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Evolutionary Tree of Life: Building Phylogenetic Relationships

BIOS4YOU
AR 2.0

BIO-INSPIRED STEM TOPICS FOR ENGAGING YOUNG GENERATIONS
THANKS TO THE USE OF AUGMENTED REALITY

Project Number: KA220-BW-23-30-126516

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General topic of the learning path	Evolutionary Biology and Bio-Inspired Systems
Specific name of the learning unit	Evolutionary Tree of Life – How Species Are Related
Age of the target users	14-18 years
Requirements for the learner	Basic knowledge of biology, including concepts such as species, adaptation, and evolution. Familiarity with simple digital tools is recommended. No prior experience with phylogenetics or Augmented Reality is required.
Description of the learning unit	This unit introduces students to the Tree of Life, explaining how species are classified based on their genetic, morphological, and evolutionary relationships. Students explore how scientists use phylogenetics to identify common ancestry and reconstruct evolutionary relationships between organisms. To make the learning process interactive and immersive, students use Augmented Reality (AR) to build, manipulate, and analyze a phylogenetic tree. Through hands-on AR activities, learners visualize evolutionary connections between species, explore patterns of divergence, and understand how adaptation and natural selection contribute to biodiversity.
Subject: Parties involved	Biology, Evolutionary Science, Bioinformatics, Augmented Reality
Keywords	Phylogeny, Tree of Life, evolutionary relationships, common ancestry, biodiversity, homologous traits, Augmented Reality, bio-inspiration, systems thinking
Key qualifications, skills and knowledge that can be acquired	• Understanding of phylogenetic concepts and evolutionary relationships • Ability to interpret and construct phylogenetic trees • Skills in comparing biological traits and evaluating evidence • Development of systems thinking and bio-inspired reasoning

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	• Experience with AR-supported inquiry-based and collaborative learning
Resources and didactic aids used	• Augmented Reality platforms (e.g. Delightex) • 3D biological models (e.g. organisms and evolutionary structures from Sketchfab, Delightex) • Educational videos and online resources on phylogeny • Digital devices (tablets, smartphones, computers) • Teacher-guided discussion and collaborative activities
Assessment criteria and evaluation	Students are assessed through participation in AR-based activities, the construction and interpretation of phylogenetic trees, and their ability to justify evolutionary relationships using evidence. Evaluation focuses on conceptual understanding, analytical reasoning, collaboration, and reflective thinking. Formative assessment is supported through observation, discussion, and AR-based tasks, while final evaluation includes student-created models and explanations.

Introduction

Life on Earth is extremely diverse, yet all living organisms are connected through evolution. The evolutionary Tree of Life helps scientists understand these connections by revealing shared ancestry and evolutionary relationships. This unit introduces students to phylogenetic thinking and shows how scientists build and interpret evolutionary trees to explain biodiversity.

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Explore - Understanding Evolutionary Relationships and Common Ancestry

1.1 What Is the Tree of Life?

The Tree of Life is a scientific model that represents the evolutionary relationships between organisms. Rather than ranking species as “more” or “less” evolved, it shows how all living beings are connected through common ancestors. Each branch represents evolutionary change over time.

1.2 What Is Phylogeny?

Phylogeny is the study of evolutionary relationships between organisms and how different species are connected through common ancestry. Scientists use phylogeny to determine how closely related organisms are by comparing **shared characteristics**, such as anatomical features, developmental patterns, and **genetic information**. Species that share more traits inherited from a common ancestor are considered more closely related.

Phylogenetic trees are visual models that represent these relationships. They are not fixed diagrams, but **scientific hypotheses** based on the best available evidence at a given time. As new data become available—such as fossil discoveries or advances in DNA analysis—phylogenetic trees can be revised and improved. This makes phylogeny a dynamic and evidence-based field that reflects how scientific understanding evolves over time.

Understanding phylogeny helps scientists explain biodiversity, trace the origins of species, and identify evolutionary patterns. It also teaches an important scientific principle: **biological knowledge is built through comparison, evidence, and continuous refinement**, rather than absolute or unchanging answers.

