

Lecture 2: Science

(Why should I believe what you tell me?)



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

Caveat: what do I mean when I say “dinosaur”?

- In the first class, I explained how birds are dinosaurs
- The technical term for the group we traditionally think of is “non-avian dinosaurs”
- In this class, assume I mean “non-avian dinosaurs” unless I say otherwise



One way to find a dinosaur ([source](#))

Why should I believe what you tell me?

- Case study: a paleontological expedition in 1923
- Setting: the Late Cretaceous (~75-71 My) Djadokhta Formation of Mongolia (a.k.a. the Flaming Cliffs)



Dr. Roy Chapman Andrews expedition in the Gobi desert ([source](#))

Why should I believe what you tell me?



Protoceratops at the American Museum of Natural History ([source](#))

- Called the *Protoceratops* zone because of multiple specimens of the dinosaur, including nests with eggs
- Also discovered *Velociraptor* and *Oviraptor* on this expedition

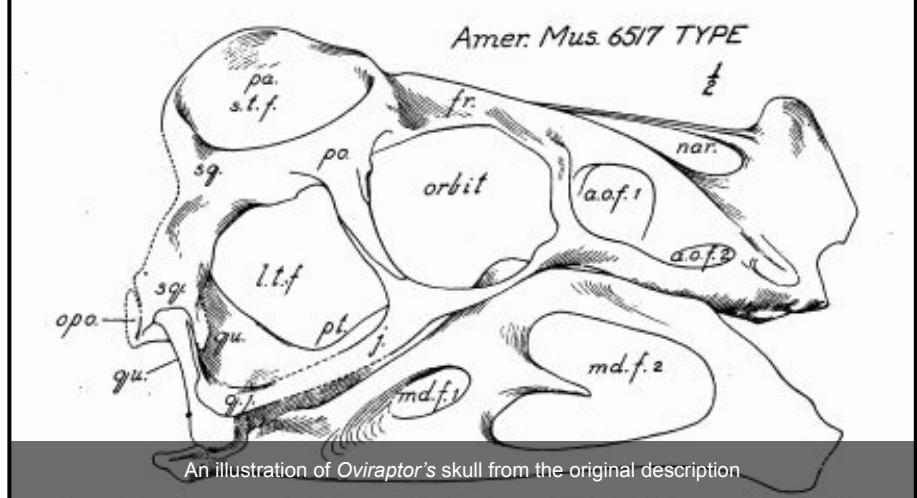
Osborn, Henry Fairfield, Peter C. Kaisen, and George Olsen. "Three new Theropoda, *Protoceratops* zone, central Mongolia." *American Museum Novitates* 144 (1924).

Why should I believe what you tell me?

- A small theropod (meat-eating dinosaur) with an unusual **morphology**
- **Morphology:** the form and structure of a biological organism
- Found on a nest of *Protoceratops* eggs

