TRODUCTION

Explaning Bio - how & why

- Time dimension
  - proximate: immediate cause of an effect (how, mechanism)
  - Ultimate: higher level reason for an effect (why, historical or functional)
- Biological organization dimension
  moleales, proteins → genes, → organisms → communities → ecosyst., biomes
- Spatial dimension
  local to global

B. Organism - alive?

- Energy: acquire and use energy
- Cells: membrane bound units the regulate structure and function
- genes/Information: to pass on Info to next gen, process and respond to stimuli.
- Replication: sexual and asexual
- Evolution: organism are products of evolution and populations of orgnisms the continuously evolve

C. Diversity

scale ↓
- Genetic diversity: variation in genes → adapt and evolve
- Taxonomic diversity: number, abundance, distribution of species (taxa)
- Ecosystem diversity: Variety of habitats and communities of different species that interact in interdependent relationships

D. Ecology vs Evolution

→ Ecology: hows, whys organisms interact, and their physical environment

- Evolution: change in allele (genetic variant) frequency in a population over time.

02 Evolution

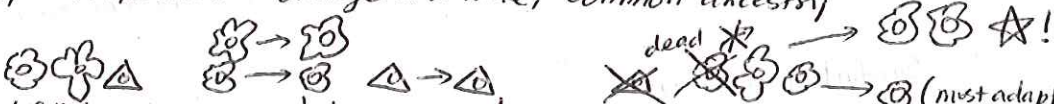
change in allele (gene variant) frequencies over time.

A. Mechanisms of change:
- Selection (fitness advantage to some alleles)
- Randomness (drift)
- Movement (gene flow)
- Mutation (direct change to genes)

B. Darwin's Revoluntionary theory

1. Natural Selection: slight variation of a trait will be preserved, if useful
2. Desent w/ modification: change over time, common ancestry

four postulates



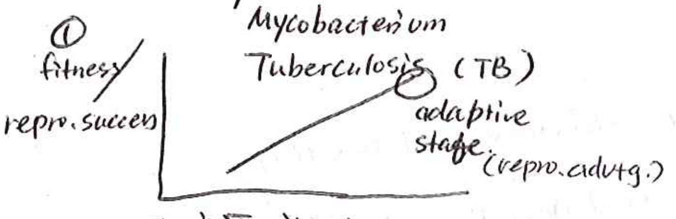
Individual vary, some variations are heritable / some individual ↑ success in survive, reproduce (NOT random)

individual w/ heritable traits ↑ to survive, reproduce

↑ in frequency of favorable traits in populations over time = adaption by natural selection

case study

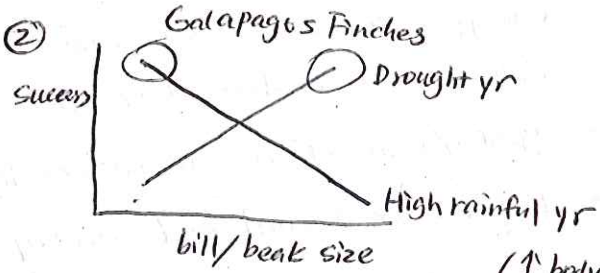
① Mycobacterium Tuberculosis (TB)



= drug resistence

Some TB mutated → drug → ↑ TB (mutated)
↓ TB (normal)
Individual cells did not evolve!

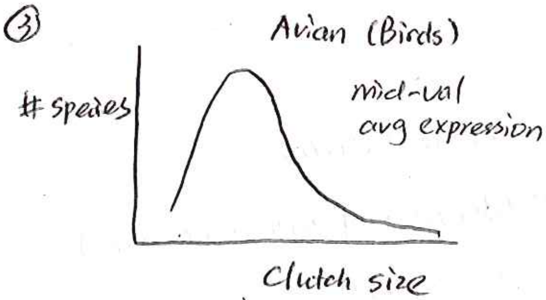
② Galapagos Finches



Drought yr → tough fruits → ↑ beak size ↑ to eat large seed (↑ body size, ↑ blunt beak)

High rainful → ↓ beak size → ↑ small seeds (↓ body size, ↑ pointed beak)

③ Avian (Birds)



- Natural Selection does NOT change individuals
- Acclimatization ≠ Adaptation

Theory: well-substantiated explanation of some aspect of natural world based on body of facts, repeated/confirmed thru exp. and observation. used to make predictions abt natural events not been observed

Hypothesis: a proposed explanation for a natural phenomenane (prediction)

03 Behavior Ecology

Behavioral → population → community → global

- Some complex behavior can occur without Complex cognition or decision making
- some behaviors involve cognition and are learned
- Behavior is a heritable trait that can respond to selection pressure

Tinbergen's 4 Questions

proximate (immediate)
① Causation / mechanism = genes, neurological / physiological pathway to cause trait to occur — immediate cause & effect (biological / environmental)
② Development = how this trait/behavior develops over the lifetime of the individual (developmental mechanism or processes)

Ultimate (long term)
③ Function = selected advantage related to fitness increase + function
④ Evolution: Evolution history (behavior in a shared common ancestor with other species), phylogenetic interpretation

CASE STUDY

1. Rovers vs Sitters in fruit fly
   ① A gene's associated w/ rover, sitter difference to cause difference in forgaging traits.
   ② Innate behavior depending on food supplies
   ③ Rovers = ↑ population density, ↓ food supply, ↑ find unused
   Sitters: ↓ ↑ ↓ energy used to move for more
   ④ Inherited from ancestors

2. Male Zebra Finch Song
   ① hormones predicate sexual behavior, cued by day length exchange. Air passing syrinx produces song
   ② Song learned from tutor (father), requires acoustic & visual information
   ③ ↑ attractiveness to females → individual fitness
   ④ Neutral circuitry inherited from ancestors, song may have evolved.

3. Sexual Activity in Lizards
   ① hormones → male bobs up & down, ↑ sexual organs in female; change in day length
   ② bobing dewlaps (visual cue) → trigger female readiness
   ③ to synchronize the sexual readiness → avoid predators; show good male quality → sexual select. (mate w/ good traits)
   ④ Inherited from ancestor, the push-up ↑ during select.

4. Sexual Select. In Australia Redback spider
   - long copulation, ↑ eggs. ↑ nutrients for offspring.
   - ↓ accept 2nd suitors to mate

Reciprocal Altruism (exchange of good act return)
Kin Selection. Apprent Altruism

$Br > C$ (B: Benefit, r: coeffient, C: cost)

direct fitness: care for own offspring → ↑ offspring → ↑ fitness of parents
indirect finess: others (relatives) → ↑ → ↑

Full-Siblings: Mom, Dad → Actor, Reip. (0.5 each)
$r = 0.5 \times 0.5 + 0.5 \times 0.5 = 0.5$

Half-Siblings: Dad, Mom (shared), Dad → Actor, Recip (0.5, 0.5)
$r = \frac{1}{2} \times \frac{1}{2} = \frac{1}{4}$

Cousins: Dad $\xrightarrow{\frac{1}{2}}$ Aunt; Actor ($\frac{1}{2}$), Recip ($\frac{1}{2}$)
$r = \frac{1}{2} \times \frac{1}{2} \times \frac{1}{2} = 1/8$

Haplo-Diploid (male) (female)
Mom, Dad D → Sister, Sister ① (0.5, 0.5, 1)
$r = 0.75$
Sis-sis.