Below are examples of phylogeny:

1. Tree of life of amniotes that includes reptiles, birds, and mammals. All these classes of vertebrates evolved from the same ancestral form of the stem reptiles at the bottom of the tree (Sourse: https://www.researchgate.net/figure/Tree-of-life-of-amniotes-that-includes-reptiles-birds-and-mammals-All-these-classes-of_fig2_323780429)

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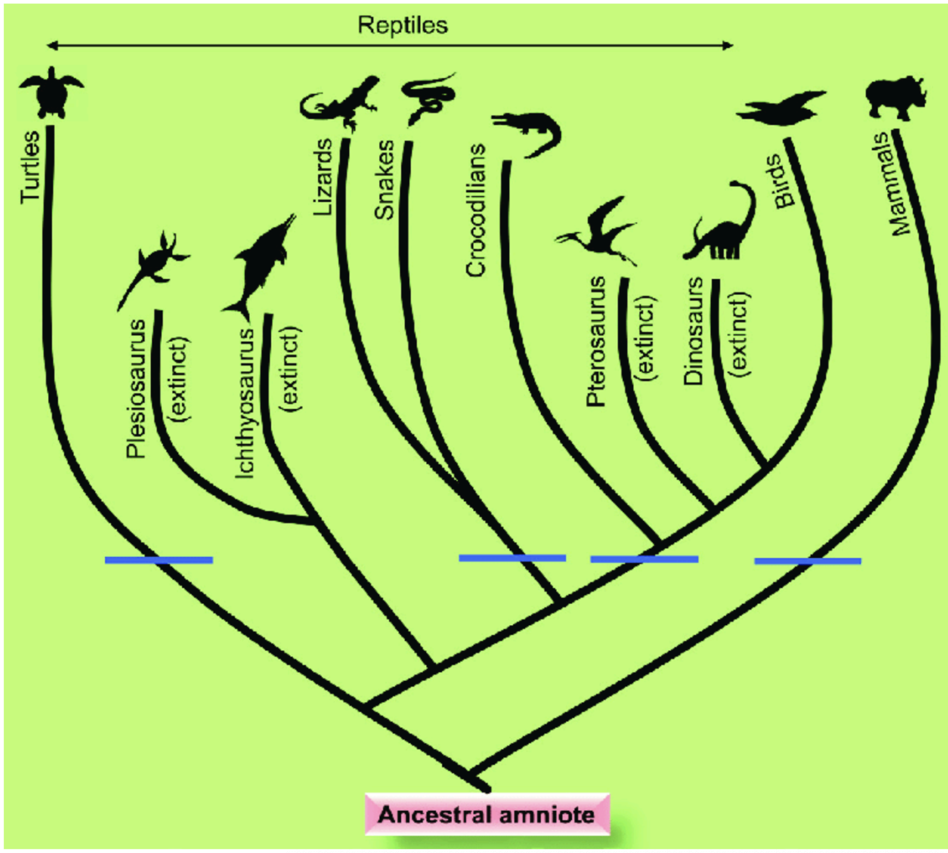
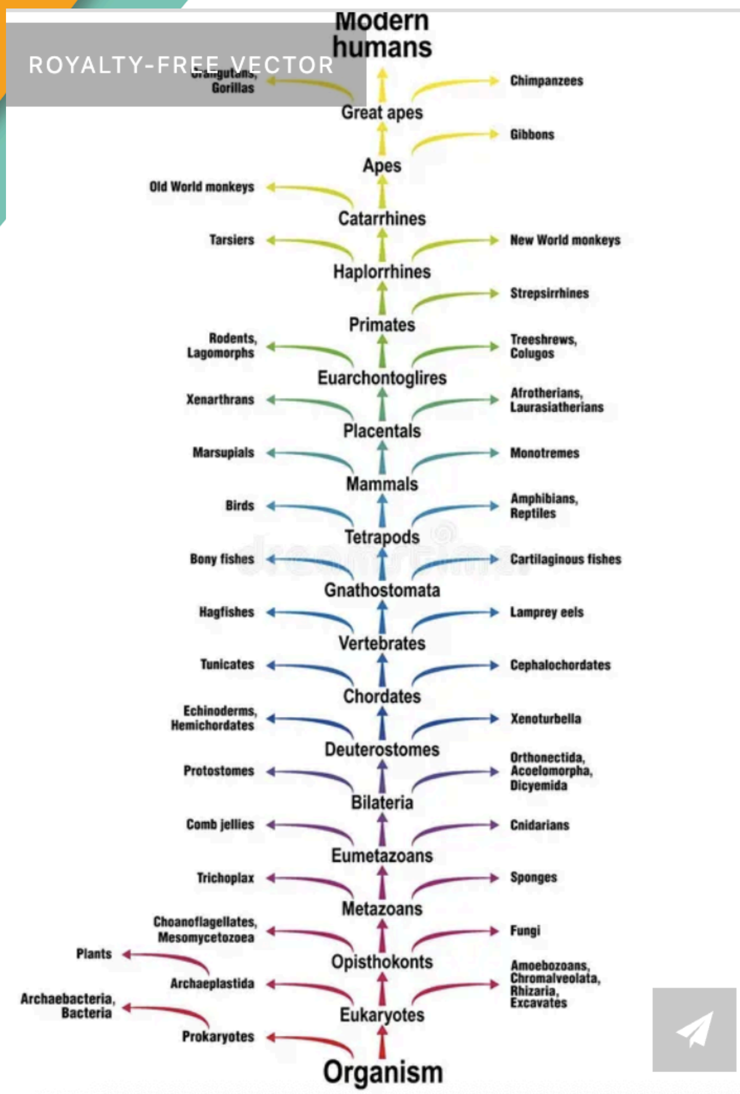