Oviraptor

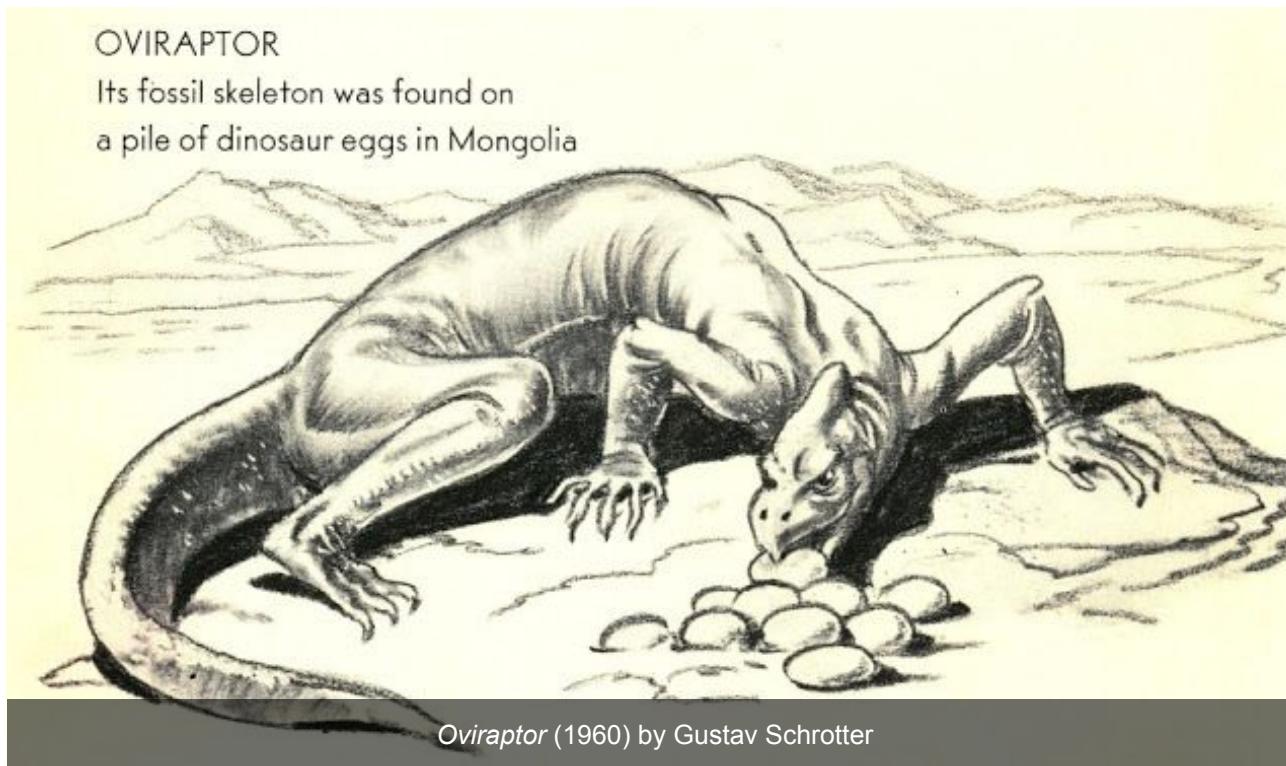
Greek: ‘ovos’ = egg; ‘raptor’ = thief



An illustration of *Oviraptor*'s skull from the original description

Osborn, Henry Fairfield, Peter C. Kaisen, and George Olsen. "Three new Theropoda, *Protoceratops* zone, central Mongolia." *American Museum Novitates* 144 (1924).

The evolving image of *Oviraptor*



The evolving image of *Oviraptor*



Oviraptor (1985) by John Sibbick ([source](#))

One of the most unusual dinosaurs, *Oviraptor* was 5-6 ft (1.5-2 m) long. It had a short head, and the jaws were relatively more massive than those of the

bones were completely toothless; but they might have been covered with a horny sheath. This, and the massive curved shape of the lower jaw, suggests that

powerful forces were applied on them. As its name suggests ('egg thief'), *Oviraptor* probably fed on the eggs of other dinosaurs which it cracked open by biting.

