# Phylogeny Exhibits and Understanding Geological Time

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Introduction

GeoTAT Question 3a: The illustration below represents a fossil bearing rock exposure. The fossils are the remains of bones from the feet of unidentified species of mammals. Try and describe the process that took place between rock layer 1 to layer 4.

5
4
3
2
1

Evolution **and** Time Vector

2
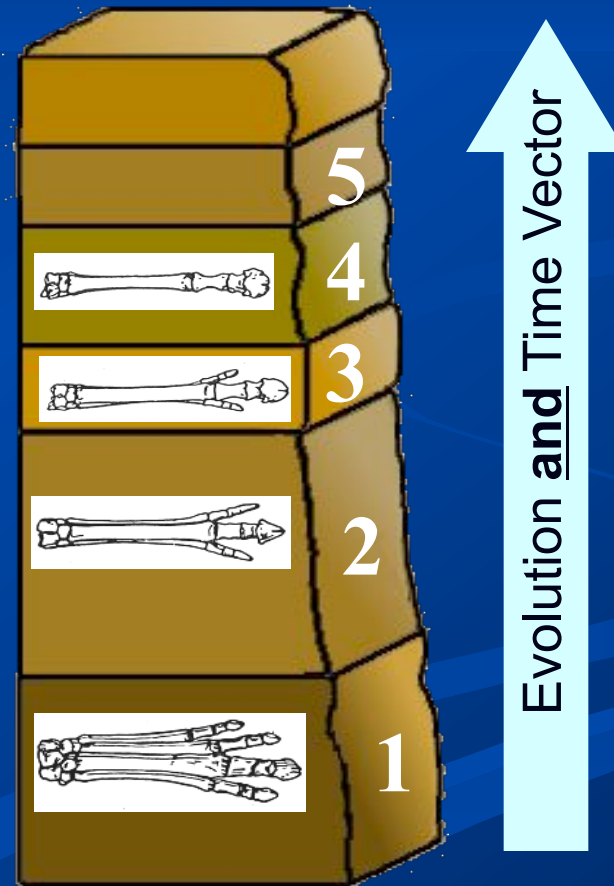
Introduction

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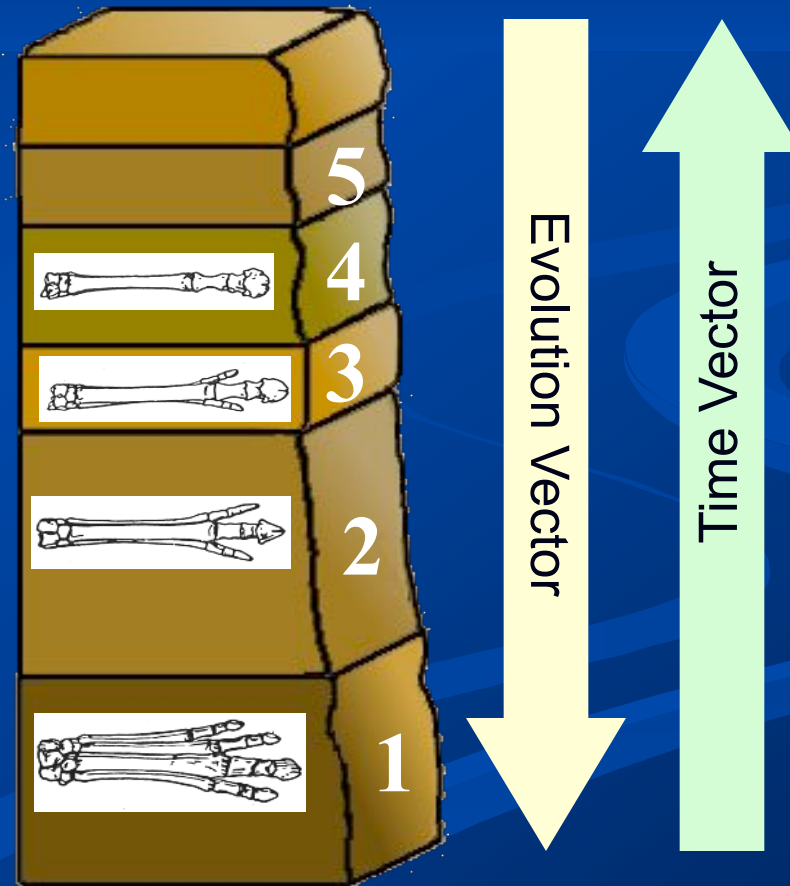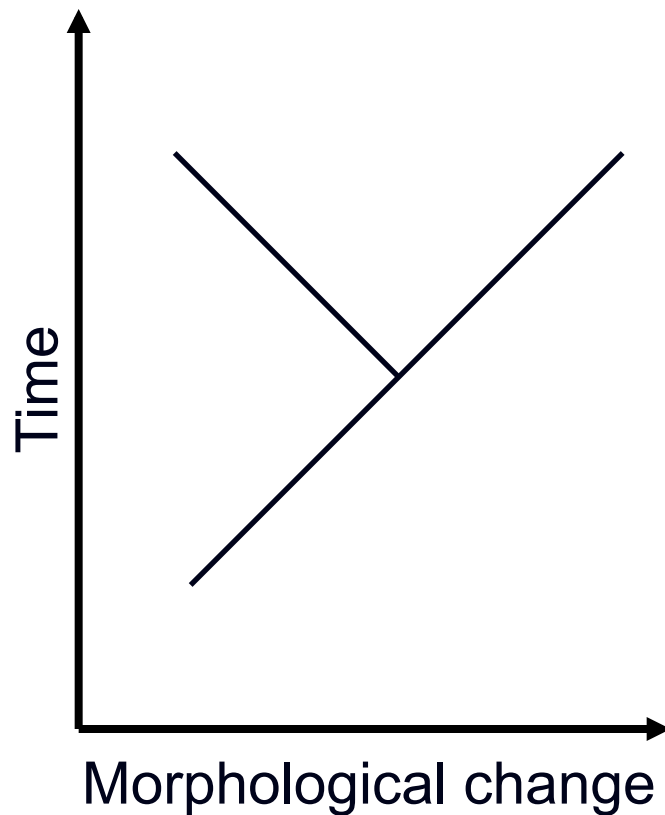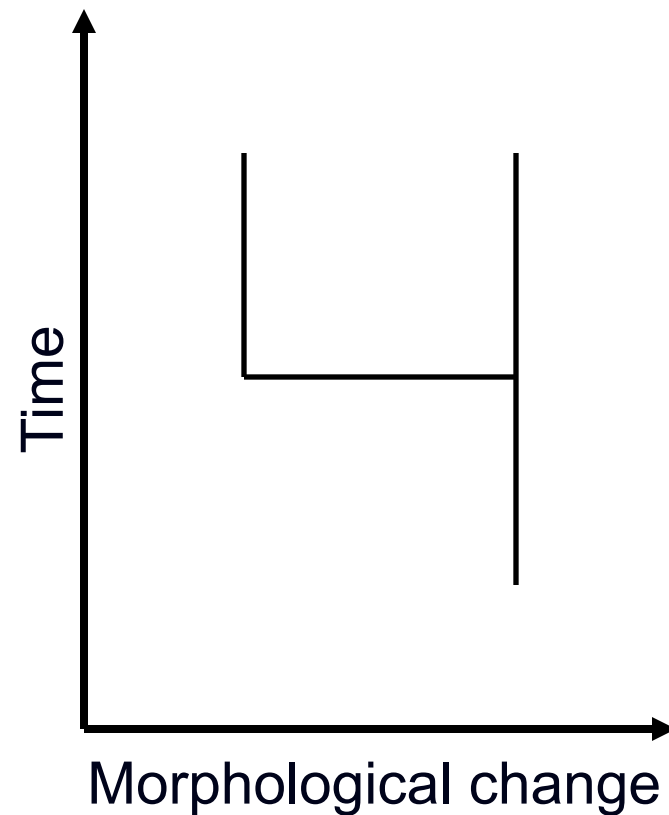
Introduction

