THE GREAT FOSSIL FIASCO:

Teaching About Peer Review

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Peer Review in High School Science

Peer review is a fundamental aspect of conducting scientific research. The scientific community relies on peer review in making important decisions, including whether or not a research project should be funded and whether the results should be published in a particular journal. Peer review also is used to provide input to help scientists improve the design of their experiments and the presentation of their results. In schools, peer review can provide analogous opportunities for students to help focus their research questions and improve their methods, and can challenge them to think critically about their results (Carlsen et al., 2001; Trautmann et al., 2000). Because peer review is such a fundamental part of conducting scientific research, it should be an important component of inquiry-based science teaching (NRC, 1996, 2001).

The Cornell University Environmental Inquiry program has developed an Internet-mediated system for high school students to peer review each other's research reports (http://ei.cornell.edu/), as well as a rubric-based system for face-to-face peer review at student congresses or within individual classrooms (Krasny et al., 2002; Trautman et al., 2001). These efforts to teach peer review in the context of students conducting independent research have proven promising; lower level as well as high performing students were motivated to do well in science when they knew their work would be critiqued by peers. In addition, when students all had conducted similar research, they were able to ask insightful questions and provide meaningful reviews of each other's work (Carlsen et al., 2001; Trautmann et al., 2000). However, not all classroom teachers find the time to engage students in hands-on research combined with peer review.

The purpose of this paper is to describe a lesson that engaged middle school students in learning about peer review, using a pair of articles describing a real life story of how peer review forced scientists to critically reexamine a fossil discovery. Because we incorporated this lesson into a paleontology unit, it demonstrates how one might combine teaching about the "nature of scientific research" with a subject matter that is normally taught as part of middle school science. Furthermore, we found that including the hands-on activity with fossils motivated students, whereas an earlier pilot activity in which students only read the articles, but did not handle fossils, failed to engender enthusiasm. We also present some preliminary results of the impact of this lesson on student understanding of peer review.

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The Fake Fossil

In November 1999, the *National Geographic* published an article (see Appendix) about the discovery of a new fossil, *Archeoraptor liaoningensis,* that appeared to have the tail of a land-based dinosaur and the body and head of a more bird-like creature (Sloan, 1999). The fossil generated a great deal of excitement because it purportedly provided the missing link in the search for a bird-like creature that evolved from a dinosaur. It was *National Geographic* policy not to publish an article prior to it being published in a scientific journal; in this way, the *National Geographic* could be assured that it only published work accepted by the scientific community. In the case of *Archeoraptor liaoningensis,* the finders of the fossil assured *National Geographic* that the article would be published in a scientific journal; when this did not happen as scheduled, *National Geographic* made the decision to publish their article anyway.

In October 2000, *National Geographic* revealed that the fossil had, in fact, been a composite of the two types of creatures, and thus was a fake. With encouragement from the editor, the author of the second article offered a very detailed explanation of how the fossil had gotten published as a new species in the first place. In what may sound like a bizarre statement about scientists, who most students and many adults assume are unbiased, the author of the second article claimed, "It's a tale of misguided secrecy and misplaced confidence, of rampant egos clashing, self-aggrandizement, wishful thinking, naïve assumptions, backbiting, lying, corruption, and, most of all, abysmal communication" (Simons, 2000). More importantly, the second article provides insight into the peer review process, and how the fact that the article was not accepted for publication by a scientific journal led the scientists to eventually discover the disturbing truth about the fossil.

Implementing the Fossil Fiasco Lesson

The lesson, which included a fossil activity and discussion of the Simons (2000) article, took place over one 80-minute (double) classroom period. It was conducted by a Cornell graduate student teaching fellow (N. Gift) working in four different classes in a rural middle school, but could easily be taught by a classroom teacher. The lesson began with a short (5 minute) introduction, during which the instructor described a local fossil collection site and students were invited to define the term "fossil." The instructor next divided students into groups of 3 to 5 and gave each group about 50 small partial or whole fossils to divide into species or groups by features. Students spent between 10 and 15 minutes sorting the fossils, and then drew some of the

Table 1.
Definitions of terms used in the *National Geographic* article.