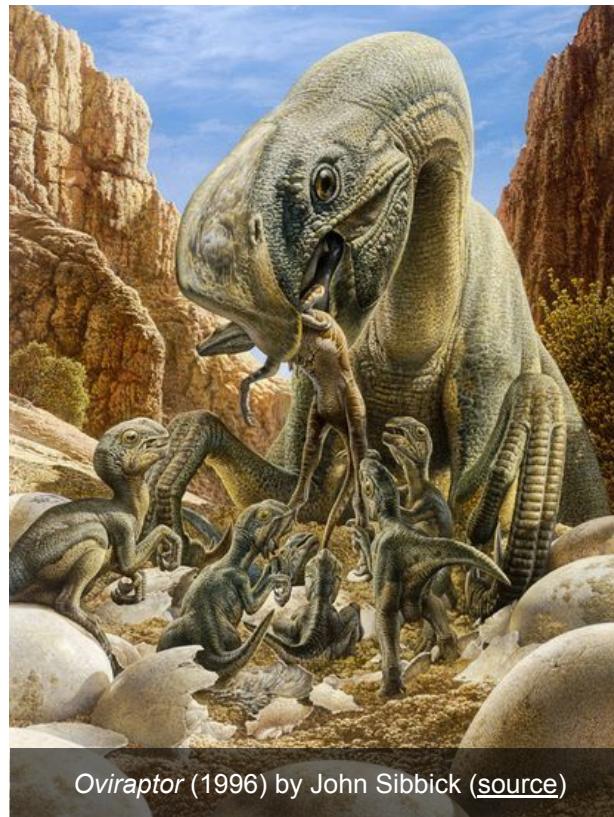
Norman, David. The Illustrated Encyclopedia of Dinosaurs. New York: Crown, 1985.

A new scientific discovery changes what we think



Norell, Mark A., James M. Clark, Luis M. Chiappe, and Demberelyin Dashzeveg. "A nesting dinosaur." *Nature* 378 (1995): 774–6; Norell, M. A.; Clark, J. M.; Dashzeveg, D.; Barsbold, R.; Chiappe, L. M.; Davidson, A. R.; McKenna, M. C.; Altangerel, P.; Novacek, M. J. (1994). "A theropod dinosaur embryo and the affinities of the Flaming Cliffs Dinosaur eggs". *Science*. 266 (5186): 779–782

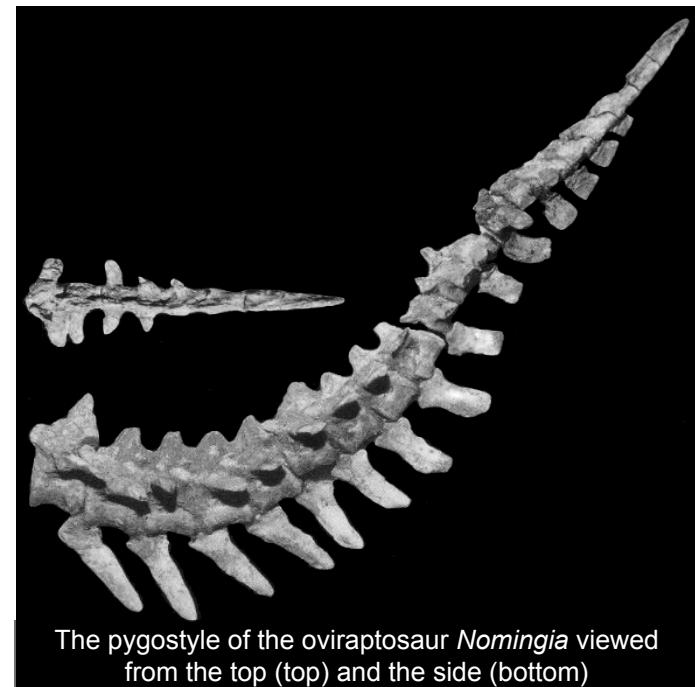
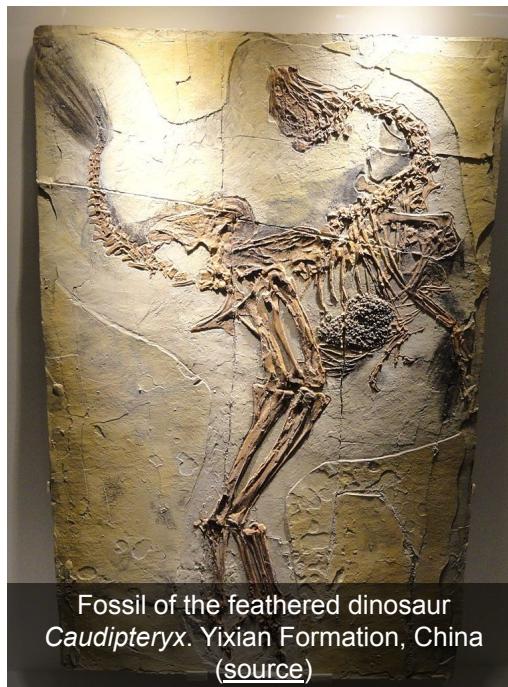
A new scientific discovery changes what we think



