Tell tail signs of dual dog domestication

Educator guide

PAPER DETAILS

Original title: Genomic and archaeological evidence suggest a dual origin of domestic dogs

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DISCUSSION QUESTIONS

	LEARNING STANDARDS
1. In evolutionary studies, why is it useful to study mitochondrial DNA?	LS4.A EK3.A.4
2. Why do you think it is so difficult to be sure of dog evolution compared to monkeys, for example?	Patterns Cause and Effect EK1.A.1
3. What are some of the reasons the authors present for why the dog population in Western Europe might have been replaced or partially replaced? When do they propose this bottleneck event to have happened?	SEP4 LS4.B LS4.C SP6
4. Throughout the research paper, the authors propose time frame windows for genetic events in dog domestication. Why are the scientists only able to give estimate divergence times and not specific years?	Cause and Effect EK1.A.1 Nature of Science
5. If ancient dog fossils were found in Central Asia, how could this change the theory of how dogs were domesticated?	SEP7 Nature of Science

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ACTIVITIES FOR INTERACTIVE ENGAGEMENT

	LEARNING STANDARDS
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** **Nature of Science**
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** **Nature of Science**
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 based on the article.	**RST.11-12.5** **RST.11-12.6** **RST.11-12.8**
Dog Genomics and Single Nucleotide Polymorphisms (SNPs) Students may watch a 28-minute lecture by Dr. Elinor Karlsson of the Broad Institute, where she discusses the history of the dog/wolf divide and the breed differences between modern-day dogs. Students may then conduct an interactive activity involving mapping genes to traits in dogs using SNPs. Students may also perform a statistics activity using chi-squared analysis. https://www.hhmi.org/biointeractive/mapping-genes-traits-dogs-using-snps	**SEP5** **LS3.A** **Patterns** **EK1.A.2**
Phylogenetic trees and evolutionary history Students consider the phylogenetic trees described in the research. Then, students may use this self-paced tutorial in tree thinking. Afterwards, students may reevaluate their previous thinking on the relationship between dogs and wolves. https://evolution.berkeley.edu/evolibrary/search/lessonsummary.php?&thisaudience=13-16&resource_id=511	**SEP7** **LS4.A** **Systems and System Models** **EK1.B.2**
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.	**SP5** **Nature of Science**

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ARTICLE OVERVIEW

Article summary (recommended for educator-use only)

Newgrange is an ancient grave site in Ireland. Recently, fossils from a dog were found there. Scientists extracted DNA from the dog, leading the authors to discover new information about how dogs were domesticated. They compared the DNA sequences of the Newgrange dog to those of a large, diverse group of other dog DNA samples to create a map of dog ancestry—a phylogenetic tree. Using genetics, archaeology, and statistics, the scientists concluded that dogs were domesticated in two separate locations—Western Eurasia and East Asia—from different populations of wolves. However, the Western Eurasian dogs were partially or complete replaced by dogs transported from East to West.

Importance of this research

Dogs are our best friends, and their path from wolf to dog has long fascinated and perplexed us. Dogs have resided alongside humans for thousands of years and understanding their history can help inform us about our own. Answering the questions of where, when, and how many times dogs were domesticated can provide critical information about the past. Dogs were bred and crossbred for specific purposes—as opposed to the free breeding of most other animals—for generations, which has made evolutionary studies of dogs complicated and controversial. Previous studies proposed that dogs were domesticated once—but the location of domestication has been up for debate. This study provides valuable information about where and when dogs were domesticated. As more ancient dog fossils are discovered and ancient DNA is recovered, the story of dog evolution will continue to be amended.

Experimental methods

- Whole genome sequencing: The complete DNA sequence of the genome of the animal was obtained.
- Radiocarbon dating: Based on the amount of radioactive carbon-14 present in a sample, scientists can estimate the age of a plant or animal.
- Principal components analysis: A statistical technique used to bring out patterns within a high-dimensional data set, which helps determine the most important sources of variation in the dataset.
- D-statistics: Used to detect gene flow between closely-related species.
- TreeMix: A genetics computer program used to estimate ancestral relationships.
- Neighbor-joining tree: A type of phylogenetic tree used to display ancestral relationships based on DNA or protein sequences.
- Multiple sequentially Markovian coalescent (MSMC): A technique that looks at the pattern of DNA mutations in multiple individuals. By focusing on the most recent common ancestor between species, MSMC can provide information about the timing of shared ancestry, population sizes, population splits, and migration rates.