Mom → Sist., Sist. (0.5, 0.5)
$r = 0.5$
Mom-daughter

① Mom, Dad D → Sist., Bro. D ($\frac{1}{2}$, $\frac{1}{2}$)
① $r = 0.25$

Father ~~→ son~~ → daughter

Mom → Sist ($\frac{1}{2}$), Bro (1)
$r = 0.5$

04 ANOVA

we test H_0 instead of H_1

H_0 – Null hypothesis = no effect of treatments

H_1 – Alt. hypothesis = not explained by chance, notable difference between groups

Variance. $\sigma^2 = \dfrac{\overbrace{\sum_{i=1}^{N}(x_i-\bar{x})^2}^{\text{sum of squares}}}{\underbrace{N}_{\text{degree of freedom = SAMPLE SIZE − 1}}}$

	Sum of squares (SS)	df	Mean Square = σ^2 (MS)
TOTAL	$= \sum (x_i - \text{total mean})^2$	sample (total) − 1	
WITHIN GROUP	$= \sum (x_i - \text{treatment mean})^2$	sample − # of treatment	
BETWEEN GROUP	= TOTAL − WITHIN.	1 (if 2 groups). number of treatment − 1	

$F = \dfrac{MS_{between}}{MS_{within}}$

$F > F_{critical}$ (1) ⇒ reject H_0

$<$ ⇒ accept H_0

$F\uparrow$ $P\downarrow$

$F\downarrow$ $P\uparrow$

P = possibility to fit H_0
(reject or accept H_0)
(chance to incorrectly reject H_0)

example.

SS

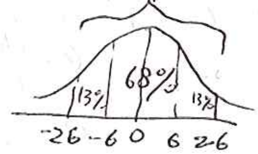
TOTAL $= \sum (x_i - \text{total mean})^2$

Within (noice) $= \sum (x - \text{mean walking})^2 + \sum (x - \text{mean running})^2$

between = Total − Within

Standard deviation (σ) $= \sqrt{\dfrac{\sum_{i=1}^{N}(x_i-\bar{x})^2}{N}}$

95% confidence level



Standard Error of Mean (SEM) $= \dfrac{\sigma}{\sqrt{N}}$

2 SEM = 95% confidence level

population: a group of individuals of the same species that live in the same area at the same time

05. POPULATION ECOLOGY

Behavioral→ ***Population***→Community→Global

3 properties of populations

1. Size
2. Distribution
3. Density

Life Table in conserv. Biology sea turtle

Protect eggs ⇒ protect adult female

1. Population Size

↑Young mortality ↓adult mortality +fec.

$\Delta N = N_2 - N_1$ = **B**irth – **D**eath + **I**mmigration - **E**migration

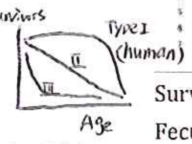
- Assessing Birth and Death

Life Tables

Life Table for *Lacerta vivipara* Females in the Netherlands

Age Class (x)	# of survivors	Survivorship	Age-specific fec.	Average Births/Year Original Female
0	1000	1.000	0.00	0.00
1	424	0.424	0.04	0.02
2	308	0.308	1.47	0.45
3	158	0.158	2.07	0.33
4	67	0.067	2.44	0.16
5	13	0.013	3.25	0.04
6	7	0.007	3.25	0.03
7	2	0.002	3.25	0.01

$R_0 \approx 1.00$ net reproductive rate



Type II: songbirds

III: insects, plants

Survivorship = $\frac{\text{\# of offspring survived}}{\text{\# of inital population}}$

Fecundity = #of offspring produced by a female

Net reproductive rate $R_0 = \Sigma$ (survivorship × fecndity)

$R_0 > 1$, Population increase; $R_0 < 1$, population decrease

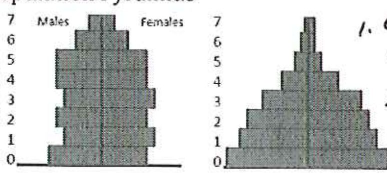
Application: increase survivorship of adult female

Life-history continuum

Low resist. High fec. Low fec. High surv. long life High resists Low surv. Short life

fitness trade-offs (b/c limited resources)

Population Pyramids



$R_0 = 1$ $R_0 > 1$

1. age of those who can reproduce
2. compare size

Factors limiting population size

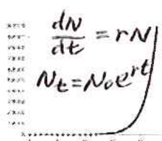
- Density-indep. abiotic environ.
- Density-depend. competition for resources, disease & parasitism, predation, Toxic wastes, social behavior

- Prediction of Population Size - Per Capita Growth Rate r (for each head)

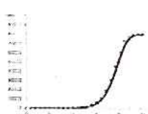
$r = \ln(R_0)/g$

g = generation time, r = B rate−D rate

Population size = Initial Population × $(e^r)^n$, n = year (exponential growth)



$$\frac{dN}{dt} = rN\left(\frac{K-N}{K}\right)$$ (Logistic growth)



(Density-dependent population growth)

K = carrying capacity determined by the environment (food, resources, etc.)

N = current population size ,

N > K, population decrease; N < K, population increase.

Example: fecundity of sparrows declines at high population density

- Measuring Population Size

sedentary

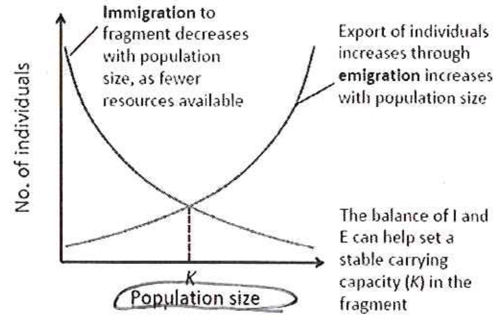
1. Transects (Line): count everything along a predetermined survey line (within a range)
2. Quadrats: count at random locations, inside rectangular plots

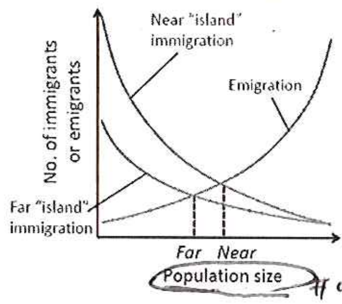
mobile

3. Capture-mark-release-recapture: $\frac{n_{mrk}}{N_{total}} = \frac{n_{mrk\ in\ recap}}{N_{recap}}$ $\left(\frac{M}{N} = \frac{m}{n}\right)$

- Metapopulations (E and I)

Individuals from a species occupy many small patches of habitat ⇒ independent populations ⇒ Meta-popul. (beyond populations)





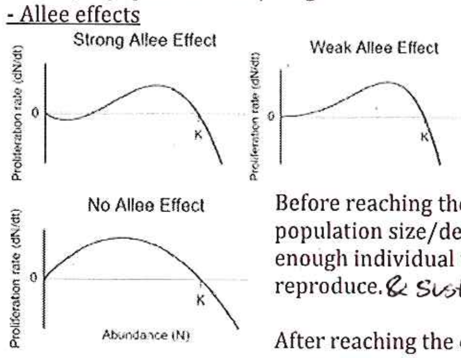
2. Population Distribution

- Random: individuals don't exclude each other
- Clumped: patchy, clustered resources and enhance fitness/survival by presence of others
- Uniform/overdispersed: competitive exclusion by others (resource competition)

3. Population Density

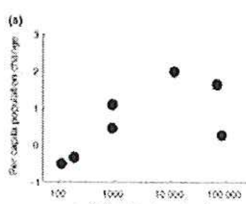
Density = population size/range

- Allee effects



Before reaching the critical population size/density: not enough individual to reproduce. & sustain themselves

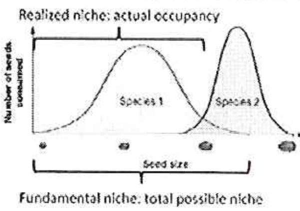
After reaching the critical value: continue to reproduce until reaching K, carrying capacity.



