

What is biodiversity and how did we get here?

WEEK 1

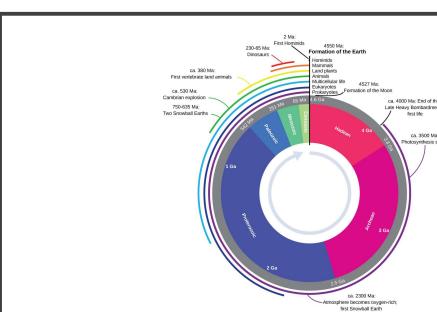
1

Part I: The origin of life

Learning goals:

- Describe origin and history of life on the planet
 - Explain events that led to the origination of life
 - Describe the Miller-Urey experiment
 - Describe the evidence of how life originated

2



3

Early atmosphere (reducing atmosphere)

carbon dioxide (CO_2)
nitrogen gas (N_2)
water vapor (H_2O)
hydrogen gas (H_2)
hydrogen sulfide (H_2S)
ammonia (NH_3)
methane (CH_4)

What is missing?

4

Fate of CO₂ in early atmosphere

The early atmosphere had high levels of CO₂, but reduced over 2 million years through the weathering of rocks by **carbonic acid rain**

This acted to cool early Earth.



5

Where did life come from?

Some of the original organic molecules may have been extraterrestrial in origin
Organic molecules may have also originated **in the early oceans** under a reducing atmosphere



6

How did life form in a reducing atmosphere?

Miller-Urey Experiment 1953

- Assembled reducing atmosphere rich in hydrogen with no oxygen gas
- Atmosphere placed over liquid water
- Temperature below 100 °C
- Simulate lightning with sparks

7

Understanding check

What is a reducing atmosphere?

How can life originate from inorganic molecules in a reducing atmosphere?

How long ago did this (likely) happen?

8

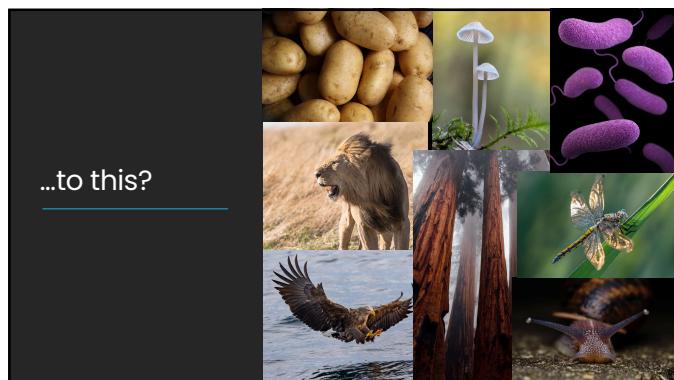
Early life

Single-celled organisms were the first life-forms
3.5 bya microfossils resembled prokaryotes
3.2 bya microfossils resembled eukaryotes ([our group](#))

9



10



11

Part II: The gene and evolution

Learning goals:

- Define evolution and population genetics
- Explain the Hardy-Weinberg principle
- Explain the five agents of evolutionary change

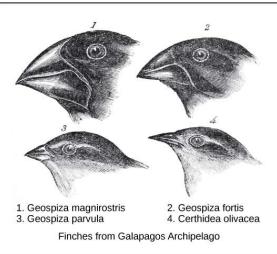
12



DNA (Deoxyribonucleic Acid)

- Base pairs of nucleic acids
 - Adenine (A)
 - Thymine (T)
 - Cytosine (C)
 - Guanine (G)
- Carriers of genetic information (**traits**)
- Passed down by parents to offspring
- Can change over time (**mutation**)

13



Genes: Sequences of DNA that codes for a specific trait

Alleles: Specific base-pair sequences for a particular gene that produces a particular **phenotype**

Genetic variation: Differences in alleles found among individuals in a population

This can lead to differences in traits among individuals

Evolution: Change (in population traits) through time

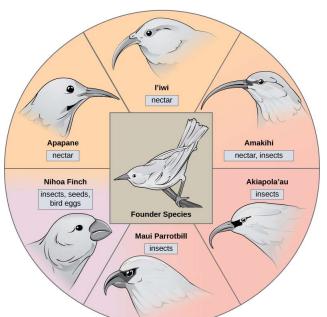
Gregor Mendel (1822 – 1884): Traits are passed down from parent to offspring

14

How does genetic variation lead to evolution: Natural selection

Charles Darwin

- Proposed **Natural Selection**
- Change happened at the **population level**



15



Individuals with advantageous physical or behavioral characteristics are more likely to survive and reproduce than those without such characteristics



As the frequency of these characteristics increases in the population, the nature of the population as a whole will gradually change.