Oviraptor (1996) by John Sibbick ([source](#))

New scientific discoveries change what we think

- Feathered dinosaurs are discovered in the late 1990s
- Close relatives of *Oviraptor* are found with **pygostyles**



Barsbold, R.; Osmólska, H.; Watabe, M.; Currie, P.J.; Tsogtbaatar, K. (2000). "New Oviraptorosaur (Dinosauria, Theropoda) From Mongolia: The First Dinosaur With A Pygostyle". *Acta Palaeontologica Polonica*. 45 (2): 97–106.

Ji, Q.; Currie, P.J.; Norell, M.A.; Ji, S. (1998). "Two feathered dinosaurs from northeastern China" (PDF). *Nature*. 393 (6687): 753–761.

The evolving image of *Oviraptor*



Oviraptor (2005) by Sydney Mohr
[\(source\)](#)

The evolving nature of scientific understanding

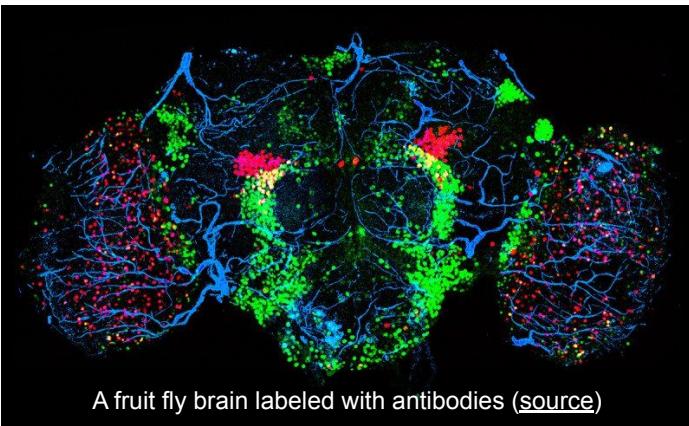
- If ideas are always changing, how do we know what's true?
- Today's goals:
 - Understand the strengths and limits of science
 - Describe the scientific hypothesis



I will be teaching you ideas as if they are true, but in reality they are hypotheses, theories, and laws



- In science, the only facts are *observations* about the empirical world: objects, measurements, images, the “raw” data



- **Empirical:** things that can be recognized by the senses (sight, touch, etc.)

I will be teaching you ideas as if they are true, but in reality they are hypotheses, theories, and laws

- Hypotheses, theories, and laws have specific meanings in science that are different from common language:
- **Law:** a *generalization* about some aspect of the natural world that appears to be true in all cases
- A descriptive account of how nature will behave under certain conditions



Apples fall to Earth because of the law of gravity
([source](#))

		pollen ♂	
		B	b
pistil ♀	B	BB	Bb
	b	Bb	bb

The punnett square demonstrates Gregor Mendel's law of the segregation of genes ([source](#))

I will be teaching you ideas as if they are true, but in reality they are hypotheses, theories, and laws

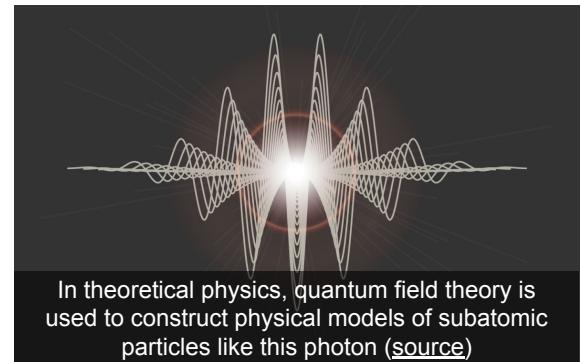


A scientist “doing science” ([source](#))