Application: Low population density areas are crucial for conservation efforts

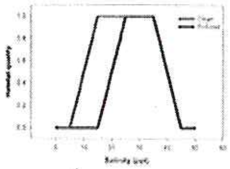
06. COMMUNITY ECOLOGY
Behavioral→ Population→***Community***→Global
Interactions between populations/species. in a certain area

1. Niche and Species Interaction



Niche: the range of resources (shelter from predator, weather, environment conditions like temp, etc.) that a species uses and the habitat it can tolerate.

Niche overlap determines interspecies competition.
We can only measure realized niche ← caused by competition and human cases like pollution

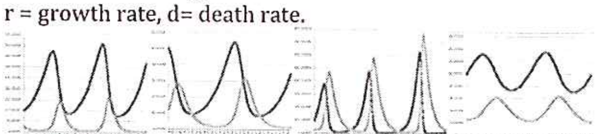


(uniform popup. distribution)

Species Interaction
intraspecific
interspecific
1. competition Competitive exclusion (evolved to avoid each other) leading to narrower realized niches. (-, -) e.g. fox & coyotes
2. Commensalism (+, 0) e.g. birds follow cattle
self-interest → max fitness 3. Mutualism (+, +) e.g. Plants & pollinators, digestive bacteria
(survive, produce) 4. Consump. Parasitism (+, -) has a cost, but not necessarily killing
Predation and Herbivory (+, -)
constitutive
inducible defense
Predator (N_1) & Prey (N_2) (Predator depends on Prey)

$$\frac{dN_1}{dt} = N_1 + r_1 N_1 N_2 - d_1 N_1$$
$$\frac{dN_2}{dt} = N_2 + r_2 N_2 - r_1 N_1 N_2$$

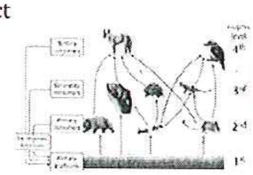
r = growth rate, d= death rate.



High Pred. death | High Pred. Growth. | High Prey Growth | Normal

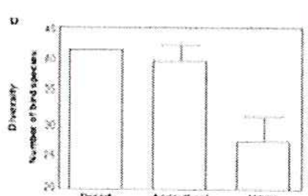
2. Food Webs/Tropic Levels
Species Classification
Keystone: low biomass (proportional mass, not individual mass→population), high impact
Dominant: high biomass, high impact
Rare: low biomass, low impact
Common: high biomass, low impact

Food Web

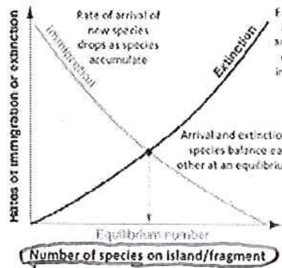


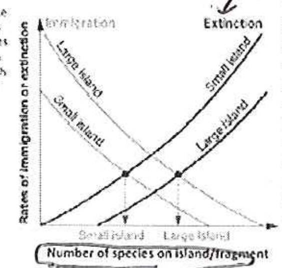
3. Determinants of Biodiversity
Top-down: predators → other species
Button-up: producers → other species
Case Study: (*Dorresteijn et al. 2015*) The top-down effects of humans (on apex predators, mesopredators, and herbivores) is stronger than most "natural" relationships.

Island Biogeography Theory
Desert, Agriculture, Urban
Urban dominant species ⥣ foraging efficiency→exclude other species
Giving Up Density (GUD)



Desert ⥣ GUD (less efficient); Urban ⥥ GUD

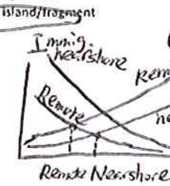




size of island
niches available
diversity, ...

Larger islands have more colonists and lower rates of extinction compared to smaller islands = greater biodiversity on larger islands or fragments

Island Biogeography Theory:
Extinction rate relates to forest patch size

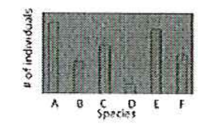


b/c rescue effect

4. Biodiversity and Measurement
Biodiversity
- Genetic Diversity: gene, fuel for evolution (⥣ Variation in a heritable trait → ⥣ fitness); Helps populations cope with environmental change

extinct → immigration of same species → offset.

- Taxonomic Diversity
Richness (# of total different species in an area)
Evenness (evenness of different # of species *exist* in that area. Non-existent species not in consideration) "0" drop out
Species composition (who the species are)
Be sure to look for changes in y-axis when examining different graphs.
- Ecosystem diversity



Richness: 6
Evenness: Low

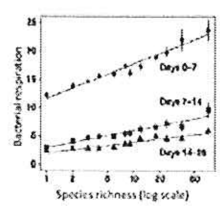
Richness = 6
Evenness: High

$$\text{Evenness} = -\sum_{i=1}^{S} p_i \times \ln(p_i)$$

p_i = # portion species A / whole.

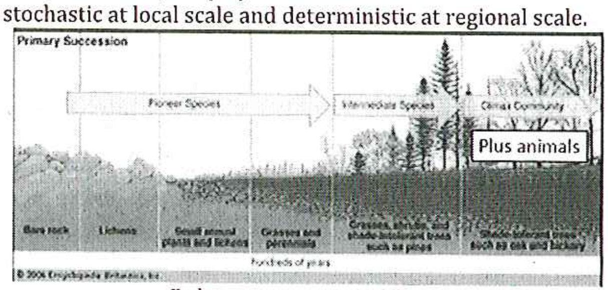
Measurement: Hotspots: species are condensed in biodiversity hotspots, but protecting the hot spots may not save endangered species b/c many mismatches between biodiversity and threatened species hotspots

5. Value of Biodiversity
A. Ecosystem Functions: water, Nutrient storage, Soil, Pollution, Climate stability
B. Biological Resources: Food, medical, wood, Breeding stocks, gene reservoirs
C. Social Benefits: Research, tourism, culture, natural disasters



⥣ diverse, ⥣ ecosys function.
⥣ days, ⥥ food, ⥥ respiration.

6. Ecological Succession
Biodiversity (species composition), trophic interactions, and ecosystem structure are not static—change over time.
Can be fast (e.g. after major storm, fire, landslide, volcanic eruption, human influence) or slow (e.g. after mass extinction) Vary by scale and tend to be more stochastic at local scale and deterministic at regional scale.



Early | Middle | Late
←←←Disturbance | Succession→→→

07 Global Ecology

A. Seasonality

seasonality $\underline{\text{affect}}$ sunlight, temp. $\xrightarrow{\text{drive}}$ primary productivity $\xrightarrow{\text{affect}}$ other trophic level

cause of seasonality: 23.5° tilt. annual rotation

productivity of primary producers

Latitudinal gradients:

poles are cooler than tropics

productivity tropics > poles

equator 90° — more sunlight – ↑ Energy

↑ Immune sys — ↑ fecundity

B. Water Cycle:

organisms need H_2O to grow & survive. H_2O $\xrightarrow{\text{nutrients}}$ move globally, locally $\xrightarrow{\text{drive}}$ ecological processes & structure of ecosyst.

movement by wind →

Evaporation ↑ ↓ precipitation

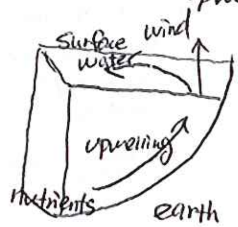
Evap. (forest) ↑ ↓ precip.

