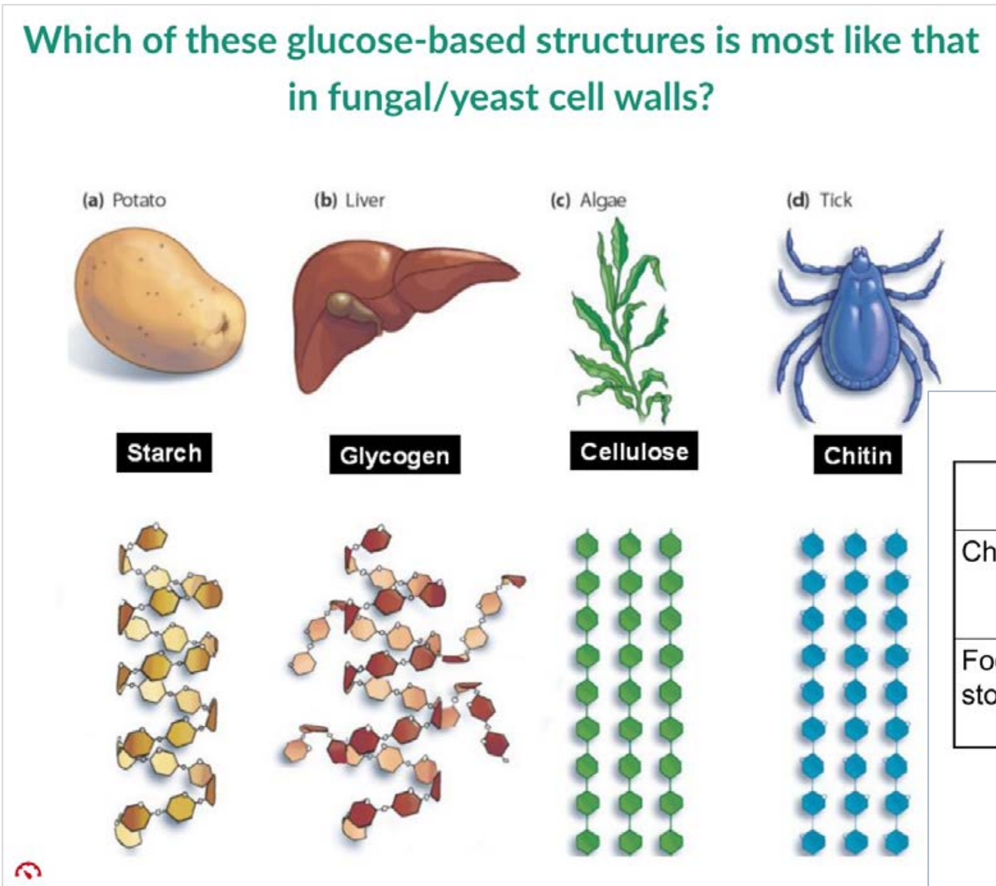
Ergosterol In fungal membranes

Cellulose Plants :

Chitin Fungi and Invertebrates:



Fungus (Yeast)
More Closely Related to Animals vs. Plants ...

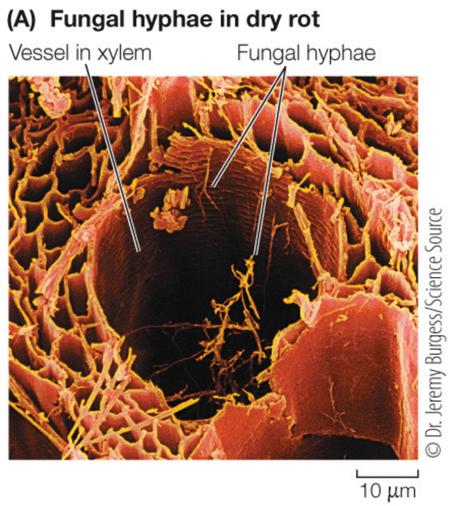


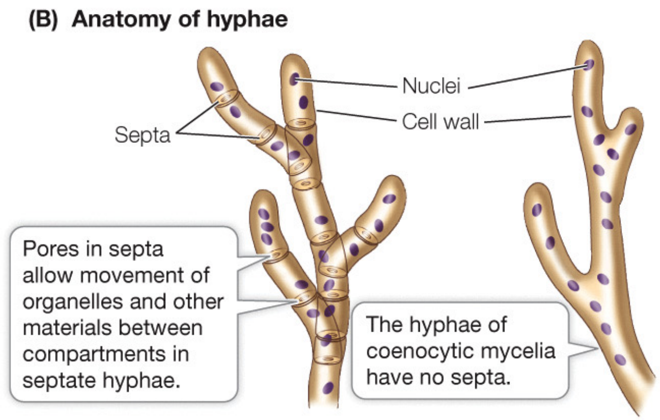
Data ... GLUCOSE Structures

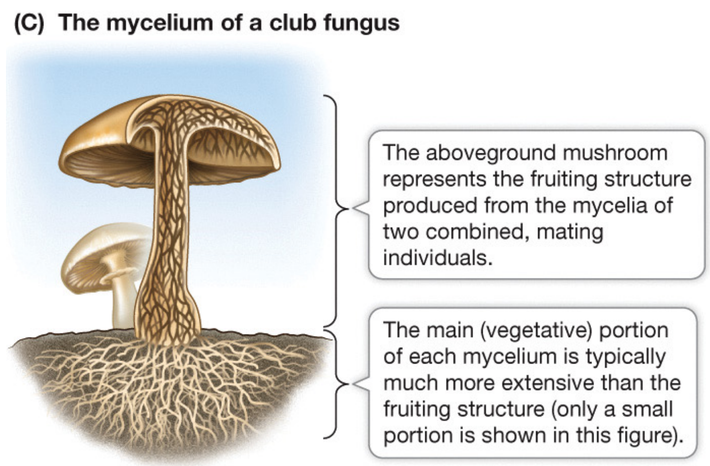
A fungus is not a plant.

	Fungus	Animal	Plant
Chitin	yes	yes	no
Food storage	glycogen	glycogen	starch


Mycelium is composed of hyphae







PRINCIPLES OF LIFE 3e, Figure 21.3

Mycelia: interwoven filaments of hyphae.

Some species have **septate hyphae**—hyphae are subdivided by incomplete cross-walls called **septa**. Organelles can move between compartments.

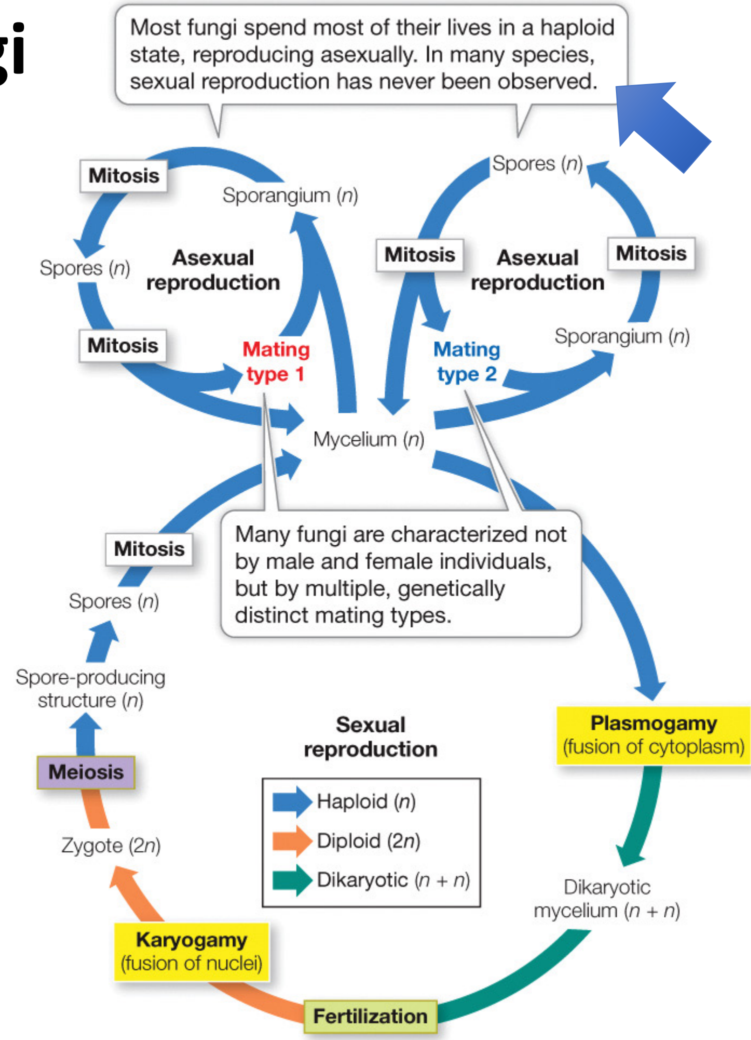
Some species are **coenocytic**—no septa, but many nuclei (from mitosis without cytokinesis).

Reproduction of Fungi

Asexual > Sexual

Basidiomycete

PRINCIPLES OF LIFE 3e, Figure 21.4

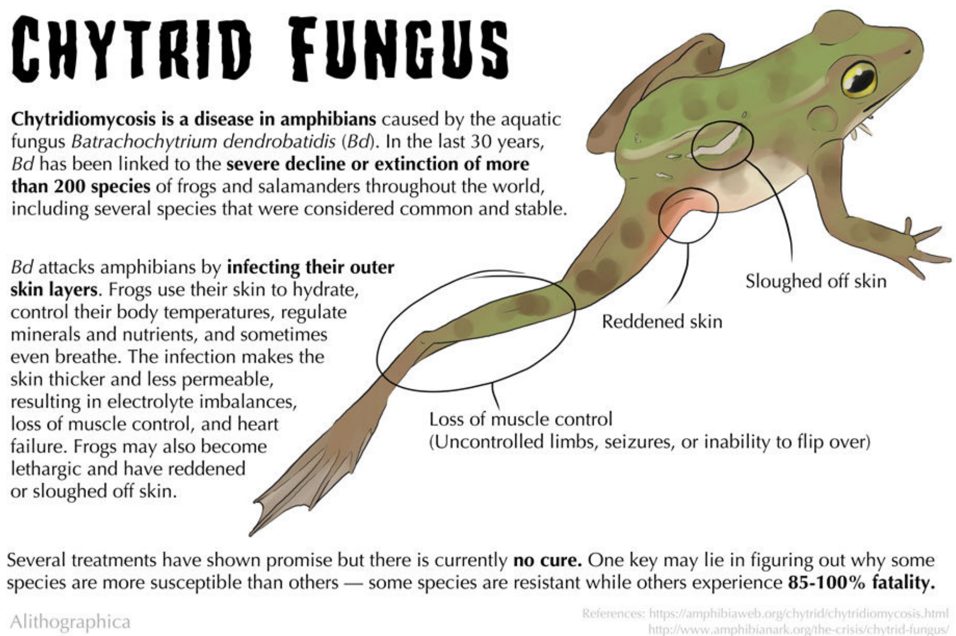


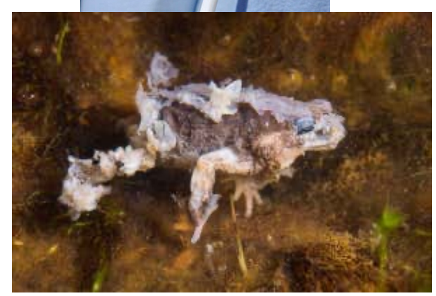
PRINCIPLES OF LIFE 3e, Figure 21.11

Chytrid Fungi and the Decline of Amphibians (Video)

Chytridiomycosis is caused by two chytrid fungi called

- *Batrachochytrium dendrobatidis** (we study) – frogs, toads, salamanders
- *Batrachochytrium salamandrivorans* – mostly infects and deadly to salamanders





Extinction of [> 90 Species](#) of Amphibians

Read more: [See "Chytrid Apocalypse' in Module](#)– VIDEO on NatGeo site (VBK)

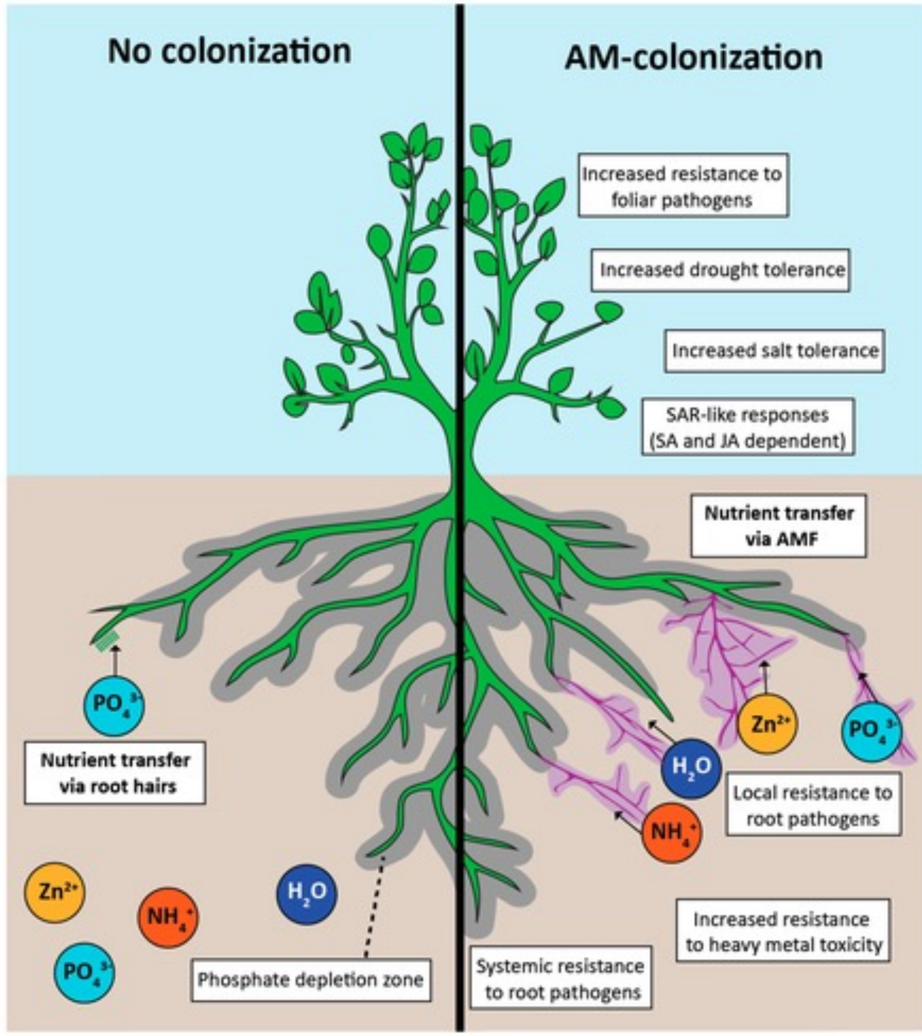
[Fungus on a Spanish Island (2015)](#)

Glomeromycete Fungi

Mycorrhizae: Fungi in PLANT ROOTS

Mycorrhizae:

Fungal partner in a mutualistic association between vascular **plant** roots and their **symbiotic** fungi … 1st evolved ~460 mya
VASCULAR PLANT *partners*
Ecto-mycorrhizae – network over root surfaces
Arbuscular mycorrhizae – infiltrate between pm/cw



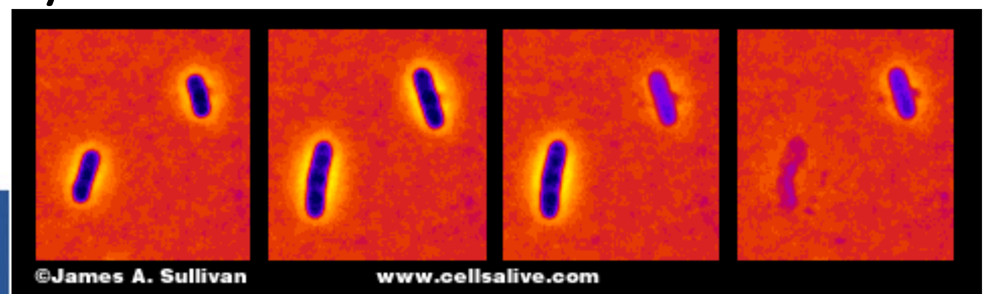
NOT Rhizoids

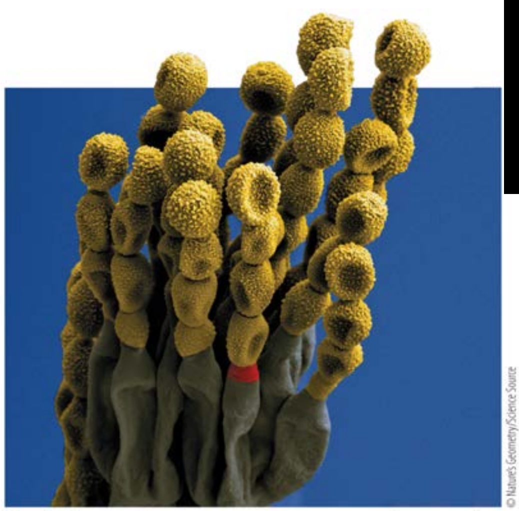
Which are filamentous outgrowth of root hairs on the underside of the thallus in some **NON-**VASCULAR plants, especially mosses and liverworts, serving both to anchor the plant and (in terrestrial forms) to conduct water.

NOT Rhizomes:

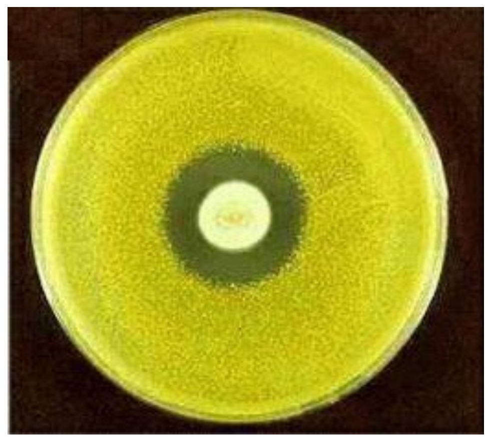
Which are underground system of ***stems*** that sends out roots and shoots in VASCULAR plants
Similar to: strawberries stolons

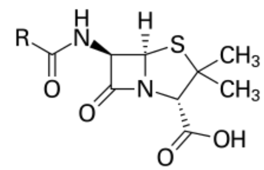
Penicillin is harvested from fungi. It kills bacteria by interfering with bacterial cell wall synthesis

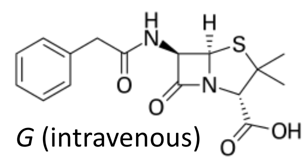




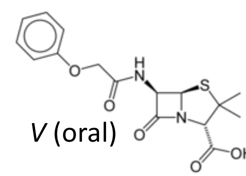
Penicillium chrysogenum 5 µm







G (intravenous)

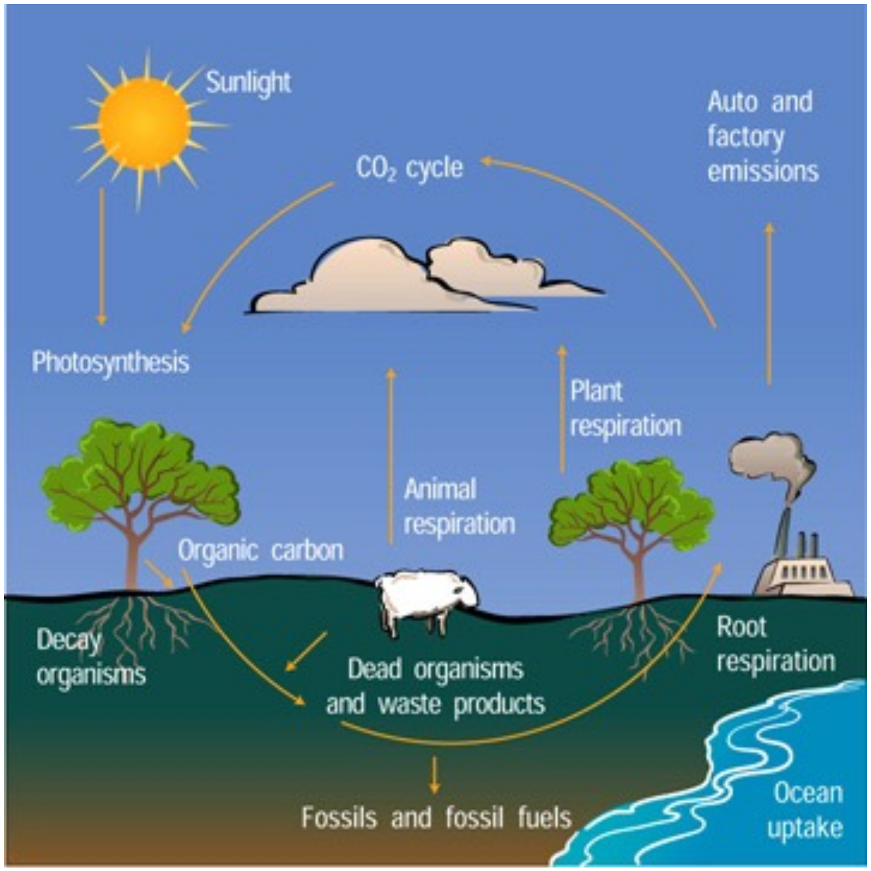


V (oral)

Ascomycete

http://textbookofbacteriology.net/themicrobialworld/bactresanti.html

Saprophytic Fungi Keep The Carbon Cycle Active

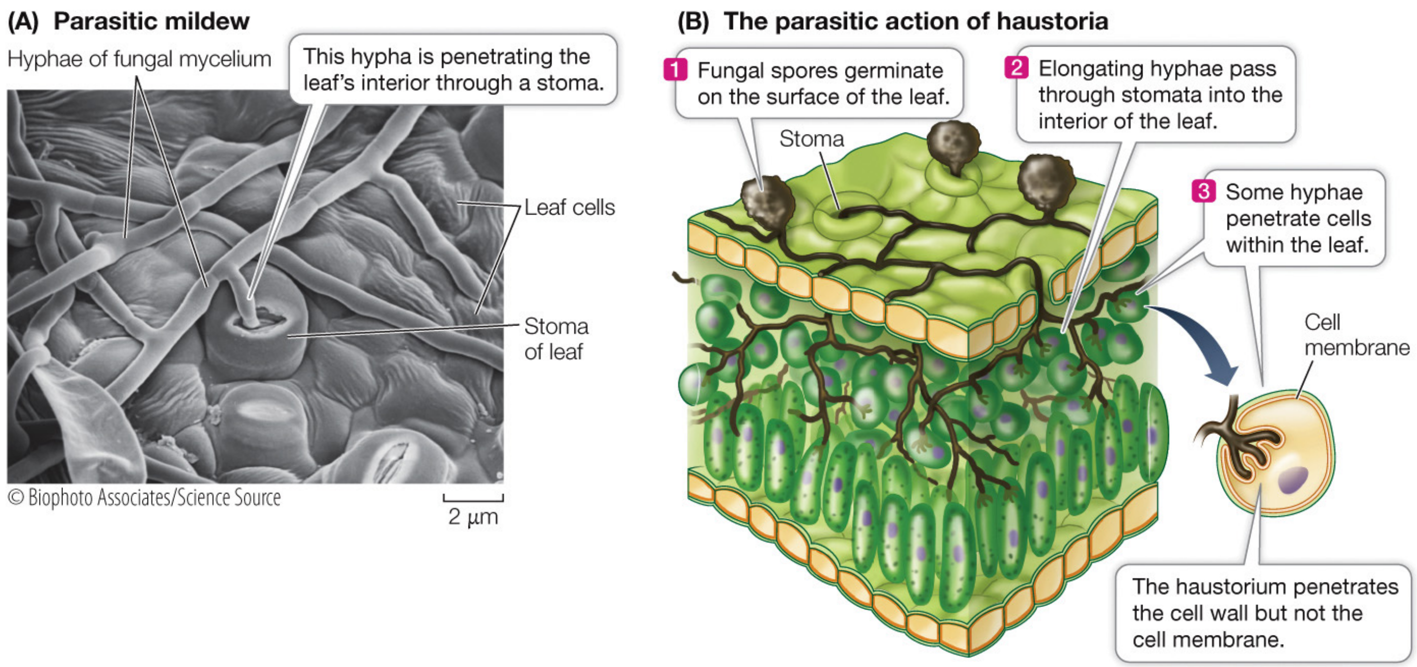


Saprophytic fungi, along with bacteria, are **the major decomposers** on Earth, contributing to decay of organic matter and recycling of the elements used by living things.

Fungi are the main **decomposers of cellulose and lignin in wood and keratin in hair and nails**.

Without fungi, the carbon cycle would fail. Most carbon would be buried instead of being returned to the atmosphere as CO_2.