2. Tree Of Life Human Evolution Biology Species Classification. Tree of life of all living beings. Phylogenetic tree of biological science with trunk orders/suborders and branches related life forms. Classification from simple organisms to modern humans. (Source: https://www.dreamstime.com/tree-life-human-evolution-biology-species-classification-tree-life-all-living-beings-phylogenetic-tree-biological-image131543711)



3. Phylogenetic history of the Hominidaedliving apes and people (Source: https://www.researchgate.net/figure/Phylogenetic-history-of-the-Hominidaedliving-apes-and-people-Dates-are-based-on-genomic_fig1_317314464)

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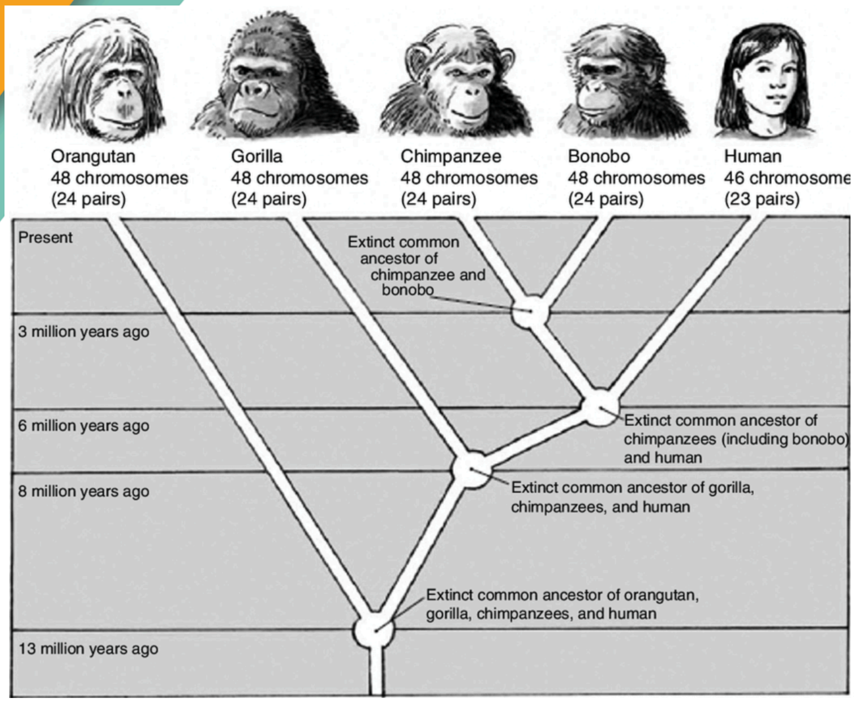

1.3 Evidence Used to Build Phylogenetic Trees

Phylogenetic relationships are reconstructed using multiple types of evidence, including:

- morphological traits (body structure and form),
- fossil records,
- genetic and molecular data,

  developmental and behavioral characteristics.

