

Lecture 2: Science - part 2

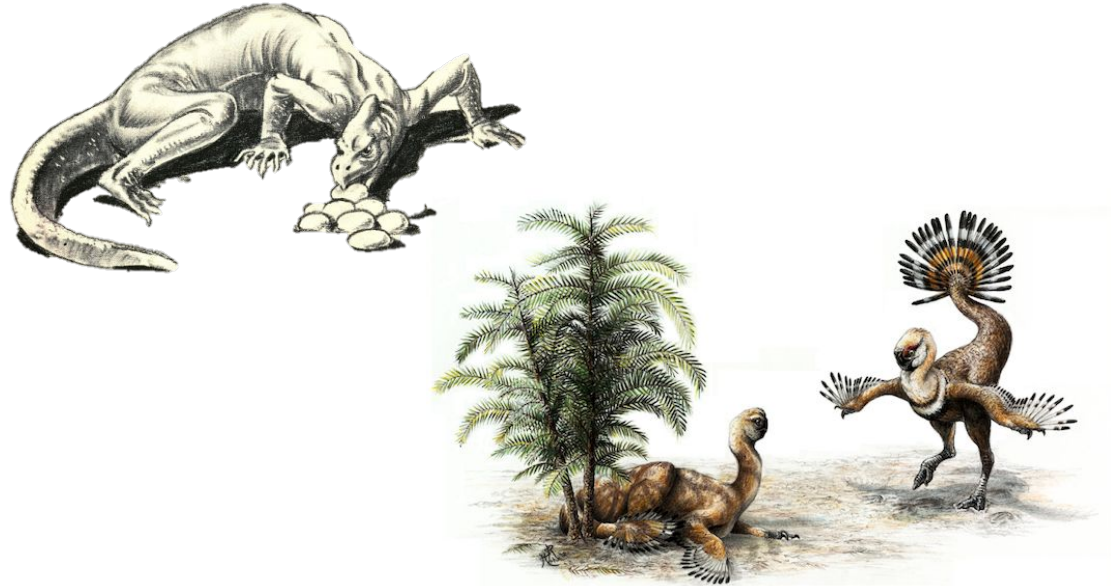
(Why should I believe what you tell me?)



Skeleton of *Oviraptor* ([source](#))

What is science?

- It is **empirical**
- It is **progressive**
- It is **falsifiable**



How is science similar to other ways of knowing?



Paleontologist Bob Bakker ([source](#))

- Science is **normative**: the culture dictates how observations are interpreted and what questions are worth asking
- This impacts what questions we ask, what data we choose to collect, what counts as “statistically significant” and the norms for designing and publishing scientific research

Ethical issues in Paleontology

- Historically, paleontology is closely linked to colonialism and resource extraction
- Used to justify land dispossession

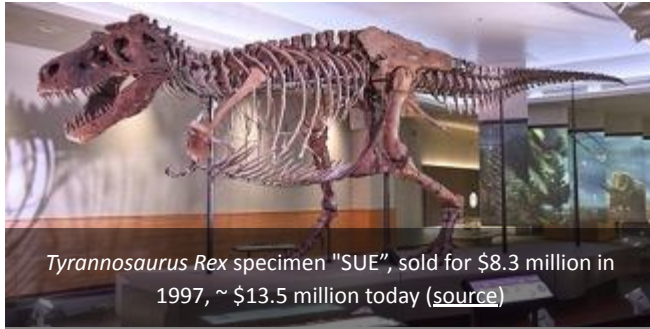


Yale students ransacking Sioux burial platforms during an 1870 expedition.

Schuchert, C., and LeVene, C.M. *OC Marsh, pioneer in paleontology*. Yale university press, 1940.