Fungal hyphae absorb nutrients from plant cells

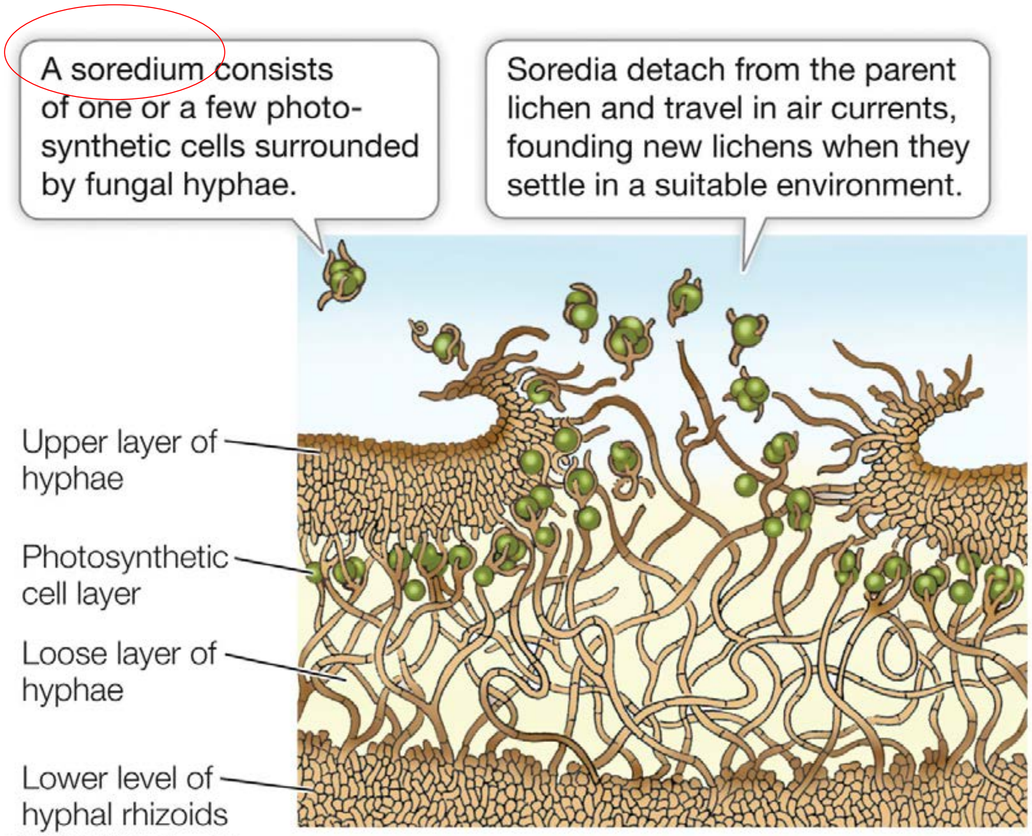


PRINCIPLES OF LIFE 3e, Figure 21.5

Hyphae can enter through stomata, wounds, or by direct penetration of epidermal cell walls.

Some produce **Haustoria**, branching projections that push through cell walls, invaginate into the cell membrane, and absorb nutrients.

Lichens



PRINCIPLES OF LIFE 3e, Figure 21.8

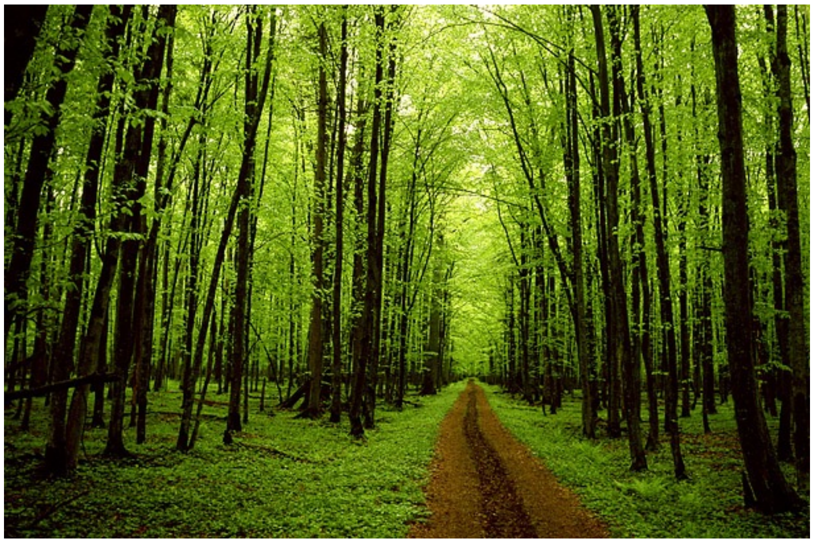
Symbiotic relationships—partners live in close, permanent contact with each other

Mutualistic—the relationship benefits both partners

Lichens: mutualistic associations of a fungus with a unicellular green alga or cyanobacterium.

… **Fungal hyphae absorb nutrients and provide a moist environment for photosynthetic algae**. **The fungi receive fixed carbon from the algae.** Neither can live independently.

Nutrients, minerals, signals, pathogens ... transferred between plants, cross-species, via mycorrhizae



Trees → Nutrients, minerals, signals, pathogens → Indian Pipe plant

Trees ← Mycorrhizae ← Indian Pipe plant

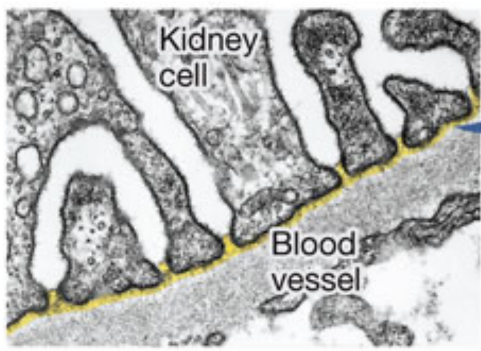
The mycorrhizal fungus gets sugars and amino acids from the plant. The plant's ability to absorb water and mineral nutrients is greatly enhanced. The fungus may also provide some growth hormones and protect roots from pathogenic microorganisms. Many plants grow poorly or not at all without their mycorrhizal partners.

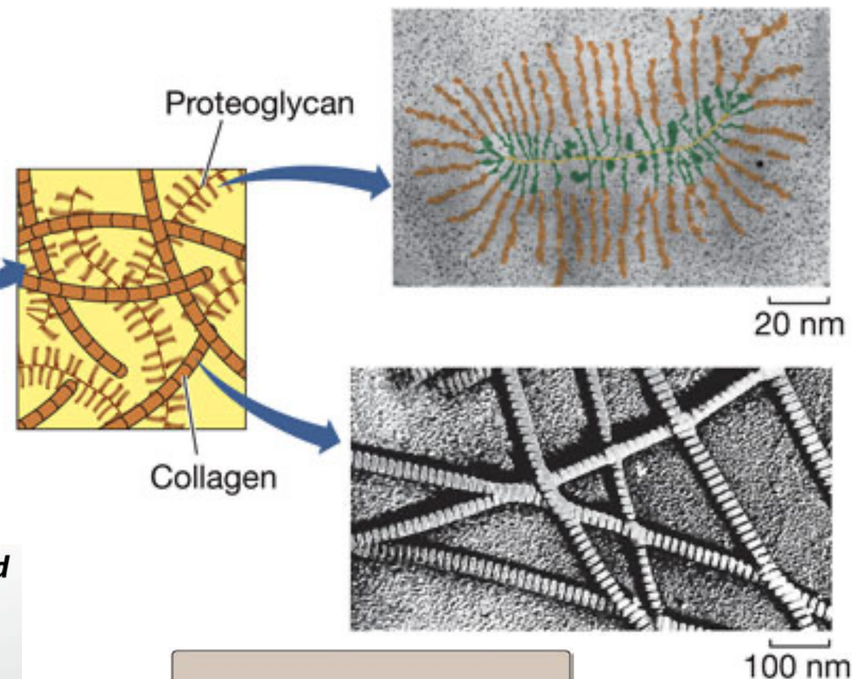
Lecture 9-10: ‘Primitive and/or Ancient’ Animals

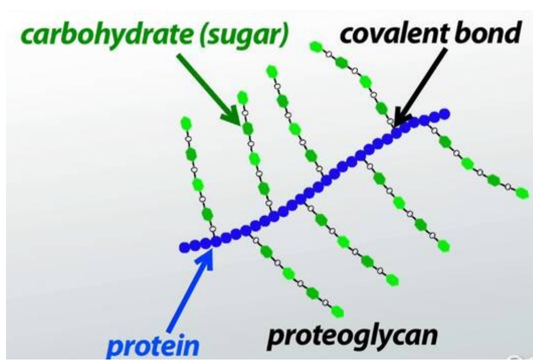
monoblasts
diploblast
Triploblast-protostomes

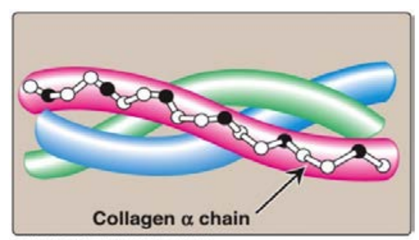
Animal cells contain *Collagen* and *Proteoglycans* as part of the extracellular matrix (*ECM)*

Fig. 4.17, **p. 88-89 (3rd Ed.)**



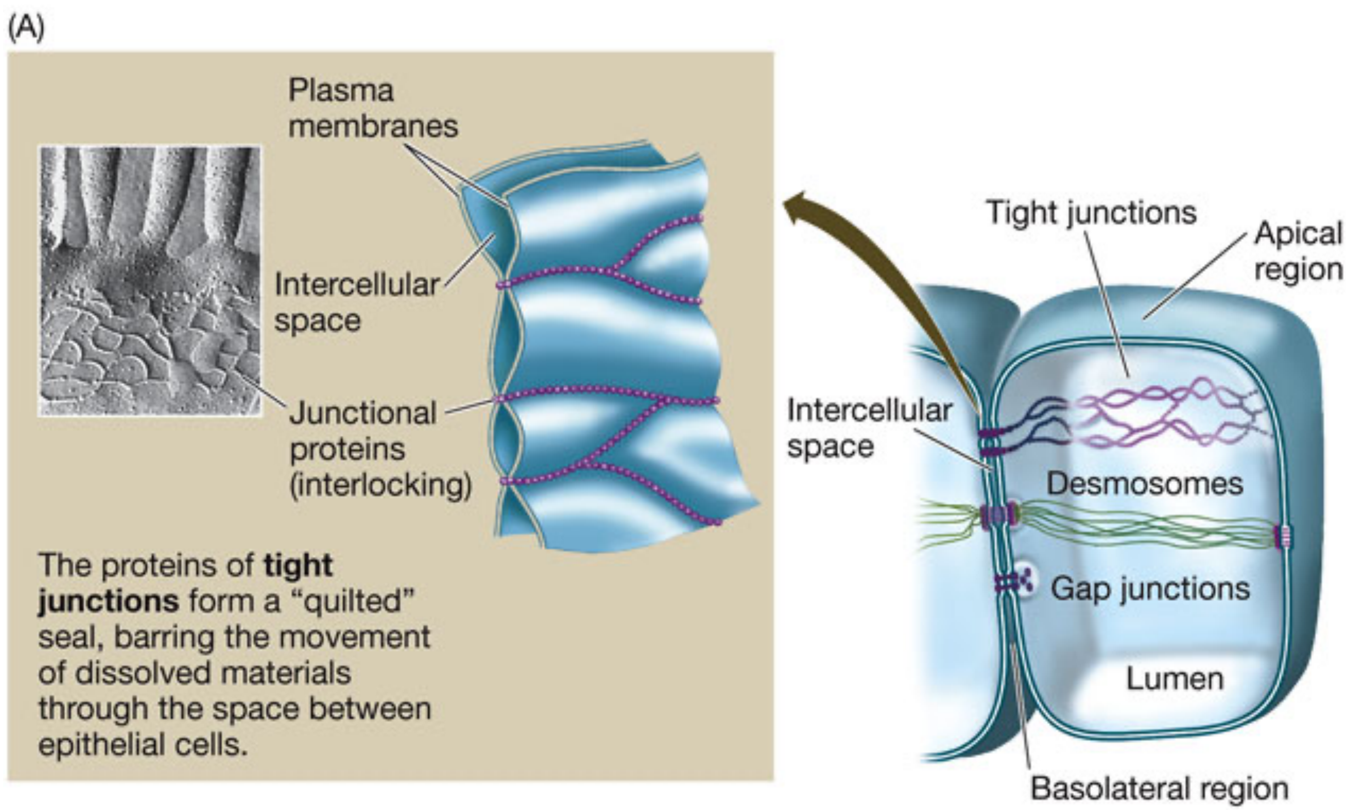






fibrous triple-helix protein

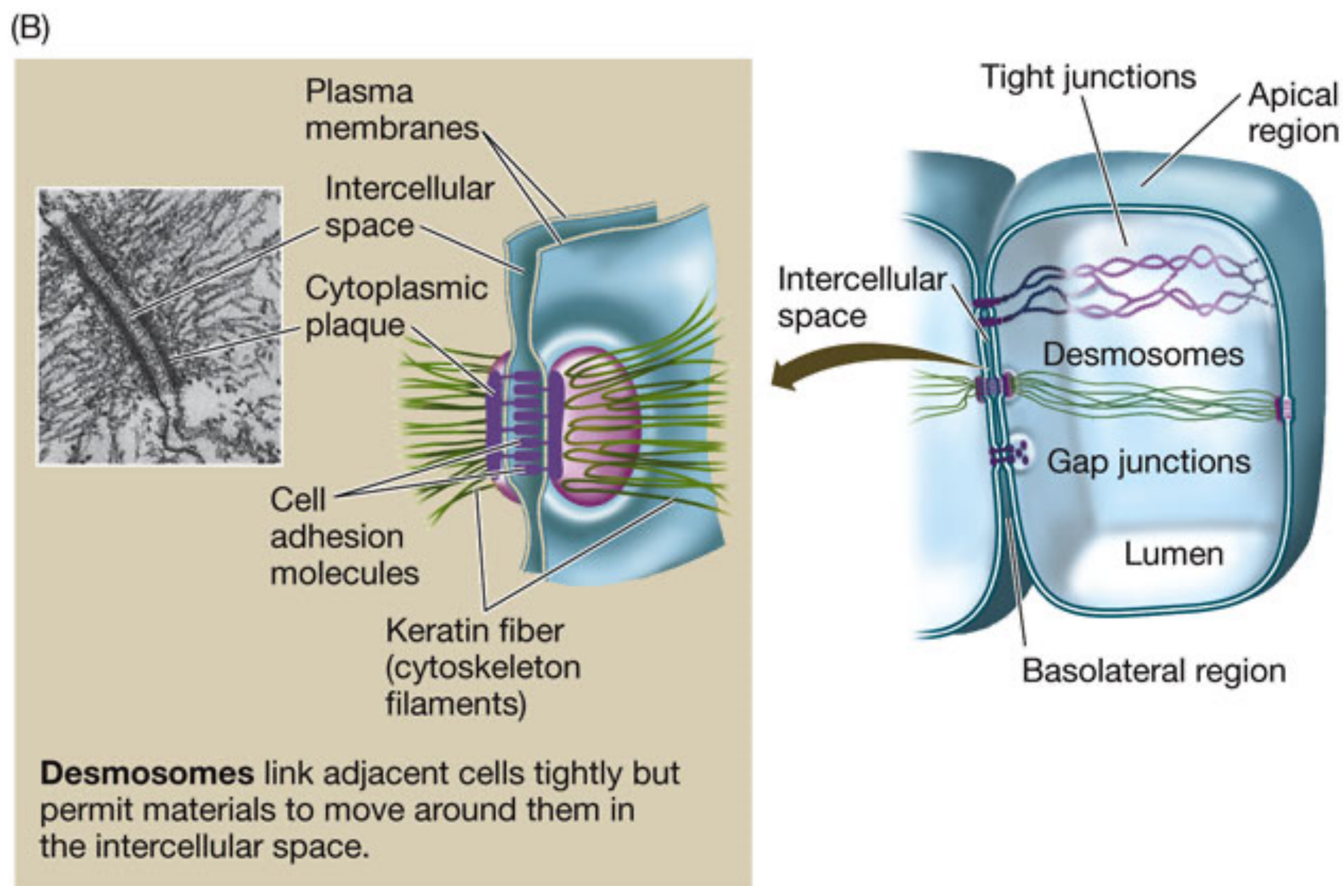
Animal cells have ***Tight Junctions***



Example: prevent organs from 'leaking' (gut)

Fig. 4.19, p. 88-89 (3rd Ed.)

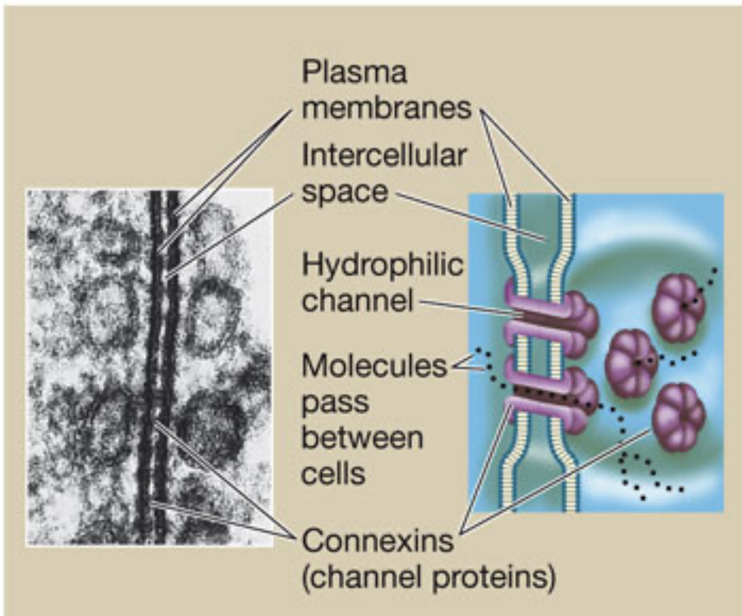
Animal cells have ***Desmosomes***



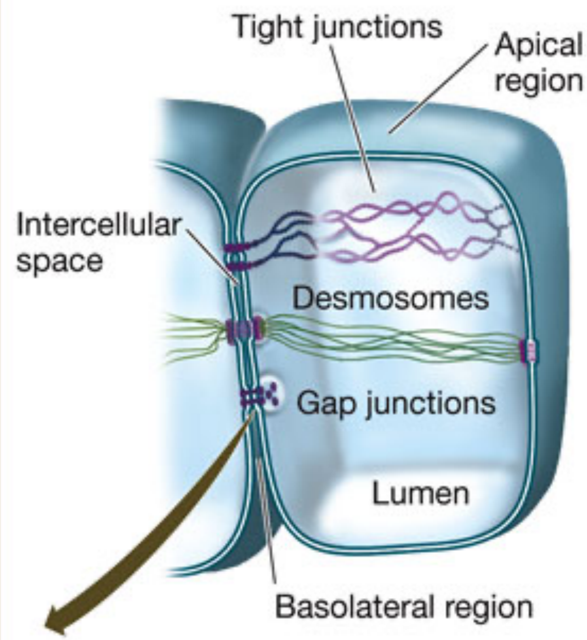
Example: mechanical stability (skin)

Animal cells have ***Gap Junctions***

(C)



Gap junctions let adjacent cells communicate.

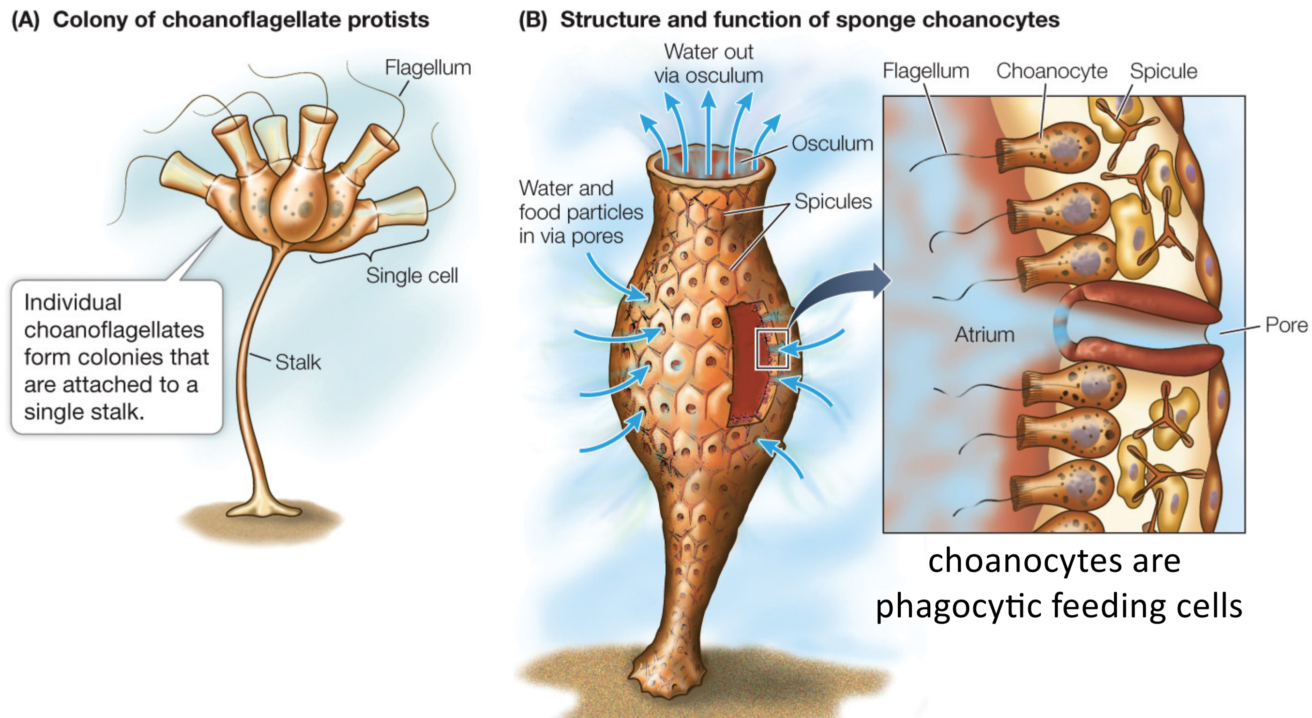


Example: share ions, electrical signals (beating heart)

Sponges have features of primitive animals

Protists – Not Animals

Sponges – Most Primitive Animals



choanocytes are phagocytic feeding cells

Sponges:

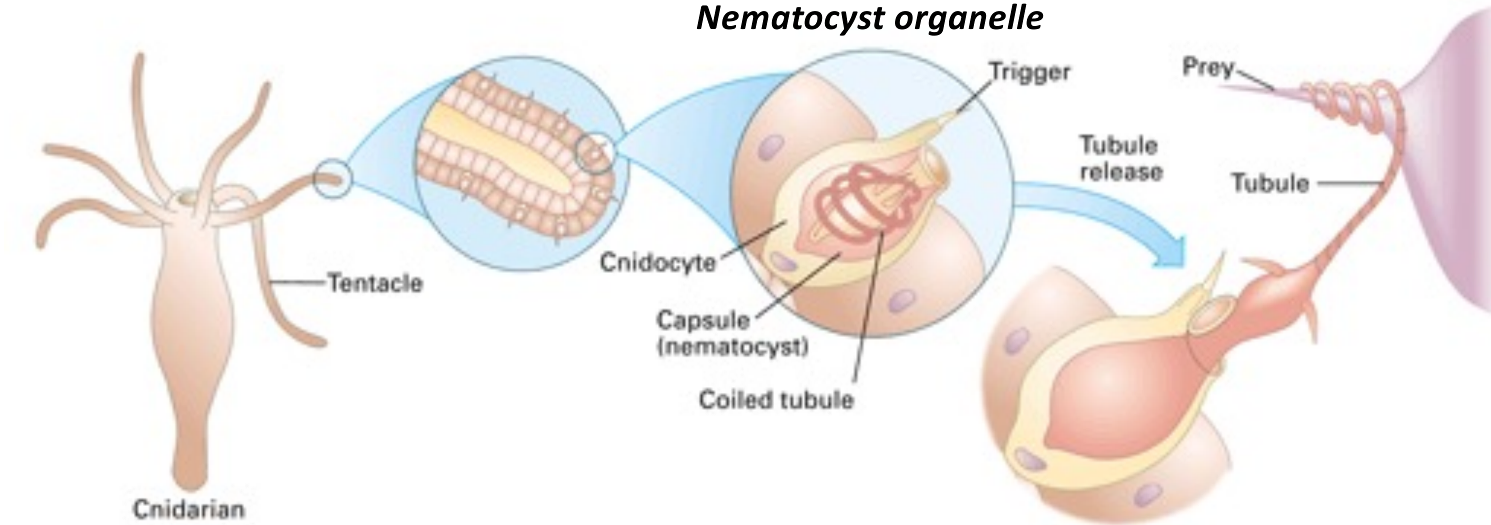
*Filter feeder, beating **flagella** moves water, **phagocytosis**, structural spicules, respiration, excretion through osculum (used all the food or oxygen)*

Diplobast Cnidarian Carnivores have *Cnidocyte* Cells:

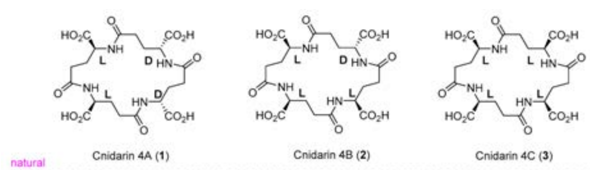
Cnidarians are the
oldest venomous animals

Cnidocyte cell with
Nematocyst organelle

Captures & Stings!