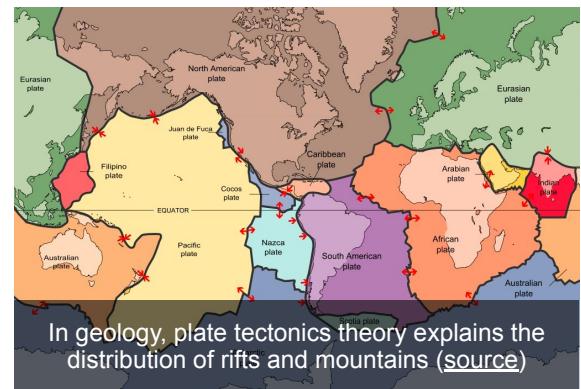
- **Hypothesis:** a proposed *explanation* for a set of observations about the natural world
- In science we often think of hypotheses as “educated guesses”
- The goal of science is to come up with hypotheses and find ways to test them

I will be teaching you ideas as if they are true, but in reality they are hypotheses, theories, and laws

- **Theory:** an *explanation* about some aspect of the natural world that has been repeatedly tested and confirmed
- Theories are the most reliable form of scientific knowledge
- Theories are always at risk of being replaced by a more sophisticated description of nature



In theoretical physics, quantum field theory is used to construct physical models of subatomic particles like this photon ([source](#))



In geology, plate tectonics theory explains the distribution of rifts and mountains ([source](#))

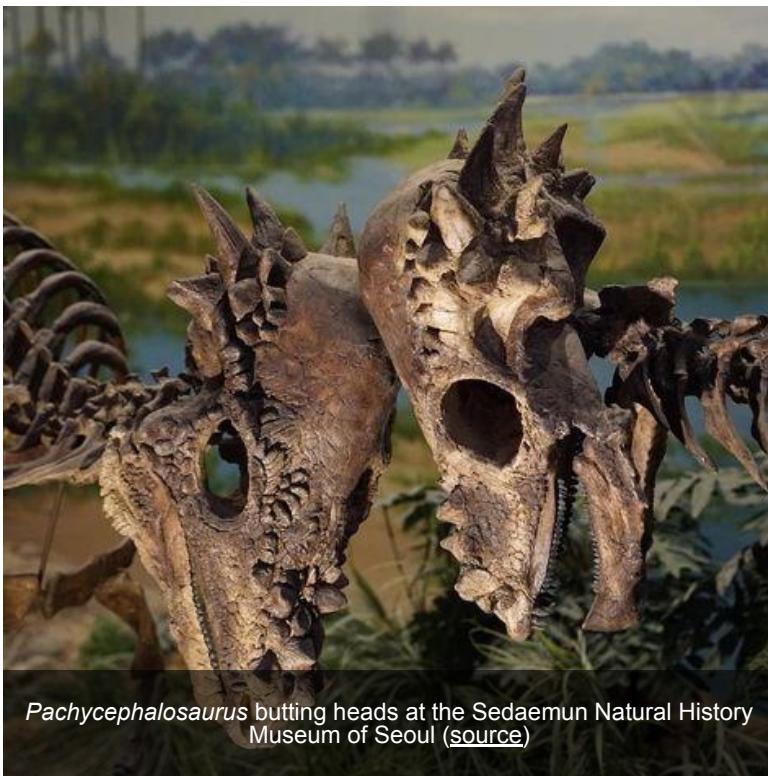
All scientific ideas are subject to being replaced

- In this sense science ***can never prove anything***
- However, we can test ideas and discard incorrect ideas (falsifiability)
- Using this methodology, we gain a better understanding of the empirical world over time through theory building



Popper, Karl. 1959 [2002], *The Logic of Scientific Discovery*, translation by the author of *Logik der Forschung* (1935), London: Hutchinson. Republished 2002, London & New York: Routledge Classics.