Illustration from Ridley (2003) discussing rates of evolution:
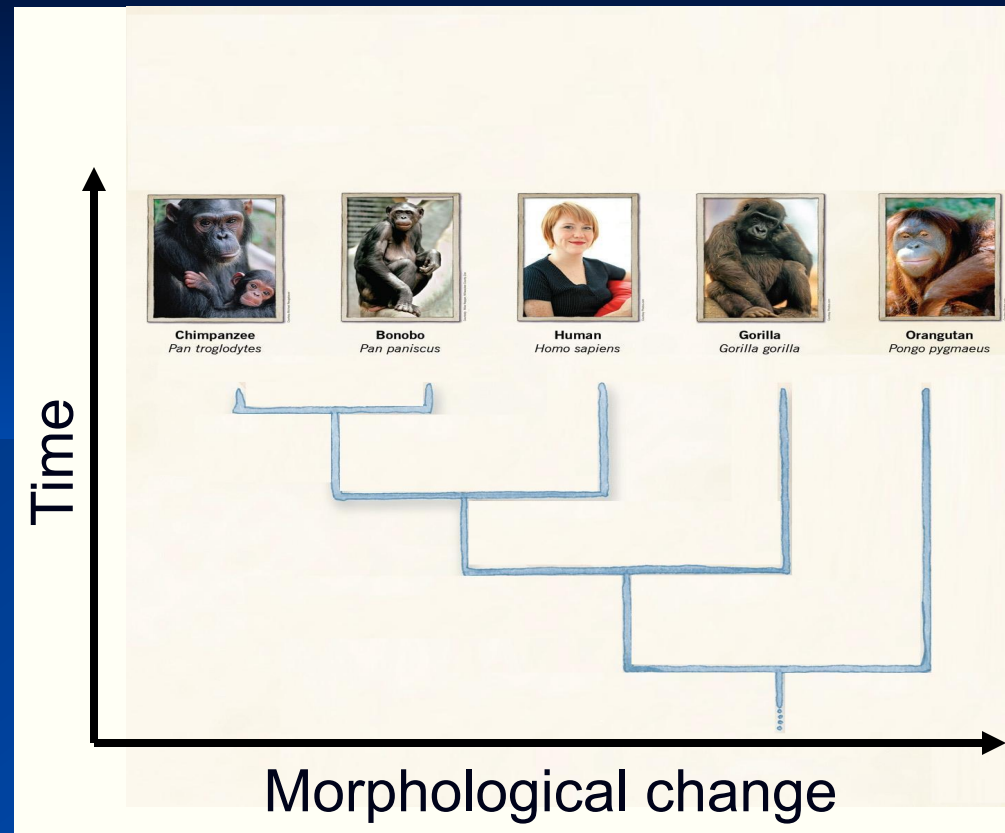
Introduction

Hypothesis: Understanding the true direction of the Vector of (Geological) Time affects one's ability to understand phylogenetic trees. In it's **explicit absence** people are more likely to read phylogeny along the tips.

The Research

Purpose: To understand how people understand phylogenetic relationships in (geological) time.

Research Questions: How do the subjects tested understand:

1. Temporal nature of local branching events in phylogenetic trees

2. The evolutionary relationships amongst taxa (based on local branching events)

3. Temporal vector of a phylogenetic tree

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Research Sample

School	Background	Female	Male	Age
MS stud. (Sec. sys.)	Integrated Science	5	1	13-15
HS stud. (Sec. sys.)	5-Science 4-Humanities	4	5	16-18
Adult (Sec. sys.)	Uni. Stud. / Univ. grads	6	9	24-75

Method

Quasi-Experimental Method: In depth semi-structured interviews in which the subjects interpret visual representations of evolution: phylogenetic trees.
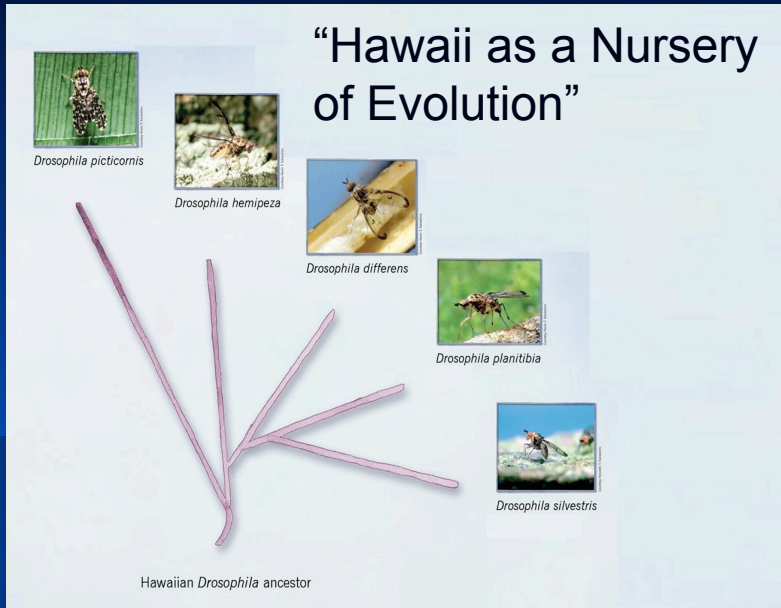
- Classification of Trees Used in this study:

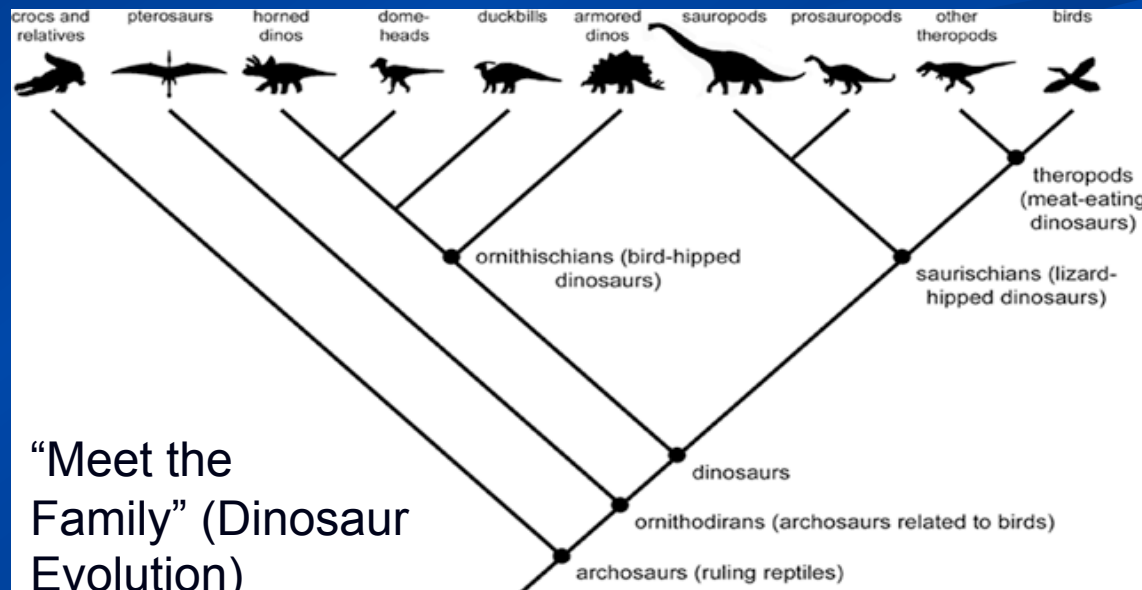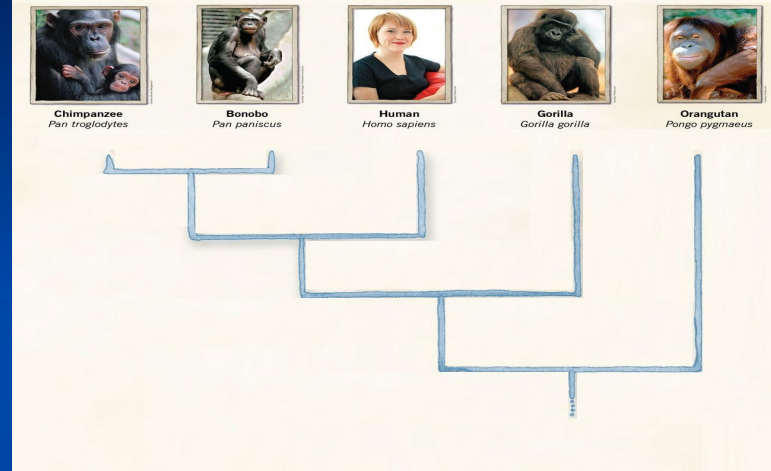|	Familiar scenario	Unfamiliar scenario
Extinct organisms	"Meet the Family" (Dinosaur Evolution)	---
Extant organisms	"Our closest living ancestors" (Hominid Evolution)	"Hawaii as Nursery of Evolution" (*Drosophilae*)

Method

"Hawaii as a Nursery of Evolution"

"Our closest living ancestors"

"Meet the Family" (Dinosaur Evolution)

Method

Sample Interview question:

"Our Closest Living Ancestors"
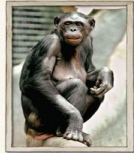
Chimpanzee
Pan troglodytes

Bonobo
Pan paniscus

Human
Homo sapiens

Gorilla
Gorilla gorilla

Orangutan
Pongo pygmaeus
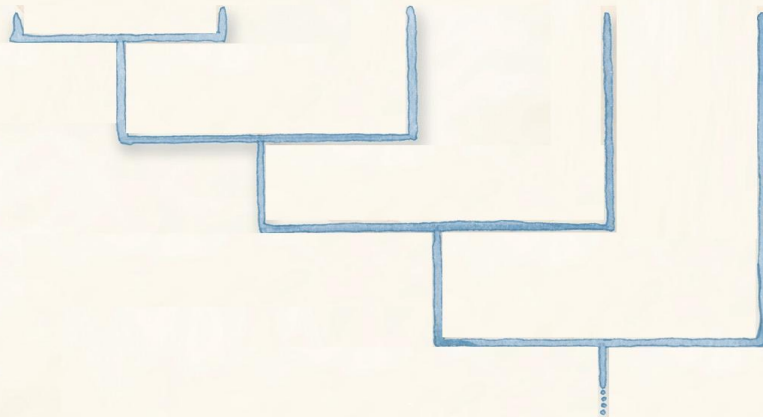
Questions:

1. Based on this tree, which organism is (evolutionarily) "closest" to the Chimpanzee? Human, Gorilla or Orangutan? Please provide your reasons for you answer.