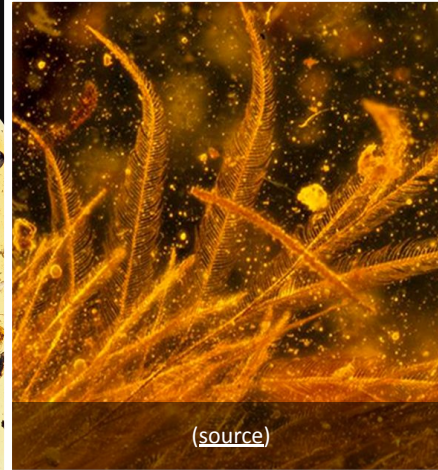
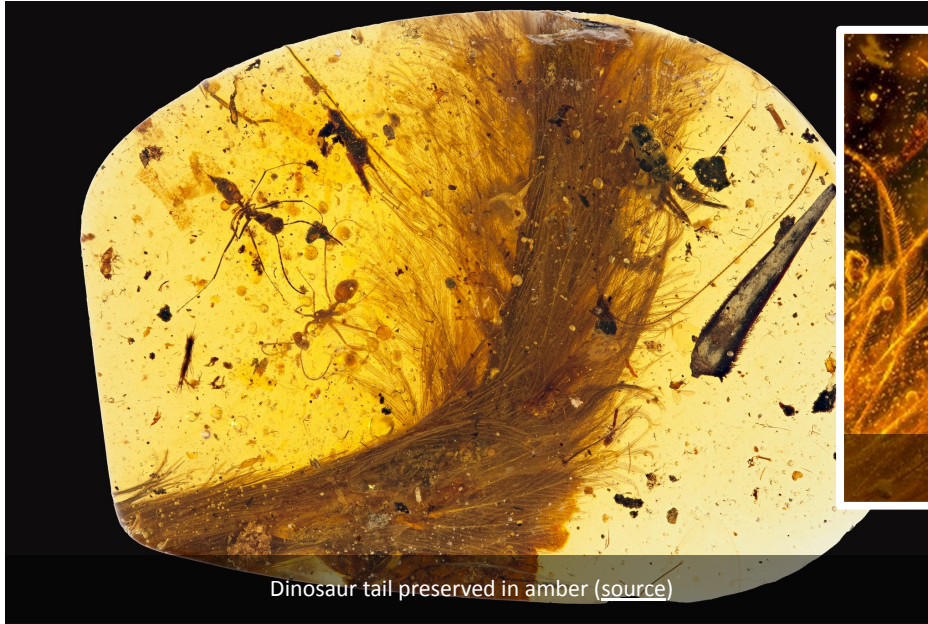
Bradley, L.W. *Dinosaurs and Indians: Paleontology resource dispossession from Sioux lands*. Outskirts Press, 2014.

Ethical issues in Paleontology



- In America, landowners have rights to the fossils on their property, and they can sell those rights to others
- The private sale of fossils has seen an exponential increase in value
- This drives black markets in many parts of the world

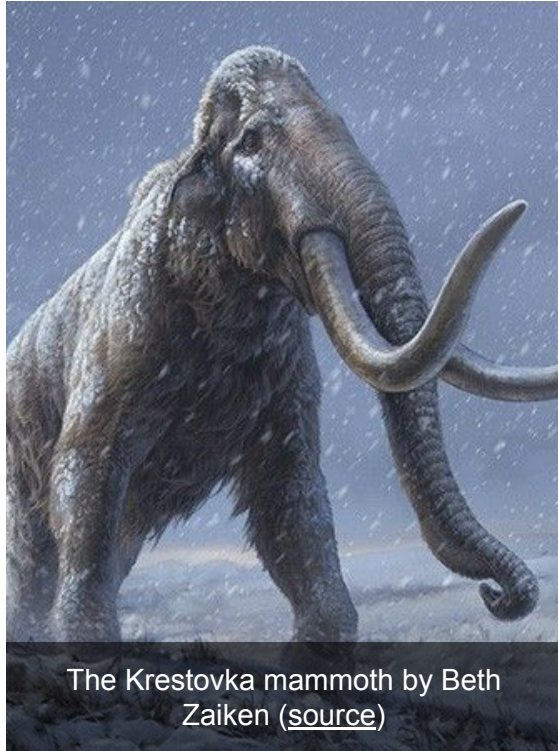
Ethical issues in Paleontology



Xing, Lida, et al. "A feathered dinosaur tail with primitive plumage trapped in mid-Cretaceous amber." *Current Biology* 26.24 (2016): 3352-3360.

