Hair, feathers, and scales: an evolutionary tale

Educator guide

PAPER DETAILS

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LEARNING STANDARDS ALIGNMENT

Learning Performance: Students will evaluate the evidence for a theory of common ancestry between mammals, reptiles, and birds to understand how current evidence can be used to infer historical patterns of change.

The following tables provide an overview of the learning standards covered by this article, including the A Framework for K-12 Science Education (Framework), Common Core State Standards English Language Arts-Literacy (CCSS ELA), Common Core State Standards Statistics and Probability (CCSS HSS), AP Science Practices, and Vision and Change for Undergraduate Education. Where applicable, activities and information will be marked with specific standards to which they are linked.

A Framework for K-12 Science Education		
Science and Engineering Practices	Disciplinary Core Ideas	Crosscutting Concepts
Analyzing and Interpreting Data (SEP4) Analyzing data in 9-12 builds on K-8 experiences and progresses to introducing more detailed statistical analysis, the comparison of data sets for consistency, and the use of models to generate and analyze data. **Engaging in Argument from Evidence (SEP7)** Engaging in argument from evidence in 9-12 builds on K-8 experiences and progresses to using appropriate and sufficient evidence and scientific reasoning to defend and critique claims and explanations about the natural and designed world(s). Arguments may also come from current scientific or historical episodes in science.	**LS1.A: Structure and Function** All cells contain genetic information in the form of DNA molecules. Genes are regions in the DNA that contain the instructions that code for the formation of proteins. **LS1.B: Growth and Development of Organisms** In multicellular organisms individual cells grow and then divide via a process called mitosis, thereby allowing the organism to grow. The organism begins as a single cell (fertilized egg) that divides successively to produce many cells, with each parent cell passing identical genetic material (two variants of each chromosome pair) to both daughter cells. Cellular division and differentiation produce and maintain a complex organism, composed of systems of tissues and organs that work together to meet the needs of the whole organism. **LS4.A: Evidence of Common Ancestry and Diversity** Genetic information, like the fossil record, provides evidence of evolution. DNA sequences vary among species, but there are many overlaps; in fact, the ongoing branching that produces multiple lines of descent can be inferred by comparing the DNA sequences of different organisms. Such information is also derivable from the similarities and differences in amino acid sequences and from anatomical and embryological evidence.	**Patterns** Different patterns may be observed at each of the scales at which a system is studied and can provide evidence for causality in explanations of phenomena. **Stability and Change** Much of science deals with constructing explanations of how things change and how they remain stable. Change and rates of change can be quantified and modeled over very short or very long periods of time. Some system changes are irreversible.

Common Core State Standards English Language Arts-Literacy		
Key Ideas and Details	Craft and Structure	Integration of Knowledge and Ideas
RST.9-10.1 Cite specific textual evidence to support analysis of science and technical texts, attending to the precise details of explanations or descriptions. **RST.9-10.2** Determine the central ideas or conclusions of a text; trace the text's explanation or depiction of a complex process, phenomenon, or concept; provide an accurate summary of the text. **RST.9-10.3** Analyze how the author unfolds an analysis or series of ideas or events, including the order in which the points are made, how they are introduced and developed, and the connections that are drawn between them. **RST.11-12.1** Cite specific textual evidence to support analysis of science and technical texts, attending to important distinctions the author makes and to any gaps or inconsistencies in the account. **RST.11-12.2** Determine the central ideas or conclusions of a text; summarize complex concepts, processes, or information presented in a text by paraphrasing them in simpler but still accurate terms.	**RST.9-10.4** Determine the meaning of symbols, key terms, and other domain-specific words and phrases as they are used in a specific scientific or technical context relevant to grades 9-10 texts and topics. **RST.11-12.4** Determine the meaning of symbols, key terms, and other domain-specific words and phrases as they are used in a specific scientific or technical context relevant to grades 11-12 texts and topics. **RST.11-12.5** Analyze and evaluate the effectiveness of the structure an author uses in his or her exposition or argument, including whether the structure makes points clear, convincing, and engaging.	**RST.9-10.8** Delineate and evaluate the argument and specific claims in a text, assessing whether the reasoning is valid and the evidence is relevant and sufficient; identify false statements and fallacious reasoning. **RST.9-10.9** Compare and contrast findings presented in a text to those from other sources (including their own experiments), noting when the findings support or contradict previous explanations or accounts. **RST.11-12.7** Integrate and evaluate multiple sources of information presented in different media or formats (e.g., visually, quantitatively) as well as in words in order to address a question or solve a problem.