All scientific ideas are subject to being replaced

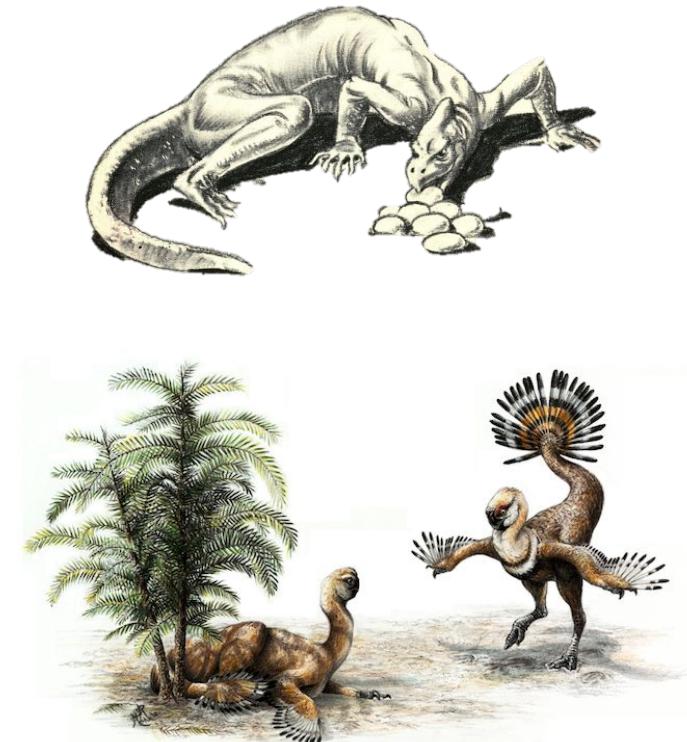


Pachycephalosaurus butting heads at the Sedaemun Natural History Museum of Seoul (source)

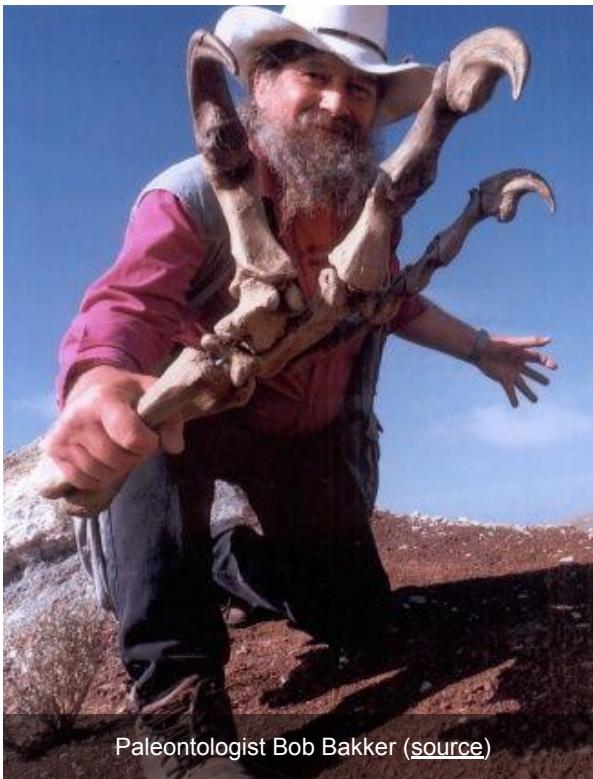
- Testing hypotheses about dinosaurs can be difficult, and sometimes impossible without new discoveries or technologies
- In such cases, the hypotheses are grounded in science but not truly scientific
- We will discuss many clever ways scientists have gotten around this

How is science different from other ways of knowing?

- It is **empirical** (unlike law, logic, mathematics)
- It is **falsifiable** (unlike many psychological and social theories)
- It is **progressive** (unlike art)
- This restricts the kinds of questions science can answer.