Fossil: rock imprint or mold of dead plant or animal

Paleontologist: one who studies fossils

Archeoraptor liaoningensis: genus and species names given to what scientists thought was a fossil hybrid of a bird and a dinosaur

Evolution: the study of how organisms change over time, for example, changes in dinosaurs to become more like birds

Missing link: a fossil that gives new information about evolution by linking two events or fossils

Peer review: the process by which scientists judge each other's research to determine whether or not it is of sufficient quality for publication, and to provide feedback to each other to improve the quality of their research

Scientific journal: a magazine reporting the results of scientific research in which all articles have been peer reviewed before publication

Red flag: a warning that something is wrong

Table 2.
Homework questions for Fossil Fiasco.

Who found the *Archeoraptor* fossil?

Did the fossil come from one rock or several?

Why did the pieces of rock get put together into one fossil?

What was exciting about this fossil to scientists?

Was the resulting animal "real"? (that is, did all those parts actually belong to one animal?)

Why did the owners of the fossil want it to be a real animal?

Why didn't any scientific journals publish the article about *Archeoraptor?*

Drawing on your experience in looking at parts of fossils, can you suggest a way this mistake could have been avoided?

Why do scientists value peer review?

species they saw on the blackboard. A short identification lesson followed, with an emphasis on how easy it is to mistake one fossil organism for another if only incomplete fossils are available.

The instructor next gave a brief overview of the difficult vocabulary in the Simons (2000) article (Table 1) while introducing the plot of the article. The students then took turns reading 16 paragraphs that the instructor had highlighted in the article, and which emphasized the importance of the peer review process that eventually helped reveal the truth about *Archeoraptor.* (See the Appendix for a copy of the complete article with highlighted paragraphs. It is also available at http://ceirp.cornell.edu/review/ngarthlt.html.) The instructor guided the students in reading the excerpts, filling in details about the players in the incident (scientists, authors, fossil collectors, and their actions and motives) and discussing unfamiliar vocabulary words. More advanced students were observed reading the entire article, leading us to conclude that providing the complete article with highlighted paragraphs was an effective means of engaging students of different reading abilities.

Student Response

Students' answers to the first eight questions in the homework assignment (Table 2) indicated that they generally understood the content of the article, including what the fossil was and how it was created, and which of the players in this incident might have had motives other than seeking the truth about the fossil (e.g., money, fame). In response to question 9, "Why do scientists value peer review?", 76 of 96 students who turned in the homework wrote comments related to helping the author and journal ensure the quality of the article (Table 3). Only 13 students saw the purpose of peer review as supporting a desire to have others affirm their work or agree with them; these responses may reflect students assuming that scientific communities act like classrooms with teachers' (or scientists') comments on assignments affirming the worth of one's efforts. Although question 9 on the homework did not directly address whether peer review is a process among scientific equals, 18 students referred in their comments to scientists wanting feedback from each other or other scientists, whereas only one student wrote that scientists want confirmation from a higher authority. As one student noted, "There are no higher classes to say it's good or not." These results indicate that most students seemed to understand that scientific communities, where there is no ultimate higher authority, function differently than precollege classrooms where teachers evaluate students' work. Thus, overall this activity appeared to be highly effective in accurately conveying the role of peer review.

Table 3.
Student responses to question 9: "Why do scientists value peer review?"

CATEGORY	SAMPLE QUOTE(S)	RESPONSES (#)
Helping the writer and/or journal to ensure that articles are true before being published.	*They need to make sure that nothing is incomplete or left out.* *Scientists value peer review because it tells them that what they have written is correct enough to publish or not. This prevents huge mistakes in scientific journals.* *So nothing totally wacko goes in the journals.* *If there is a problem it can get fixed before it gets published.*	76
Desire to have other scientists agree with them.	*Because it makes them feel better when someone else judges it good.*	13
Helps scientist make more money.	*The better [the scientists] do, the more money they get.*	2
Want OK from higher authority.	*Scientists value peer review because they are able to have an 'OK' from a higher scientist.*	1
See how good they are as scientists.	*They find out how good they are as a scientist.*	1

Conclusions

The Fossil Fiasco lesson was successful in generating student enthusiasm and in teaching students that peer review is a way of helping ensure that published articles contain high quality information and are true. Teachers who feel bound by required curricula may feel a one- or two-day lesson on the nature of scientific research is all they can afford. This lesson offers teachers an entrée into teaching one aspect of the nature of scientific research, i.e., peer review, and, if incorporated into lessons on evolution or paleontology, may require little or no sacrifice of "content" time in the classroom.