Wang et al. (2020) Exceptional preservation of reproductive organs and giant sperm in Cretaceous ostracods. *Proceedings of the Royal Society B: Biological Sciences*; 287 (1935): 20201661 DOI: 10.1098/rspb.2020.1661

An ongoing scientific controversy: ancient proteins and DNA in dinosaurs



- In some cases (discussed next class), DNA and/or proteins can be preserved in fossils
- The oldest broadly accepted DNA comes from a ~1-million year old mammoth frozen in Siberia; the oldest proteins from a ~3.8 million year old ostrich eggs.
- These examples approach the theoretical limits based on current molecular biology

van der Valk, Tom, et al. "Million-year-old DNA sheds light on the genomic history of mammoths." *Nature* 591.7849 (2021): 265-269.

Demarchi, Beatrice, et al. "Protein sequences bound to mineral surfaces persist into deep time." *eLife* 5 (2016): e17092.

The discovery of proteins in dinosaurs?

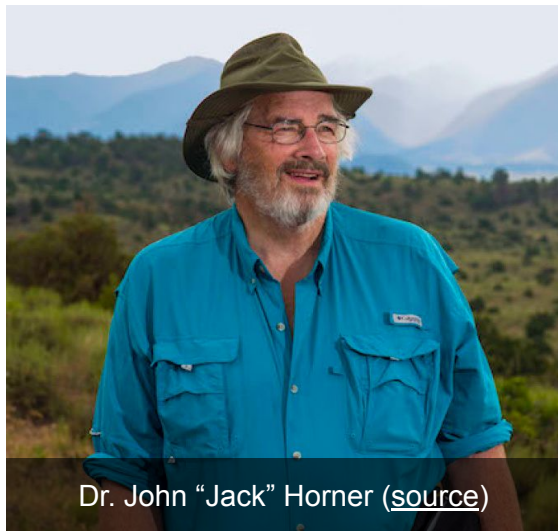
- In the mid-2000s, paleontologist Mary Schweitzer (now at North Carolina State University) thought she found in evidence of blood cells preserved in a dinosaur fossil...

Service R F , 2017, "'I don't care what they say about me': Paleontologist stares down critics in her hunt for dinosaur proteins", *Science*, Portland, Oregon, 13 Sep, 2017.



Dr. Mary Schweitzer ([source](#))

Presenting the idea to her PhD advisor



Dr. John "Jack" Horner ([source](#))

"They are in the right place to be red blood cells," she recalls telling [Dr. Jack Horner]. "But they can't be red blood cells. We all know that."

"Prove to me they're not," he said.

*"It was the second most impactful thing anyone has ever said to me...That's the way science should work. **You can't prove something is true. But you can disprove it.** I've been trying ever since to disprove it. I still haven't."*

- Mary Schweitzer

Service R F , 2017, "'I don't care what they say about me': Paleontologist stares down critics in her hunt for dinosaur proteins", *Science*, Portland, Oregon, 13 Sep, 2017.

The discovery of (possible) proteins in dinosaurs

- Mary Schweitzer wrote up her findings and submitted it to peer-review in a scientific journal
- In 2007 Mary Schweitzer and colleagues reported proteins from a *Tyrannosaurus rex* skeleton
- In 2009 they reported proteins from a second dinosaur, a *Brachylophosaurus*.

Scientific journal: a specialized publication for evaluating and sharing scientific research between scientists

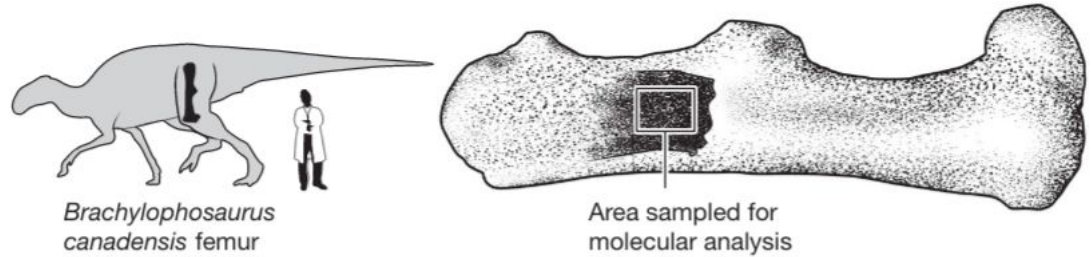
Peer review: a process used in scientific journals where multiple scientists (usually anonymously) argue for the publication or rejection of an article

Schweitzer, Mary Higby, et al. "Analyses of soft tissue from *Tyrannosaurus rex* suggest the presence of protein." *Science* 316.5822 (2007): 277-280.