Theory of Natural Selection

16

Understanding check

What provides the code for specific traits in individuals?

Why is it important that traits are passed on to offspring?

How does this relate to evolution acting at the population level?

17

Population genetics

The study of genes in populations

Evolution leads to changes in genetic composition within populations

Natural populations contain substantial genetic variation



18



19

If all things are equal, gene frequencies will not change over generations within populations

A population that is not experiencing changes in gene frequencies is said to be in **Hardy-Weinberg equilibrium (HWE)**

If a population is in HWE we can assume:

1. No mutations
2. No genes from other sources (immigration or emigration)
3. Mating is random
4. The population is very large
5. No selection occurs

We can use these **assumptions** to test for changes in gene frequencies observed in real-world populations

20

Genetic Terms

- **Phenotype:** visible trait (eye color)
- **Genotype:** underlying genes/alleles that contribute to expression of the phenotype
- **Alleles:** Region of a gene that codes for a phenotype (one per parent in diploid species)
 - **Dominant:** Allele, when present, that expresses phenotype
 - **Recessive:** Allele, when the dominant is absent, expresses alternative phenotype
 - **Homozygous:** Two of the same allele (two dominant or two recessive)
 - **Heterozygous:** One dominant, one recessive

21

Gene frequencies (mating pair)

Start with a visible trait (**phenotype**)

- Coat color
- Black (B) = **dominant allele**
- White (b) = **recessive allele**
- What are the possible combinations?

NOTE: Mammals are diploid (i.e., have two pairs of chromosomes)



22

Building the Hardy-Weinberg Equation

(1) Allele Frequencies

Allele frequencies:

p = frequency of the dominant allele

q = frequency of the recessive allele

- Note
 - Frequency is the proportion out of 1.0
 - All frequencies need to add up to 1.0

23

Building the Hardy-Weinberg Equation:

(2) Genotype frequencies

Homozygous dominant:

Homozygous recessive:

Heterozygote:

24

Hardy-Weinberg Equation

25

Hardy-Weinberg Equation

$$p^2 + 2pq + q^2 = 1$$

26



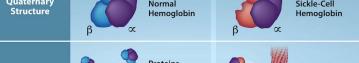
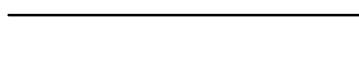
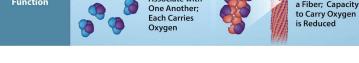
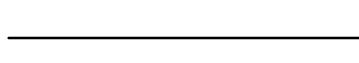
The assumptions of HWE are rarely met in real-world populations

- Changes in HWE can lead to evolution
- Mutation
 - Immigration
 - Choosy mating (non-random mating)
 - Natural selection

27

Mutation

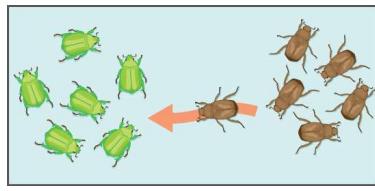
Mutations are the random changes in DNA bases
This is the ultimate source of variation but is very rare
It is important to remember, however, that the likelihood of a particular mutation occurring is not affected by natural selection

	Normal	Sickle-Cell
Primary Structure		
Secondary and Tertiary Structures		
Quaternary Structure		
Function	 Proteins Do Not Associate with One Another; Each Carries Oxygen	 Proteins Aggregate Into a Fiber; Capacity to Carry Oxygen is Reduced

28

Gene flow (immigration and emigration)

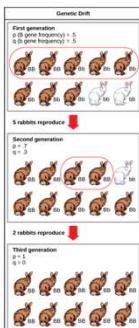
Gene flow: the movement of alleles from one population to another



29

Genetic drift

Genetic drift: frequencies of particular alleles may change due to **random chance** in small populations



30

Choosey mating

Mates may be chosen based on specific phenotypes

- This can lead to selection for more extreme phenotypes
- E.g., female birds of paradise prefer males with bright colors and large plumage

Small populations may experience **inbreeding** due to lack of available mates



31

Natural selection

Selection can produce **adaptive evolutionary changes**. Adaptation to avoid predators, match climate conditions, resistance to pesticides and antibiotics