2. In what direction does time flow in this diagram? Please provide your reasons for your answer.

Method

Analysis:

- Questions: Classified into three super categories (based on research questions)
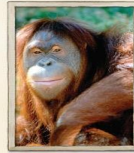
- Answers: Classified into 7 **conceptual categories** based on content analysis

- Analysis of answers: each of the 7 conceptual categories classified into **3 levels of evolutionary thinking** and **3 levels of non-evolutionary thinking**

- Correlations: Vector of time vs. different levels of evolutionary thinking

Method

Conceptual Categories based on content analysis

Parameters	Description
"Branching" points	Concepts and ideas that represent branching points.
Evolution	Expressions which represent evolutionary understanding.
Visual	Visual elements in the diagram (ex. Taxa).
Direction	Directions of the vector of time.
Time	Concepts and phrases that represent perception of time.
Religious sensibilities	Ideas that relate to religious understanding.
Former knowledge	Ideas based on former knowledge.

Results

Table 1: Percentages of answers on the question: "In what direction does time flow in the following (phylogenetic) diagram".

Tree Subject	Type	Correct (1-direction)	Semi-Correct (2-direction)	Incorrect
Hominids	Tree	36%	26%	48%
Drosophilae	Ladder	25%	15%	60%
Drosophilae	"Fan"	47%	9%	44%
Dinosaur	Ladder	27%	7%	68%

Note:

Adults significantly better ($p < .05$) than students for both Drosophila Ladder and Fan diagrams.

Results

"Meet the Family" (Dinosaur Evolution)
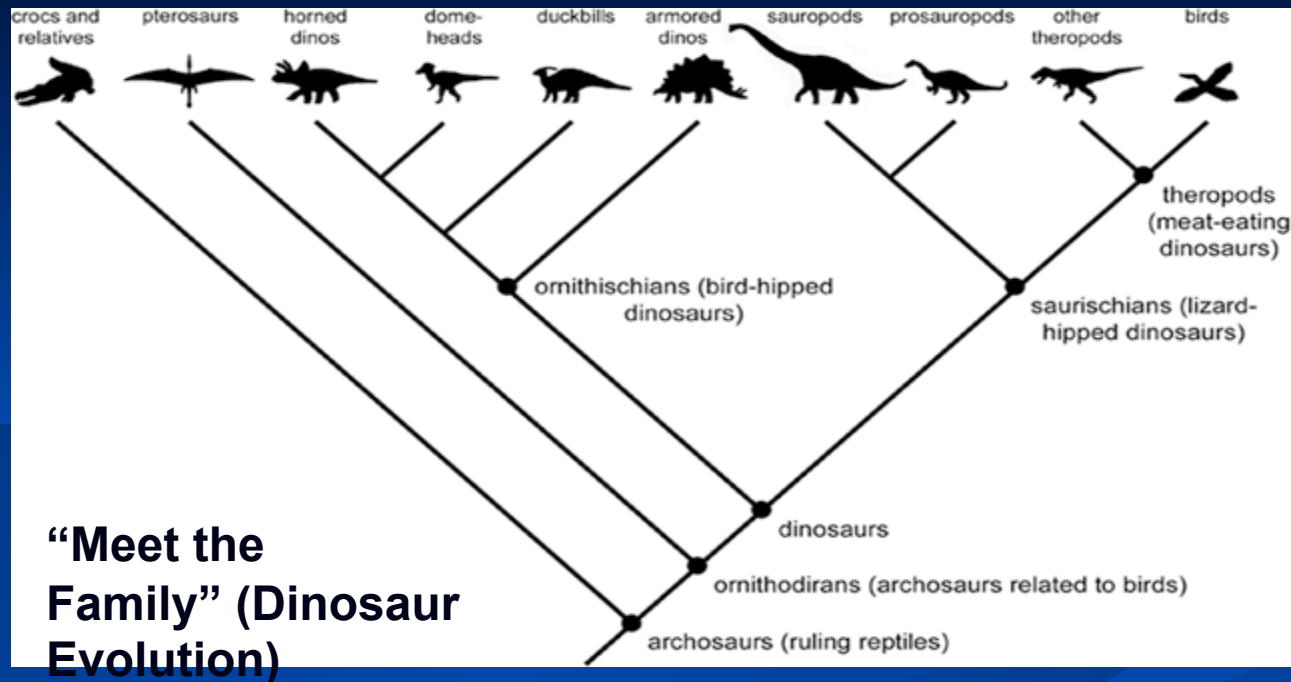
Sources of misunderstanding:

• Visual: Size of terminal taxa ("Cope's Law")

• Visual: Familiarity of Taxa (Crocodiles vs. Dinosaurs)

• Evolution: From extinct to extant taxa

• Tendency to speculate incorrectly when scenario familiar

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Results

"Our closest living ancestors"

Chimpanzee *Pan troglodytes* — Bonobo *Pan paniscus* — Human *Homo sapiens* — Gorilla *Gorilla gorilla* — Orangutan *Pongo pygmaeus*
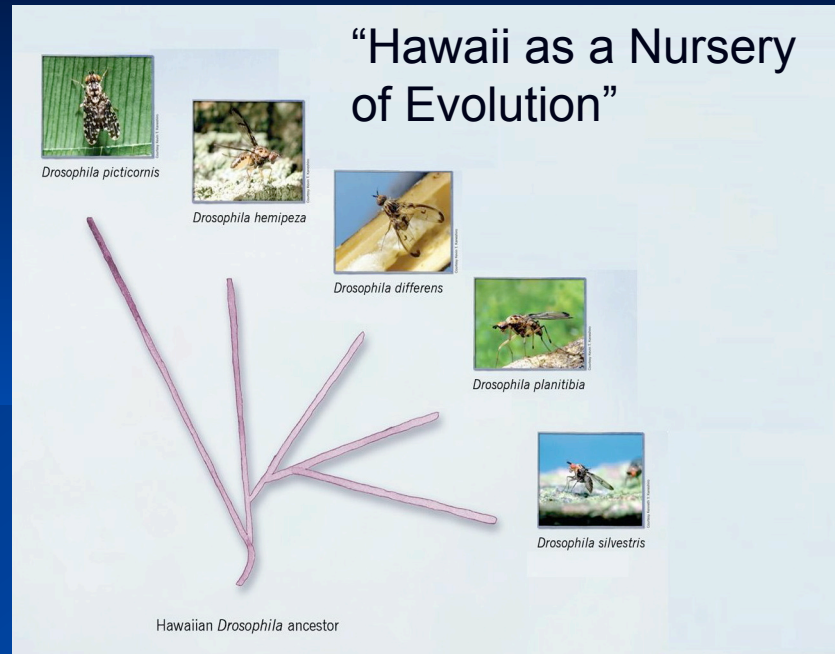
Sources of misunderstanding:

• Evolution: Hominid evolution leads to man

• Former knowledge: Primitive to advanced features

• Note: Rotation of figures had no appreciable affects

• Tendency to speculate incorrectly when scenario familiar

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Results

"Hawaii as a Nursery of Evolution"

Source of error:

• Visual: Length, angle and direction of branches

• Evolution: Primitive appearance

• Former knowledge: Less protected body

Results

Table 2: Spearman Coefficients between "Evolutionary thinking" and knowledge about the temporal vector of time in phylogenetic trees. (Comparison amongst entire sample).

| Tree Subject	Type	Spear. rho	p
Hominids	Tree	0.112	0.701
Drosophilae	Ladder	0.756	0.001
Drosophilae	"Fan"	0.736	0.002
Dinosaur	Ladder	0.567	0.048

Results

Table 3: Spearman Coefficents between "Evolutionary thinking" and knowledge about the temporal vector of time in phylogenetic trees. (Comparison between adults and students)

Tree Subject	Type	Adults		Students	
		Spear. Rho	p	Spear. rho	p
Hominids	Tree	0.188	0.722	-0.022	0.9588
Drosophilae	Ladder	**0.943**	0.0004	0.686	0.049
Drosophilae	"Fan"	**0.801**	0.005	0.694	0.03
Dinosaur	Ladder	0.452	0.261	**0.884**	0.047