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Appendix

***National Geographic* article referred to in manuscript with paragraphs students were asked to read highlighted. Reprinted with permission from the National Geographic Society.**

Archaeoraptor Fossil Trail

By Lewis M. Simons
October 2000, *National Geographic* magazine

Its name—*Archaeoraptor liaoningensis* Sloan—is almost as long as its tail, but to my untutored eye the smattering of scrawny bones resembled nothing more than last Sunday's chicken dinner.

To some prominent paleontologists who saw it, though, the little skeleton was a long-sought key to a mystery of evolution.

To others among this frequently hirsute and determinedly individualistic fraternity, it was a cheap hoax. And to Bill Allen, Editor of NATIONAL GEOGRAPHIC, it was a giant headache.

Last November the magazine trumpeted the fossil's discovery in an impoverished region of northeastern China as providing "a true missing link in the complex chain that connects dinosaurs to birds" and patted itself on the back for helping fund the research. Two months later, when it turned out that the fossil had been artfully assembled from parts of unrelated creatures, that is, it was a fraud, Allen was in quick succession shocked, humiliated, and furious.

After cooling down, Allen asked me to try to find out what had happened. "Learn everything you can about it. How did we get into this mess? Who put this thing together? How did it make its way from a hole in the ground to our pages? Who's at fault? Let the chips fall where they may."

Assured of carte blanche, I traveled through parts of China and the United States, as well as up and down the halls of the GEOGRAPHIC in Washington; interviewed peasant farmers and Ph.D.'s, hucksters, journalists, zealots, and cranks; stared through microscopes, magnifying glasses, and into a room-size, lead-lined scanner; sent and received scores of documents, e-mails, faxes, and phone calls.

Using what I've seen, heard, and read, I've assembled a brief history of *Archaeoraptor*. It's a tale of misguided secrecy and misplaced confidence, of rampant egos clashing, self-aggrandizement, wishful thinking, naive assumptions, human error, stubbornness, manipulation, backbiting, lying, corruption, and, most of all, abysmal communication. It's a story in which none of the characters looks good. And, like the little rack of bones itself, this account inevitably is missing some bits and pieces.

The story began on an oven-hot day late in July 1997, when a farmer digging in a shale pit in Xiasanjiazi, in China's northeastern Liaoning Province, hacked out a thin, buff-colored slab measuring roughly a foot square. Like many of his neighbors, he regularly dug for fossils, which he sometimes sold to a collector or a dealer for a few dollars. But this piece was extraordinary: It contained the fossilized bones of what seemed to be a bird, including a faint aura of feathers and a beak lined with tiny teeth.

He'd been digging with a pick and shovel and had shattered the slab. Some breaks were edgewise splits through the plane of the fossil itself that resulted in what paleontologists term slab and counterslab, or part and counterpart. Something like an Oreo cookie pulled apart, they're essentially mirror images.

Continuing to dig, he uncovered another, smaller slab a couple of yards away. This one contained a tail, rigid and about the size of a crocheting needle, a skull, a foot, and some other parts. It, too, was split into slab and counterslab. Pleased with the day's finds, the farmer scooped up the fragments, shouldered his tools, and walked the two miles or so back across the red dirt fields to his tiny brick house.

I do not know the name of this farmer, nor was I able to speak with him. When I visited Xiasanjiazi last March, no one I met acknowledged knowing such a person. I promised anonymity, but they had good reason to play dumb. A police official in the county seat, Beipiao, told me that only farmers authorized by the police may dig, and they must turn over their findings, in return for a small payment. Anyone keeping a fossil is subject to arrest. In the nearby city of Jinzhou a judge said that punishment could range from two or three years in jail to—in exceptional cases, such as when a fossil is smuggled out of China and sold abroad for tens of thousands of dollars—execution.

Archaeoraptor was taken to the U.S., where it sold for $80,000.

So, what I write of the farmer is based on what I saw in the village and in the pits and on relayed responses to questions that I left for him with the dealer who bought the specimen from him. In his one-room house, the farmer laid the counterslab of the tail aside.