Ocean (Major reservoir) ← (sub)surface runoff ← Land

Land ↓ percolation → Aquifers

(global)

- Ocean Upwelling

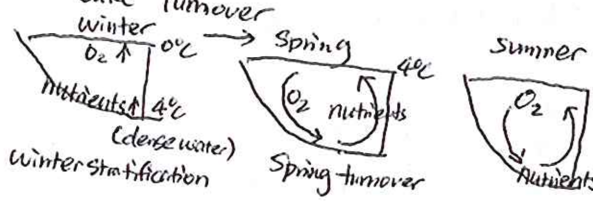


wind blows along the coast + rotation of the earth → moves H_2O at the surface

→ productivity at/near shoreline highest

(local)

- Lake Turnover



difference in dissolved oxygen's not high

But DO conc. ↑ w/ wave action

C. Nutrient Cycles = Global Carbon Cycle

Atmosphere CO_2

photosynthesis CO_2 ↓ / ↑ CO_2 Respiration — Ocean (Major reservoir) Organisms

photosyn. CO_2 → $C_6H_{12}O_6$ ↓ / ↑ Resp. CO_2 — Terrestrial Organisms, forest

deforestation, landuse (landscape change) CO_2 ↑ — Fossil Fuel

↑ CO_2 $\xrightarrow{\text{natural selec.}}$ ↑ fav. high assimilation efficiency (plants $\xrightarrow{\text{Photo syn}}$ sugar)

D. Global Nitrogen Cycle

Atmosphere N_2 (major reservoir)

N-fixing bacteria ↓ — Ocean (~~reservoir~~)

runoff → Ocean

bacteria N_2 ↑ — bacteria N-fixing in roots ↓ — Terrestrial Plants

lighting rain ↓ — industrial fixation ↓ — Industry

Terrestrial Plants: NH_3, NH_4, NO_3 ↓ Decompose / ↑ Assimilate

Overuse of fertilizer → ↑ Nitrogen $\xrightarrow{\text{runoff}}$ ↑ algae cyanobacteria

→ ↑ Aerobic bacteria → ↓ oxygen

⇒ dead zone (river)

fish kill.

Shrimp in Amer. Catch

E. Trophic Level & Pollution

bioaccumulation / biomagnification

Fossil fuel, metal production (excluding gold)

gold production, etc → mercury pollution

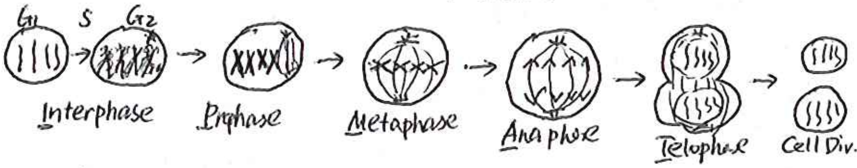
↑ 10% Energy lost thru each level. — etc. Tertiary, Secondary, primary — ↑ biomagnif.

Aquatic $\overset{\text{pollution}}{\rightleftharpoons}$ Terrestrial Food web

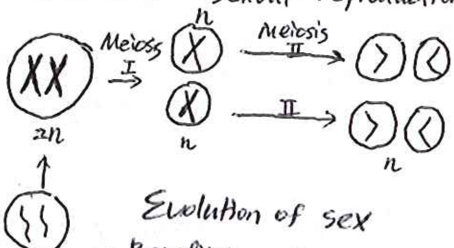
08 Microevolution

A. Mitosis, Meiosis, Phenotype genetics

1. Mitosis : repair, asexual reproduction



2. Meiosis : sexual reproduction, reduction division

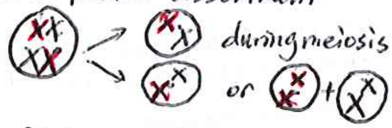


	Meiosis	Mitosis
# cell divisions	2	1
# chrom. compared to parent cell	half	same
cross-over	(genetic variation) 1 or more	No
Makeup in daughter cells	different	identical

Evolution of sex

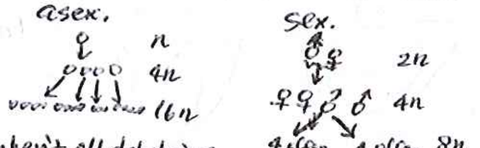
- Benefits: greater genetic diversity ex. worm P286. outcrossing (sexual) (mate w/ gene diffe. indiv.)
  some may be resist rapidly evolving pathogens & parasites
  (worm sexual > asexual under pathogens)

(a) Independent assortment



(b) Cross-over in prophase I.

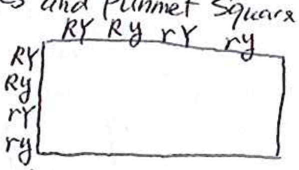
- Costs: "two-fold cost of males"



* Inherit all deleterious alleles harmful BAD!
inefficient

Mendelian genetics and Punnet Square

RRYY x rryy
↓
RrYy x RrYy →



Dominant/Recessive genes
Homo/Heterozygous

B. Evolutionary genetics

1. Ho = Hardy-Weinberg Equilibrium (without evolution what will happen)

	Genotype Frequencies		
	MM	MN	NN
observed	0.179	0.502	0.319
Expected	p^2	$2pq$	q^2

① Allele Freq.

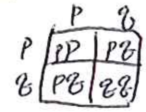
M: $MM + \frac{1}{2}MN = p$

N: $NN + \frac{1}{2}MN = q$

$p + q = 1$ (Allele Freq)

↓ ②

$p^2 + q^2 + 2pq = 1$ (genotype freq.)



All should be portion instead of #s.

i.e. $0.179 = \frac{\text{\# of MM indiv.}}{\text{\# of total indiv.}}$

Chi-Square : $\sum \frac{(obs. - exp.)^2}{exp}$
X^2 test

chi-square val. < critical val.
⇒ fail to rej. Ho ⇒ fall into H-W, no evolution.

Deviation from Ho

2. Selection

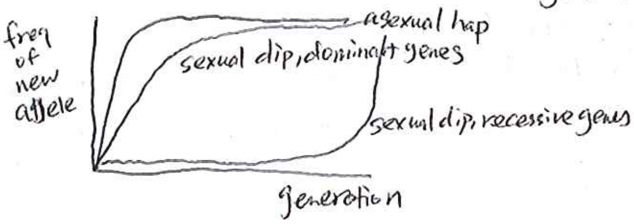
- Modeling selection

most common: asexual haploid

i.e. bacteria, cyanobact. prokaryotes

2st most common: sexual diploid

i.e. multcellular plants, animals, algae



- Sexual Selection (under natural selection)

selection, different reproduce. success → nonrandom mating

- male use sexually selected traits to compete for mates
- female choose mates based on physical character. signals male genetic quality
  behav. charact. → ability to provide parental care

- Directions in Selection

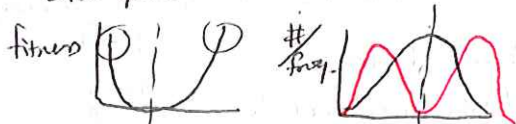
① Directional

ex. cliff swallows — cold weather → no insect for food → favors large body size

② Stablizing

ex. very small and very large baby more likely to die
narrowing birthweights

③ Disruptive



bimodal distrib.