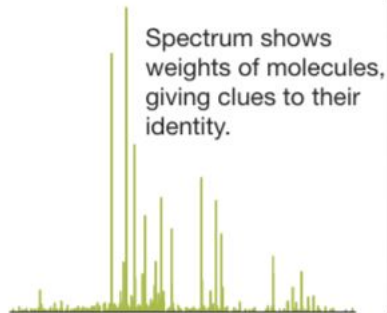
Schweitzer, Mary H., et al. "Biomolecular characterization and protein sequences of the Campanian hadrosaur *B. canadensis*." *Science* 324.5927 (2009): 626-631.

How are ancient proteins detected?

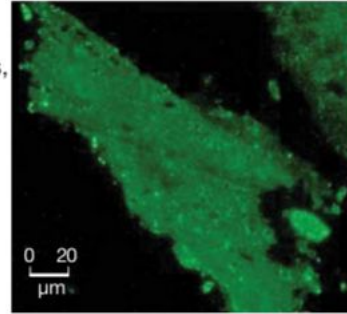
Corroboration: when multiple studies / techniques support the same hypothesis. Corroboration is a critical part of theory building.



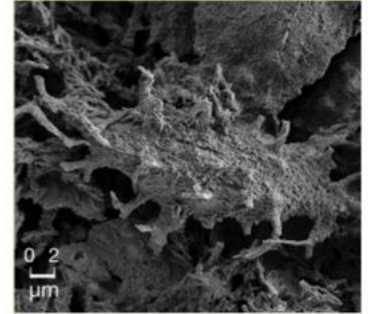
Controversial clues



Mass spectrometry
Identifies protein fragments and provides the sequence of amino acids that make up each fragment.



Antibody fluorescence
Lights up target proteins when fluorescent-labeled antibodies bind to them.



Microscopy
Reveals features in demineralized fossils. Here, what appears to be a bone cell nestles within a fibrous matrix that may be collagen.

Service R F , 2017, "'I don't care what they say about me': Paleontologist stares down critics in her hunt for dinosaur proteins", *Science*, Portland, Oregon, 13 Sep, 2017.

CREDITS: (GRAPHIC) K. SUTLIFF/SCIENCE; (IMAGES, LEFT TO RIGHT): M. SCHWEITZER ET AL., *SCIENCE* 324, 5927 1 MAY 2009 (2); M. SCHWEITZER, N. EQUALL, ICAI, MONTANA STATE UNIVERSITY

The scientific community was excited but skeptical

- The implications would dramatically impact other fields of science

- **Possibility 1:** proteins decay much slower than currently thought (conflicts with modern theories in molecular biology) or some unknown mechanism of preservation exists

- **Possibility 2:** these fossil are much younger than currently thought (conflicts with modern theories in paleontology, geology, isotope chemistry)

- **Possibility 3:** these are not actually dinosaur proteins

Arguments and counterarguments



- Antibody tests can have “non-specific” responses
- The mass-spec data was cherry-picked
- Fossils are “open systems” where bacteria, fungi, and other organisms can live
- Multiple labs have been unable to replicate this work (a lack of **corroboration**)
- In many of these cases Dr. Schweitzer came back with new studies to test these arguments

Saitta, Evan T., et al. "Cretaceous dinosaur bone contains recent organic material and provides an environment conducive to microbial communities." *Elife* 8 (2019): e46205.

Going from science to the media

Analyses of Soft Tissue from *Tyrannosaurus rex* Suggest the Presence of Protein

Mary Higby Schweitzer,^{1,2,3*} Zhiyong Suo,⁴ Recep Avci,⁴ John M. Asara,^{5,6} Mark A. Allen,⁷ Fernando Teran Arce,^{4,8} John R. Horner³

We performed multiple analyses of *Tyrannosaurus rex* (specimen MOR 1125) fibrous cortical and medullary tissues remaining after demineralization. The results indicate that collagen I, the main organic component of bone, has been preserved in low concentrations in these tissues. The findings were independently confirmed by mass spectrometry. We propose a possible chemical pathway that may contribute to this preservation. The presence of endogenous protein in dinosaur bone may validate hypotheses about evolutionary relationships, rates, and patterns of molecular change and degradation, as well as the chemical stability of molecules over time.