Results

Hawaii as a Nursery of Evolution

More than 800 species of *Drosophila* flies live on the islands of Hawaii and nowhere else on Earth. They may all descend from a single pregnant fly that came there several million years ago.
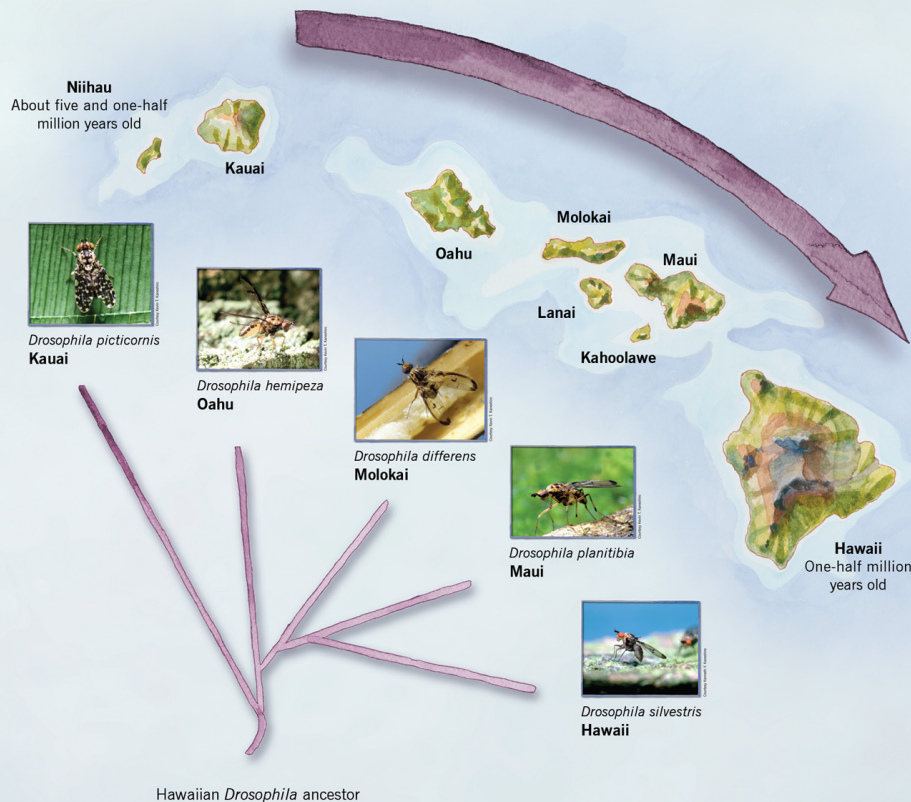
Questions:

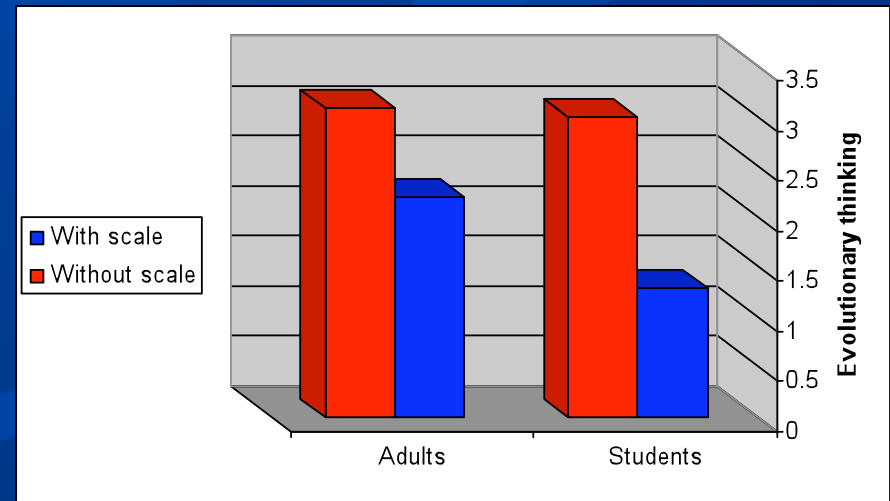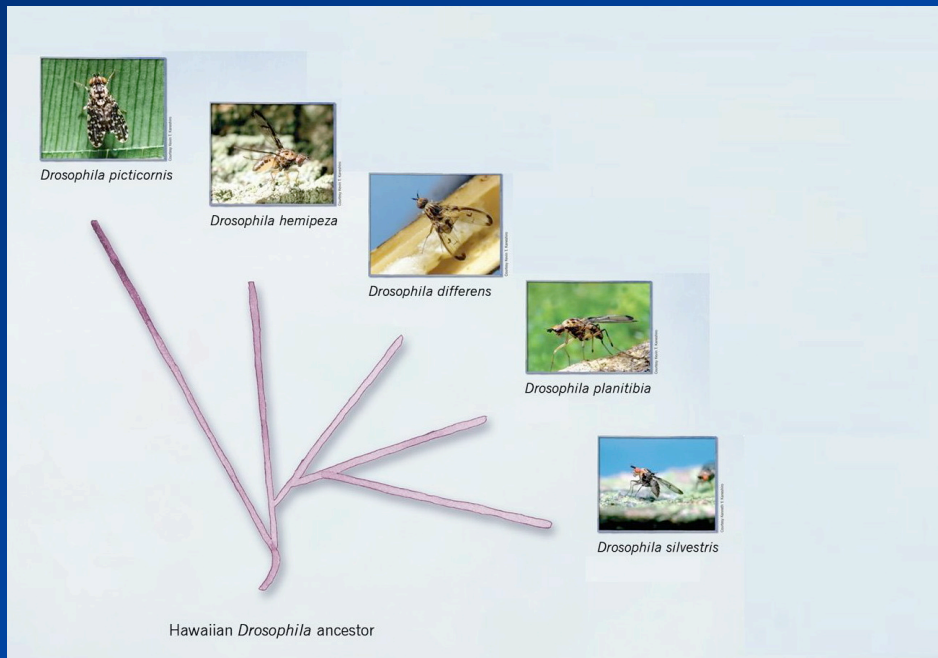1. Based on this tree, which evolutionary event occurred first, the evolution of D. plantibae or D. silvestris?