Using a homemade paste, he glued the slab of the tail to the lower portion of the birdlike body. With counterslab pieces from the body itself—and possibly other scraps he'd kept over time—he glued in missing legs and feet. Aware that fossil fanciers, unlike paleontologists, prefer specimens assembled and suitable for display, the farmer was following basic market economics.

The result was the "missing link"—the body of a primitive bird with teeth and the tail of a landbound little dinosaur, or dromaeosaur. In time the tail, and the question of whether or not it belonged where it was stuck, would wag the dinosaur.

Whether the farmer was deliberately creating a fraud to earn extra money or earnestly connecting fragments he thought belonged together, I can't say positively. According to his response to my queries by way of the dealer, he believed then and still believes that "the tail belongs to the body [and] was pushed away from the body when it was

buried" more than 120 million years ago. But, when he found it, he had to have seen that the tail was connected to another body.

The dealer, with whom I spoke at length and whose name I will not disclose, for his safety, was the only character in the story who did not admit some culpability. He said he bought the fossil from the farmer in June 1998 and insisted that he had no knowledge then or now of it being a fake. "Fossils are my sole source of income, and I sell to the same people regularly," he told me. "I would be finished if I sold fakes." But he acknowledged that he often sold "composites." The difference, in his mind, is that a fake is created to fool the purchaser, while a composite is intended "to make the specimen look complete." I found this point too fine to grasp.

I have no doubt that the dealer knew he was smuggling, though he went to great pains to explain his way around Chinese law. Through a "partner" at a scientific institute in the city of Guilin, he obtained a paper titled "certificate," which states that the fossil was "legally acquired" and "is legal to be exported from China" as part of a "specimens exchange program."

A 1982 Chinese law prohibiting export of vertebrate fossils is now undergoing its sixth revision, and the dealer argued that "at the moment there's no law." While authorities in Beijing insist that no fossils may leave the country legally, the reality is that huge quantities are taken out, most through the expediency of bribing local officials.

The dealer sold *Archaeoraptor* in early February 1999 at a bazaar-style gem and mineral show in Tucson. The buyer, Stephen A. Czerkas, director of a nonprofit dinosaur museum in the small town of Blanding, Utah, told me he was "stunned" when he was shown the fossil in the dealer's motel room. Never doubting its authenticity, he raised the $80,000 asking price with a phone call to M. Dale Slade, a Blanding businessman and an active backer of the museum.

Czerkas and his wife, Sylvia, are artists who create life-size dinosaur figures, some of which are displayed in major museums around the world. They're utterly consumed by their work, and their home in the fields outside Blanding is filled indiscriminately with dinosaur kitsch and art, from plastic knickknacks and movie posters to paintings, bronzes, and textbooks. Although they've written books and papers, neither holds a doctorate. This is a sensitive nerve with them and an irritant to some Ph.D.-equipped paleontologists, who dismiss them as hobbyists.

The Czerkases and Slade anticipated the new specimen would become the crown jewel of the Blanding Dinosaur Museum. While intelligently conceived and attractively laid out, the museum is off the beaten track and draws about 9,000 visitors during the six months a year it's open, just covering expenses. They could see the fossil becoming a magnet for huge crowds of tourists as well as serious researchers. Despite their dream being shattered, neither Slade nor the Czerkases has attempted to get the $80,000 back. The dealer told me he has made refunds and exchanges in the past. "Why should we want our money back?" Slade asked me incredulously. "We got better than our money." According to him, the fossil has been appraised at "between $1 million and $1.5 million," and his company plans to write that off as a contribution to the Blanding museum.

A week or so after taking the fossil home, the Czerkases discussed it with an old friend, Philip J. Currie, a renowned Canadian scientist based at the Royal Tyrrell Museum of Palaeontology in Alberta. The couple wanted Currie to join them as co-author of a paper they would write. Currie was interested. Since he often consulted for NATIONAL GEOGRAPHIC, he mentioned it to Christopher P. Sloan, the magazine's art editor. Sloan thought there could be a story in the little fossil.

But Currie and Sloan didn't want to jeopardize their organizations' access to China by becoming associated with a specimen the authorities would doubtless consider smuggled. With difficulty, they convinced the Czerkases to return *Archaeoraptor* to China after completing the study. (The fossil was eventually handed over last May 25.)