To support understanding of how these different data sources are combined, students may explore a short educational video (*see below*) that visually explains how scientists build phylogenetic trees using real evidence. This multimedia resource helps clarify abstract concepts and prepares learners for the practical construction of evolutionary relationships in the Execute phase.

Combining these data sources allows scientists to build more accurate and reliable evolutionary models.

Video "[Intro to Cladograms and Phylogenetic Trees](https://www.youtube.com/watch?v=cIQobFHFwcM)"
(https://www.youtube.com/watch?v=cIQobFHFwcM)

After observing how scientists use evidence to construct phylogenetic trees, students apply the same principles by analyzing traits and building their own evolutionary models using Augmented Reality.

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1.4 Homologous vs. Analogous Traits

Not all similarities between organisms indicate close evolutionary relationships. Some traits may look similar on the surface but have very different evolutionary origins. For this reason, scientists distinguish between **homologous** and **analogous** traits when building phylogenetic trees.

Homologous traits are characteristics inherited from a **common ancestor**, even if they serve different functions today. For example, the forelimbs of humans, bats, and whales have different shapes and uses, but they share the same underlying bone structure. These similarities provide strong evidence of shared ancestry and are therefore highly valuable for reconstructing evolutionary relationships.

Analogous traits, on the other hand, perform similar functions but evolved **independently** in different evolutionary lineages. For example, the wings of birds and insects both enable flight, but they developed from different ancestral structures. Analogous traits often arise due to similar environmental pressures rather than close genetic relationships.

Understanding the difference between homologous and analogous traits is essential for correctly interpreting phylogenetic trees. Mistaking analogous traits for homologous ones can lead to incorrect conclusions about relatedness. By carefully analyzing which traits reflect shared ancestry, scientists are able to construct more accurate models of evolution and better understand how different forms of life are connected.

1.5 How to Read a Phylogenetic Tree

Phylogenetic trees show evolutionary relationships through branching patterns that represent how species diverged from common ancestors over time. Each branching point, or node, represents a common ancestor shared by the organisms that branch from it. Species that share a more recent common ancestor are considered more closely related than those whose common ancestor lies deeper in the tree.

The length or position of branches does not indicate that one organism is more advanced or “better evolved” than another. Instead, branches reflect patterns of evolutionary divergence and shared history. All living species at the tips of the branches have been evolving for the same amount of time.

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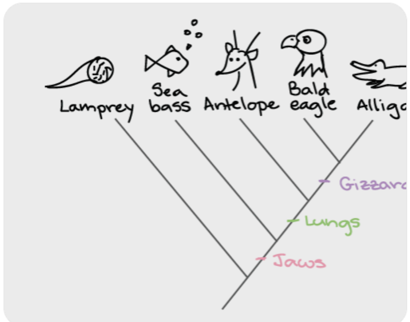
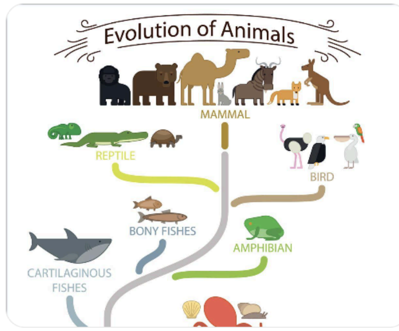
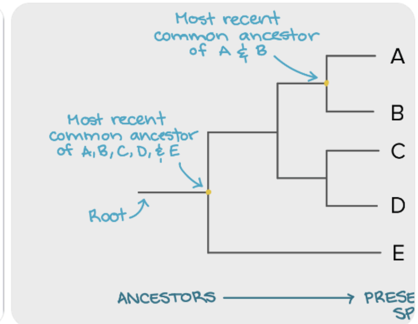






Phylogenetic trees can be displayed in different formats—horizontal, vertical, or radial—without changing the underlying relationships. Rotating or rearranging branches does not alter the evolutionary meaning of the tree, as long as the branching order remains the same. Understanding how to read these trees correctly is essential for interpreting evolutionary relationships and for constructing accurate phylogenetic models.