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

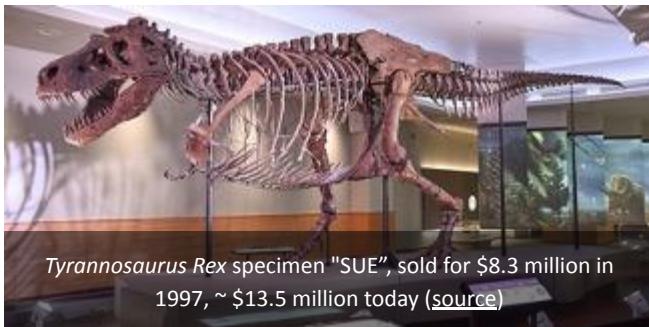
- Historically, paleontology is closely linked to colonialism and resource extraction
- Used to justify land dispossession



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



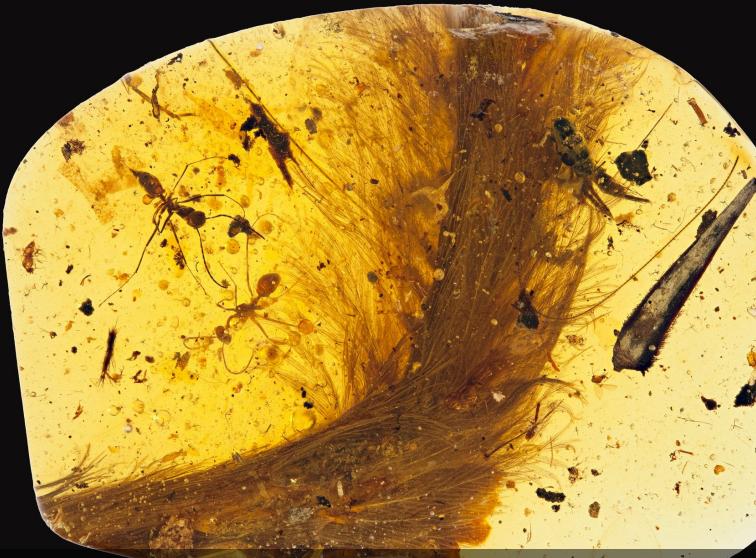
Tyrannosaurus Rex specimen "SUE", sold for \$8.3 million in 1997, ~ \$13.5 million today ([source](#))



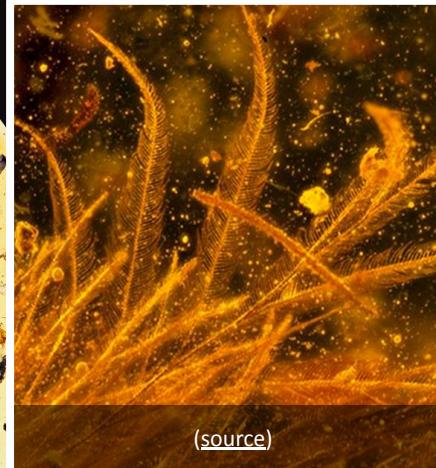
Tyrannosaurus Rex specimen "Stan", sold for \$31.8 million in 2020 ([source](#))

- 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



Dinosaur tail preserved in amber ([source](#))



([source](#))



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

Conclusion



- The “facts” of science are the observable data
- Scientific ideas can be divided into laws, hypotheses, and theories
- No scientific idea is proven, but they are testable and falsifiable
- Science is normative and is not free from ethical dilemmas found in other human endeavors

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DINOSAURS • Published March 3, 2020 • Last Update March 4, 2020

Traces of DNA found in fossilized dinosaur skull, scientists claim

By Chris Caccia | Fox News

In their study, the researchers stated they found "the organic matrix surrounding the fossilized cartilage cells reacted to antibodies of Collagen II," described as "the dominant protein in cartilage in all vertebrates," according to the statement accompanying the study.

"This immunological test supports the presence of remnants of original cartilaginous proteins in this dinosaur," the study's co-author, Mary Schweitzer, added.

Next class: how does science work in practice and how can you be more scientifically literate