At Currie's suggestion the director of Beijing's Institute of Vertebrate Paleontology and Paleo-anthropology, which would receive the repatriated fossil, proposed that Xu Xing, a boyish-looking scientist at the institute, spend "three to five months" in the U.S. helping study *Archaeoraptor* and contributing to the scientific paper. As it happened, a jet-lagged Xu, flown to the U.S. by NATIONAL GEOGRAPHIC, would spend just two days gazing at the fossil in Blanding before being pushed to the fore at a meeting with news media in Washington, where he had little to offer. His name on the paper would add no more than an exotic touch to the all-American cast. Ironically, it would be Xu who, two months later, dumped the whole story on its head.

Knowing that the fossil would be returned to China, Currie now felt free to become directly involved, and Sloan obtained Bill Allen's commitment to cover the story. A plan was cobbled together for the Czerkases and Currie, along with Xu, to first write a paper and have it published in the prestigious scientific journal *Nature*.

NATIONAL GEOGRAPHIC—which attempts to bridge the gap between hard-core science and popular interpretation—prefers not to break scientific discoveries without having them peer reviewed in advance by scientists. The effort to coordinate publication between *Nature* and NATIONAL GEOGRAPHIC would eventually break down, contributing in large measure to the GEOGRAPHIC publishing a false article.

The *Archaeoraptor* story was originally to appear in the magazine as a small, subsidiary part of a broader piece on feathered dinosaurs. Sloan, who'd handled the artwork for numerous articles but never written a story, had convinced Allen to let him write this one. Publication was set for November, six months ahead.

The association of Sloan and Currie would prove to be star-crossed. As a first-time writer, Sloan committed the journalist's cardinal sin—he assumed that since Currie's

reputation was so outstanding, there was no need to stay on top of him or question him. Currie became a collaborator rather than a source. Worse, Currie was so distracted by other commitments around the world that he gave the *Archaeoraptor* project short shrift.

Earlier, on March 6, Currie had flown to Blanding at NATIONAL GEOGRAPHIC's expense and examined the fossil for the first time. He raised the first red flag. "I realized that all was not right because you couldn't see a connection between the tail and body," he told me, "and clearly the legs were part and counterpart."

I told Stephen. He agreed. It was obvious—you could measure the bones and see how they lined up." The Czerkases' recollection, however, is that Currie had mentioned only one of the feet—not a grave concern—and nothing about the tail.

Discrepancies like this kept cropping up as I interviewed those involved. With the negative publicity still hanging over them, people now recall widely differing versions of what took place. In the brilliance of hindsight, what may have been foggy at best then is perceived as razor-sharp now. Few accept blame; everyone accuses someone else.

There would be more red flags. But because Allen had ordered a thick blanket of secrecy over the project, they went unseen or unreported. Had any of these warnings filtered through to him, Allen now says, he would have pulled the plug.

In a most damaging lapse of responsibility, Currie did not tell Sloan about his concern. He said he assumed the Czerkases would. They say there was no reason to. In May, Sloan visited the Czerkases himself and had his own look at the fossil. An avid dinosaur enthusiast but no scientist, Sloan was very excited. "I had no doubt that it was a weird animal," he said, "but I had no reason to suspect that it wasn't legitimate. I'd worked with Phil for years, and he'd seen it." Blindsided by his esteem for the scientist, Sloan neglected to question Currie thoroughly.

Currie's involvement was key to NATIONAL GEOGRAPHIC's own. Later in the preparation of the article, when Bill Allen told his editors to keep strict confidentiality, Kathy B. Maher, the senior editorial researcher assigned to check it for accuracy, recalls she wasn't troubled, "because Phil was on the job, and I trusted him implicitly." Currie now acknowledges that he dropped the ball. "Definitely, I should have flagged the GEOGRAPHIC directly and not relied on others to do it." As the project moved inexorably toward publication, he was in the field, darting from Canada to Mongolia to Europe to Argentina, largely ignoring what was happening in Utah.

On August 2, Currie joined the Czerkases briefly in Austin, at the University of Texas High-Resolution X-ray CT Facility founded by professor Timothy Rowe. Using a device the size of a kitchen dining nook, Rowe and his aides had scanned the fossil for more than a hundred hours and generated a series of pictures that appeared to show numerous breaks, 88 pieces in all. Some of the fractures seemed to be between unmatched pieces, skillfully pasted over. Rowe, ruggedly handsome and casually profane, agreed to charge a discounted rate of $10,000 for the scans—paid for by a National Geographic Society grant to Currie—in return for being included as another co-author of the paper.