Below are visual examples of phylogenetic trees that illustrate how evolutionary relationships are represented across different groups of organisms:

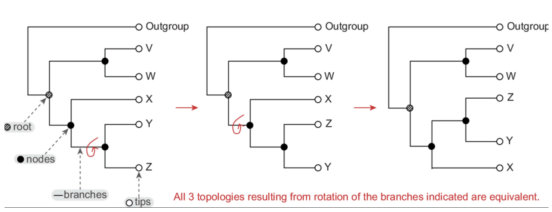
1. Example 1: Which species are more closely related?

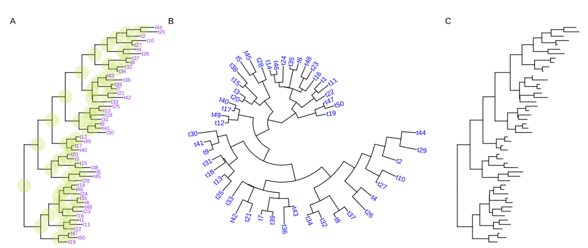
   (Source: https://www.khanacademy.org/science/ap-biology/natural-selection/phylogeny/a/building-an-evolutionary-tree; https://www.istockphoto.com/vector/biological-evolution-animals-scheme-gm500509454-80808691; https://www.khanacademy.org/science/ap-biology/natural-selection/phylogeny/a/phylogenetic-trees)

   In this phylogenetic tree, Species A and Species B share a **more recent common ancestor** than either does with Species C. This means that A and B are more closely related to each other, even if Species C may look similar or live in a similar environment.

   Closeness is determined by shared ancestors, not by appearance or position on the page.

2. Same relationships, different tree shapes





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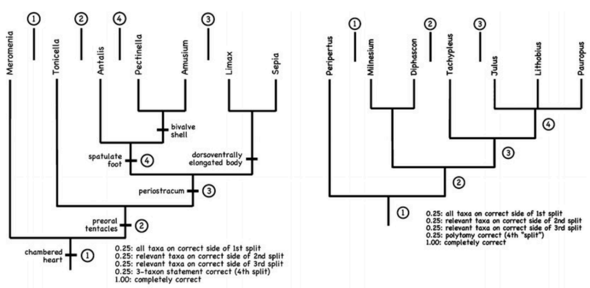
Source:
https://www.researchgate.net/figure/The-different-parts-of-a-rooted-phylogenetic-tree-showing-the-root-branches-nodes-and_fig1_43022487;
https://yulab-smu.top/treedata-book/chapter4.html;
https://users.ugent.be/~avierstr/principles/phylogeny.html)

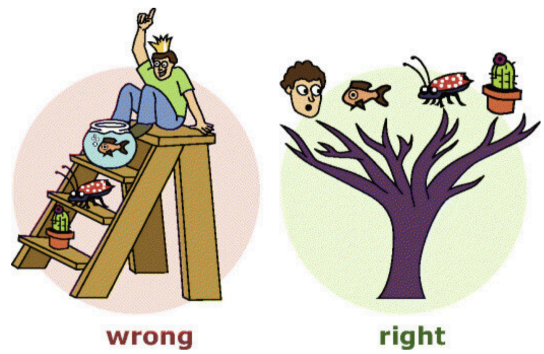
These trees look different (horizontal, vertical, or radial), but they represent **the same evolutionary relationships**. Rotating branches or the layout does not alter the meaning of the tree, as long as the branching order remains unchanged.

Tree shape does not change evolutionary relationships.

3. Misconception – evolution is not a ladder



(a) Correct answer and scoring key for the ladder in Fig. 1a
(b) Correct answer and scoring key for the ladder in Fig. 1b



(Source:
https://www.researchgate.net/figure/Tree-format-translations-for-the-ladders-shown-in-Figs-1a-b-along-with-the-associated_fig3_226685940

This comparison highlights a common misunderstanding. Evolution is often incorrectly shown as a ladder or linear progression. In reality, evolution works through **branching**, where multiple lineages evolve simultaneously from common ancestors.