ex. black-bellied seedcrakers with extreme beak size are most likely to survive (handle small/large seeds efficiently)

explaining/measuring selection

(1) heritability - heritable traits

(2) fitness - related to fitness differences

(3) change overtime in population under selec. pressure (environment)

3. Genetic Drift: a change in allele freq in a population due to chance. (conseq. of sampling error)

- Mendelian Lottery

{ randomness in meiosis: crossover & indep. assortment

{ randomness in gamete fusion. zygote on allele A or B or C due to chance

- Random (non-fitness related) Events: volcanic eruption

- Population reduction: founder effect.

change in allele freq. when a new population's established i.e. American Catch

A: homo for A_1 B: hetero C: homo for A_2

[A A / CB CB / C C] → immigrants → recolonize (A B) repopulate

i.e. lizard on the tree → rain → drift in ocean → new island

i.e. Amish People

Bottleneck effect: sudden red. in allele freq. [A B A / B C C] → overharvesting → [A C] survive

i.e. cheetah

△ random events can be significant in small population (drift most important) over long time periods

△ Outcomes

(1) loss of genetic diversity: random fixation & loss of alleles

(2) random chances to traits may/may not influence fitness

4. Gene Flow (migration) = immigration of new alleles or emmigration of old alleles → change in allele freq.

homo [A A A] ⇌ [B B B] homo

hetero [A B A C] [B A C]

Human affect gene flow: (biased gene flow) hatchery fish - lower fitness; highway - human barrier

Outcomes

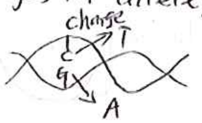
(1) Homogenization of populations

(2) Potential breakdown of local adapt, (hatchery fish)

(3) Potential intro of new alleles

5. Mutation = physical changes in alleles

- Point Mutation
  change in nucleotide seq. → diff. protein



i.e. Sickle cell anemia
less O_2 uptake

- DNA Duplication (chromosome-level)
  change in # or composition of chromosome
  XX → XXX chang in # or gene deletion
- Inversion : single chromosome rearrange after breakage
  XX → XX change in composition
- Lateral gene transfer
  gene transfer from one species to another or inclusion of DNA from environment
  i.e. Finches get carotenoid pigments from food
  genome from fungus → pea aphid → synthesize own carotenoid

Outcomes:

(1) Intro of new alleles
Primary mech for generation of genetic variation

(2) Slowest/weakest evol. force

(3) work w/ other 3 forces
w/out mutation, evolution will stop

Evolutionary processes

	Variation	avg Fitness
Natural Selection	~, ↑, or ↓	↑
Genetic drift	↓	↑ or ↓ (most)
Gene flow (immig. / emmig.)	↑ intro or ↓ remove alleles	~, ↑ or ↓
Mutation	↑	↑ or ↓ (most)

example p477
deletion of red genes
→ green aphid genome
→ avoid predation

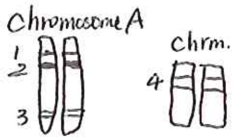
8-3

09 Coevolution

Coevolutionary Interactions

Within-species

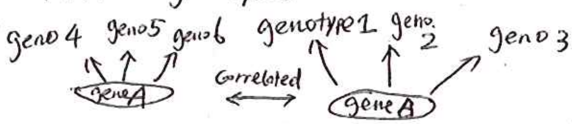
A. Genetic correlations and pleiotropy



genes located close to each other on the SAME chromosome tend to be related

Gene 1, 2, 3 correlated
Gene 1, 2 more correlated & ↑ likely to exchange together
Gene 3 could be uncoupled by crossover
Gene 4 not correlated w/ any gene here.

Pleiotropy: 1 gene has multiple trait/phenotypic effect
Selection on gene A can cause correlated responses in other genotypes



① gene B highly beneficial (selected for)
gene A slightly deleterious
⇒ gene A maintain in population

② Genotype 3 highly beneficial
Genotype 1 slightly deleterious
⇒ genotype 1 maintain in population

ie: P-53 in human { Prevent rep of mistaken/broken cells in mitosis (highly beneficial) - avoid cancer
aging (deleterious)

Among species

B. Mutualistic Interactions

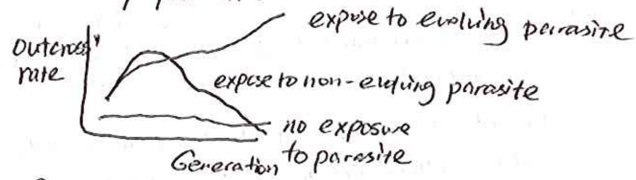
reduced pathogen infections

processes/functions
nitrogen uptake
communication
disease dection
nutrient cycling

Honeyguides (birds) & humans

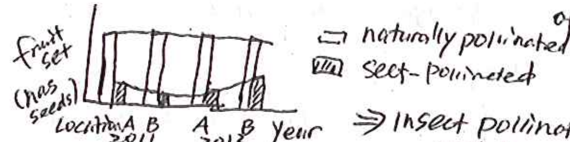
C. Predator - prey / Parasite - host Interactions

(1) (Red Queen hypothesis)
Worm both produces sexual & asexually. (more cost) see 8-1
+ deadly parasite



Const. { ① host evolve to fight off parasite
② parasite evolve to fight off defence mech } co-evolu.

(2) predator-prey Song et al 2014
Ho: the fly has no effect on the seed formation of flowers



⇒ Insect pollination ① stablize and ② increase the fitness

fly lays eggs on flowers and larves eat seeds
pollinated → more seeds & outweight seeds being eaten

10. Macroevolution

A. Paleontology & History of Life

Fossil: trace of an extinct organism
morphology, behavior, rarely genetic info
- phenotypic record of the history of life

Formation of Fossil

- Compression = organism cemented into rocks by sediment LEFT: external phenotype
  eg. leaf imprint, dinosaur footprints
- Casts/Molds: buried in sediment, then decomposes to leave external cast or internal molds
  LEFT: external or internal phenotype (shell)
- Permineralization: mineral infiltrate cells & replace organic material w/ rock
  LEFT: ex or internal phenotype, 3-D shape, fine structures (dinasour)
- Intact remains: protected (eg. in amber), decomp. stop.
  LEFT: entire organ., possibly genetic info

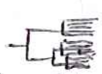
Limitations / Bias

- Taxnomic/Tissue: hard shells > soft parts
- Abundance: large population size
- Habitat: fast sedimentation (forest, deserts < marine syst.) anaerobic (less decomps.)
- Temporal: younger > older rocks

Bias in Biology

- Ecology: terrestrial (land), diurnal (day) organisms
- Evolution: short gen times, simple genetic syst.
- Genetic: model organisms, human medical correlates

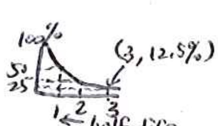
Interpretation of Fossil



Adaptive Radiation: origination of large number of lineages from a common ancestor in a short time
- Driven by: 1) new niches available (ecological oppt./environ. change)
  2) evolution of new morphology → use niches
eg. feathers originally in display → gliding & fly → dinosaurs → birds
eg. Cambrian Explosion (Radiation): MANY animals w/ different brains, muscles, etc occurred
hypothesis
- ↑O_2 levels → ↑body size (adaptation)
- Ca^{2+} in oceans from volcano → shells, skeletons
- Arm race bet. predator-prey — coevolution

History of Life

Radiometric dating: isotope decay



Earth formation 4.6b — First record of life 3.7b (prokaryotes) — Orig of Eukaryotes 1.8b — 1.2b orig of sexual produc. — first animals 600m — Cambrian explosion 540m — K-P mass extinction 65M — human 200,000

B. Speciation

Biological Species Concept (BSC)

- reproductive isolation (no hybrid, no gene flow)

(1) prezygotic isolation

(time) Temporal (breed at different times)

(space) Habitat (breed in diff. habitats)

(before mate) Behavior (courtship displays differ) song type of finch

(after mate) Gametic barrier (egg/sperm incompat.)