Venom: enzymes and organic chemical molecules:



Ex: Jellyfishes, Anemones

Two stages of the Diploblas Cnidarian life cycle

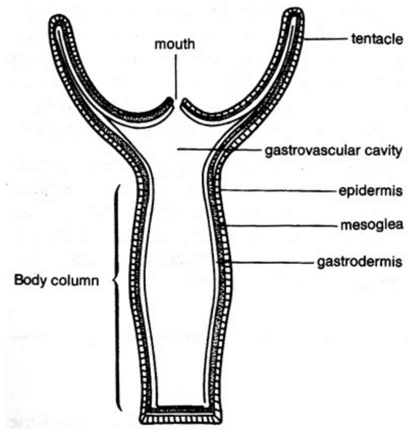
Polyp

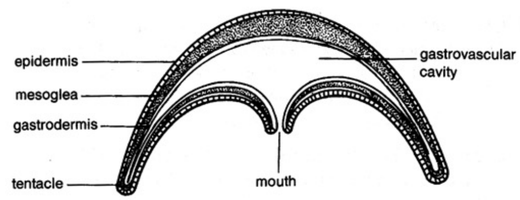
sessile

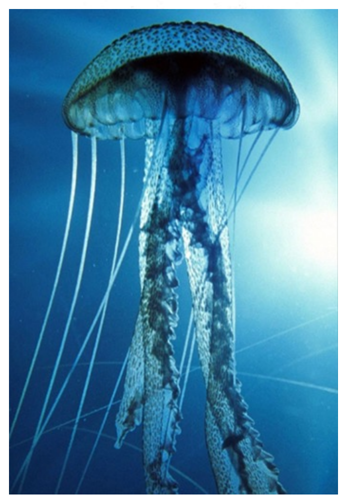
Medusa

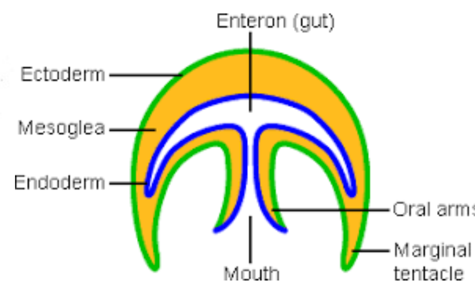
motile

****coordinated movement***









Radial Symmetry
Throughout Life
'Gastrovascular Cavity'
(Food AND Waste)

Corals: Animals (+ Dinoflagellates)

Jellyfish: Energy from Light

Fluorescent (absorb then emit light)

Corals

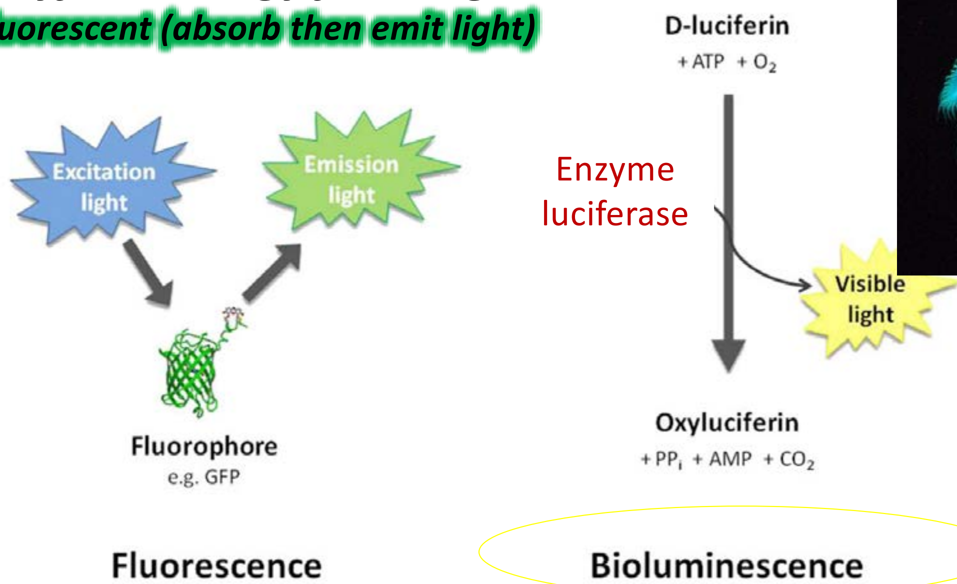


Fig. 1 Basic principles of fluorescence and bioluminescence. With fluorescence, a fluorophore is excited by light at a specific wavelength, and emits light from another wavelength. For bioluminescence, D-luciferin is oxidized by luciferase in the presence of ATP and oxygen, generating visible light, pyrophosphate (*PPi*), adenosine monophosphate (*AMP*) and carbon dioxide (CO_2)

Bioluminescent:
uses **ENZYMES** + ATP
to ***create*** light
Energy from Cells:

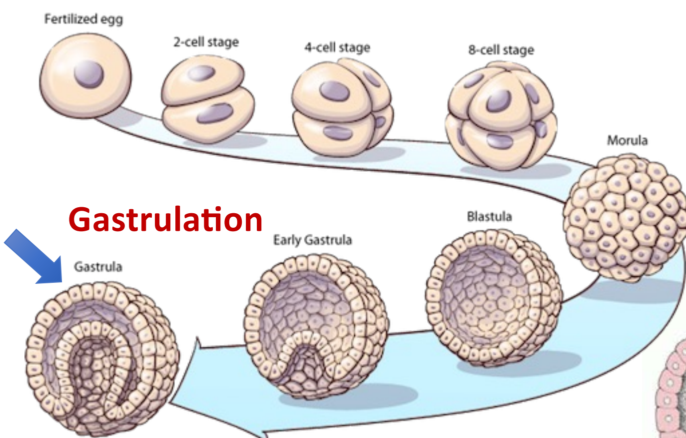
Dinoflagellates make pigments
"Bleaching"
Dying
Loses its symbionts

Developmental Biology: Gastrulation

determines

***phylogeny* of an organism**

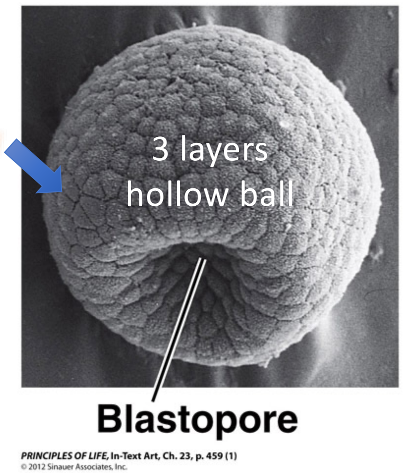
Animal Egg to 1st Ball of Cells: Gastrulation



Cell Cleavage
Process by which the number of cells in a developing embryo is multiplied through cell division.

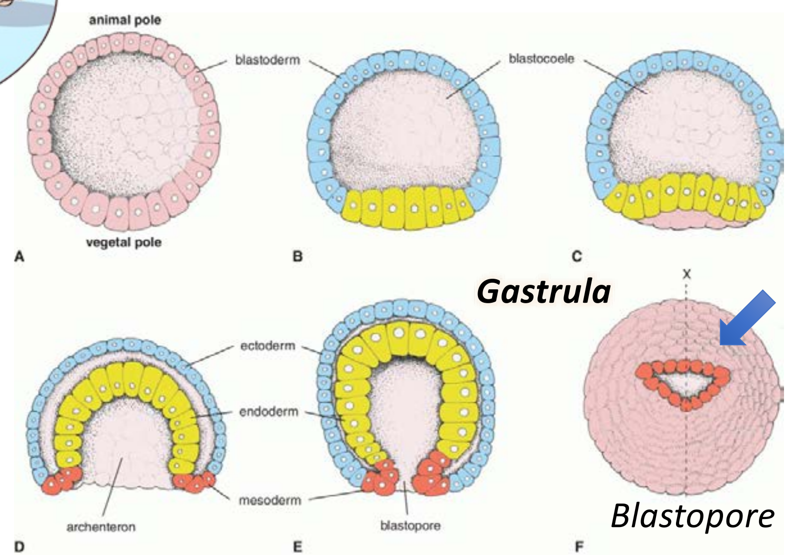
Gastrula

Blastopore
first pore
of GI tract
Protostome vs.
Deuterostome ...



Gastrulation layers:

- **Ectoderm**
- **Endoderm**
- **Mesoderm**



Mollusks

largest group of
marine animalsnimals

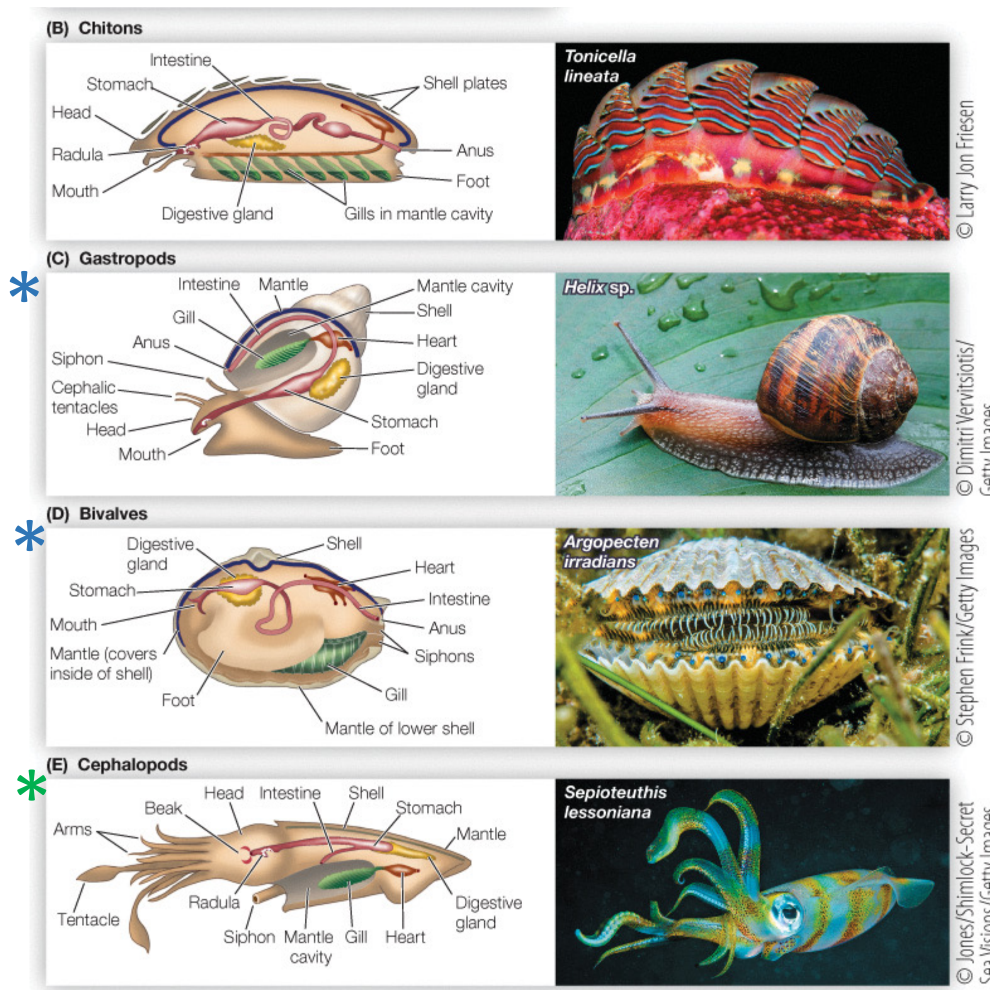
Mantle epidermis secretes shell for protection. Fold of tissue covering the visceral mass; it secretes the calcareous shell ($CaCO_3$)

Mantle cavity contains **gills for gas exchange**. Some species use gills for filter feeding.

Most mollusks have open circulatory system w/ exception of Cephalopods with closed system,no hemocoel.

[Shark vs. Octopus]

[My Octopus Teacher]



PRINCIPLES OF LIFE 3e, Figure 22.23

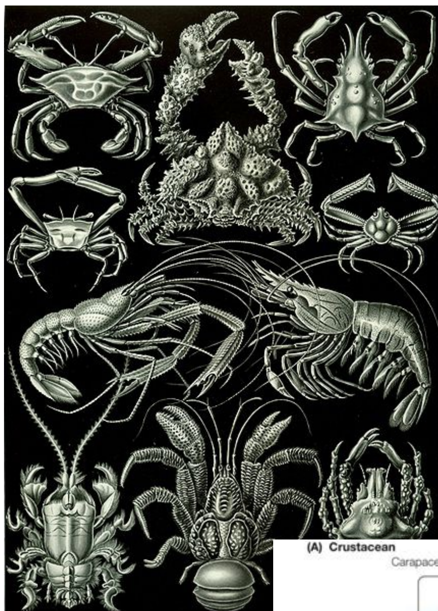
Dominating Arthropods … *Lots !!!*

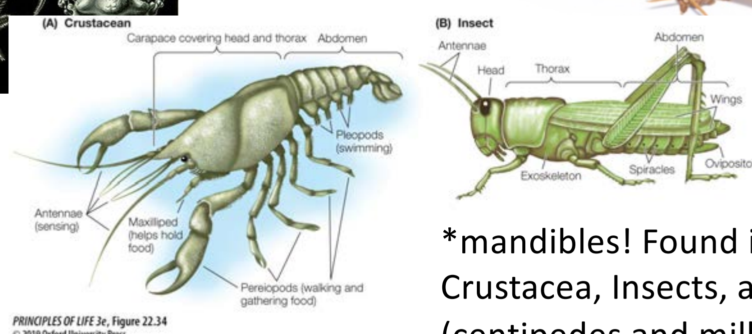
Crustaceans

marine arthropods in water

Insects

terrestrial hexapods on land





*mandibles! Found in:
Crustacea, Insects, and Myriapods
(centipedes and millipedes)

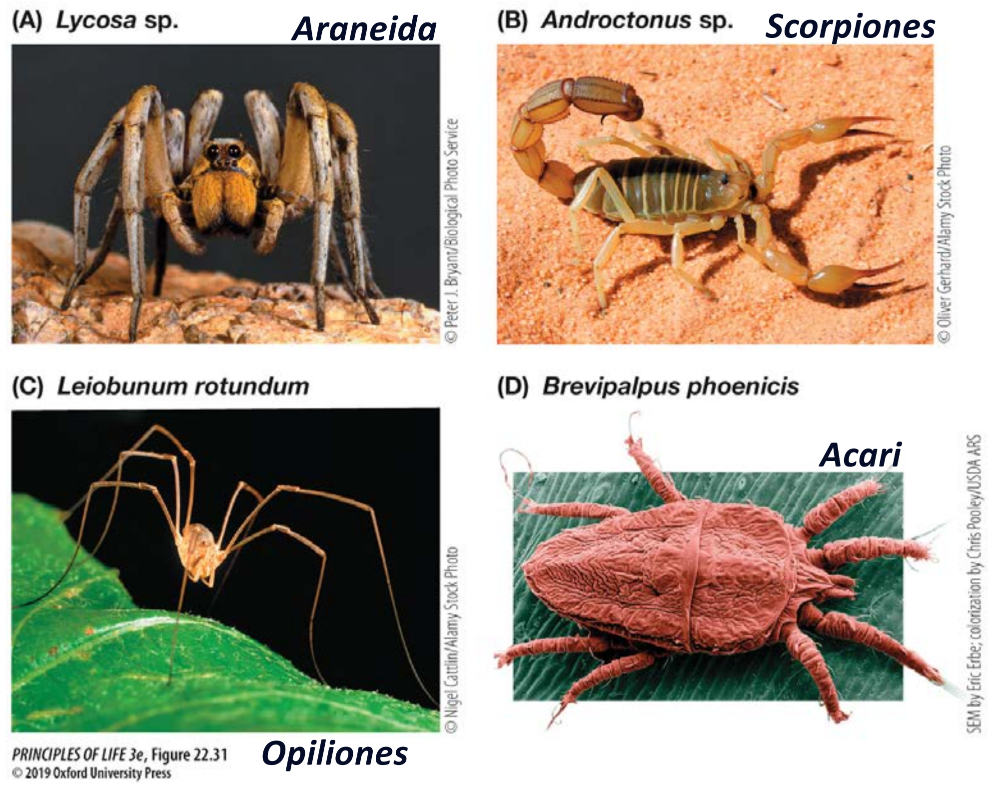
Other Arthropods … *Arachnids !!!*

Also Ecdysozoa

ALL Chelicerates:

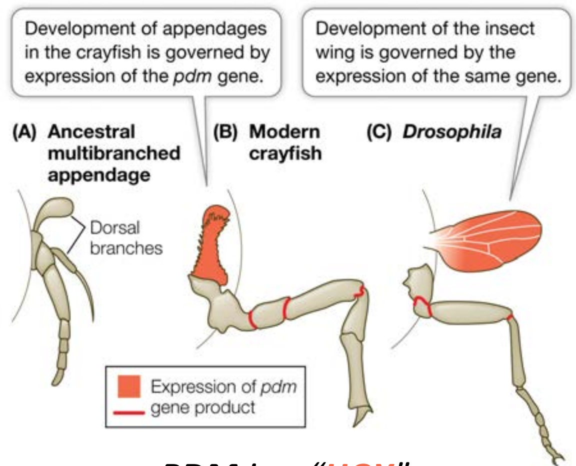
- Mouth pointed, graspers
- NOT-chewing mouthparts
  Spiders may have hollow **celicerae** with venom

- **4 pairs of appendages = 8 “legs”**



Link: cool info about “Harvestmen” a.k.a “Daddy Longlegs”

Evolution of the INSECT WINGS: gene *HOMOLOGY in* ***Arthropods***

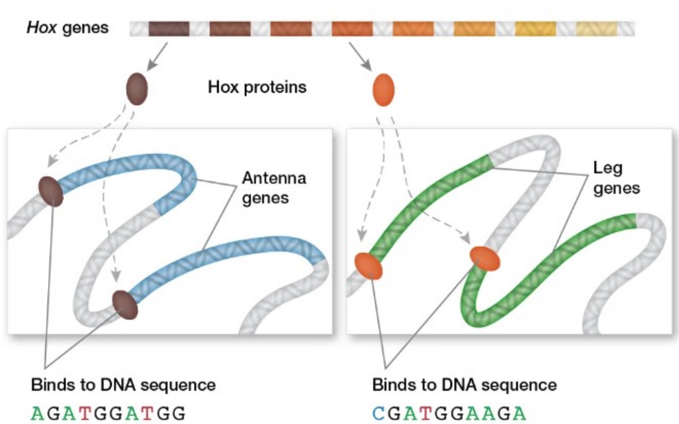


***PDM** is a "HOX" gene*

Homeotic Genes = *"HOX" genes code for Hox Proteins*

- Transcription Factors that bind DNA to regulate the activity of <u>many target genes at the same time</u>
- Hox proteins turn **mRNA synthesis** – transcription – ON or OFF, to determine **body parts like wings!**

Hox proteins regulate other genes



Hox genes code for proteins that attach to molecular switches on DNA, turning other genes on and off. The DNA-binding piece of a Hox protein is called the homeodomain, and it's encoded by the homeobox. The homeodomains in different Hox proteins are similar but not identical—they bind to different DNA sequences. So different Hox proteins regulate different sets of genes, and combinations of Hox proteins working together to regulate still other sets of genes.

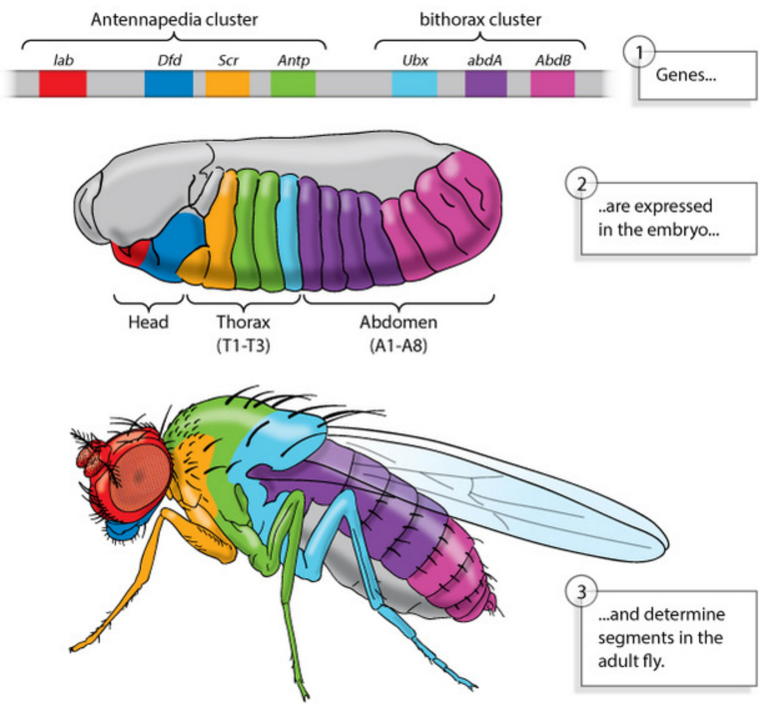
As regulators of other genes, Hox proteins are very powerful. A single Hox protein can regulate the activity of many genes. And sets of genes work together to carry out "programs" during embryonic development—programs for building a leg or an antenna, for example—much like computer programs carry out specific tasks.

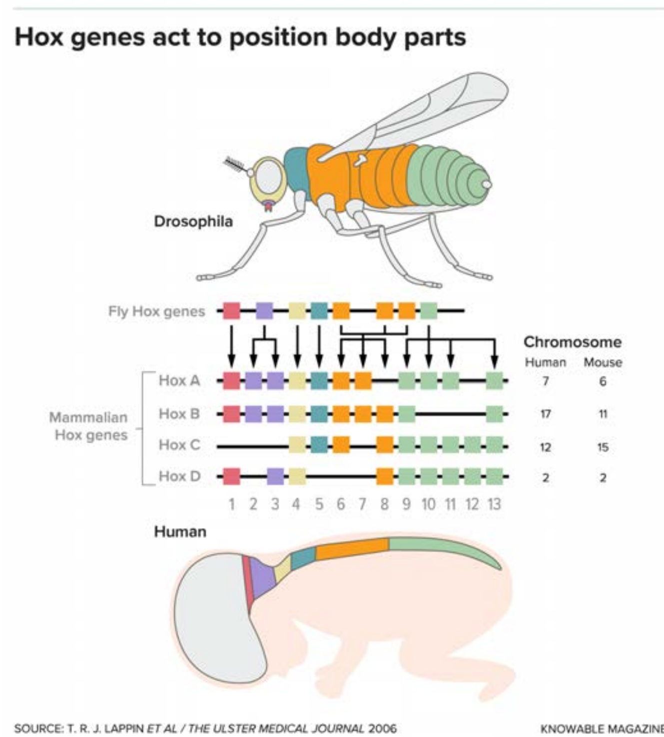
Image ref: link

HOX genes are **Conserved Through Evolution**

Insects: ***Mammals:***

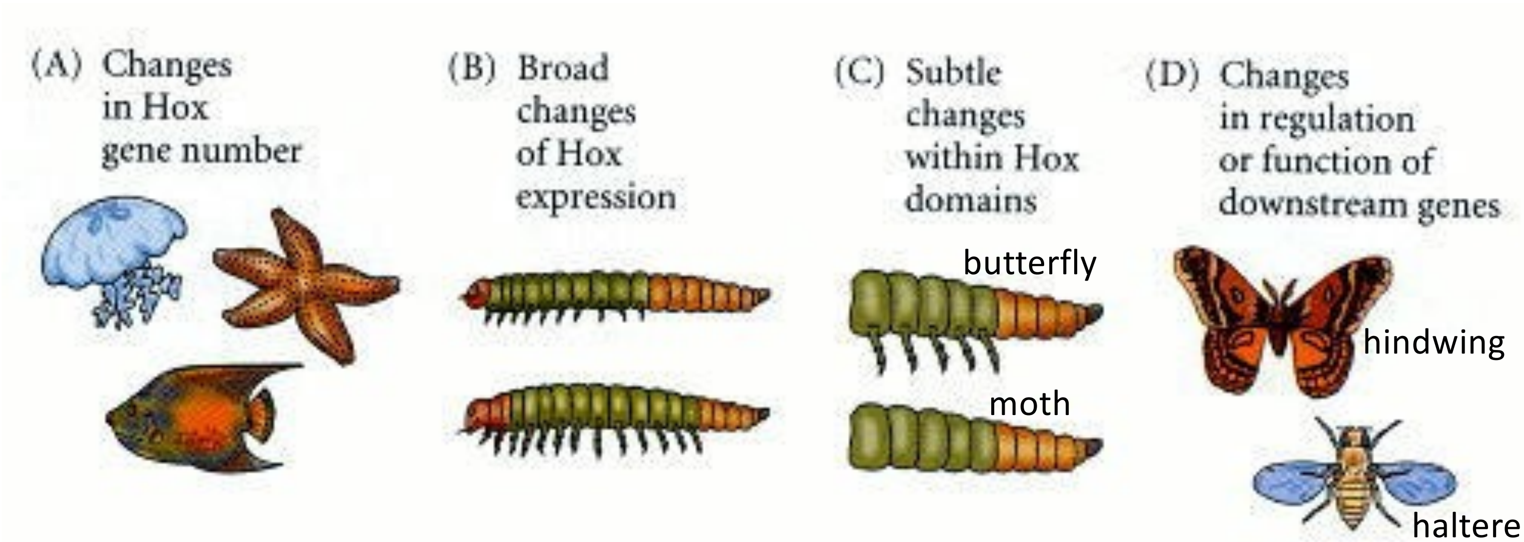
HOX genes determine body segment identity. *HOX genes* are similar (not identical) in all animals





p. 360 – 362 textbook

<u>Changes</u> in HOX Genes
correlate with evolutionary changes in ***<u>Symmetry, Segment Number, Segment Identity, Body Morphology</u>***



Number of Genes:
Changes symmetry axis and body pattern
More genes
= more complex

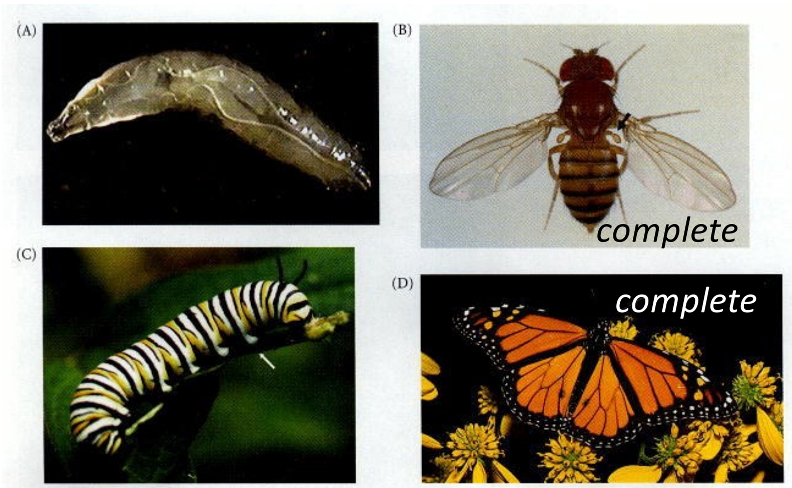
Range of Expression:
Changes number of body segments

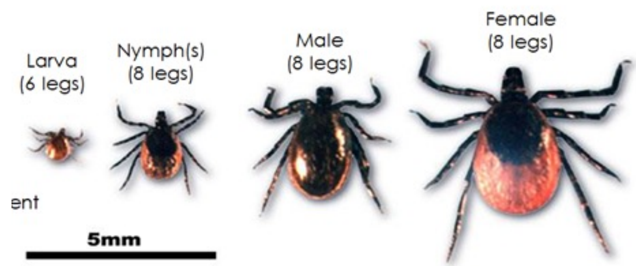
Different Alleles:
versions of genes change form
(ex: legs or no legs)

Hox Genes are 'transcription factors' = direct expression of other genes →
change form/function... ***WINGS***

Developmental Biology. 6th edition. Gilbert SF.