AP Science Standards	
AP Science Practices	AP Biology Content Standards
Science Practice 5 (SP5) The student can engage in data analysis and argument from evidence	**Essential knowledge 1.B.1: Organisms share many conserved core processes and features that evolved and are widely distributed among organisms today.** Structural and functional evidence supports the relatedness of all domains. DNA and RNA are carriers of genetic information through transcription, translation and replication. **Essential knowledge 2.E.1: Timing and coordination of specific events are necessary for the normal development of an organism, and these events are regulated by a variety of mechanisms.** Observable cell differentiation results from the expression of genes for tissue specific proteins. **Essential knowledge 3.B.2: A variety of intercellular and intracellular signal transmissions mediate gene expression.** Signal transmission within and between cells mediates gene expression.

Connections to the Nature of Science	
Vision and Change for Undergraduate Biology Education Core Competencies and Disciplinary Practices	A Framework for K-12 Science Education Understandings About the Nature of Science
Ability to use modeling and simulation Use mathematical modeling and simulation tools to describe complex living systems	**Scientific Investigations Use a Variety of Methods** • Scientific inquiry is characterized by a common set of values that include: logical thinking, precision, open-mindedness, objectivity, skepticism, replicability of results, and honest and ethical reporting of findings. • Scientific investigations use a variety of methods, tools, and techniques to revise and produce new knowledge. **Scientific Knowledge is Open to Revision in Light of New Evidence** Most scientific knowledge is quite durable but is, in principle, subject to change based on new evidence and/or reinterpretation of existing evidence.

ARTICLE OVERVIEW

Article summary (recommended for educator use only)

No fossil evidence exists that documents the origin of feathers, scales, and hair. Scientists have relied on other forms of evolutionary evidence to infer their relationship. In this paper, the authors explore this question by investigating a scaleless lizard with a single mutation in EDA, a key protein in the development of the anatomical placode (an embryonic structure associated with development of feathers and hair). Disruptions in placode development in mammals and birds lead to malformations in hair and feathers, and this similarity indicates that the three structures are evolutionarily related.

Importance of research

This research gives us insight into developmental processes, showing how specific genes and molecular signaling systems control the formation of physical traits. The linking of these traits between different species allows us to understand the evolutionary history of species.

Experimental methods

- Breeding experiments
- Cellular staining: immunofluorescent staining, H&E staining, TB staining
- Scanning electron Microscopy
- RT-PCR

Conclusions

This paper shows that the *EDA* gene plays a significant role in development in scales and it is known to have a large effect in the placode. Since the placode is essential for the development of hair and feathers as well, it is shown that these traits all have a common ancestor.

ACTIVITIES FOR INTERACTIVE ENGAGEMENT

Learning Performance: Students will evaluate the evidence for a theory of common ancestry between mammals, reptiles, and birds to understand how current evidence can be used to infer historical patterns of change.

Writing an abstract Students write a new abstract for the article at a grade-appropriate reading level.	**RST.9-10.2** **RST.11-12.2**
Locating this study in the larger field Students use the annotated list of references to explain how this research builds on the published work of at least one other independent group of scientists. Students will evaluate whether data from this research supports or contradicts previous conclusions, and reflect on the statement that scientific knowledge is a "community effort."	**RST.9-10.8** **RST.11-12.8**
Science in the news Students explore news stories in the Related Resources tab and evaluate the stories for tone, accuracy, missing information, etc. They may then write their own news stories on the article.	**RST.9-10.5** **RST.11-12.5** **RST.9-10.6** **RST.11-12.6** **RST.9-10.8** **RST.11-12.8**
Results and conclusions Students diagram each of the experiments presented in the study (divided up by figure, if appropriate). They then consider the results depicted in each figure, and how these results support the conclusions of the study.	**SEP4** **SP5** **LS4.A**
The next steps Students design a follow-on experiment to this study that either addresses flaws or unanswered questions in the research at hand, or builds on it to explore a new question.	**LS4.A**

DISCUSSION QUESTIONS

1. This article discusses homologous structures—traits in different species that are evolutionarily connected. How are homologous structures identified, and what are their implications?	LS1.A LS1.B LS4.A Patterns EK1.B.1
2. The case of the Scaleless lizard showed that the anatomical placode is associated with scale morphogenesis in reptiles. Describe how this represents evidence for a shared common ancestry between feathers, scales, and hair, and how mutants such as the lizard are valuable to reconstructing evolutionary history.	SEP4 LS3.B Stability and Change SP5
3. What are some of the problems with using current genetic evidence to infer historical relationships? How can scientists address these problems to increase the accuracy of their predictions?	SEP7 LS1.B LS4.A Stability and Change SP5 EK1.B.1
4. Drawing examples from the article, compare and contrast the effectiveness and importance of genetic tests like WMISH and physical observations when studying evolution. Is one method more effective than the other? Explain your reasoning.	SEP7 LS1.A LS4.A Structure and Function SP5
5. Prior to the authors' discovery, what models were used to explain the evolution of hair, feathers, and scales? Why had the anatomical placode in reptiles been previously overlooked?	Patterns EK2.E.1 EK3.B.2