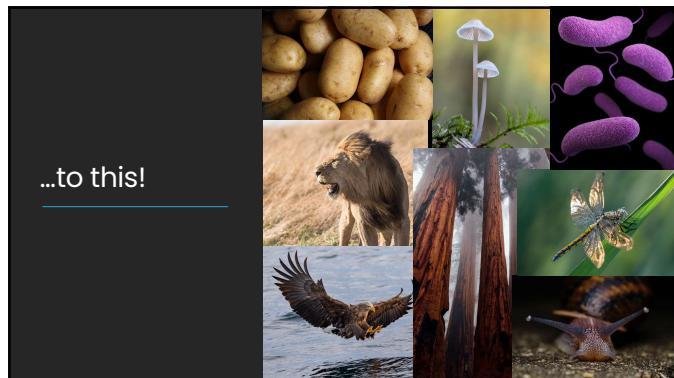


32

And that is how we got from this...



33



34

Part III: Organizing life

Learning goals:

- Describe the evidence that supports Darwin's views on evolution (*i.e.*, the Modern Synthesis)
- Define a species/biological species concept
- Explain ways that species are isolated from each other
- Discuss how common ancestry is determined
- Compare and contrast ancestral vs derived traits
- Construct and explain a cladogram

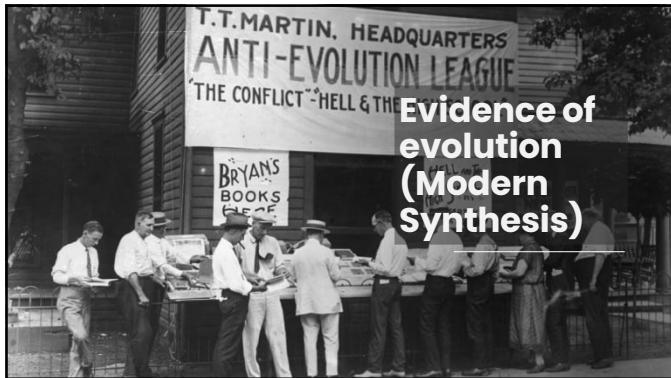
35

 Individuals with advantageous physical or behavioral characteristics are more likely to survive and reproduce than those without such characteristics

 As the frequency of these characteristics increases in the population, the nature of the population as a whole will gradually change.

REFRESHER: Theory of Natural Selection

36



37



Age of the Earth

Evolution takes a really long time

The earth is over 4.5 billion years old

- Plenty of time for evolution to act to produce the biodiversity we see today

38

The fossil record:
transitional forms and
vestigial structures



39

Mechanism of 'stored' and transferred changes

A series of evolutionary changes over time should involve a continual accumulation of genetic changes in the DNA (e.g. mutations)



40

What is a species?

A group of organisms that occur together at a single locality that are connected in such a way as to be unique to any other group.

Sympatric species:

- Occur together in an area
- Are distinctive entities
- Are phenotypically different
- Utilize different parts of the habitat
- Behave separately



41

The biological species concept

Groups of actually or potentially interbreeding natural populations which are reproductively isolated from other such groups

Reproductive isolation: Do not mate with each other or do not produce fertile offspring

- Prezygotic isolation
- Postzygotic isolation

42

Ecological isolation

Species occur in the same area, but they occupy different habitats and rarely encounter each other.




(a) *Gryllus pennsylvanicus* prefers sandy soil.
 (b) *Gryllus firmus* prefers loamy soil.

43

Behavioral isolation

SPECIES DIFFER IN THEIR MATING RITUALS



44

Temporal isolation

Species reproduce in different seasons or at different times of the day

These two related species of frogs reproduce at different times of the year

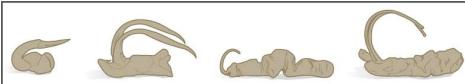



(a)
 (b)

45

Mechanical isolation and/or prevention of gamete fusion

- Morphological differences preventing mating.
- If copulation can happen, gametes of one species function poorly with the gametes of another species



46

Postzygotic isolating mechanisms

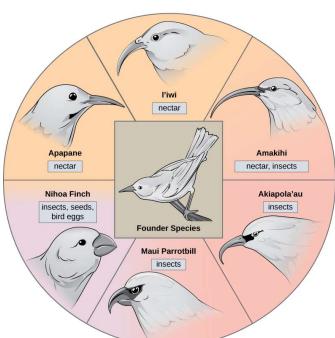
Hybrid embryos do not develop properly
Hybrid adults do not survive in nature
Hybrid adults are sterile or have reduced fertility



47

Speciation

1. Initially identical populations must diverge
2. Reproductive isolation must evolve to maintain these differences



48

The slide features a hand-drawn tree diagram on the left and a photograph of a large, gnarled tree on the right.