(before mate) Mechanical (incomp. rep. structures, sizes)

(2) postzygotic isolation

(embryos) Hybrid viability (hybrid offsp. die as embryos)

(adults) Hybrid sterility (mature but sterile as adults) horse x donkey ↓ mule ↓X

probs

(1) difficult to apply in field studies (need to be close geography)
species need to be co-located to demonstrate barriers

(2) cannot tested in fossil records/specimens (sample)
BSC = observ. of habitat, behavior difference

(3) does not apply to asexual, parthenogenic, selfing popul
无性生殖 单性生殖

(4) plant species - many can hybridize

process of Speciation

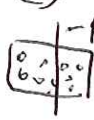
1. Isolation of populations

physically/ Allopatric (different homeland) isol.

- dispearsal, colonization

founder effect

- Vicariance



- physical splitting (river, mountain) forest, lava

genetic/Sympatric (same-home) isolation.

- change in chromosomes

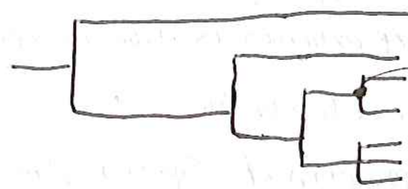
2. Divergence between populations

- Genetic drift
- Selection : speciation via adaption to novel environments

i.e. apple tree - novel food source
apple fly vs hawthorn fly

Phylogenetic Species Concept (PSC)

(evolutionary)



- need to generate hypothesis
- Species defined by stats. differences in diagnostic traits (DNA) among populations → testable!

probs

(1) not too many good phylogenies
(2) controversy of trival traits
may result from mutation & drift
(3) # of extant species would ↑ w/ PSC

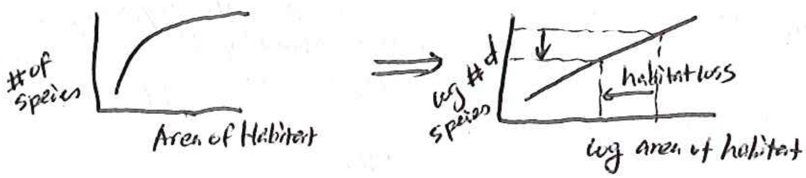
3. Reproductive isolation of popul.
population diverged
if hybrid, offspring → ↓ fitness
→ selection for assortative mating
→ Reinforcement → Speciation

C. Extinction

flip-side of speciation

rate of extinction is the concening element of current biodiversity crisis

- Direct Observations
- Interpretation of Species-Area Curves



evidence/observations from Pimm et al. 2014.

1. rate of human-induced mass extinction is 1000 times stronger than background rate of extinction
2. Species w/ small geographic ranges were more at risk of extinction

Solutions

1. protected terrestrial areas are slowing extinction. Marine are less effective
2. Crowd-sourced citizen science provide crucial data about realtime extinction threats

Mass Extinction

global, broad range, rapid effect

K-P mass extinction

meteorite impact, (shocked quartz, microtekites) high concentration of Ir in impacted layer, impact crater

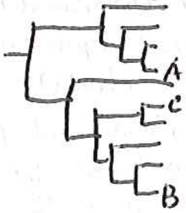
effects of impact: SO_2, dust, fires, earthquake, Vocanism

cooling, darkening — ↑CO_2, ↑ Temp (long term)

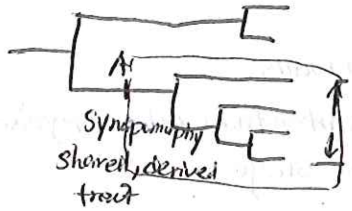
loss of lineages : dinasaurs, etc.

11. Phylogenetics

- nodes can be rotated
- find common ancestors instead of counting nodes when finding relations

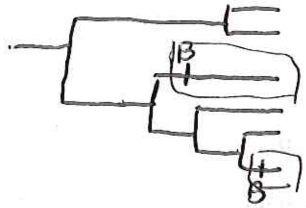


A = B = C related equally

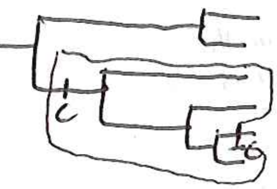


homology: similarity thru common evolutionary descent (shared ancestry)

monophyletic group
ancestral population + all its descendants, no others



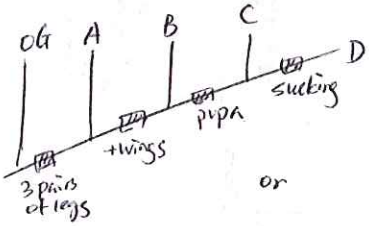
Homoplasy: shared traits not thru shared ancestry
Analogy: similarity due to convergent evolution
Polyphyletic group (NOT shared ancestry)
does not include the most recent common ancestor
Analogy: similarity not due to shared ancestry



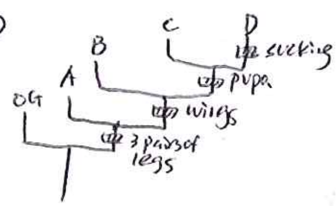
paraphyletic group
does not include all descendants from the common ancestor

- Collecting data to construct Phylogeny
  morphological, molecular (occasionally behavioral, develp., physiological)
  must be homologous across all taxa studied
  data must vary, have different character states
- from data matrix to a tree
  parsimony rule

Synapomorphy	Outgroup	A	B	C	D
# of pairs of legs	3+	3	3	3	3
Wings	absent	abs.	pres.	pres	pres
Develp mode	Direct	Dir	Dir	Pupa	Pupa
mouthparts	Grinding	Gri	Gri	Gri	Sucking

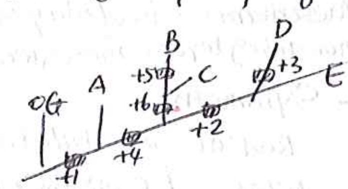


or



Syn/trait	OG	A	B	C	D	E
1	0	1	1	1	1	1
2	0	0	0	0	1	1
3	0	0	0	0	1	0
4	0	0	1	1	1	1
5	0	0	1	0	0	0
6	0	0	1	1	0	0

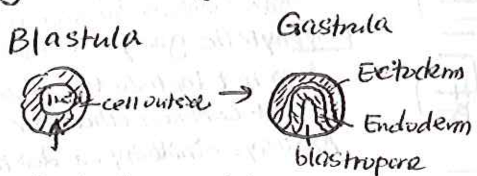
A: 1
B: 1,4,5,6
C: 1,4,6
D: 1,2,3,4
E: 1,2,4



traits can add or loss

12 Animals

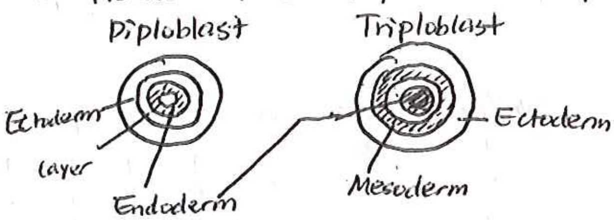
- multicellur, lack cell walls
- Heterotrophs : obtain carbon from other organisms
- embryos show gastrula stage
- Collagen : fiberlike protein
- motile
- gastrula stage



