Ancient footprints offer clues into early humans' body size

Educator guide

PAPER DETAILS

Original title: New footprints from Laetoli (Tanzania) provide evidence for marked body size variation in early hominins

Reference: *eLife* 2016;5:e19568

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DISCUSSION QUESTIONS

1. Do you think the feet of the Laetoli hominids are more similar to the feet of modern humans or those of chimpanzees and gorillas? Were they bipedal?	SEP2 SEP2 SEP7 LS4.A Patterns Structure and Function RST.11-12.8 SP6
2. Is it possible to determine if the Laetoli hominins exhibited a limited degree of sexual dimorphism? Provide evidence to support your answer.	SEP7 LS4.A Patterns Structure and Function RST.11-12.4 SP6 Nature of Science
3. What evidence is there that the Site G and Site S individuals were walking as a group in the same direction?	SEP4 Patterns RST.11-12.8 EK1.A.4 Nature of Science
4. Discuss how the research done by Leakey, Masao, and their associates has broadened our understanding of human evolution.	LS4.A EK1.A.4 Nature of Science
5. Is there enough evidence provided by the work of Masao *et al.* to dispel the hypothesis that early hominins were shorter than more recent hominin species?	SEP7 Patterns Structure and Function RST.9-10.8 SP6 Nature of Science
6. Is it more important to cover and preserve the footprints at Sites S and G or to make them available for further research? Explain your reasoning.	Nature of Science

ACTIVITIES FOR INTERACTIVE ENGAGEMENT

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

New Laetoli footprints and hominin body size

Using the scatter plot, activity prompts, and discussion questions found in the HHMI BioInteractive education resource, students engage with one of the graphs presented in the Masao *et al*. paper.
https://www.hhmi.org/biointeractive/new-laetoli-footprints-and-hominin-body-size

SEP4
LS4.A
RST.11-12.4
SP2

Human feet are strange

In this hands-on activity, developed by HHMI BioInteractive, students examine the evidence for the evolution of human bipedality as revealed by a trail of fossilized footprints.
https://www.hhmi.org/biointeractive/human-feet-are-strange

SEP4
SEP7
LS4.A
LS4.C
Structure and Function
SP6
EK1.A.4

Using the scientific process to study human evolution

Students engage in HHMI BioInteractive's "Click and Learn" activity, while completing the accompanying worksheet to learn how paleoanthropology serves as an example of the scientific process at work.
https://www.hhmi.org/biointeractive/using-scientific-process-study-human-evolution

LS4.A
Patterns
Structure and Function
RST.11-12.8
Nature of Science

Great transitions: The origins of humans

Students watch this short film, produced by HHMI BioInteractive, to learn about the evolutionary origins of modern humans. The film discusses the Laetoli footprints and goes even further back into the fossil record.
https://www.hhmi.org/biointeractive/great-transitions-origin-humans

LS4.A
LS4.C
EK1.A.4
Nature of Science

ARTICLE OVERVIEW

Article summary (recommended for educator-use only)

The discovery of a new set of footprints in Laetoli, Tanzania raises complex questions. Using 3D photogrammetric elevation models at four different test-pit locations and careful stratigraphic analysis, the authors posit that the newly unearthed footprints at Site S were made by the same hominin species, walking in the same direction at the same time, as those discovered by Dr. Mary Leakey at Site G in 1976. Careful measurements of both sets of prints resulted in the authors concluding that the footprints indeed indicate individuals of the same species with limited sexual dimorphism.

Importance of this research

The authors built on the work done by Leakey, White, Dingwell, Alexander, and others. When the new set of prints became available, it was the perfect time to conduct an in-depth study. The footprints at Site G had been covered in order to preserve them and only casts are available. Features of the new prints could be carefully analyzed. Masao *et al.* were able to build on work done by others analyzing footprints as a source of information about foot size, step length, stride, and gait. These data were also used to determine relative stature and body mass. By comparing estimated sizes of the five individuals, Masao and associates inferred the degree of sexual dimorphism and mating behavior.