Hand-drawn tree diagram:

- Roots: A, B, C
- Trunk: D
- Branches: E, F, G, H, I, J, K, L, M, N, O, P, Q, R, S, T, U, V, W, X, Y, Z
- Leaves: 1, 2, 3, 4, 5, 6, 7, 8, 9, 10, 11, 12, 13, 14, 15, 16, 17, 18, 19, 20, 21, 22, 23, 24, 25, 26, 27, 28, 29, 30, 31, 32, 33, 34, 35, 36, 37, 38, 39, 40, 41, 42, 43, 44, 45, 46, 47, 48, 49, 50, 51, 52, 53, 54, 55, 56, 57, 58, 59, 60, 61, 62, 63, 64, 65, 66, 67, 68, 69, 70, 71, 72, 73, 74, 75, 76, 77, 78, 79, 80, 81, 82, 83, 84, 85, 86, 87, 88, 89, 90, 91, 92, 93, 94, 95, 96, 97, 98, 99, 100, 101, 102, 103, 104, 105, 106, 107, 108, 109, 110, 111, 112, 113, 114, 115, 116, 117, 118, 119, 120, 121, 122, 123, 124, 125, 126, 127, 128, 129, 130, 131, 132, 133, 134, 135, 136, 137, 138, 139, 140, 141, 142, 143, 144, 145, 146, 147, 148, 149, 150, 151, 152, 153, 154, 155, 156, 157, 158, 159, 160, 161, 162, 163, 164, 165, 166, 167, 168, 169, 170, 171, 172, 173, 174, 175, 176, 177, 178, 179, 180, 181, 182, 183, 184, 185, 186, 187, 188, 189, 190, 191, 192, 193, 194, 195, 196, 197, 198, 199, 200, 201, 202, 203, 204, 205, 206, 207, 208, 209, 210, 211, 212, 213, 214, 215, 216, 217, 218, 219, 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49

Systematics: The study of evolutionary relationships

50

Analogous structures like bird, insect, and bat wings do not show common ancestry.

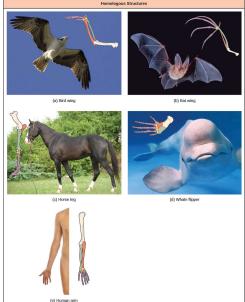
(a) Bat wing

(b) Bird wing

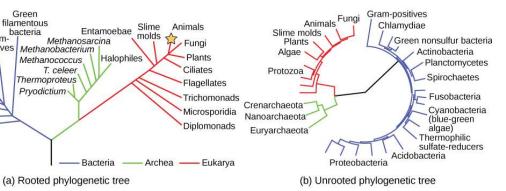
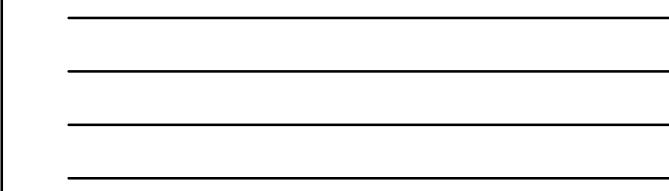
(c) Insect wing

51

Homologous structures like the arms of mammals do show common ancestry



52

Cladograms | Map evolutionary relationships between different species

53

Cladistics: building a cladogram

Ancestral characteristic: Inherited from the most recent common ancestor

Derived characteristic: Arose more recently and is shared only by a subset of species

Traits to study need to be identified

Use a trait that has a recognizable character states

Morphology

Physiology

Behavior

DNA

54

Examples of traits

- **Ancestral trait:** jaws in mammals
- **Shared derived trait:** hair in mammals

55

Taxonomy: The naming and organization of evolutionarily related groups.

- Species (Genus + specific epithet)
- Genus
- Family
- Order
- Class
- Phylum
- Kingdom
- Domain

56

Taxonomy: The naming and organization of evolutionarily related groups.

- Species (Genus + specific epithet)
- Genus
- Family
- Order
- Class
- Phylum
- Kingdom
- Domain

Levels we will cover in class

57