Protostome = blastropore at mouth
Deuterostome = blastropore at anus

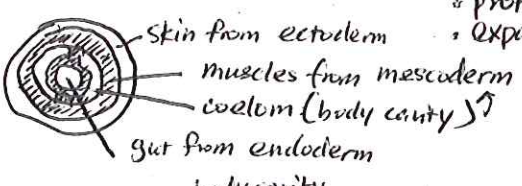
Key synapomorphies / traits

- Tissue layers = Diploblast vs Triploblast



Ectoderm = skill, nervous syst
Endoderm: lining of digestive tract
Mesoderm = circulatory sys. musle, organs, bones
non-living layer = mesoglea 中胶层

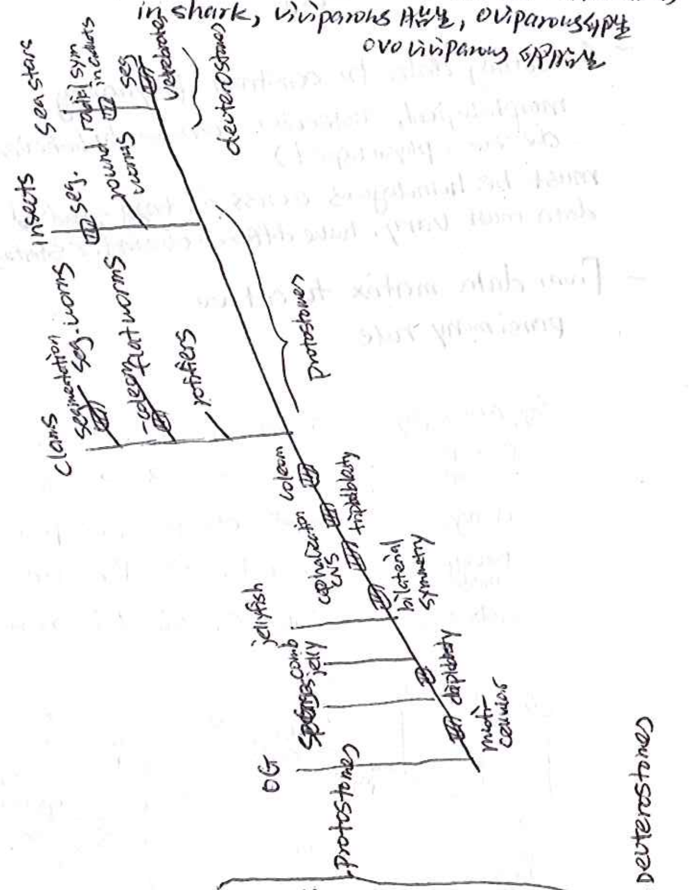
- Symmetry
  - Radial vs bilateral
  - bilaterial { distinct head, tail; direct ways to find prey, seek shelter; sensation organs; structure on sides for movement/sensing environment
- Central Nervous Syst. & Cephalization
  - Radial = diffuse nervous net
  - Bilateral = CNS, cluster nervous sys, directional sensation, sensation in head (cephalization)
- Coelom

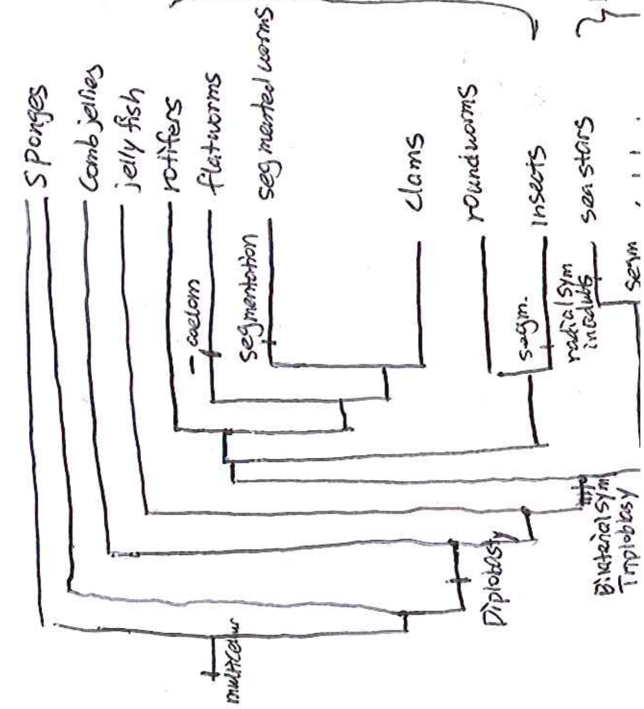


- protection of organs
- expansion of digestive tract
- hydrostatic skeleton, movement in a direction

Coelomates = ~~coelom~~ body cavity surround internal organs (digestive tract)
Acoelomates: no coelom surround
Pseudo coelomates = body cavity does not completely surround internal organs

- Hox genes
  - group of related genes that control the body plan of an embryo
  - small variation in location and gene expression timing gives variation in body plans
- other features
  - Sensory organs (light, sound, touch, electromag field)
  - types of feeders (suspension, fluid, deposit, chunks)
  - limbs (lobe-like, jointed, tube feet, tentacles)
  - reproduction (sexual, asexual, internal fertilization) in shark, viviparous 胎生, oviparous 卵生, ovo viviparous 卵胎生





13 Plants

A. Societal importance, Biological importance

- Fuel & energy, food, secondary compounds (drugs, rubber, glue, oil, etc.), quality of life
- photosyn, carbon sink, slow down run-off, Primary producers

B. key Evolutionary Events

1 - Origin of Chloroplast from cyanobacteria within a eukaryotic cell (endosymbiosis)

2 - Ability to live on land

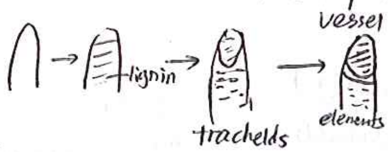
Waxy layer Cuticle

Stomata

O_2 CO_2

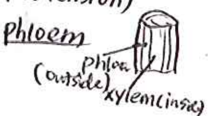
3 - Vascular Tissue

water and nutrient transportation



able to transport water thru Xylem due to evaporation, gaps through cell walls (surface tension)

transport nutrients thru Phloem



4 - Seeds protected in an Ovary

Gymnosperm vs Angiosperm

裸子 被子

monocots (one cotyledon) dicots (2 cotyledons)

seeds Embryo nutrients

key features ⟹

anther $\xrightarrow{\text{meiosis}}$ microspore n $\xrightarrow{\text{mitosis}}$ multicellular pollengrain (male gametophyte) n → Pollination

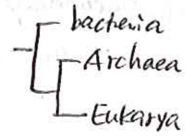
Ovary → megasporangium $2n$ $\xrightarrow{\text{meiosis}}$ megaspore n $\xrightarrow{\text{mitosis}}$ femal gametophyte n → egg

double fertilization → Endosperm $= 3n$, Zygote $2n$ $\xleftarrow{\text{mitosis}}$ fruit ← Seed embryo $= 2n$, Nutritive tissue $= 3n$ ← Sporophytes $= 2n$ dev. → Sporophyte (spores - flower) $2n$