Differences in Larval and Adult Morphology due to HOX Gene Differences





incomplete

Metamorphosis:

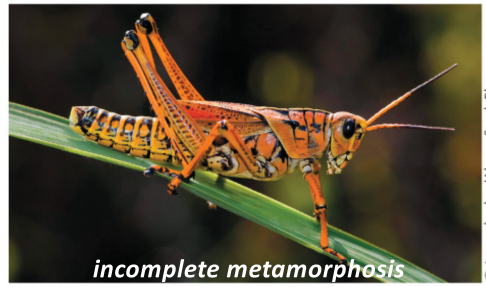
substantial morphological changes between developmental stages.

- ***Complete*** **:** changes are **dramatic.** ***HOX*** genes expressed in juvenile rudiments but not in the metamorphosing larval tissues
- ***Incomplete*** **:** changes **gradual, less dramatic.** ***HOX*** genes activate in larval trunk region, and throughout metamorphosis.

PROTOSTOMES – Insects

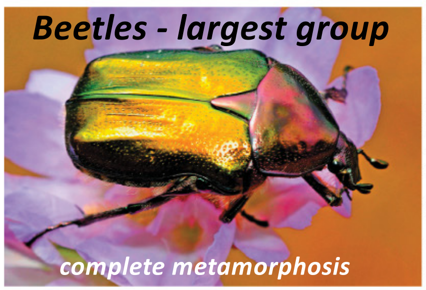
(A) ***Libellula depressa*, Odonata**

(B) ***Brachystola magna*, Orthoptera**

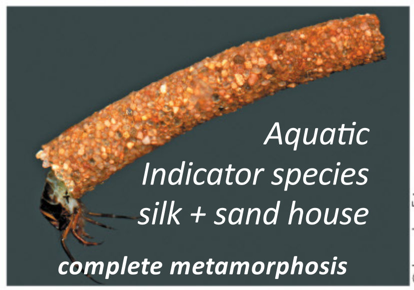


(C) ***Graphosoma lineatum*, Hemiptera** "plant bugs"

(D) ***Cetonia aurata*, Coleoptera**



(E) ***Gumaga* sp., Trichoptera**



(F) ***Papilio machaon*, Lepidoptera**

(G) ***Poecilanthrax willistoni*, Diptera**

(H) ***Mischocyttarus flavitarsis*, Hymenoptera**

Diversity of Winged Insects

PRINCIPLES OF LIFE 3e, Figure 22.37

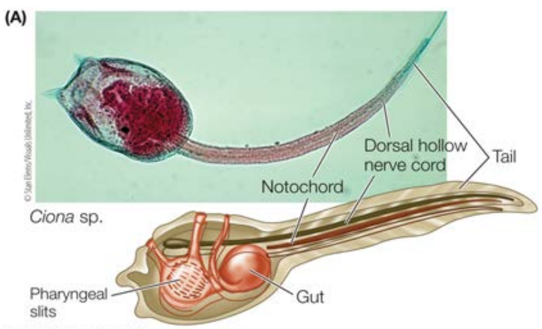
Lecture 11: Triploblast-deuterostomes

Chordates-
vertebrates-
fish-
amphibian-
reptiles(+birds)-
mammals.

Chordates

Evolving Hallmarks ***only in Embryos for Tunicates***:

1. a dorsal hollow nerve cord → precursor to spinal cord evolves
2. post-anal tail, only in larvae → precursor to adult animal tails
3. notochord, only posteriorly → recursor to vertebrae
4. pharyngeal basket slits → precursor to gills → to jaws ears



PRINCIPLES OF LIFE 3e, Figure 22.41 (Part 1)
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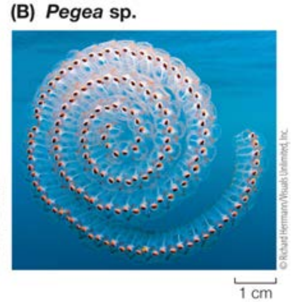
[Sea Squirt Diversity]

colony of salps

(A) *Clavelina dellavallei*

pharyngeal basket

(B) *Pegea* sp.



PRINCIPLES OF LIFE 3e, Figure 22.42
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Bluebell tunicates. [1]

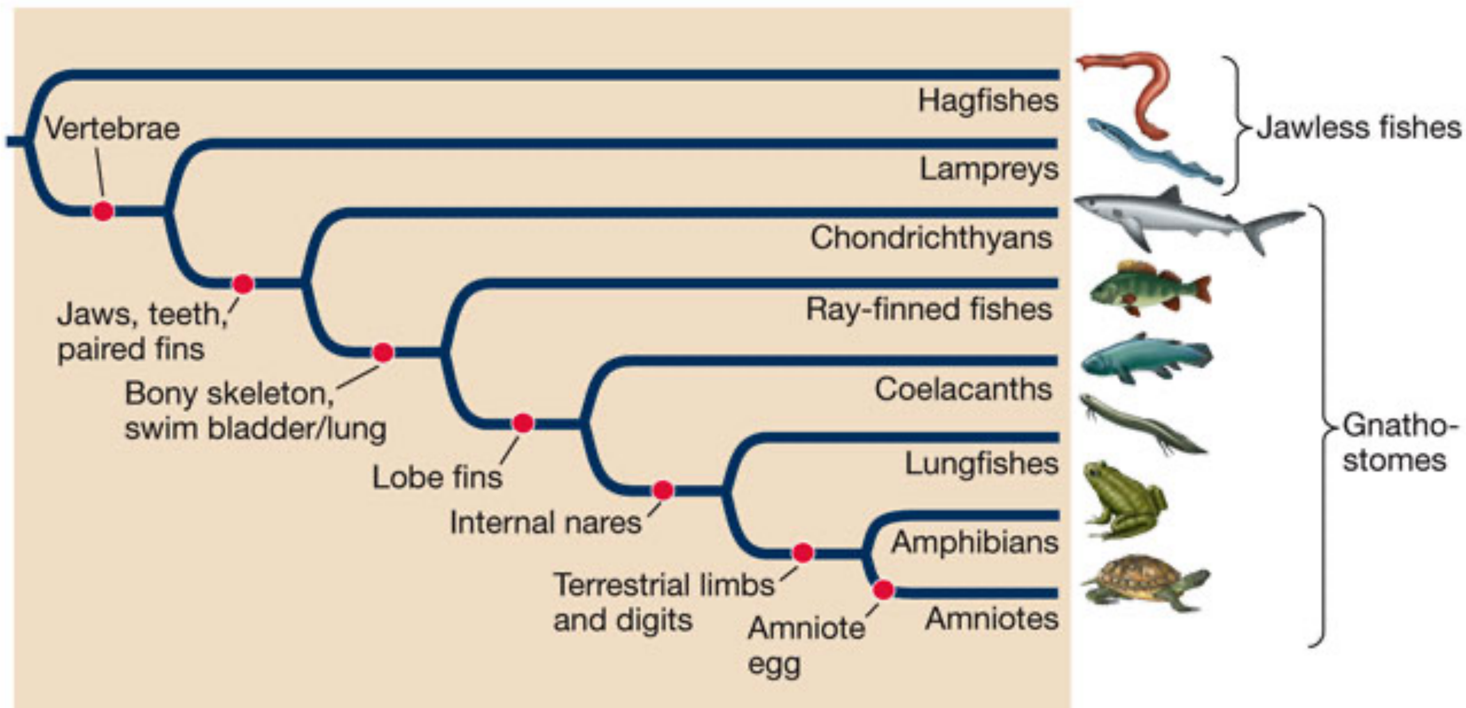
Strawberry tunicates. [2]

[3]

https://www.coraldigest.org/index.php/Tunicates

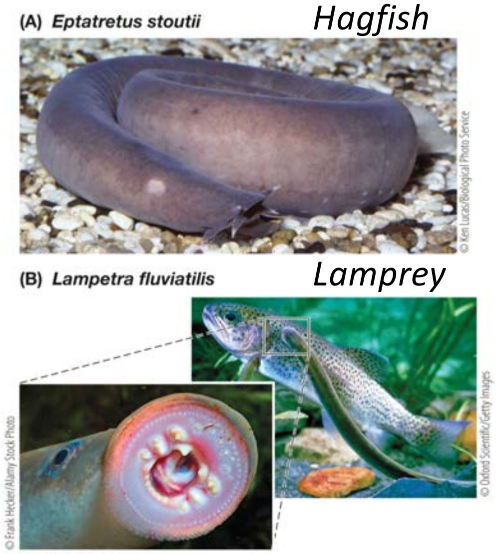
Phylogeny of the Vertebrates

FISH !!! a closer look … gills! vertebrae, jaws (from gills), paired appendages without exoskeleton, bone/teeth, air bladder→lung, lobed appendages, more muscle, ribs! eye position, evolve to amphibia, respiratory skin, to reptiles tough outer scales, lungs, amniotic eggs, to mammals, milk, internal gestation ...

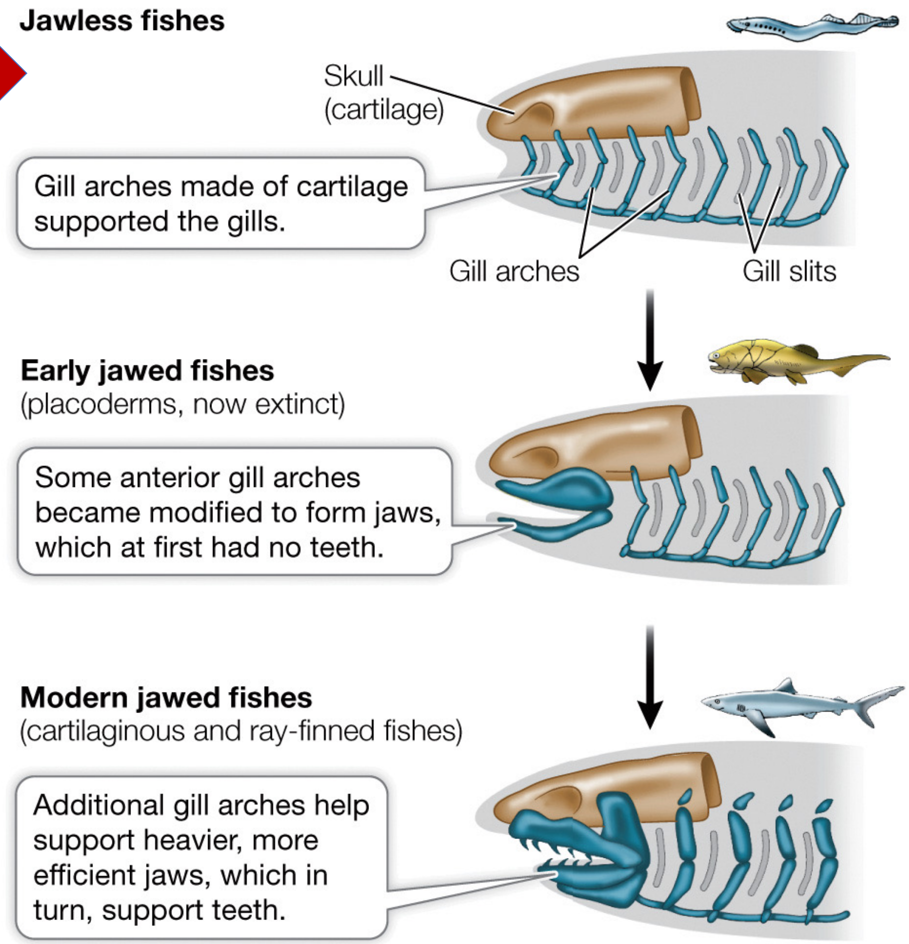


Vertebrate Jaw Evolution

Jawless Fishes

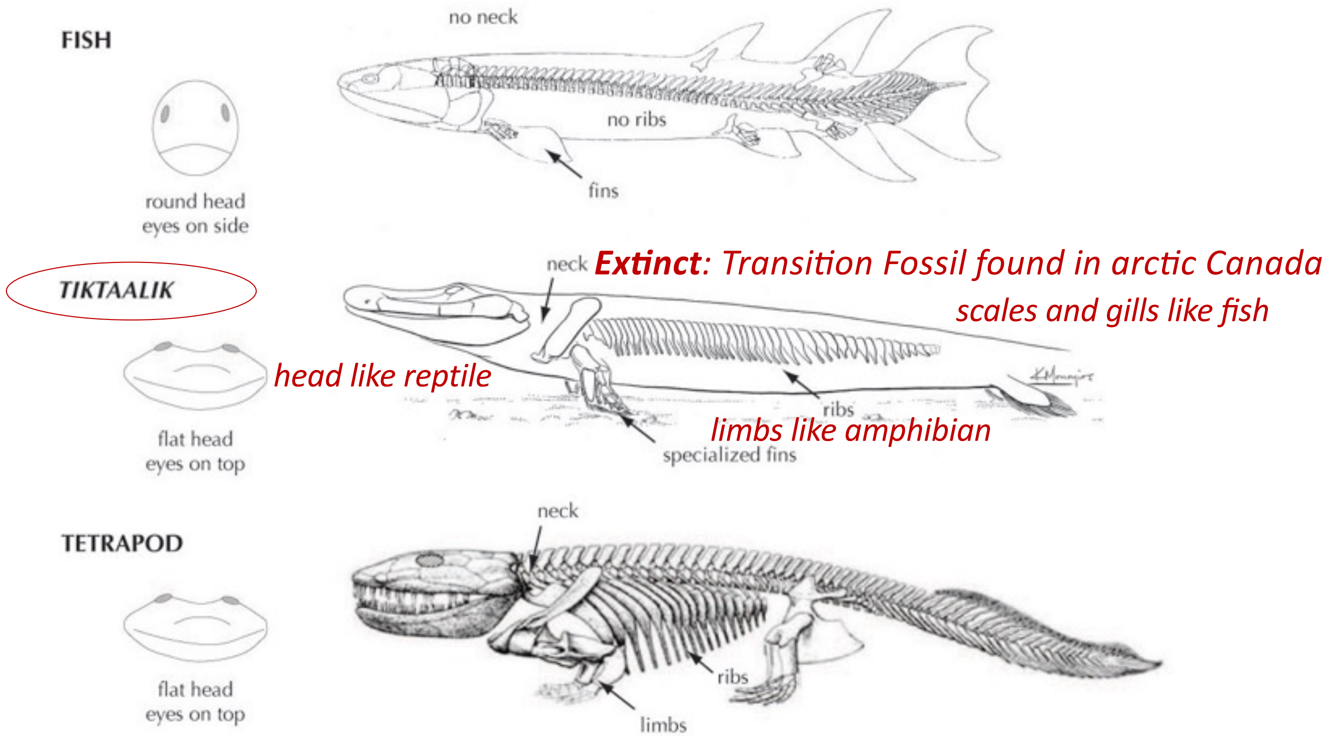


PRINCIPLES OF LIFE 3e, Figure 22.45



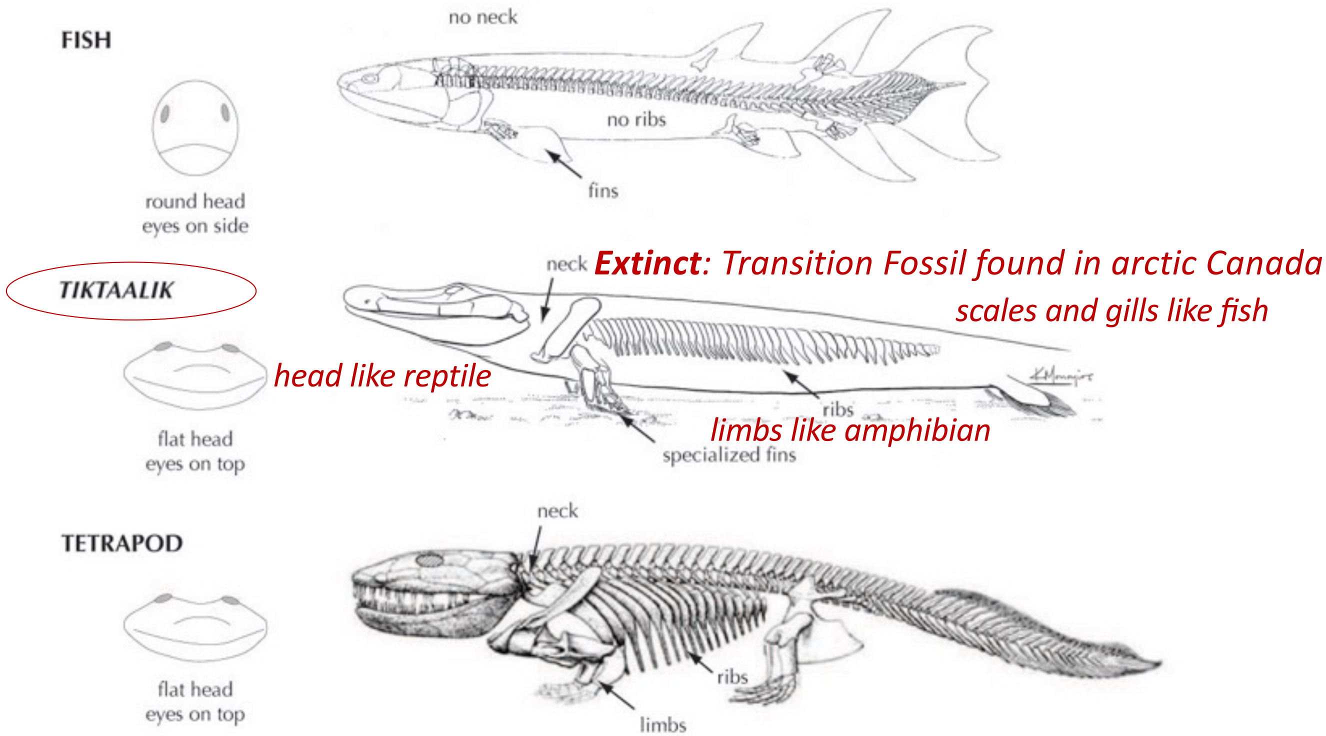
PRINCIPLES OF LIFE 3e, Figure 22.46

Tiktaalik roseae, a transitional fossil between lobe-finned fishes and tetrapods



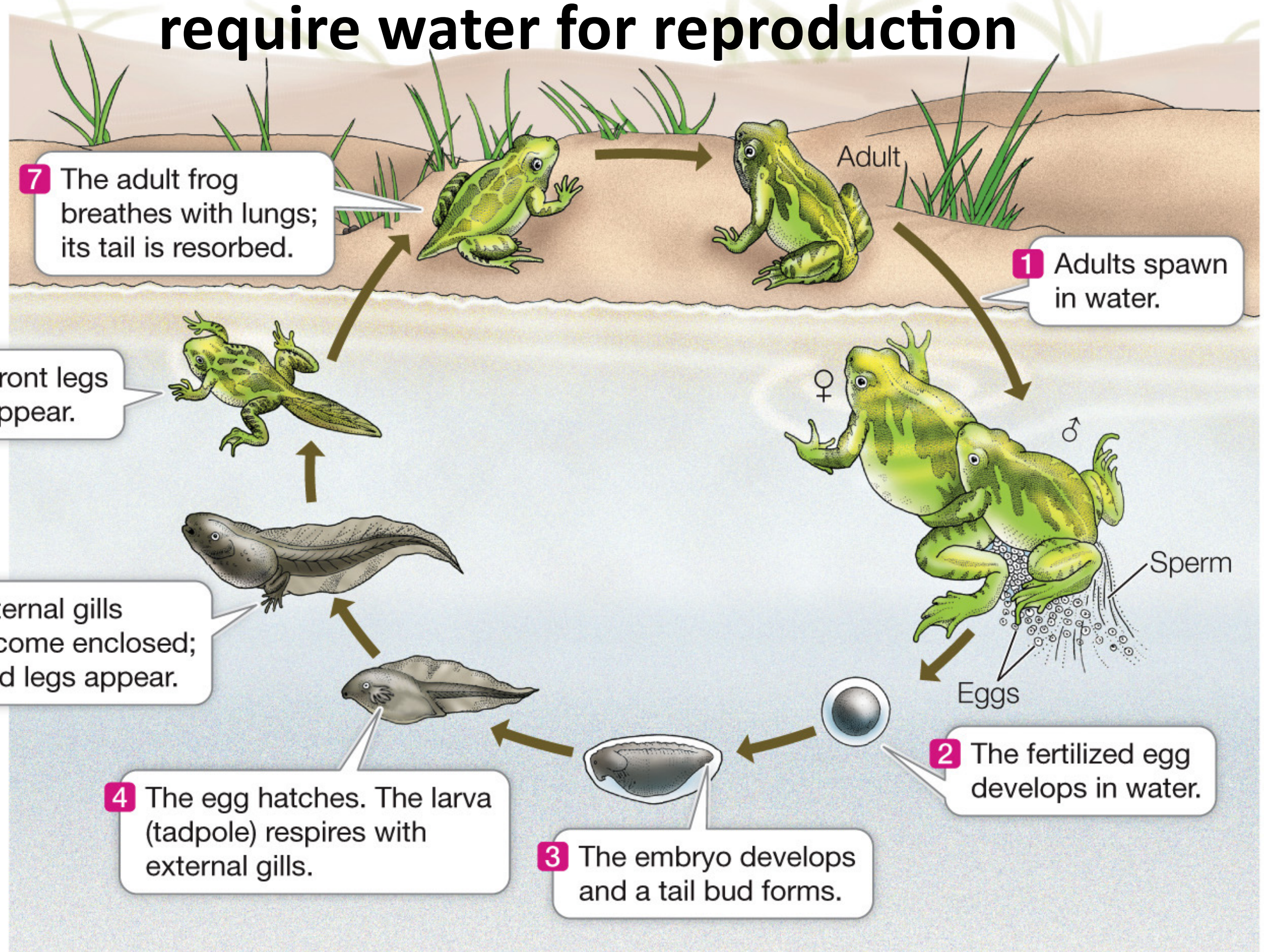
This figure says it all. *Tiktaalik* is intermediate between fish and primitive land-living animal.

Tiktaalik roseae, a transitional fossil between lobe-finned fishes and tetrapods



This figure says it all. *Tiktaalik* is intermediate between fish and primitive land-living animal.