The New York Times


Study Identifies Dinosaur Protein



Repeated analysis of proteins from a *Tyrannosaurus rex* found new evidence of a link between dinosaurs and birds: Of the seven reconstructed protein sequences, three were closely related to chickens.

Left, Tara Todras-Whitehill/Reuters. Right, Koichi Kamoshida/Getty Images


How can you be a better consumer of scientific information?




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Hot Topics Troops heading to border Questionable Soros cash Pruitt fires back


Dinosaurs




DIGGING HISTORY 1 day ago
Rare dinosaur prints made 170 million years ago found in Scotland
Scientists are trumpeting a globally important find with the discovery of dozens of rare giant dinosaur footprints in Scotland from 170 million years ago.



DINOSAURS 6 days ago
Stunning dinosaur discovery: Experts may have unearthed a baby Tyrannosaurus fossil in Montana
Paleontologists in Montana have unearthed a fossil that may be the remains of a baby Tyrannosaurus rex.



DINOSAURS February 08
Dinosaur-killing space rock may have triggered huge volcanic eruptions
The giant space rock that wiped out the dinosaurs may have set off a chain of cataclysmic volcanic eruptions on land and undersea, claims a new study that is already dividing ...



VIDEO February 02
'This is a big deal': Dinosaur tracks found on NASA site
Paleontologists excited by discovery of about 70 tracks from the Cretaceous period.

Does the news story provide a link to the peer-reviewed reference?



The dinosaurs died a cold, dark death, new study shows

It's widely acknowledged that the Earth was a cold, dark place after a giant meteor, measuring roughly six miles across, struck Mexico about 66 million years ago.



These boxes are where I provide citations from scientific journals



Schweitzer, Mary Higby, et al. "Analyses of soft tissue from Tyrannosaurus rex suggest the presence of protein." *Science* 316.5822 (2007): 277-280.

While the comet strike likely meant the end for the dinosaurs, it did make way for the evolution of the human species. And though extinction was cold and dark for the prehistoric creatures, it'll likely be quite toasty for us.

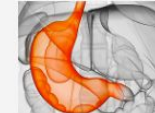
"It's a certain irony that today the most immediate threat is not from natural cooling but from human-made global warming," Bragger said.

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Gundry MD

Does the news story provide a link to the peer-reviewed reference?

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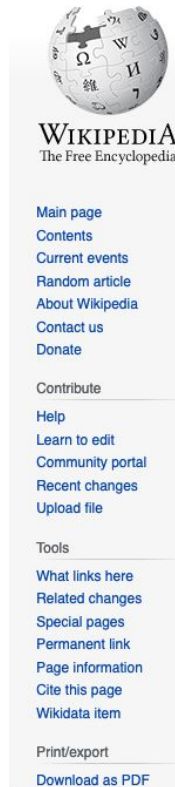
Materials provided by **North Carolina State University**. Note: Content may be edited for style and length.

Journal Reference:

1. Elena R. Schroeter, Caroline J. DeHart, Timothy P. Cleland, Wenxia Zheng, Paul M. Thomas, Neil L. Kelleher, Marshall Bern, Mary H. Schweitzer. **Expansion for the Brachylophosaurus canadensis Collagen I Sequence and Additional Evidence of the Preservation of Cretaceous Protein.** *Journal of Proteome Research*, 2017; DOI: [10.1021/acs.jproteome.6b00873](https://doi.org/10.1021/acs.jproteome.6b00873)
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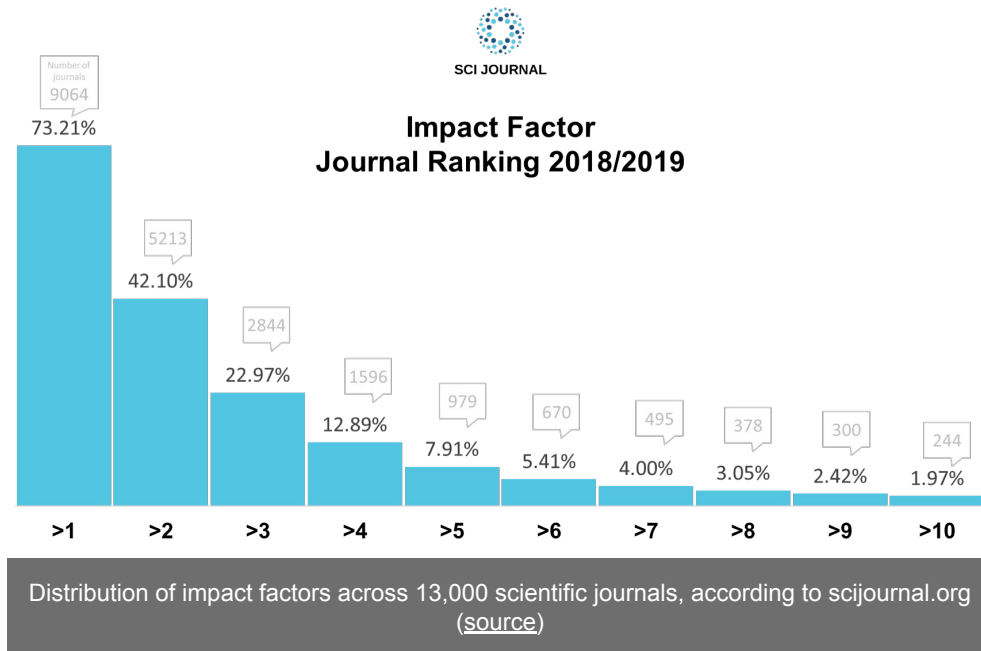
Quick check: Wikipedia

- A good place to get started and gain general knowledge
- Not good enough for your writing assignments (check the references Wikipedia cites)

A screenshot of the Wikipedia article for "Dinosaur". At the top right, it says "Not logged in" with links for "Talk", "Contributions", "Create account", and "Log in". Below this is a search bar with the text "Search Wikipedia" and a magnifying glass icon. The article title "Dinosaur" is in large blue font, with a star and lock icon to its right. Below the title is the text "From Wikipedia, the free encyclopedia". A note says "For other uses, see *Dinosaur (disambiguation)*." The main text starts with "Dinosaurs are a diverse group of **reptiles**^[note 1] of the **clade Dinosauria**. They first appeared during the **Triassic period**, between 243 and 233.23 million years ago, although the exact origin and timing of the **evolution of dinosaurs** is the subject of active research. They became the dominant terrestrial **vertebrates** after the **Triassic–Jurassic extinction event** 201.3 million years ago; their dominance continued throughout the **Jurassic** and **Cretaceous** periods. The **fossil record** shows that **birds** are modern **feathered dinosaurs**, having **evolved** from earlier **theropods** during the **Late Jurassic epoch**, and are the only dinosaur lineage to survive the **Cretaceous–Paleogene extinction event** approximately 66 million years ago. Dinosaurs can therefore be divided into **avian dinosaurs**, or birds; and the extinct **non-avian dinosaurs**, which are all dinosaurs other than birds. A paragraph follows: "Dinosaurs are a varied group of animals from **taxonomic**, **morphological** and **ecological** standpoints. Birds, at over 10,700 living **species**, are among the most diverse group of vertebrates. Using fossil evidence, **paleontologists** have identified over 900 distinct **genera** and more than 1,000 different species of non-avian dinosaurs. Dinosaurs are represented on every continent by both **extant** species (birds) and fossil remains. Through the first half of the 20th century, before birds were recognized as dinosaurs, most of the scientific community believed dinosaurs to have been sluggish and **cold-blooded**. Most **research conducted since the 1970s**, however, has indicated that dinosaurs were active". To the right of the text is a box titled "Dinosaurs" with the text "Temporal range: **Late Triassic–Present**, 233.23 – 0 Mya (Range includes birds (Aves))". Below this is a geological time scale bar with labels: Pre, C, C, S, D, C, P, T, J, K, Pg, N. The box also contains a collage of dinosaur skeletons and reconstructions. At the bottom of the box is the text: "A compilation of dinosaur skeletons. Clockwise from top left: *Microaptor gui* (a winged **theropod**), *Apatosaurus louisae* (a giant **sauropod**),".