Please provide the reasons for your answer.

Results

Questions:

1. Based on this tree, which evolutionary event occurred first, the evolution of D. plantibae or D. silvestris?

Please provide the reasons for your answer.

Drosophila picticornis
Drosophila hemipeza
Drosophila differens
Drosophila planitibia
Drosophila silvestris
Hawaiian *Drosophila* ancestor

With scale
Without scale

Adults   Students

Evolutionary thinking

Summary

❖   There appears to be a strong correlation between understanding the direction of the **vector of time** and the ability to correctly explain specific evolutionary problems as represented in phylogenetic diagrams.
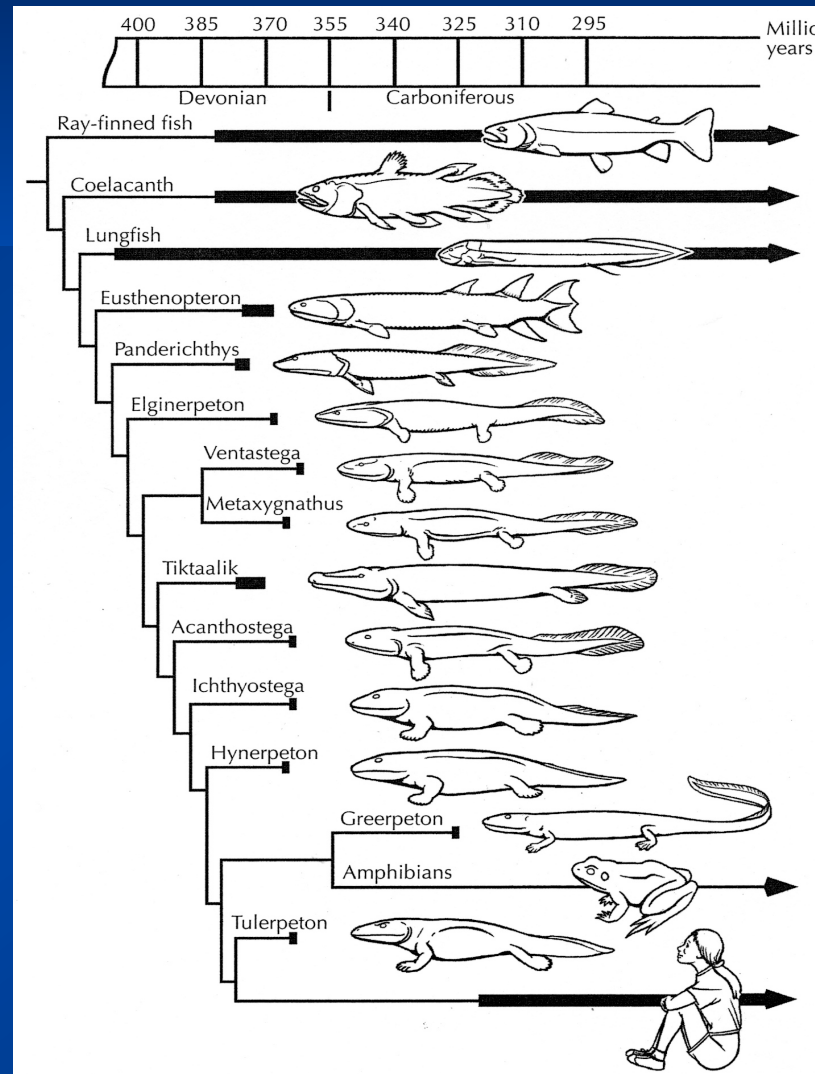
❖ Possible reasons:

    • Correlated with understanding of common ancestor

    • Ability to search deeply within diagrams

    • Ability to ignore extraneous clues along tips

❖ Implications:

    •Providing explicit temporal information (if possible) and/or understandable common ancestry could clue visitors into a deeper search of trees providing greater understanding.

    •Soliciting temporal information might serve as a quick indicator of evolutionary misconceptions.

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Post-Script

From Prothero and Buell (2007), *Evolution: What the Fossils Say and Why It Matters.*

Post-Script (2)

1) Dinosauria