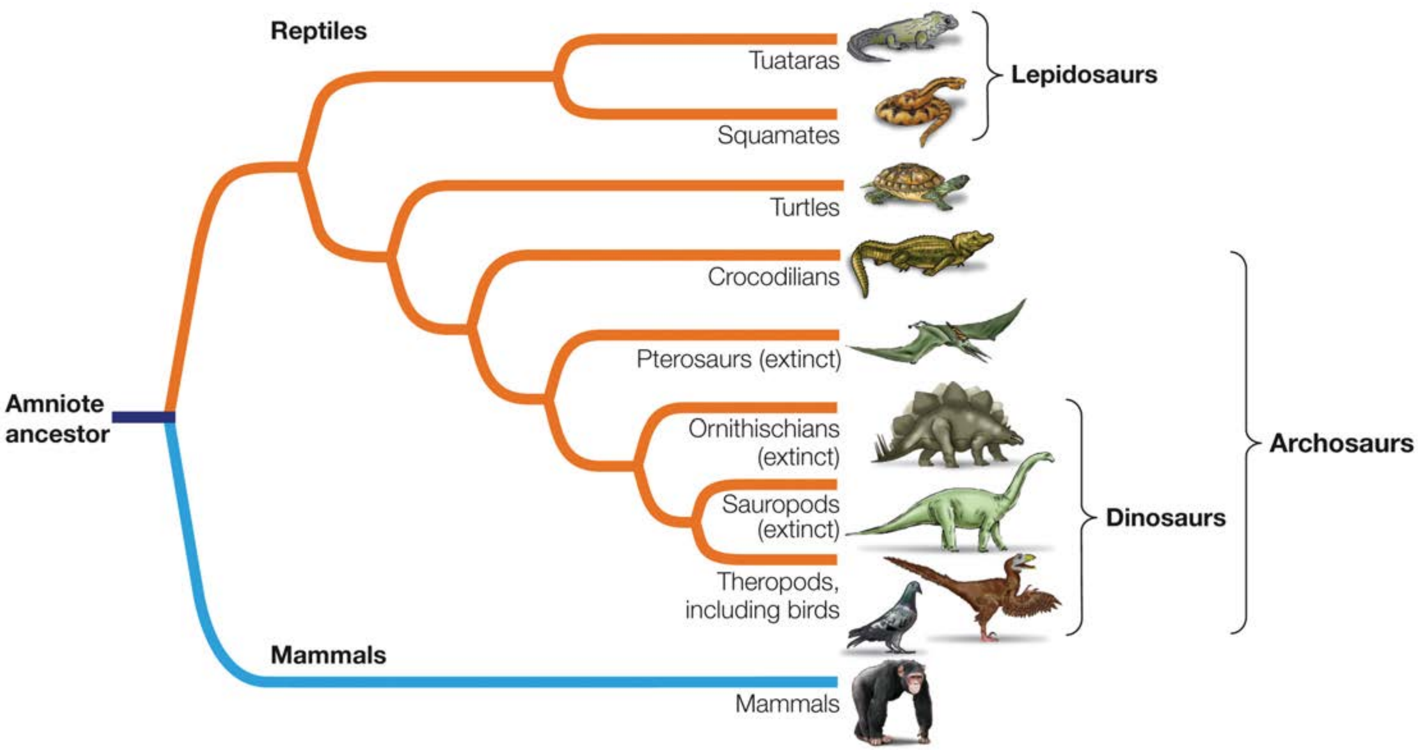
Amphibians have adapted to life on land, but still require water for reproduction



PRINCIPLES OF LIFE 3e, Figure 22.51

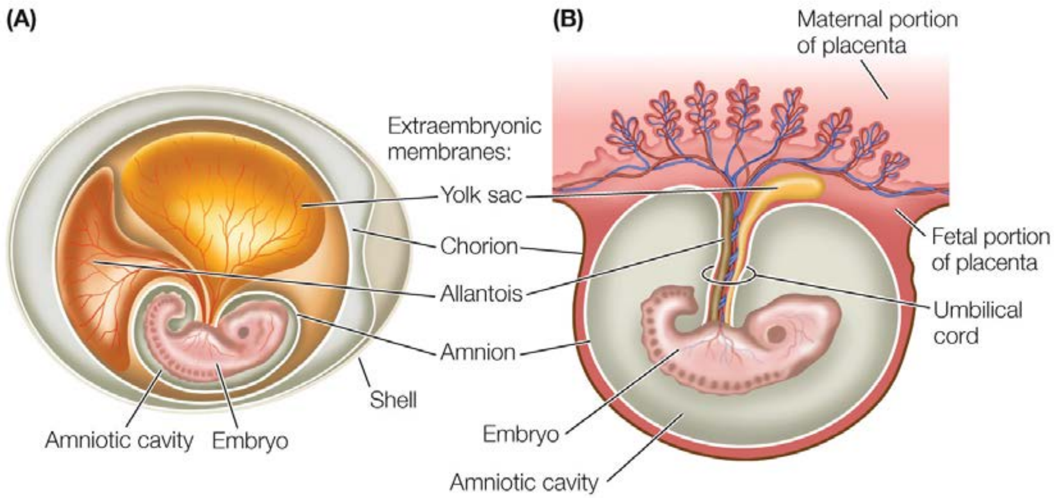
Gas exchange: gills, skin, AND lungs!

The *amniotic* egg allowed animals to move further onto land



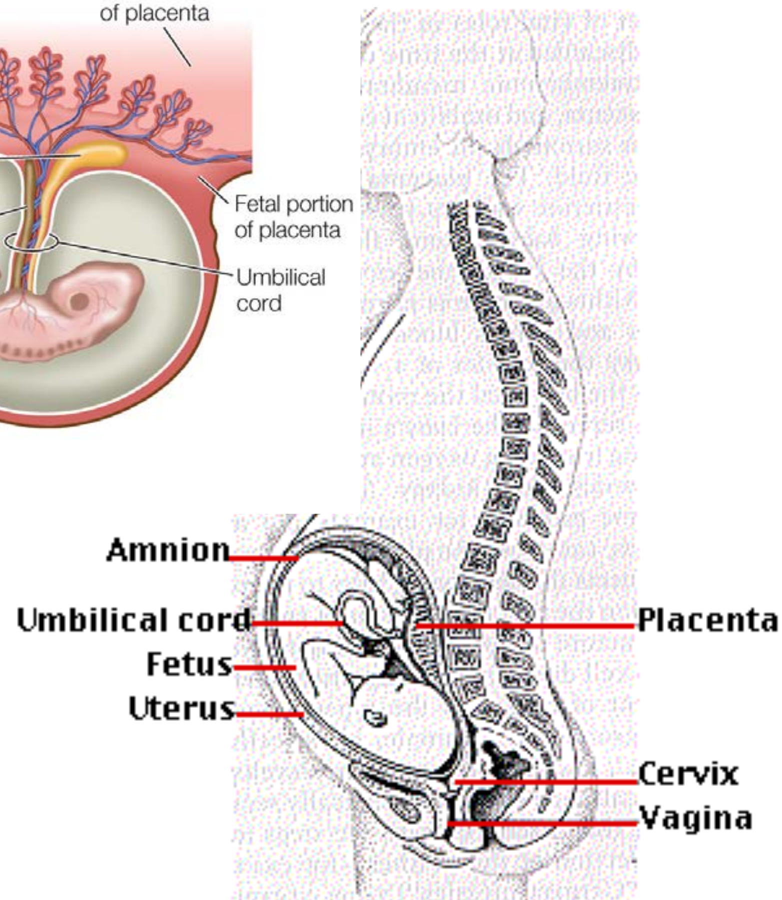
PRINCIPLES OF LIFE 3e, Figure 22.54

The amniotic egg became modified in mammals



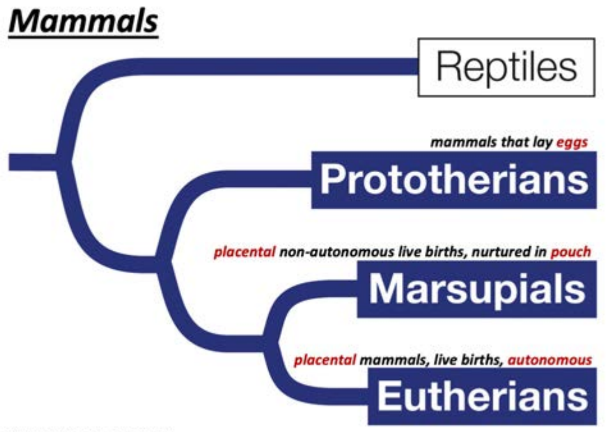
PRINCIPLES OF LIFE 3e, Figure 22.53

Note the correspondence between the various membranes in (A) and (B).



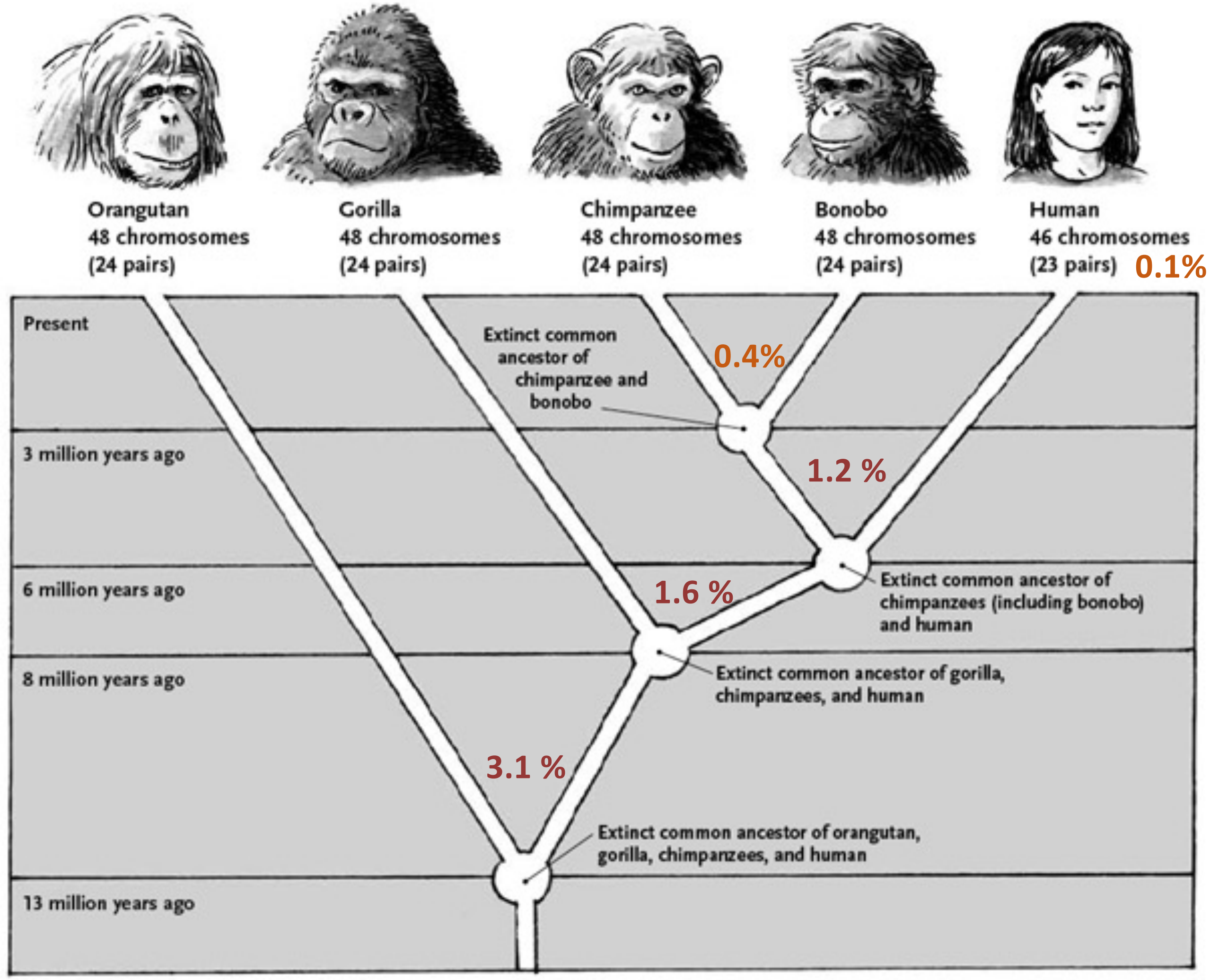
PRINCIPLES OF LIFE 3e, Figure 22.59

Mammalian Diversity



PRINCIPLES OF LIFE 3e, Figure 22.59

Mammalian Diversity



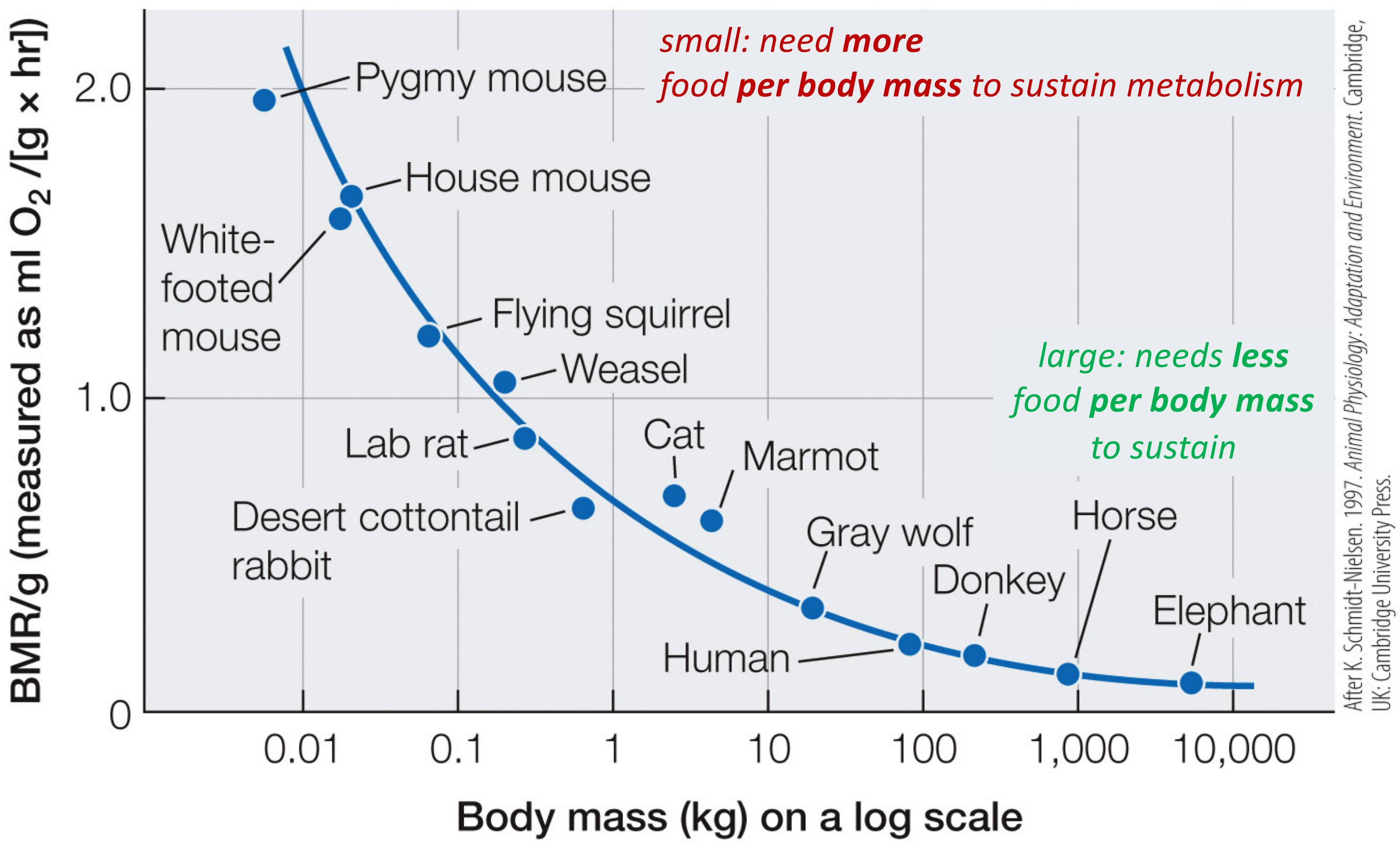
DNA sequence (A,T,C,G base differences) in *Genes*

Lecture 12:

Animal Energy (IV)

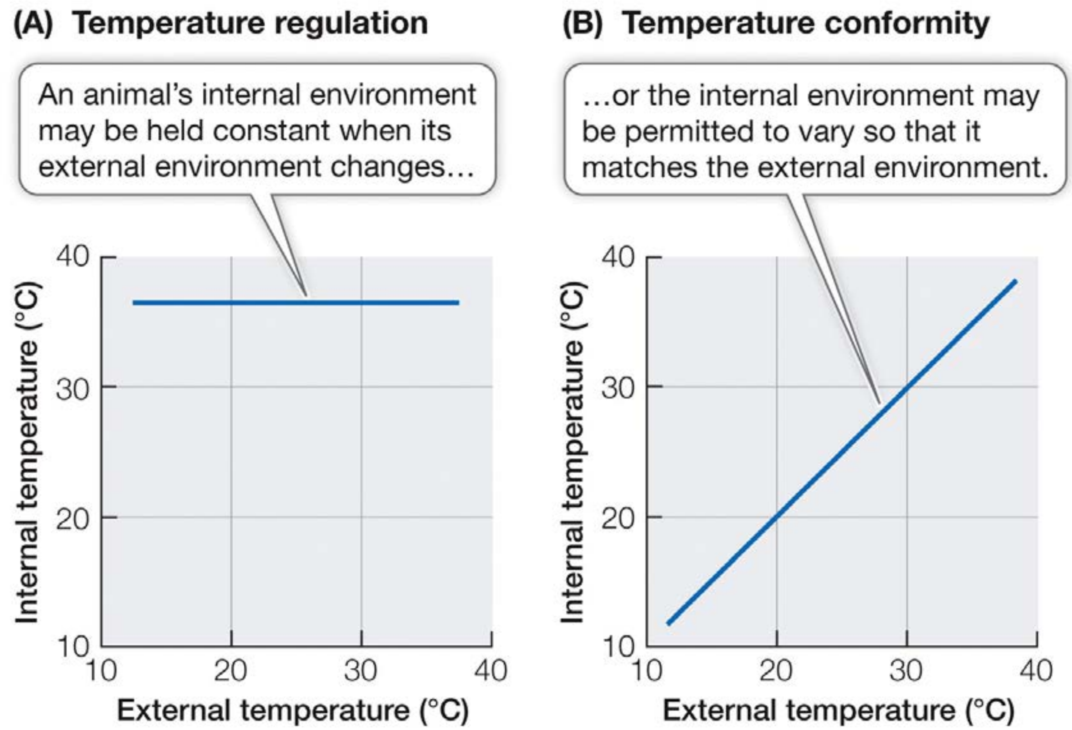
Basal Metabolic Rate *Inversely* Correlates with Body Size

*metabolic rate is measured by oxygen consumption



PRINCIPLES OF LIFE 3e, Figure 28.9

Regulation *vs.* Conformity for Internal Body Temp



PRINCIPLES OF LIFE 3e, Figure 28.10

A. Which animals <u>regulate</u>? ***B. Which animals <u>conform</u>?***

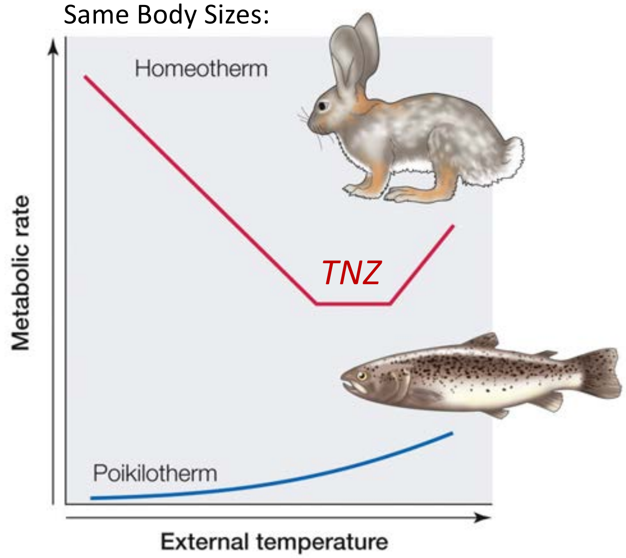
Which costs more energy to maintain?

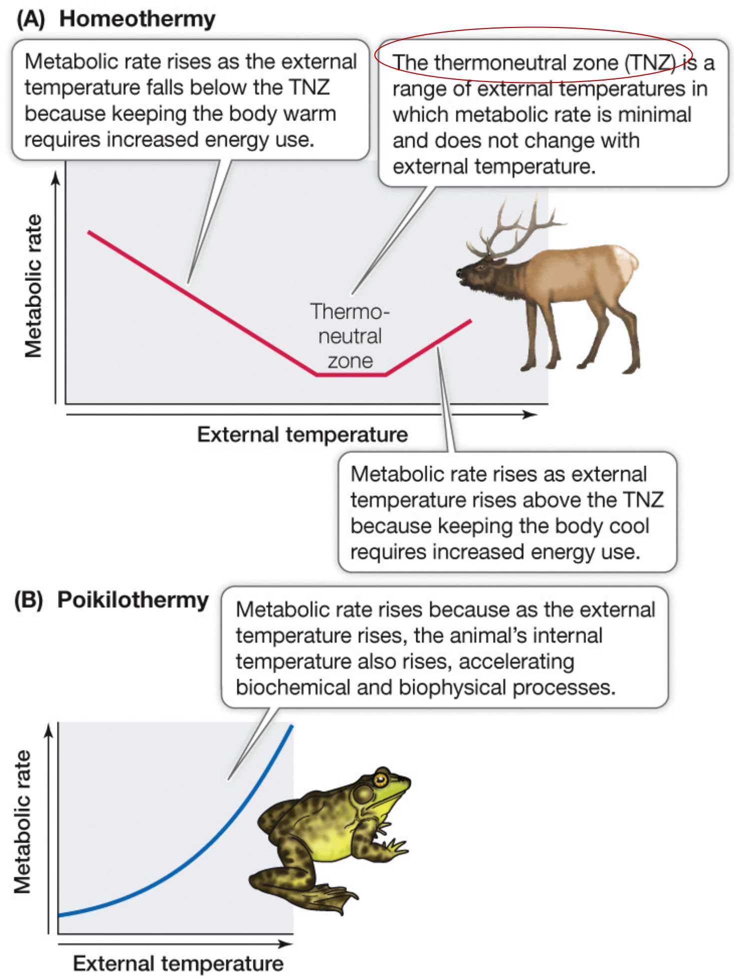
See animals on previous slide (metabolic rates) – are they in A. or B. here?

Metabolic Rates Affected by External Temperature: Homeotherm vs. ‘Poikilotherm’

Most animals are **poikilotherms** or **ectotherms**: body temperatures are variable and are determined by the external temperature

Same Body Sizes:

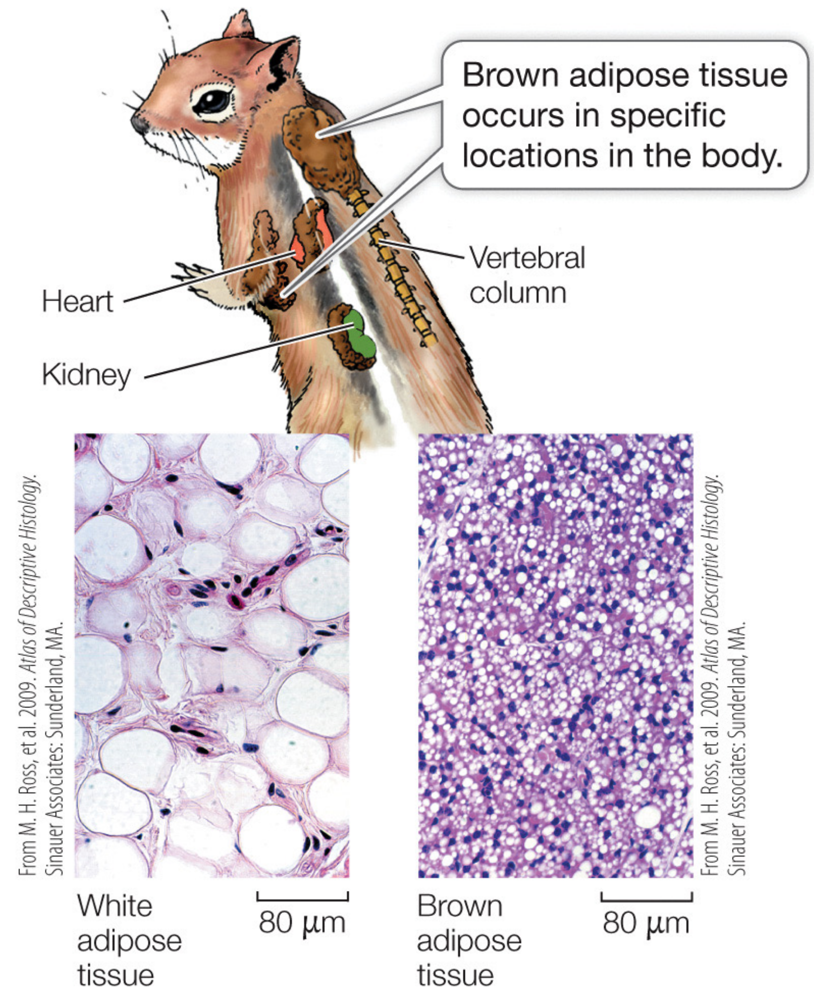




Mechanism for thermoregulation

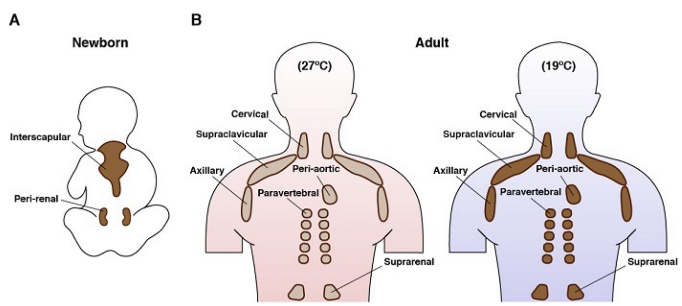
Shivering—skeletal muscles contract and **energy is converted from ATP to heat**. ***Shivering thermogenesis***

Non-shivering thermogenesis — some mammals have **brown adipose tissue** is loaded with mitochondria, which perform oxidative phosphorylation but do not make ATP; that energy goes to heat production instead, does not get bound up into ATP bonds.