All species at the tips of the tree are equally evolved.

1.6 Why Phylogenetic Trees Matter

Phylogenetic trees help scientists:

- understand biodiversity and evolution,
- track the origins of diseases,
- support conservation efforts,
- inspire bio-inspired solutions in science and technology.

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Execute - From Classification to Relationship Building

In this section, students move from learning about evolutionary concepts to actively applying them. Instead of memorizing classifications, learners analyze shared traits and evolutionary evidence to build relationships between organisms.

2.1 From Theory to Practice: Understanding Relationships in Nature

The evolutionary Tree of Life demonstrates how nature organizes diversity through branching relationships and shared ancestry. In this section, students move from theoretical concepts to **practical application**, exploring how scientists use evidence to determine evolutionary relationships between organisms.

Rather than memorizing classification systems, learners adopt a **bio-inspired perspective**, viewing evolution as a dynamic process where simple biological traits generate complex relational structures. This approach reflects how natural systems inspire modern methods of organizing information in science, technology, and design.

2.2 How Augmented Reality Supports the Learning Objective

The main objective of this unit is to help students understand phylogeny as a system of relationships, not a linear hierarchy. Augmented Reality (AR) supports this objective by allowing learners to construct, manipulate, and visualize phylogenetic trees in three-dimensional space.
Through AR-based activities, students can:

- place organisms relative to one another,
- visualize branching points as common ancestors,
- test different tree configurations based on evidence,
  observe how changes in data affect the overall structure.

This transforms phylogenetic trees from static diagrams into interactive scientific models.

2.3 Practical AR Exercise: Building the Tree of Life

Activity example: “Constructing a Phylogenetic Tree”
Students work individually or in small groups to analyze a selected organism or group of organisms. Using AR tools, each learner creates a representation that includes key traits such as morphology, habitat, or genetic information.
These individual contributions are then combined into a shared class phylogenetic tree, where students collaboratively decide:

- where branching points should occur,
- which organisms share the most recent common ancestors,
- which traits provide the strongest evidence for relatedness.

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This process emphasizes reasoning, comparison, and justification rather than correct or incorrect answers.

2.4 Bio-Inspired Learning in Practice

The construction of a phylogenetic tree reflects a core bio-inspired principle: complex systems emerge from simple, repeated rules. By organizing organisms based on shared traits, students experience how nature generates structured diversity without central control.
This principle is directly relevant to:

- systems thinking,
- data organization,
- network design,
- artificial intelligence and bio-inspired computing.

2.5 Collaborative and Inquiry-Based Learning

During the Execute phase, students engage in:

- discussion and debate about evidence,
- hypothesis testing by rearranging branches,
- collaborative decision-making when building the shared tree.

This inquiry-based approach mirrors real scientific practice and supports the development of critical thinking, communication, and teamwork skills.

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Enhance - Deepening Systems Thinking with Augmented Reality

3.1 Why Augmented Reality Enhances Phylogenetic Learning

Phylogenetic trees are abstract and difficult to understand using static images. Augmented Reality transforms these diagrams into interactive structures that students can explore, rearrange, and analyze in real space.

3.2 Making Evolutionary Relationships Visible

AR allows students to:

- visualize branching relationships in 3D,
- observe similarities and differences more clearly,
- understand common ancestry through spatial positioning.

This supports deeper conceptual understanding.

3.3 Supporting Inquiry and Systems Thinking

By manipulating AR models, students test hypotheses and explore "what if" scenarios. This inquiry-based approach strengthens systems thinking and mirrors how scientists work with evolutionary data.

3.4 Engagement and Inclusive Learning

AR supports multiple learning styles by combining visual, spatial, and interactive elements. This makes phylogenetic concepts more accessible and engaging for diverse learners.