What journal was the paper published in?

- Academic journals range in quality, including a new breed on online “predatory journals”
- Impact factors provide an imperfect way of evaluating importance
- Low impact \neq bad science



How often has the article been cited?



☒ Articles (☒ include patents) ☐ Case law

Home page of <https://scholar.google.com>

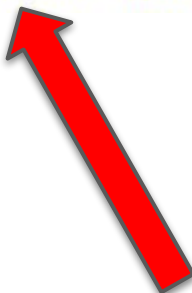
How often has the article been cited?

Bite-force estimation for *Tyrannosaurus rex* from tooth-marked bones

GM Erickson, SD Van Kirk, J Su, ME Levenston... - *Nature*, 1996 - nature.com

Abstract WHETHER tyrannosaurs occupied predatory or scavenging niches has been debated for nearly a century 1–5. Palaeontologists have turned to the study of dental morphology to address this question, but the results have been highly disparate. Some

Cited by 132 Related articles All 7 versions Cite Save



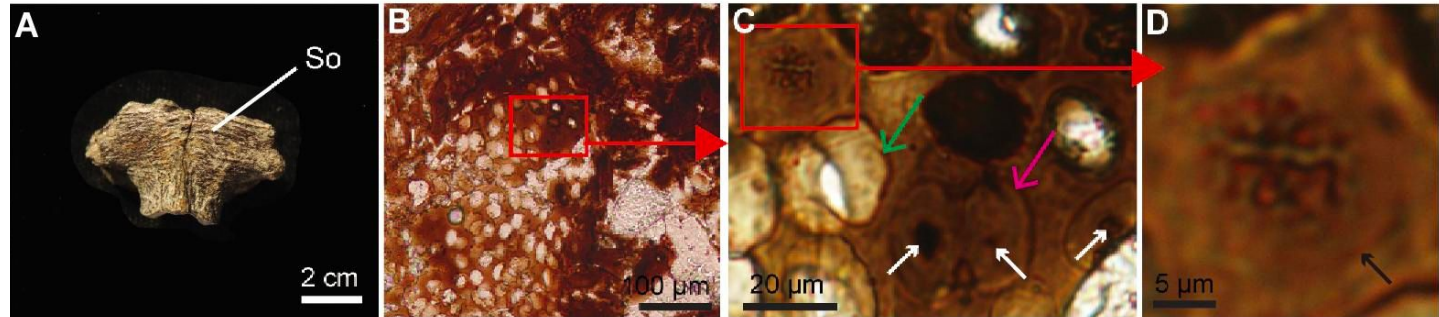
132 citations
(links)



Impact factor of *Nature*: ~42

New, bigger claim from the Schweitzer team

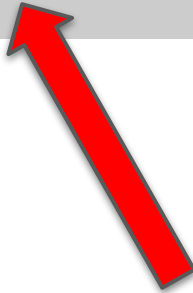
- Supposed recovery of DNA from dinosaur cartilage
- DNA is even more unstable than proteins.
- Not just DNA, but chromosomes! All ancient DNA found so far is highly degraded



Bailleul, Alida M., et al. "Evidence of proteins, chromosomes and chemical markers of DNA in exceptionally preserved dinosaur cartilage." *National Science Review* 7.4 (2020): 815-822.

New, bigger claim from the Schweitzer team

Bailleul, Alida M., et al. "Evidence of proteins, chromosomes and chemical markers of DNA in exceptionally preserved dinosaur cartilage." *National Science Review* 7.4 (2020): 815-822.



Impact factor of *National Science Review*: ~6.5
(= solid science, but low for a paper with such significant results)

Can DNA and protein be preserved in dinosaurs?

- The lack of corroboration by other scientific teams is concerning
- Important to keep an open mind, but great claims require great evidence
- This will be tested and re-tested by the scientific community until a consensus is reached



Brachylophosaurs. picture credit: Houston Museum of Natural Science ([source](#))

Conclusions



Mary Schweitzer ([source](#))

- Science is progressive because a community debates ideas through the venue of **scientific journals** and **peer-review**
- Individual scientists have their biases, but the community historically succeeds at rejecting false ideas over time
- Be a careful consumer of science news. Find good sources and learn to evaluate the papers (at least at a cursory level).