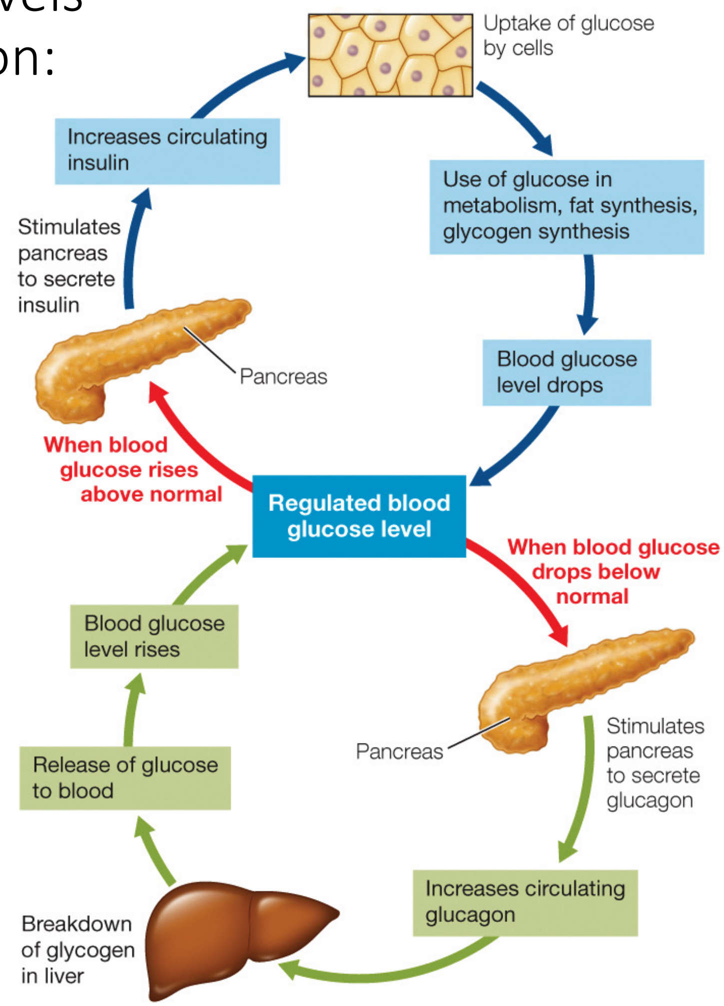


PRINCIPLES OF LIFE 3e, Figure 28.17

Regulation of Blood Glucose Levels Contributes to Thermoregulation:



[brown fat locations in humans](#)
[brown vs. white fat functions](#)



PRINCIPLES OF LIFE 3e, Figure 28.25

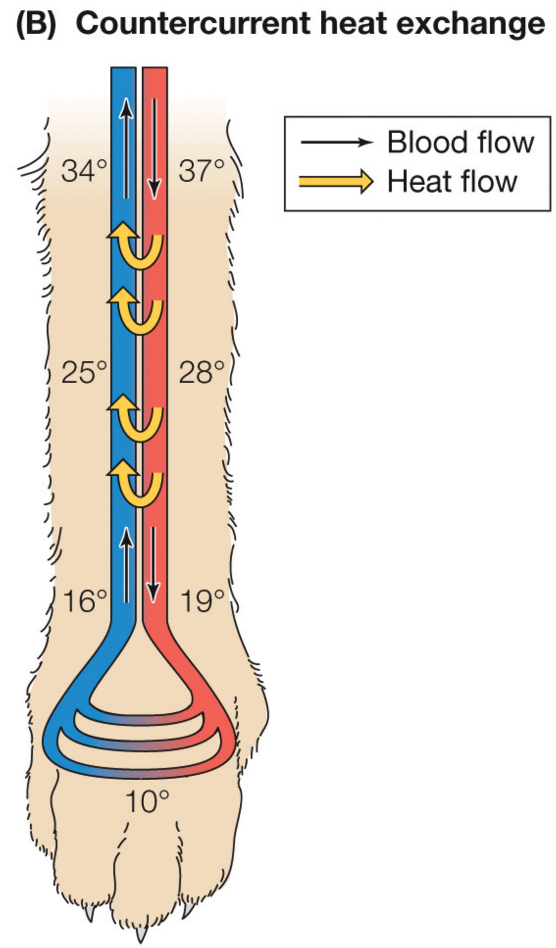
Other Temp Control Systems:
+ fur, fat, feathers
- sweating, panting

Countercurrent Heat Exchange in Mammals for Heat Conservation

PRINCIPLES OF LIFE 3e, Chapter 28 Opener

Blood flows all the way to the outer end of an appendage and back, but heat does not.

Heat takes a shortcut, enabling it to move back into the body core before it can be readily lost to the environment at the exposed outer end of the appendage.

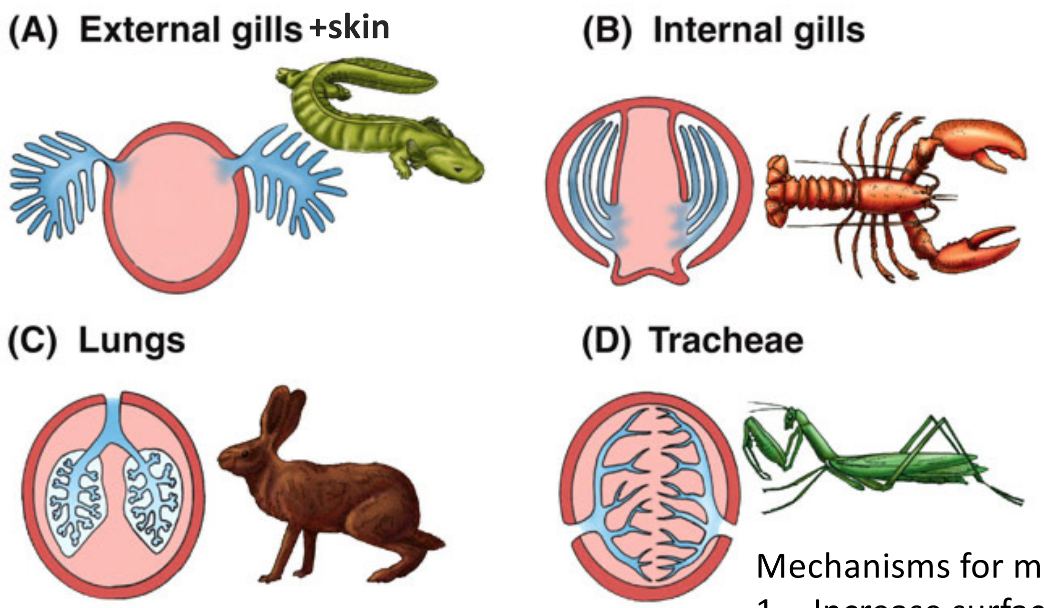


PRINCIPLES OF LIFE 3e, Figure 29.5 (Part 3)

Lecture 13-14:

Gas Exchange (Ventilation) Circulation & Blood)

Organs where gas exchange takes place have large surface areas



PRINCIPLES OF LIFE, Figure 37.1

Mechanisms for maximizing gas exchange:

1. Increase surface area
2. Minimize distance for diffusion
3. Actively move air or water across gas exchange surfaces to replenish O_2
4. Actively move blood or lymph fluid across surface

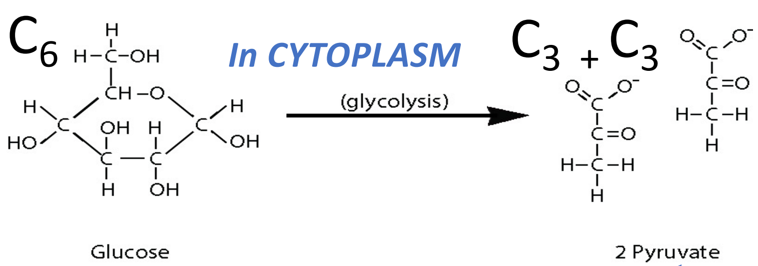
CO_2 to diffuses down gradient: out

O_2 to diffuses down gradient: in

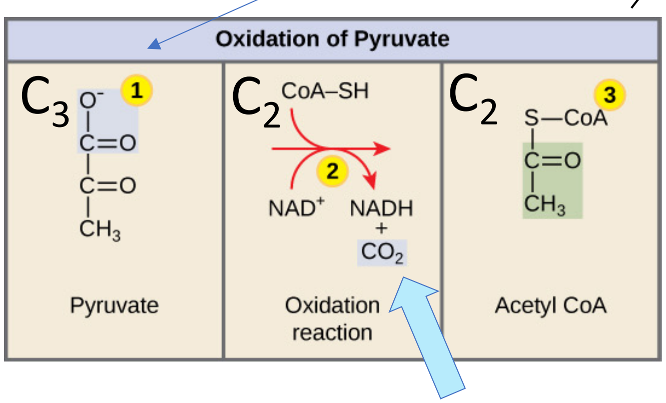
Where does CO_2 come from

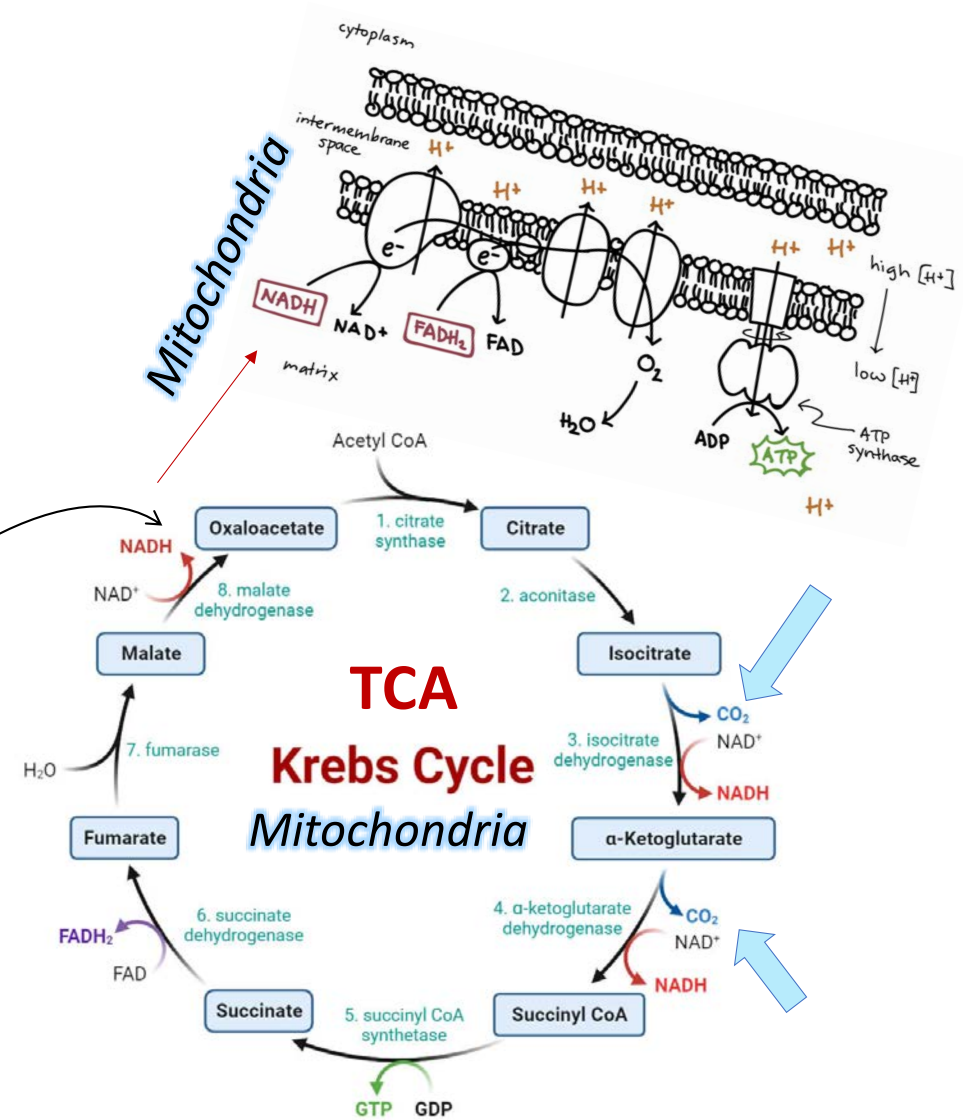
...the Mitochondria (Krebs)!

... Why do cells need O_2 ? W



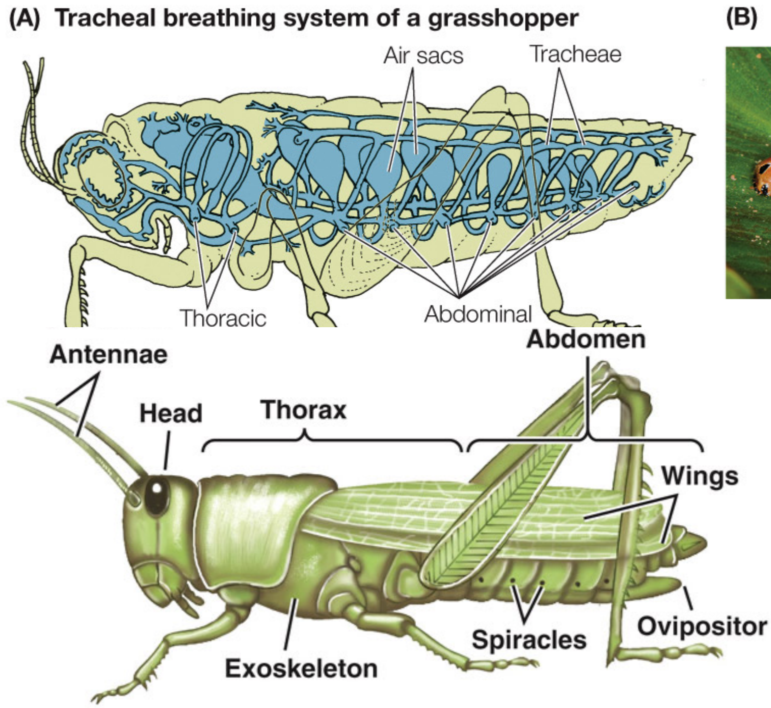
Into the Mitochondria

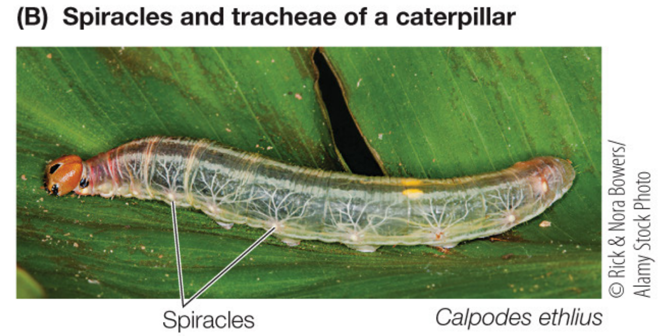


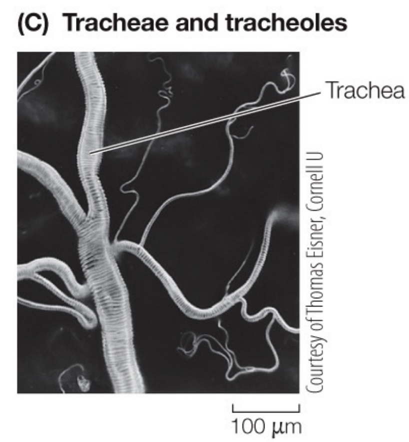


Insects have spiracles and tracheae for gas exchange

Insects have an “open” circulatory system





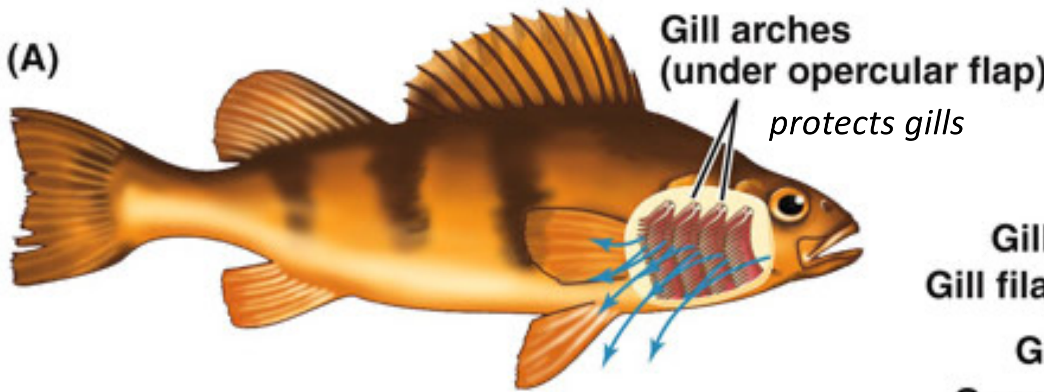


Spiracles: openings/pores

Tracheae: tube network throughout organism lined with very thin chitin – body movement can move the air

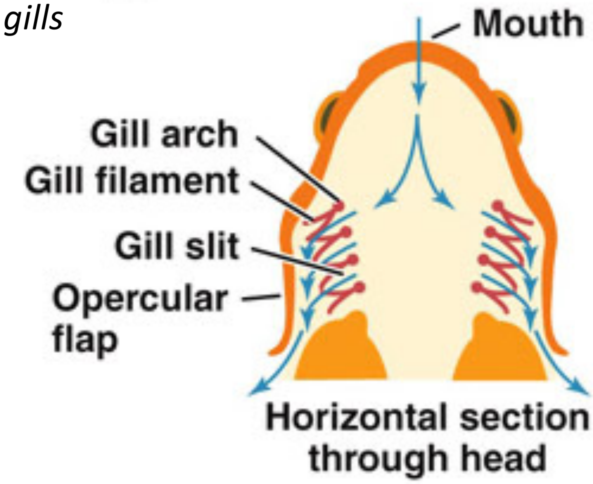
PRINCIPLES OF LIFE 3e, Figure 30.11

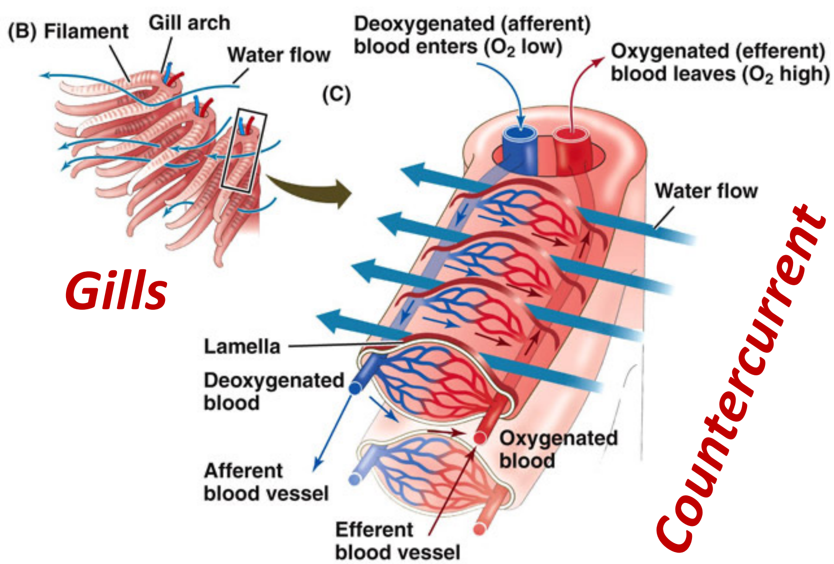
Fish have internal gills



protects gills

Countercurrent



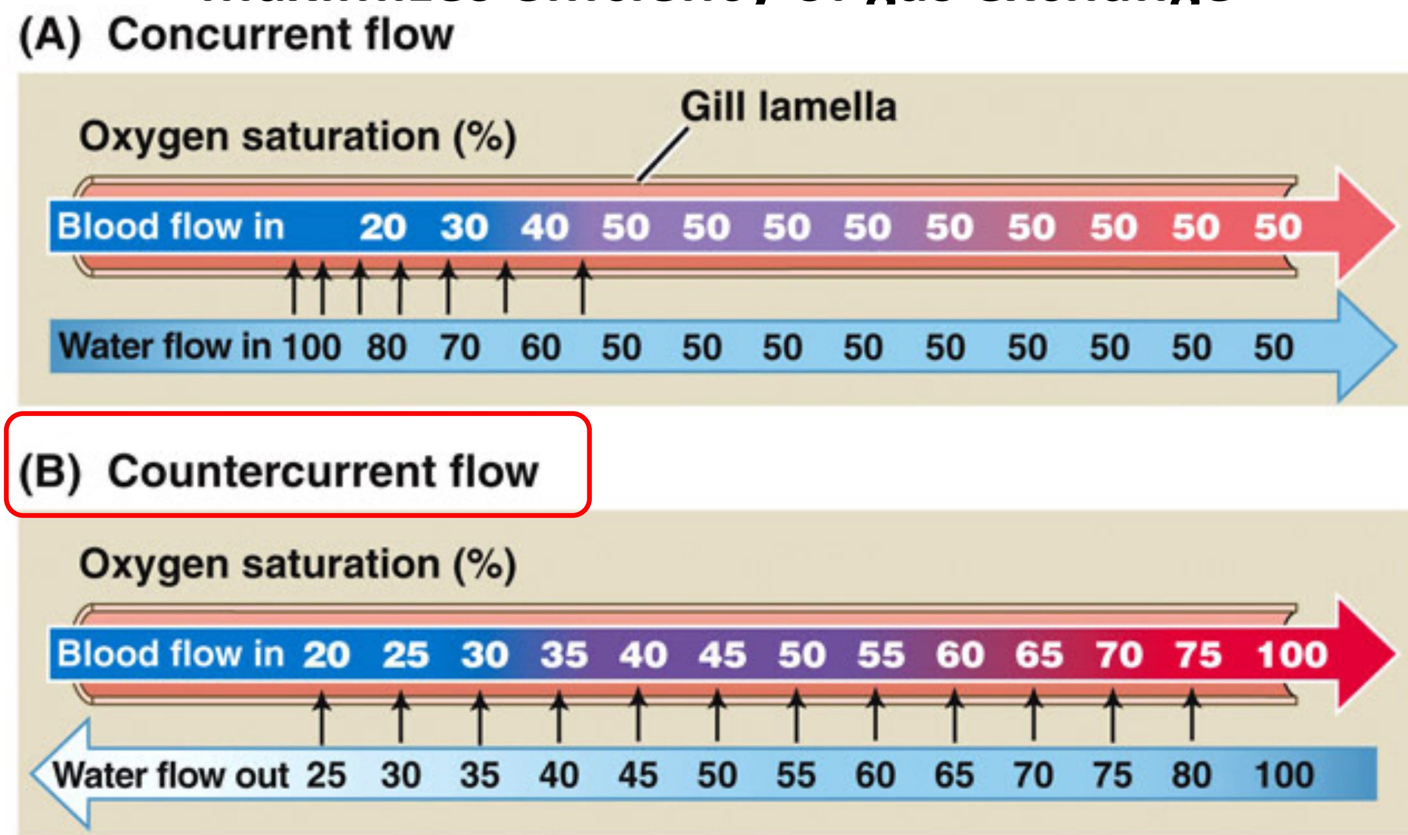


Gills

Countercurrent

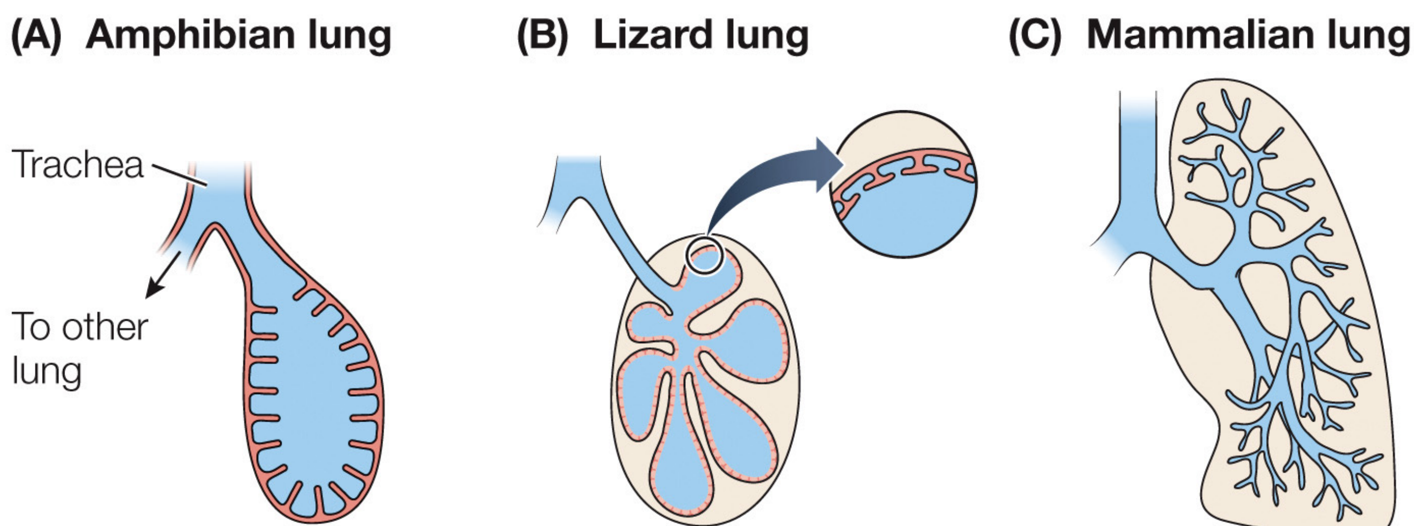
Gills highly divided
with folds
"lamellae"
increase
surface area for
O_2 – CO_2 exchange

Countercurrent flow of blood *vs* air/water maximizes efficiency of gas exchange



PRINCIPLES OF LIFE, Figure 37.3

Snapshot in Evolution: ***Amphibian*** lungs as precursors to terrestrial ***Reptilian*** and ***Mammalian*** lungs



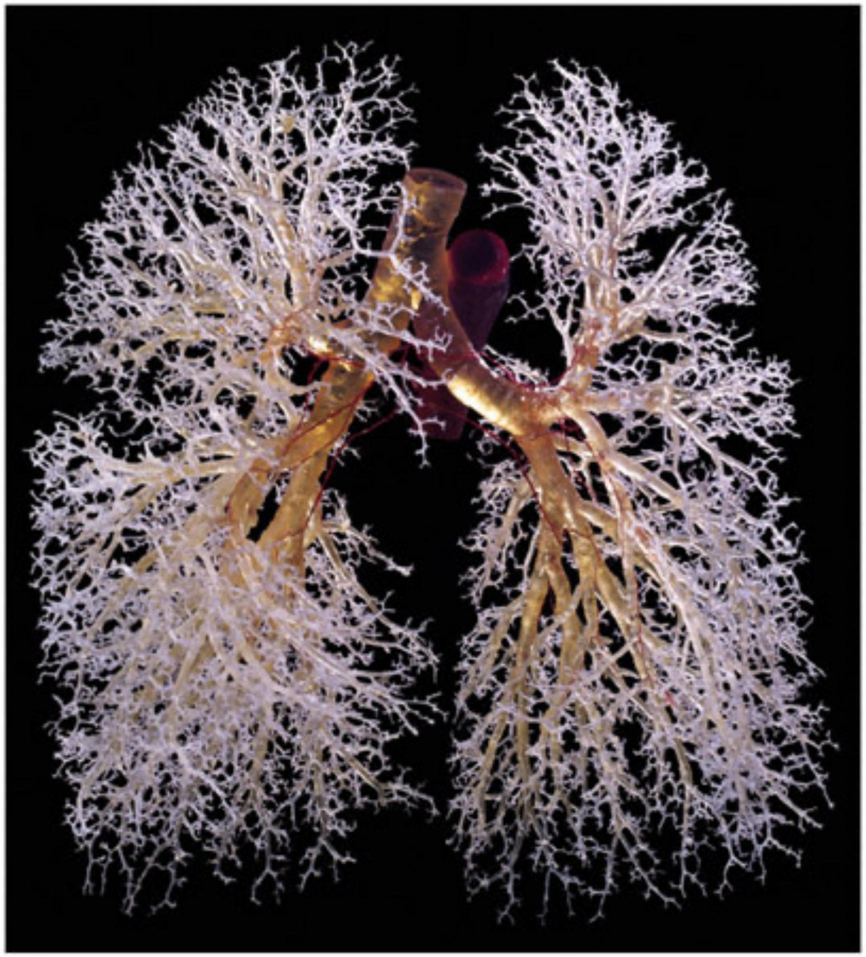
PRINCIPLES OF LIFE 3e, Figure 30.8

Lungs of ***Terrestrial Vertebrates*** have thin ***Surfactant*** of **lipids and proteins** ***to reduce surface tension*** and ***adhesion.***
avoids sticking and collapse of fragile tissues.