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Conclusion

Through the Explore phase, students developed a foundational understanding of phylogeny and the evolutionary Tree of Life. In the Execute phase, they applied this knowledge by analyzing traits and building evolutionary relationships. The Enhance phase demonstrated how Augmented Reality transforms abstract evolutionary models into interactive learning experiences. Together, these phases highlight how bio-inspired thinking helps explain the organization of life and encourages further exploration of evolutionary science.

Phase	Description
Explore	- Research and Discovery: Students explore the concept of the evolutionary Tree of Life and phylogeny by examining how scientists identify evolutionary relationships between organisms. Through guided reading, visual examples, and multimedia resources, learners investigate common ancestry, branching patterns, and the types of evidence used to reconstruct evolutionary histories.
	- Content Development: Content is developed around key phylogenetic concepts, including common ancestors, homologous and analogous traits, and the interpretation of phylogenetic trees. The learning materials emphasize evolution as a branching, evidence-based process rather than a linear progression, preparing students for practical application in later stages.
	- Needs Analysis: This phase addresses students' common difficulties in understanding abstract evolutionary diagrams, interpreting branching relationships, and distinguishing between similarity and relatedness. Visual and interactive approaches are identified as necessary to support comprehension, reduce misconceptions, and prepare learners for constructing their own phylogenetic models.
Execute	- Curriculum Implementation: The unit is implemented through inquiry-based biology lessons aligned with secondary-level curricula on evolution, biodiversity, and classification. Students apply theoretical knowledge by analyzing traits and evolutionary evidence, reinforcing curriculum goals related to scientific reasoning and systems thinking.
	- Interactive Exercises: Students participate in hands-on AR-supported activities where they individually or collaboratively analyze organisms and construct a shared phylogenetic tree. Using 3D models and interactive elements, learners compare traits, determine branching points, and justify evolutionary relationships based on evidence.
	- Feedback Collection: Feedback is gathered through teacher observation, peer discussion, and short reflective tasks. Students receive formative feedback during the construction of phylogenetic trees, allowing them to revise their reasoning and improve their understanding through dialogue and iteration.
Enhance	- AR Integration: Augmented Reality is integrated to visualize phylogenetic trees as three-dimensional, interactive structures. AR enables students to manipulate branches, explore common ancestors, and spatially organize organisms, making abstract evolutionary relationships tangible and easier to understand.
	- Interactive Learning: Through AR interaction, students actively explore, test, and modify phylogenetic models. This supports inquiry-based learning, encourages hypothesis testing, and deepens conceptual understanding by allowing learners to engage directly with evolutionary data and relationships.

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	Gamified Content: - **Points and Badges**: Students earn points for correctly placing organisms, identifying shared traits, and justifying evolutionary relationships. Badges such as *“Phylogeny Explorer”* or *“Tree of Life Architect”* recognize achievement and progress. - **Leaderboards**: Optional classroom leaderboards display individual or group progress, encouraging friendly competition and sustained engagement without emphasizing ranking over learning. - **Quests and Levels**: Learning activities are structured as evolutionary quests, where students progress through levels representing increasing complexity—from identifying simple traits to constructing complete phylogenetic trees. - **Rewards for Exploration**: Hidden AR hotspots, bonus information panels, or additional points reward students who explore models in greater depth or provide well-supported explanations, fostering curiosity and deeper inquiry. - **Collaborative Gamified Tasks**: Students work in small teams to solve challenges such as resolving conflicting evidence or refining a shared phylogenetic tree. Collaboration supports communication, collective reasoning, and shared problem-solving.
	AR-Based Assessments: Students are assessed through AR-based tasks that require them to construct, interpret, and explain phylogenetic trees. Assessment focuses on the accuracy of relationships, the quality of evidence-based reasoning, and the ability to reflect on evolutionary processes. These assessments support both formative and summative evaluation within an interactive learning environment.

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AI-based tools (ChatGPT, Perplexity AI, and NotebookLM) were used to support content drafting, research synthesis, and organization of source materials during the development of this learning unit:

- OpenAI. *ChatGPT* (large language model). https://chat.openai.com
- *Perplexity AI* [AI-powered search and research assistant]. https://www.perplexity.ai
- Google *NotebookLM* [AI-powered research and note-taking tool]. https://notebooklm.google.com

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