Conclusions

- Humans were controlling dog breeding 4,800 years ago, to a similar degree that we control dog breeding today.
- The 4800-year-old Irish dog (Newgrange dog) was able to digest starch more efficiently than wolves, which suggests that the dog and its ancestors were bred by farmers.
- There was an indigenous population of dogs in Western Eurasia in the Paleolithic era.

- There was a bottleneck in the Western Eurasian population of dogs, which is suggestive of their transportation from East to West.
- Two very different populations of dogs were present in Eastern Asia and Western Eurasia during the Paleolithic era; in other words, dogs were domesticated twice.
- Paleolithic dogs of Western Eurasia were completely or partially wiped out by dogs that were transported from East Asia.

LEARNING STANDARDS ALIGNMENT

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) Scientists use a range of tools—graphical interpretation, visualization, and statistical analysis—to identify the significant features and patterns in the data. Modern technology makes the collection of large data sets much easier, thus providing many secondary sources for analysis. **Constructing Explanations and Designing Solutions (SEP6)** The goal of science is to construct explanations for the causes of phenomena that are supported by multiple and independent sources of evidence consistent with scientific ideas, principles, and theories. **Engaging in Argument from Evidence (SEP7)** Scientists evaluate the claims, evidence, and/or reasoning behind currently accepted explanations or solutions to determine the merits of arguments.	**LS3.A: Inheritance of Traits** Each chromosome consists of a single very long DNA molecule, and each gene on the chromosome is a particular segment of that DNA. The instructions for forming species' characteristics are carried in DNA. All cells in an organism have the same genetic content, but the genes used (expressed) by the cell may be regulated in different ways. Not all DNA codes for a protein; some segments of DNA are involved in regulatory or structural functions, and some have no as-yet known function. **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. **Cause and Effect** Events have causes, sometimes simple, sometimes multifaceted. A major activity of science is investigating and explaining causal relationships and the mechanisms by which they are mediated. Such mechanisms can then be tested across given contexts and used to predict and explain events in new contexts. **Systems and System Models** Defining the system under study—specifying its boundaries and making explicit a model of that system—provides tools for understanding and testing ideas that are applicable throughout science and engineering.

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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.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.9-10.5** Analyze the structure of the relationships among concepts in a text, including relationships among key terms (e.g., force, friction, reaction force, energy). **RST.9-10.6** Analyze the author's purpose in providing an explanation, describing a procedure, or discussing an experiment in a text, defining the question the author seeks to address. **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 how the text structures information or ideas into categories or hierarchies, demonstrating understanding of the information or ideas. **RST.11-12.6** Analyze the author's purpose in providing an explanation, describing a procedure, or discussing an experiment in a text, identifying important issues that remain unresolved.	**RST.9-10.8** Assess the extent to which the reasoning and evidence in a text support the author's claim or a recommendation for solving a scientific or technical problem. **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.11-12.8** Evaluate the hypotheses, data, analyses, and conclusions in a science or technical text, verifying the data when possible and corroborating or challenging conclusions with other sources of information. **RST.11-12.9** Synthesize information from a range of sources (e.g., texts, experiments, simulations) into a coherent understanding of a process, phenomenon, or concept, resolving conflicting information when possible.

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AP Science Standards	
AP Science Practices	AP Biology Content Standards
Science Practice 5 (SP5) The student can perform data analysis and evaluation of evidence. **Science Practice 6 (SP6)** The student can work with scientific explanations and theories	**Essential knowledge (EK1.A.4)** Biological evolution is supported by scientific evidence from many disciplines, including mathematics. **Essential knowledge (EK1.B.2)** Phylogenetic trees and cladograms are graphical representations (models) of evolutionary history that can be tested.

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 Communicate and Collaborate with Other Disciplines Develop skills to participate in diverse working communities, as well as the ability to take full advantage of collaborators' multiple perspectives and skills. **Ability to Apply the Process of Science** Understand the process of science and how scientists construct new knowledge by formulating hypotheses and the testing them against experimental and observational data.	**Scientific Investigations Use a Variety of Methods** Science investigations use diverse methods and do not always use the same set of procedures to obtain data. **Science Models, Laws, Mechanisms, and Theories Explain Natural Phenomena** A scientific theory is a substantiated explanation of some aspect of the natural world, based on a body of facts that have been repeatedly confirmed through observation and experiment and the science community validates each theory before it is accepted. If new evidence is discovered that the theory does not accommodate, the theory is generally modified in light of this new evidence.