Most terrestrial vertebrates use "*TIDAL*" ventilation

Airflow NOT unidirectional: same path for inhaling and exhaling, ***no countercurrent***

Airflow NOT continuous: dead ends into sacs for gas exchange

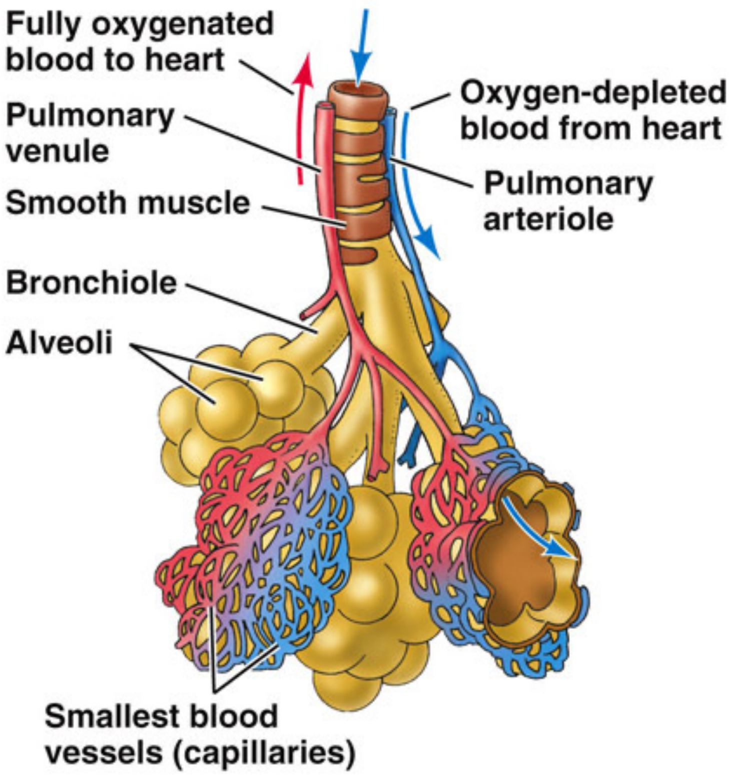


***PRINCIPLES OF LIFE*, Figure 37.6 (Part 4)**

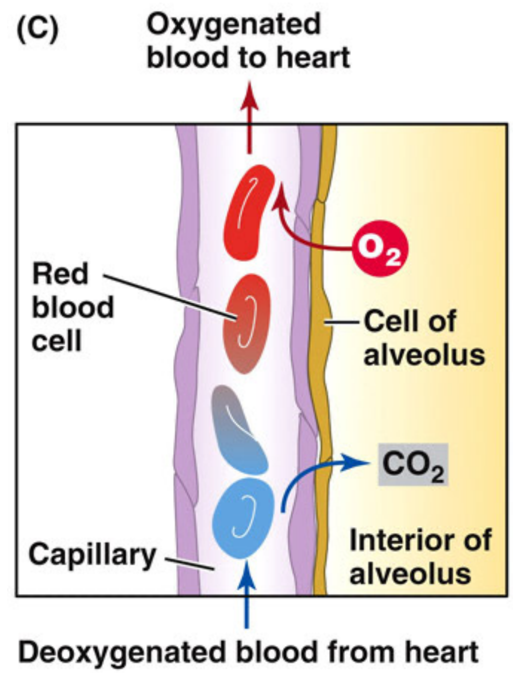
Alveoli:

small, thin-walled air sacs for gas exchange

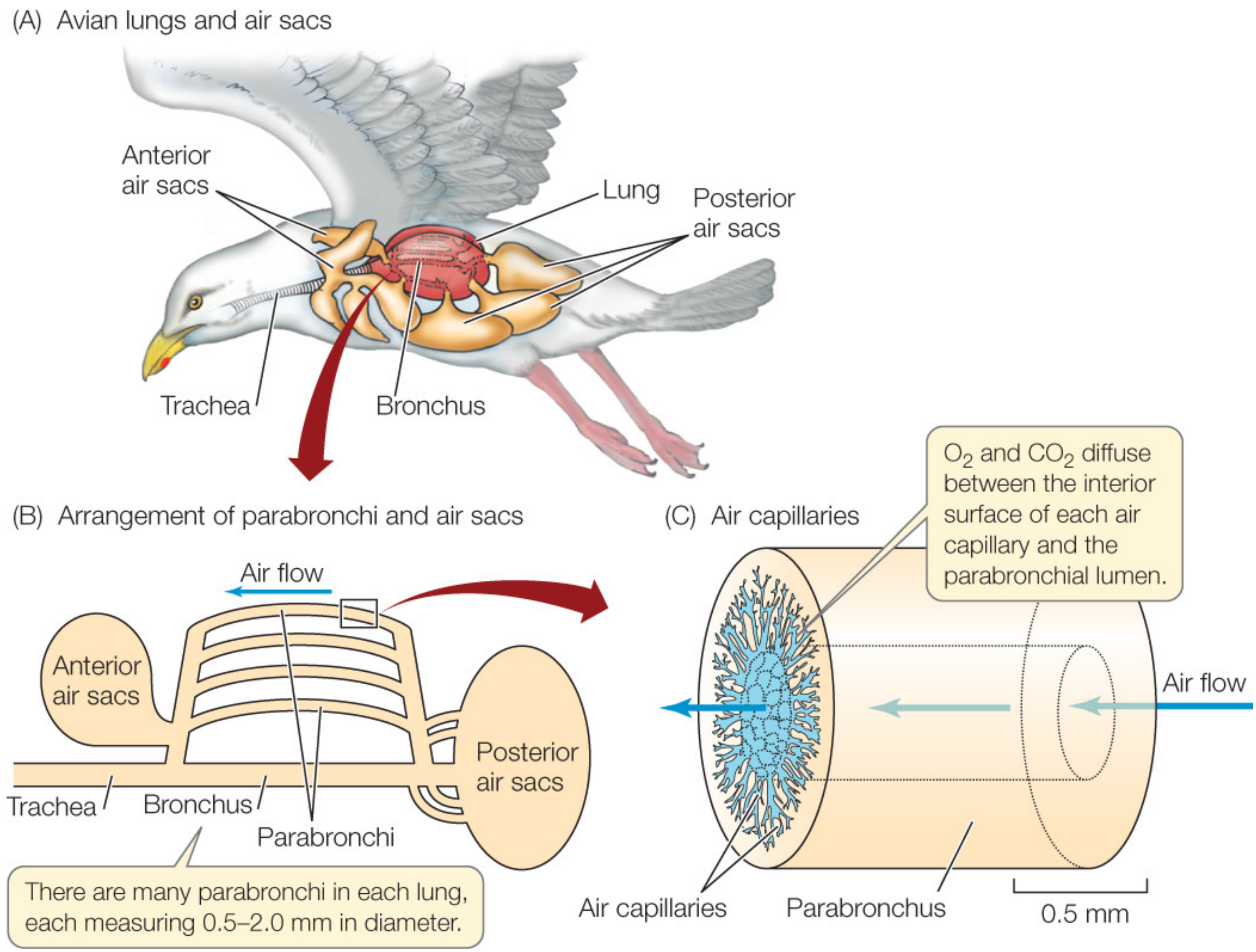
enveloped by ***capillaries*** **with a lot of surface area**



Gas Diffusion Across *TWO* very THIN membranes:

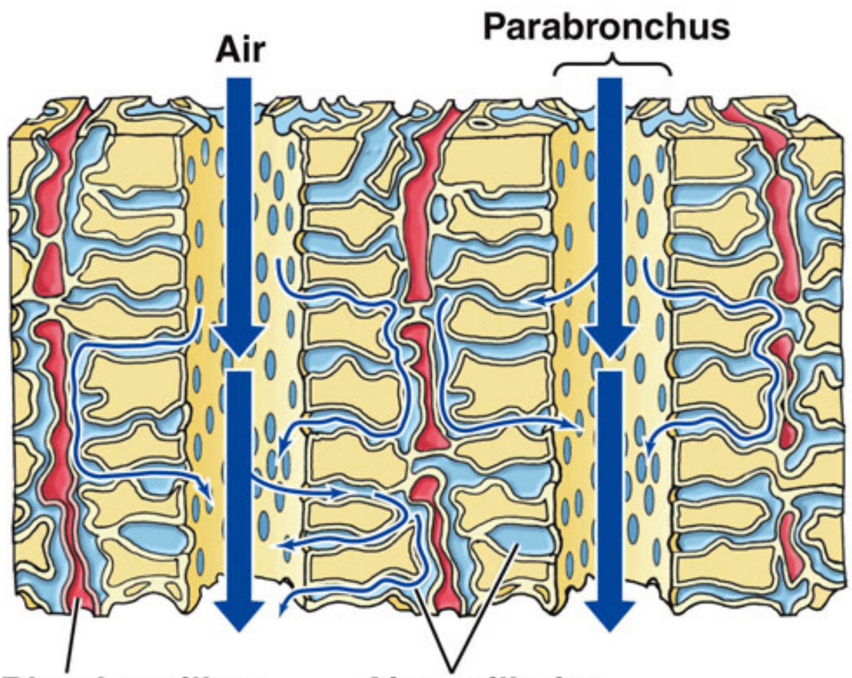


PRINCIPLES OF LIFE, Figure 37.6 (Part 3)



(A) Avian lungs and air sacs
Anterior air sacs
Lung
Posterior air sacs
Trachea
Bronchus
(B) Arrangement of parabronchi and air sacs
Air flow
Anterior air sacs
Posterior air sacs
Trachea
Bronchus
Parabronchi
There are many parabronchi in each lung, each measuring 0.5–2.0 mm in diameter.
(C) Air capillaries
O_2 and CO_2 diffuse between the interior surface of each air capillary and the parabronchial lumen.
Air flow
Air capillaries
Parabronchus
0.5 mm

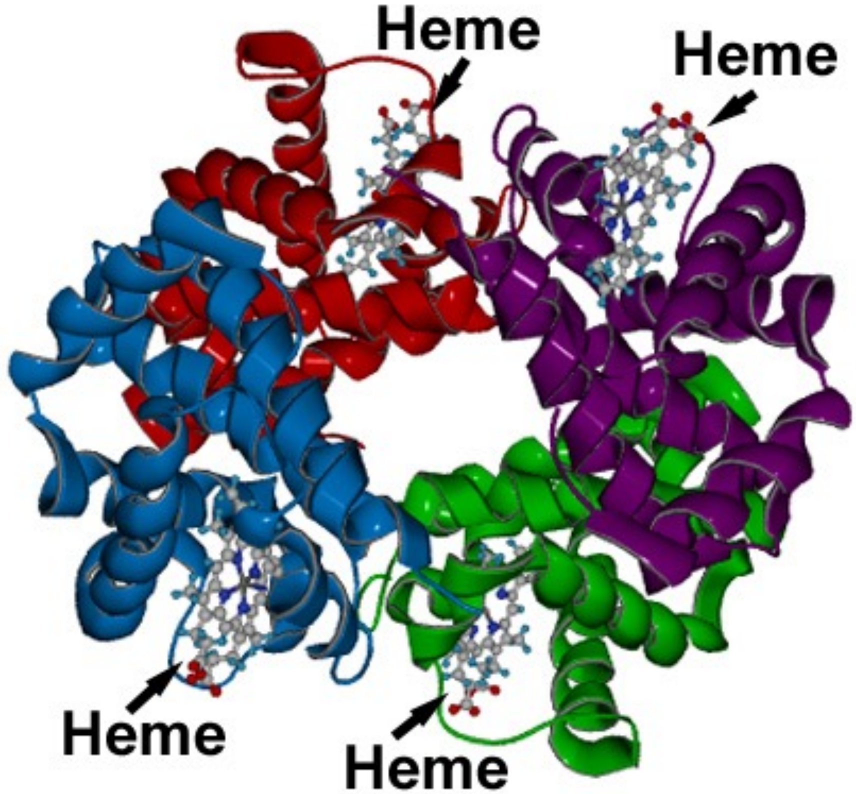
Avian (bird) lung tissue



PRINCIPLES OF LIFE, Figure 37.5 (Part 2)

Gas exchange occurs in narrow parabronchi which are rigid and firmly bound to the ribs. The parabronchi are narrow, rigid structures; birds have a thinner but mechanically stronger blood-gas barrier than equivalent mammals. The structure allows for *cross-current* air movement *(perpendicular to blood)* leading to *brief* counter-current loading. Gas exchange has **increased efficiency** in birds compared to mammals, especially at high-altitude or in a hypoxic environment. Fresh air comes through the air circuit with **both exhale and inhale.**

Hemoglobin tetramer protein transports oxygen: 4x (One Heme ← One Fe iron atom ← One O_2)

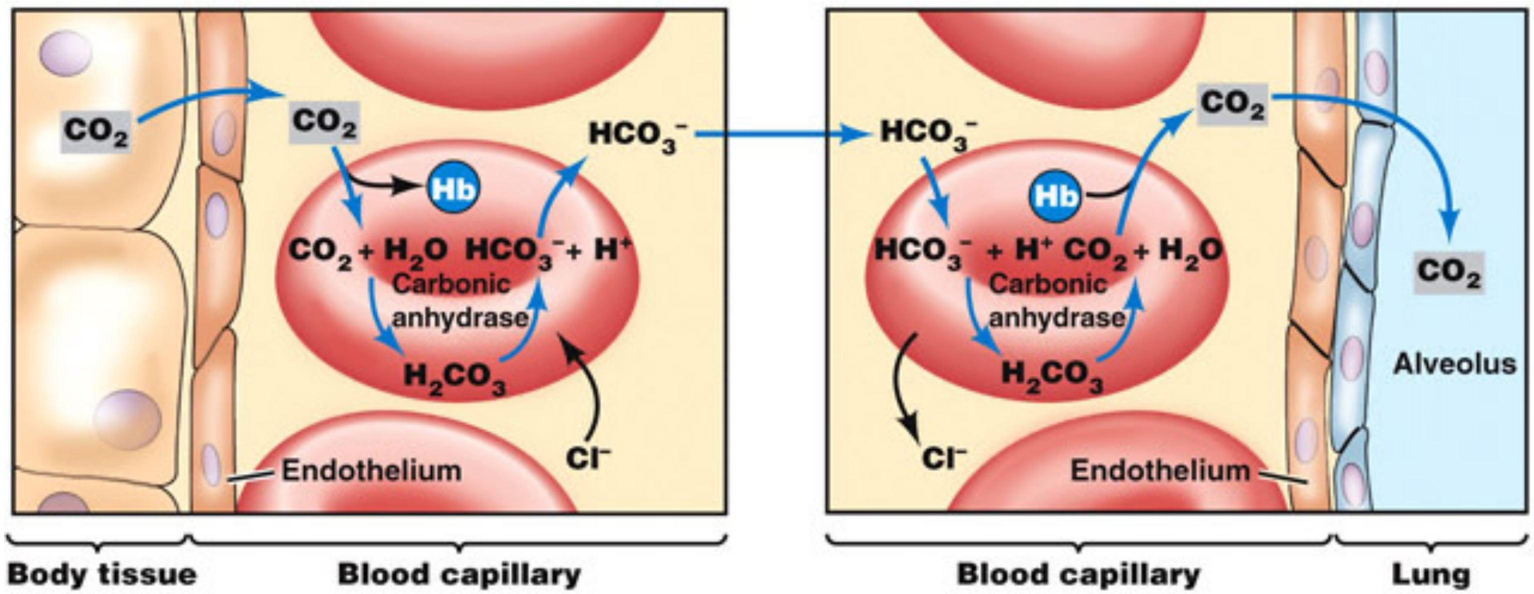


- Hemoblobin (Hb) protein stays sequestered inside RBCs, concentrates gases inside cells.
- O_2 and CO_2 are transported by diffusion and bulk flow (blood pressure)
- cell membranes are only 0.01 µm thick

•O_2 is not very soluble in water, and solubility decreases as water temperature increases, thus hemoglobin evolved – to bind and carry a lot of oxygen quickly

http://www.chemistry.wustl.edu/~edudev/LabTutorials/Hemoglobin/MetalComplexinBlood.html

CO_2 is primarily transported in the form of HCO_3^-



PRINCIPLES OF LIFE, Figure 37.13

In lung:

- Heme releases CO_2, binds O_2

In body tissues:

- Heme binds to H+ ions and CO_2, leading to release of O_2

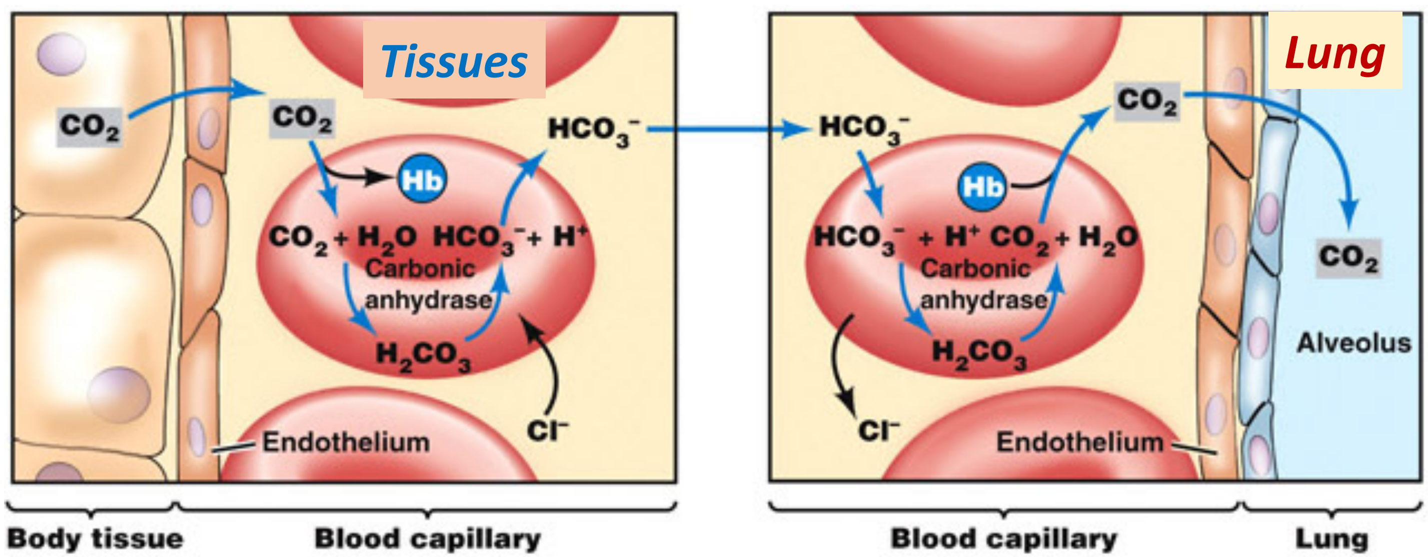
The CO_2 produced must not accumulate because it forms acid, and lowers pH of body fluids

carbonic anhydrase

$$CO_2 + H_2O \rightleftharpoons H_2CO_3 \rightleftharpoons HCO_3^- + H^+$$

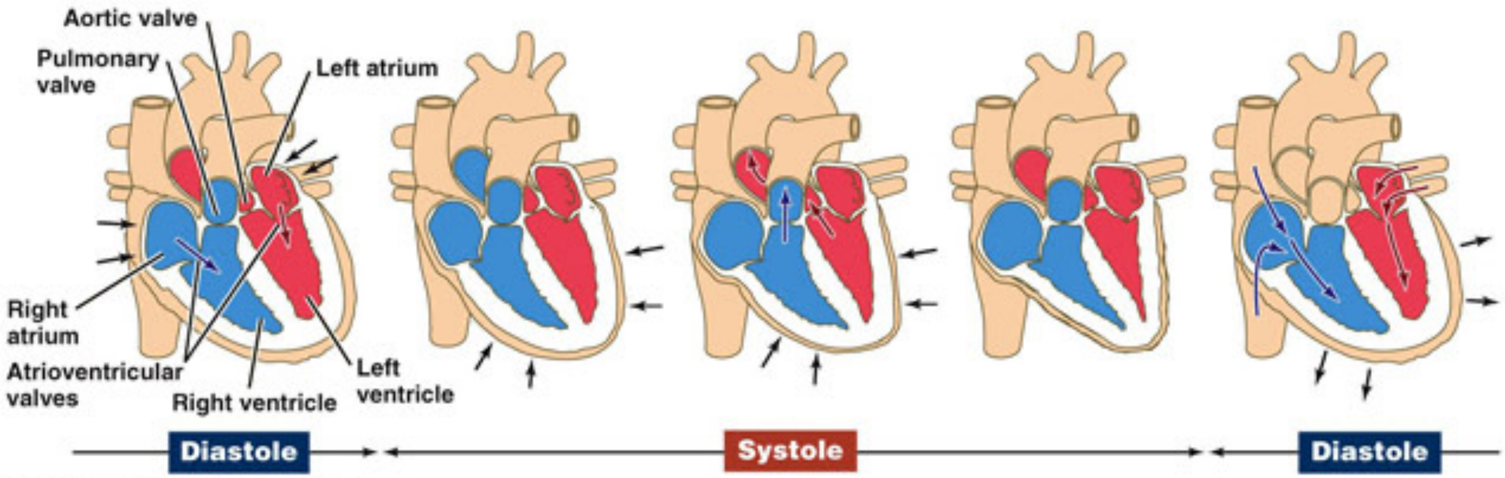
carbon dioxide + water | carbonic acid | bicarbonate + hydrogen ion

Conc of CO_2 drives the reaction left or right



The Heartbeat

Pumping Heart



PRINCIPLES OF LIFE, Figure 38.3

Blood pressure:

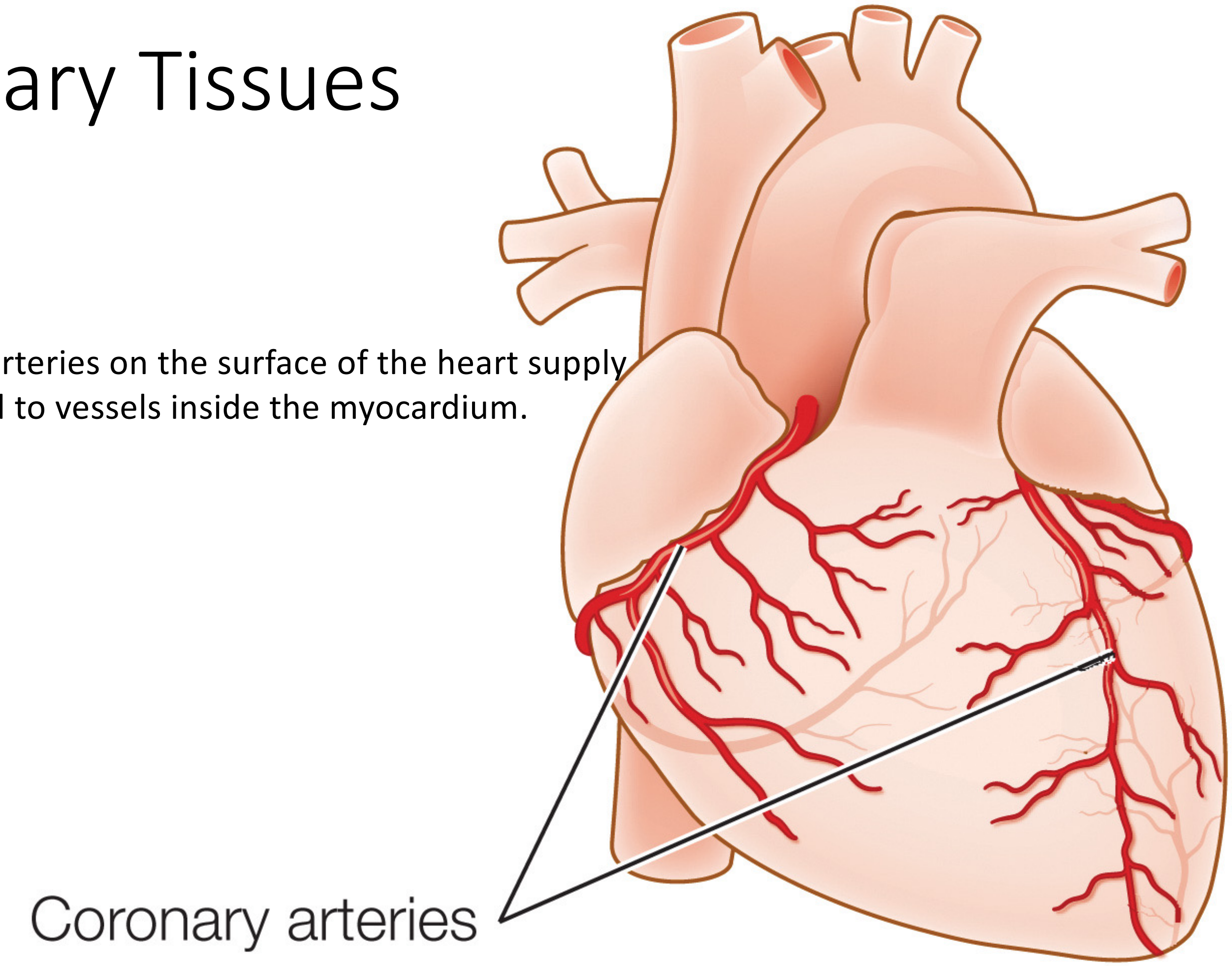
Pressure ***exerted on blood vessel walls*** by circulating blood

Varies between systolic (max) and diastolic (min) pressure

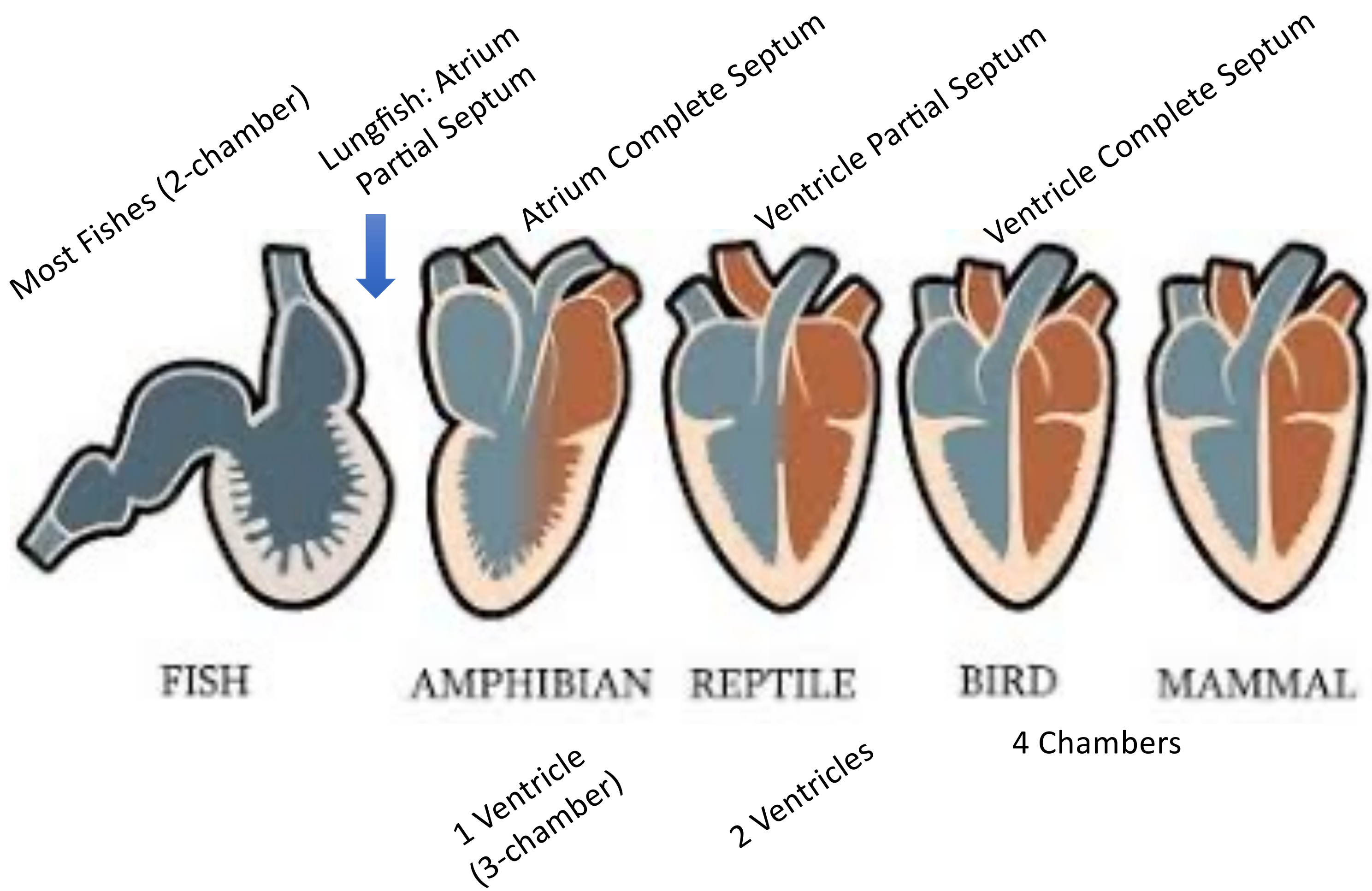
- **High** blood pressure ***requires heart to work harder***
- **Low** blood pressure may ***decrease O_2 to brain***

Coronary Tissues

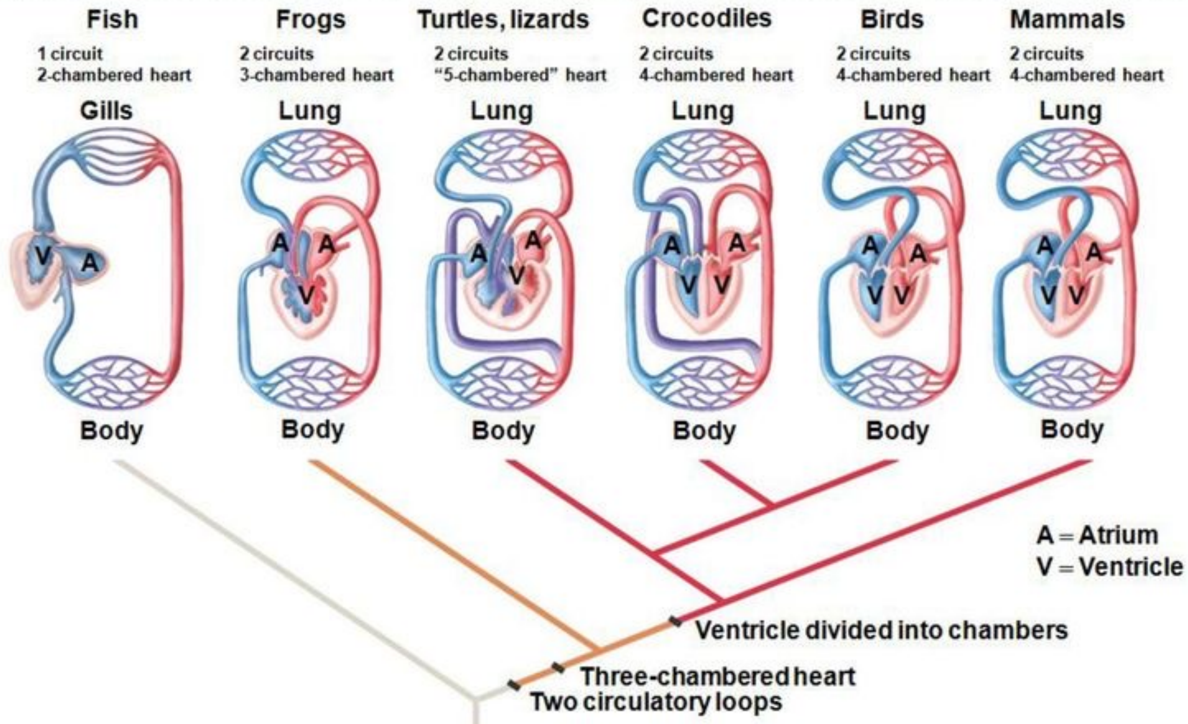
The arteries on the surface of the heart supply blood to vessels inside the myocardium.



PRINCIPLES OF LIFE 3e, Figure 30.28


Most Fishes (2-chamber)
Lungfish: Atrium
Partial Septum
Atrium Complete Septum
Ventricle Partial Septum
Ventricle Complete Septum
FISH
AMPHIBIAN
REPTILE
BIRD
MAMMAL
4 Chambers
1 Ventricle
(3-chamber)
2 Ventricles

Comparative Anatomy of Vertebrate Hearts



Lecture 15:

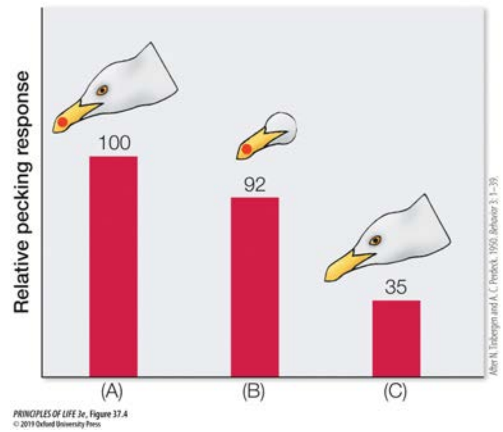
Behavior

Key Concepts

- Behavior Is
  - Controlled by the Nervous System
  - Is Influenced by Learning and Experience
- Some Genes Affect Behavior(s)
  - Genes have *alleles* (different versions, A,T,C,G)
  - Epigenetics does not change DNA, but can drastically affect gene EXPRESSION
  - EXPRESSION is as important as DNA Sequence

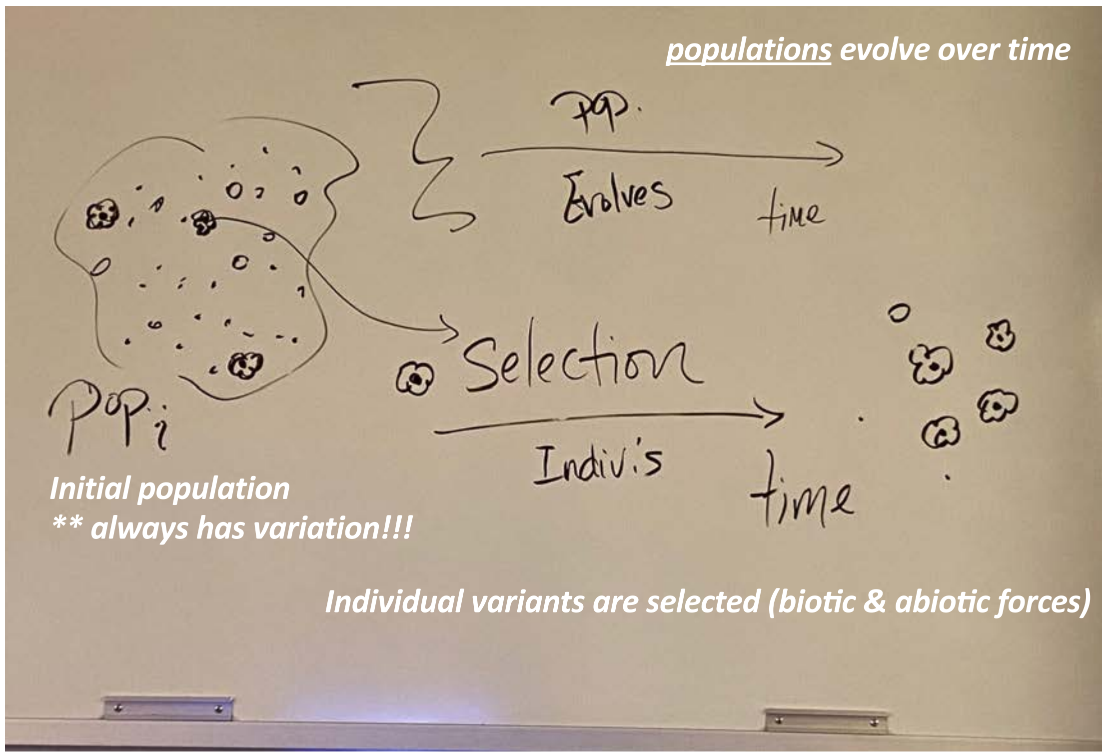
‘Fixed Action’ Behaviors – Evolved Genetics

How did pecking at spotted beak evolve?



- **Fixed action** animal behaviors. “Instincts” or *Innate Responses*
- Response to a stimulus - ***without prior learning*** and **often resistant to modification** by learning; they depend solely on a healthy nervous system to be performed (it’s genetic).
- Examples: bill-pecking behavior by gull chicks, web spinning by spiders, example: ants digging evolved in sand to make nest/survive – digs in gel
- Selection of ancestral population for advantageous behavior
  - adaptive to peck at red spotted beak:
    - ancestral predator/competitor, or ancestral prey/food

EVOLUTION (Population) *via* NATURAL SELECTION (Individual)



Behaviors Can Evolve

- if certain alleles produce more adaptive behaviors than others, natural selection can favor those alleles.

Breeding for a ****human* purpose***

- Studies in labs using ***artificial selection*** show that behavior can evolve rapidly. …. In an experiment with mice, individuals that ran the fastest on a running wheel were selected for mating. After 13 generations, the selected mice on average ran twice as far as control mice. Selected populations showed different neuronal network

Behavior Is Influenced by Experience
can change more easily, not fixed

[**Desensitization** to a startle response]

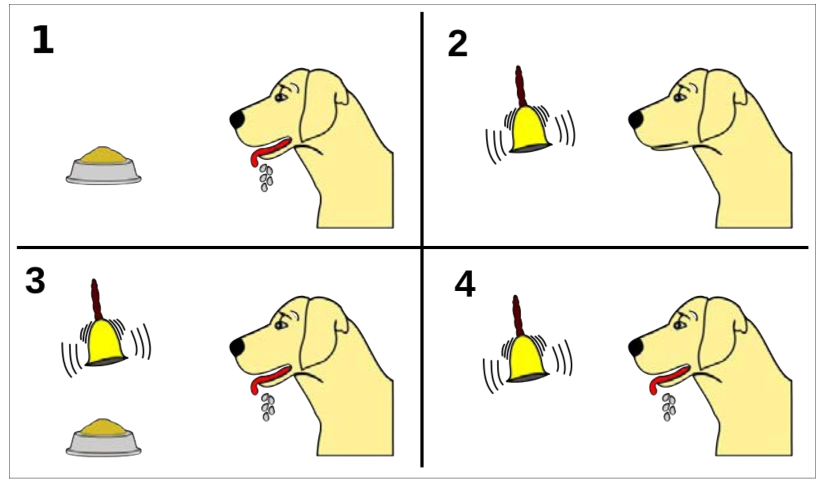
[**Habituation** to an interesting thing]

- **Learning**: ability of an individual animal to modify its behaviors as a consequence of individual experiences
- **Habituation**: the ***simplest*** form of learning

Habituation*:* a repeated stimulus results in less of a response – keeps an animal from wasting energy mounting response to non-threat. Often confused with ***Desensitization.* **They are a bit different …. rat was sensitized/desensitized. THESE DO NOT PAIR THE STIMULATION WITH A SPECIFIC REACTION!! !**

Learned Behaviors *Influenced* by Experience

Conditioning of Pavlov's Dog making an association between a stimulus and a response – can be positive or negative association, meaning response could be a **punishment (negative)** or the response could be a **reward (positive)**

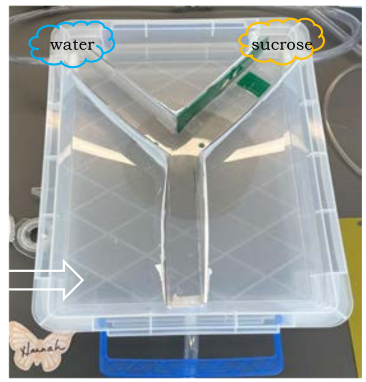


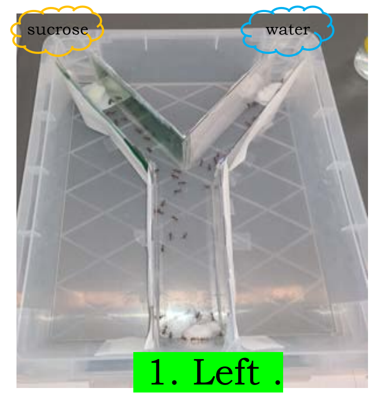
- **POSITIVE-Associative Learning** is also called Classical Conditioning where there is an *acquired* response to a formerly *neutral* signal. PAIRS are cue with a response.
- Experiments with mice show that they learn the layout and hiding places of their environment and that this learning helps them escape predation by screech owls.
- Negative-Associative Learning or *Aversive* Learning ... Examples*?

Eusocial 'Super-Organism' Community Learning

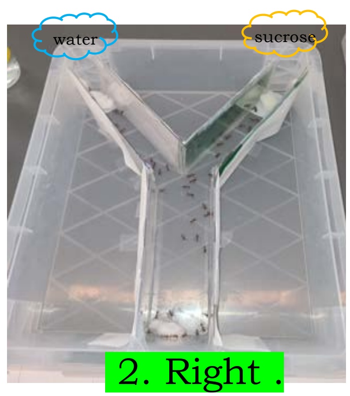
Y-maze Paradigm –

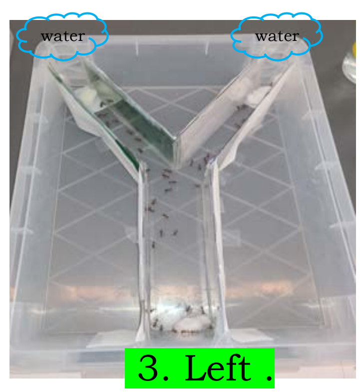
- associate color with reward
- hungry ants search for food
- place ants in stem
- record # of 'hits' to cotton





1. Learn
2. Reinforce
3. Test Memory
4. Reprogrammed





Biological Determinism (BD) = BAD Idea

*BD ideology has been used to justify eugenics, wars, slavery and slaughters …

- BD all genes *A,T,C,G DNA* determines outcomes
- BD assumes all an individual's traits can be explained by DNA sequence ***alone***.
- *Lucky Charms on the couch example

BD "data" comes from simple animal systems is "reductionist"

BD Theory *fails* in complex animals because...

EPIGENETICS!! Expression as important as A,T,C,G

Experience: Learning and Behavior

Behaviors with cognition and mood are dramatically more flexible than any other biological trait, because ***LEARNING*** modifies behavior, through *epigenetics.*

Epigenetic effects on behavior can have lifelong influences and may be transmitted from one generation to the next. Epigenetic effects are not genetically encoded; epigenetics can CHANGE with experiences or learning.

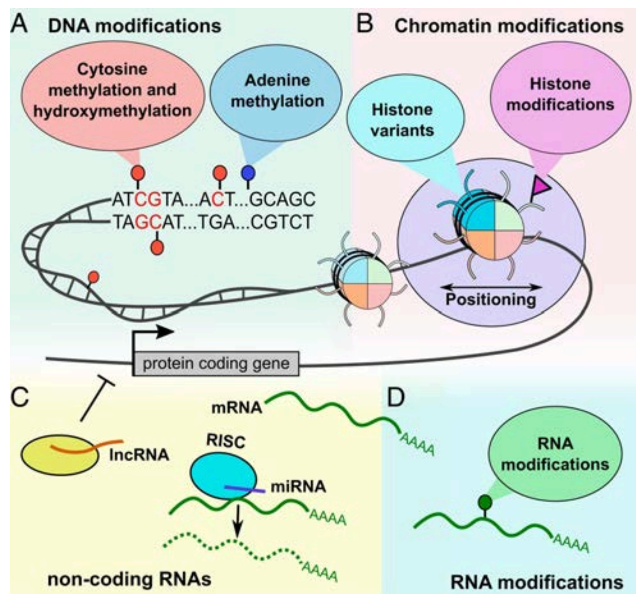
Epigenetics: is chemistry that modifies GENE EXPRESSION

**** does NOT change DNAs A,T,C,G***

**** not mutations***

Epigenetics: changes Transcription!

Epigenetic Factors CHANGE with *Experience & Learning*



These effects are EPIGENETIC, not genetic.
NOT involving mutant vs. wildtype genes

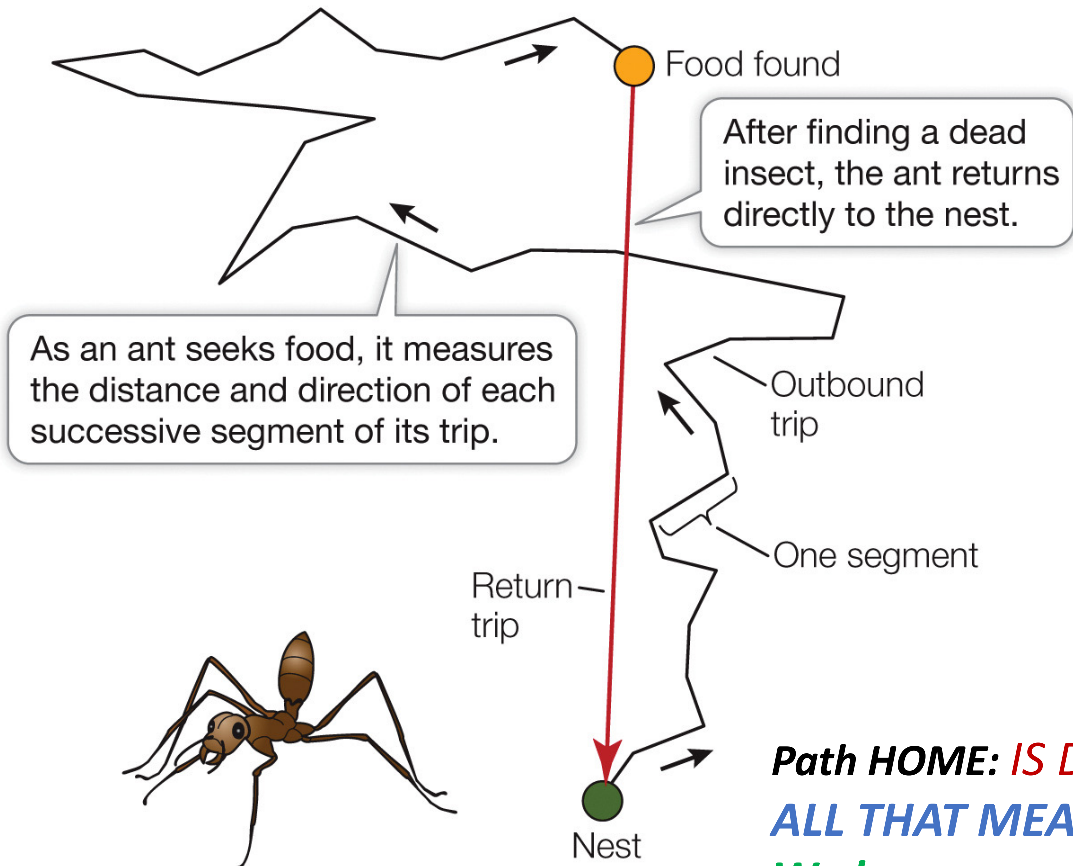
Epigenetics +/- chemical groups modifying *Genome*
CHANGES GENE EXPRESSION
→ ... and some genes affect behavior

But! Epigenetics does not change A,T,C,G's

Epigenetic states are dynamic:

Epigenetics CAN CHANGE over TIME
– more/less easily than fixing a mutated gene

Foraging by a Worker Ant of a Desert Ants



PRINCIPLES OF LIFE 3e, Figure 37.10

Path HOME: IS DIRECT ...

ALL THAT MEANDERING ... was actually Learning!

We humans could learn a lot from ants ...