Experimental methods

- Photogrammetric elevation modelling: Photogrammetry is a 3D measuring system that uses photographs. Lines-of-sight were developed from cameras to points on a footprint. The lines-of-sight were then used to mathematically produce 3D coordinates of the points of interest.
- Stratigraphic analysis of the study of rock layers. A careful analysis of the soil layers was conducted to determine age and also correlation of the Site G trackway with the Site G trackway.
- Morphological study of the hominid footprints to determine the greatest point of pressure, alignment of the big toe with the direction of locomotion, presence of claw marks, and estimated size. This allowed for comparison to other hominid footprints.
- Morphological study of nonhominid tracks. This provides information about the ancient ecology of the area.
- Mathematical modeling to determine the stature, body mass, and speed at which the hominins were walking. Several models were used to increase accuracy.
- Survey and excavation of the test-pits and clearing of debris from the fossil footprints.
- Morphometric analysis, which is a form of taxonomic analysis involving the external measurement of the form of an object or organism.

Conclusions

- The two individuals whose footprints were found at Site S by Masao *et al.* and the three individuals from Leakey's Site G were all the same species.
- The five individuals varied in stature and body mass providing evidence of sexual dimorphism.
- The shape of the early hominins' feet, based on the footprints, is similar to the shape of modern human feet and not those of chimpanzees and gorillas. Though there is still debate on the subject.
- That, as early as 3.6 million years ago, hominins were bipedal.
- Evidence does not support the hypothesis that as hominins evolved, they became taller, facilitating their migration to other regions.

LEARNING STANDARDS ALIGNMENT

Learning Performance: Students will evaluate evidence of evolution among early human ancestors based on footprints found in Laetoli, Tanzania, and learn how the data provide supporting evidence of bipedalism and limited sexual dimorphism.

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
Developing and Using Models (SEP2) Develop and use a model based on evidence to illustration the relationships between systems and their components in the natural and designed worlds. **Analyzing and Interpreting Data (SEP4)** The student can perform data analysis and evaluation of evidence, applying concepts of statistics and probability (including determining function fits to data, slope, intercept, and correlation coefficient for linear fits) to questions and problems using digital tools where feasible. **Engaging in Argument from Evidence (SEP7)** Evaluate the claims, evidence, and/or reasoning behind currently accepted explanation or solutions to determine the merits of arguments.	**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 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. **LS4.C: Adaptation** Evolution is a consequence of the interaction of four factors: (1) the potential for a species to increase in number, (2) the genetic variation of individuals in a species due to mutation and sexual reproduction, (3) competition for an environment's limited supply of the resources that individuals need in order to survive and reproduce, and (4) the ensuing proliferation of those organisms that are better able to survive and reproduce in that environment.	**Patterns** Observed patterns of forms and events guide organization and classification, and they prompt questions about relationships and the factors that influence them. **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 explain events in new contexts. **Structure and Function** The way in which an object or living thing is shaped and its substructure determine many of its properties and functions.

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.

AP Science Standards	
AP Science Practices	**AP Biology Content Standards**
Science Practice 2 (SP2) The student can use mathematics appropriately. **Science Practice 6 (SP6)** The student can work with scientific explanations and theories.	**Essential knowledge 1.A.4 (EK1.A.4)** Biological evolution is supported by scientific evidence from many disciplines, including mathematics.

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 apply the process of science Understand the process of science and how scientists construct new knowledge by formulating hypotheses and then testing them against experimental and observational data. **Ability to use quantitative reasoning** Biology relies on applications of quantitative analysis and mathematical reasoning **Ability to understand the relationship between science and society** Identify the social and historical dimensions of biology practice: evaluating the relevance of social contexts to biological problems, evaluating ethical implications of biological research	**Scientific Knowledge is based on Empirical Evidence** Science arguments are strengthened by multiple lines of evidence supporting a single explanation. **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.