- Diversity in pollinators
- Diversity in seed dispersal Mechanisms

14 Protists

- paraphyletic: all eukaryotes except for fungi, animals, land plants
- multicellular
- endosymbiosis
- cell wall outside or inside plasma membrane
- motile: cilia, flagella, amoeboid motion
- sexual / asexual reproduction



A. Importance

Chagas disease (zoonotic disease)

bug takes a blood meal → epimastigotes (上鞭毛体 (核前方)) in midgut → multiply in midget → trypomastigotes (锥鞭毛体 动虫成虫期 (核后方)) in hindgut → blood meal

(in human body) → penetrate cells → multiply in tissues → enter bloodstream

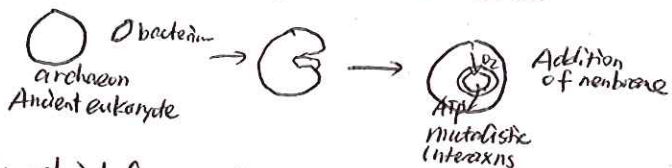
Ecological: - primary producers in oceans
- marine carbon cycle (C into hard structures on ocean floor)

B. key features

1. Nuclear envelope

   infold membrane separated from plasma membrane (mutation, selection)
   separates transcription from translation
   formation of endoplastic reticulum (ER): translation of RNA to protein

2. Endosymbiosis – origin of mitochondria

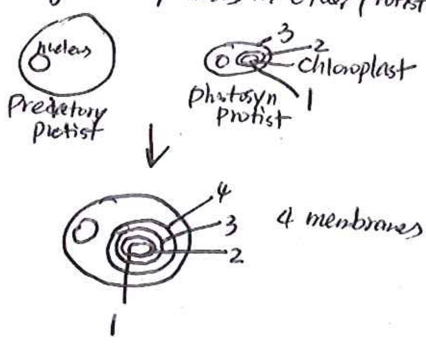


3. Amoeboid form, Supercell

   Pseudopodia 伪足 moved by actin and myosin against a cytoskeleton
   Supercell: amoebas fuse to form a single cell w/ multiple nuclei

4. plant Chloroplast

   primary endosymbiosis in plant
   Secondary endosymbiosis in other Protist clades



C. More Linages in Detail

1. Red Algae

   can fight off virus and break down cell wall of virus → health

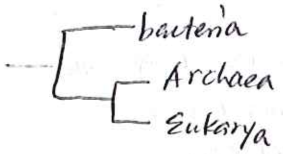
2. Dinoflagellates 腰鞭毛虫

   Ecological: cause red tide (toxic algae boom)
   kill animals, hypoxia
   Health: toxin into human food chain thru oysters, clams, etc.

3. Foraminiferans 有孔虫类

   morphology: $CaCO_3$ shells
   bio indicators of pollutions
   indicators of paleo ecology and time periods

15. Bacteria and Archaea (Prokaryote)



Prokaryotes - single-celled
- No membrane around DNA, single circular chromosome
- No energy-producing organelles
- very few cell compartments
- No sex
- flagella present

Bacteria, Archaea differences

Bacteria	Archaea
peptidoglycan in cell wall	phospholipids from isoprene in cell membrane
transcription differs from archaea	transcription similar to Eukarya

Values of Studying them
- old
- a lot!
- can live in extreme conditions
- medical
  - if virulence is heritable
  - a large genome for proteintoxin } → pathogenic bacterium
  - most bacteria not pathogenic
- bioremediation

key features
- morphological diversity
  - size, shape, motility
  - Gram-positive bacteria: cell wall made of peptidoglycan
  - -negative : polysaccharides in outer membrane
- horizontal Gene transfer
  - conjugation: cell to cell contact
  - transformation: take up DNA from the enviroment.
- Metabolic Diversity

	energy	carbon	example	analogous
photoautotrophs	sun	CO_2	cynobacteria	plants, algae
chemoautotrophs	chemical rxn	CO_2	unique to prokaryotes	
photoheterotrophs	sun	environment.	heliobacteria	N/A
Chemoheterotrophs	environment		many prokaryotes. fungi	Animals

16. Viral Diversity

Definition of the virus
- obligate intracellular parasite, dependent on host cells
- parasite of biological information systems

Can propagate
- through an extracellular stage
- within the host genome

Virus vs Organisms
1. have genes
2. not cells
3. No coping of DNA to mRNA
4. No production of protein from mRNA
5. No independent metabolism

1. Are virus Alive ?

- No :
  - Not made of cells
  - No metabolic systems, capable of synthesizing biological molecules
  - No enzymatic syst. to generate ATP
  - No ribosomes
- Yes :
  - life is self-propagating
  - can be inactivated
  - can be reactivated, be active under right conditions (like seeds)
  - "borrowed life"

- Importance :
  - Subject to evolution
  - important role in the evolution of other forms of life

2. key features

- Morphology  
  capsid or one or more membranous envelop
- Reproduction
  Lytic cycle
  animal : host specific receptor
  plants : Insects and damaging cell wall

① viral genome enters host

uncoating at cell surface

envelop protein attach to carbohydrate via endocytosis → H^+ pump → env. protein change and fuse → viral genome release

② viral genome is transcribed, production of viral protein
③ replication of viral genome
④ assemble particles inside the host
⑤ exit and release to environment or new host

budding from host cell

burst from host cell (non-enveloped)

3. Why study virus?

- Disease outbreak
- Global ecology
  Algae w/ $CaCO_3$ shells ($1°$ producers) $\xrightarrow{\text{viral infection}}$ die, sink → Carbon sink
- Diversity of life"
  - red-queen hypo: viruses will continually adapt to host's defenses via natural selection, mutation
  - high mutation rate in virus
    high RNA polymerase error rate
    lack repair enzymes
- Diversity of virus
  genomic reassortment generates new flu strains
  2 different strains infect → replication, mix → reassortment of genomic seg. → new strain!

Phylogenic & Biogeographical info to understand emerging strains
↓
continuous immunization, flu shots
geographically-predicted

17. Lytico-Bodig Disease

lytico: progressive paralysis
Bodig: parkinsonism, occasionally w/ dementia

Hypothesis by Oliver Sacks

1. Human Genetics
   colonized by Spanish, Huge bottleneck ~1% survived (heritable mutation)
   family pattern
   BUT, other ppl immigrated also developed this disease

2. Cycad - derived toxins
   seeds made into flour

3. Mineral Deficiency or metal poisoning
   Ca^{2+}, Mg^{2+} Deficiency in water, Al poisoning in soils
   Dinoflagellate toxins in local fish

4. Viral (prion or bird)
   brown tree snake killed all birds

Hypothesis (other) ("Conservation Implications of Chamorro consump of flying foxes")
Consumption of flying foxes Clark monson et al.
difference in body parts male & female eat
fruit bats of cycad toxin bioaccumulation
flying fox eradicated - overlapping the end of disease

18. Research

1. Establish Questions, hypothesis, predictions
   critial andysis of other's work, literature searching. discerning ideas
2. Design a methodology and completing it
   methodology actually test your hypothesis, analyze data
   techiques. skills practing.
3. Drawing Conclusions from findings
4. Communicate findings and conclusions

Required HW

prof Allison	in cell replication, in response to changing enviroment, requires extensive communication between cells. Understanding the transcription mechaism by which cells enters and exist cell nucleus in response to extracelluler signals
prof Saha	how cell acquire and maintain their unique identity during early vetebrate embryonic development. by focusing on nervous system
prof Bradley	single proton emission dectectors to image gene expression