By the time Currie walked into the basement-level lab, Rowe and the Czerkases had gone over the pictures. According to what Rowe told me, the scans revealed that "the tail had no natural connection to the body," and he explained this to Stephen and Sylvia. "It was hard to do, but I told them the fossil had been badly shattered and put together badly—deceptively—and there was a chance that it was a fraud. They were badly affected. I didn't know at the time that they'd invested $80,000 in it."

Currie remembered, though, that by the time he'd entered the room, "Stephen and Sylvia and Tim had come to agreement that [the body and tail] did belong together." Over the next several hours, however, it became apparent that Rowe, as well as Currie, was uncomfortable with this. But they succumbed to the Czerkases' pressure. (Had Xu Xing never lucked into the farmer's second fossil, Currie and Rowe could be basking in *Archaeoraptor's* and the Czerkases' shared glory today.)

So, they contented themselves at the time with voicing reservation in private and never demanded that their doubts be strengthened in print. Stephen had insisted that they move ahead quickly and play down their differences because NATIONAL GEOGRAPHIC was on deadline, said Rowe. This was true, but according to Bill Allen, "if anyone here had any inkling that something of this magnitude was wrong, I'd have stopped it, even on the day the magazine went to press [September 19], even though it would have cost us as much as $200,000."

The Czerkases' own take on what happened was that Rowe's CT scans were inadequate," that they showed "less than what was visible to the naked eye," and that Rowe was "jumping on" the break between the tail and the body "in order to justify the importance of his lab." A key element of the disagreement between Rowe and the Czerkases turned on ego and personality: Rowe disdaining the couple for their "controlling ways" and lack of formal education, and they biting back at him as "an ivory tower elitist, ambitious to the point of being willing to sacrifice anyone."

As Currie left, a National Geographic Television team arrived at Rowe's lab to film *Archaeoraptor* for a program on feathered dinosaurs. No one informed the TV crew or Sloan back in Washington of the discrepancies they'd just discussed. Rowe told me that since he was "just a hired hand" and that the Geographic's funding had gone to Currie, he owed Currie confidentiality. Besides, he added, "you know what happens to the messenger bearing bad news. Little did I know that Stephen and Sylvia would suppress it." Red flag number two.

Currie dispatched Kevin Aulenback, a fossil technician at the Tyrrell Museum, to Blanding the first week in

September to "prep" the specimen—a painstaking process of microscopically cleaning the bones and removing the surrounding dirt of millennia so that scientists may better examine the fossil. Things got off to a bad start. Aulenback said he was certain that pieces had been amalgamated, though he couldn't say if the pieces came from one animal or more. The Czerkases angrily replied that his evidence was insufficient. On the plane back to Alberta, Aulenback wrote a detailed and acerbic memo of his findings and e-mailed it to Currie, then in the Gobi desert, concluding that *Archaeoraptor* "is a composite specimen of at least 3 specimens ... with a maximum ... of five ... separate specimens." He did not send it to the Czerkases. This third red flag was not relayed to Sloan either. When Sloan asked, "How did the preparation of *Archaeoraptor* go?" Aulenback replied with excruciating specificity, "Preparation of *Archaeoraptor* is quite good."

"Why not tell him about your findings?" I asked. He replied: "If he'd asked me what I thought about the fossil, I would have told him. But that's not what he asked."

In Washington, Sloan recalled, "we were only waiting for Stephen and Phil to agree on whether *Archaeoraptor* was capable of flight. Once they decided that it was, I went to Bill and told him, "This is hot." Allen agreed to move the *Archaeoraptor* segment up and make it the dramatic lead of the story.

At about the same time, on August 13, after rewriting and revising their paper perhaps 20 times, the scientists submitted it to *Nature,* sending it by express mail from Blanding to London, with a copy to Sloan in Washington. Titled "A New Toothed Bird With a Dromaeosaur-like Tail" and under the names of Stephen Czerkas, Currie, Rowe, and Xu, it stated in the lead paragraph that "the primitive bird from China ... is more derived ... than *Archaeopteryx,* the oldest known fossil bird ... [and] has elongate rod-like extensions ... remarkably like those in dromaeosaur dinosaurs. "

On its second page the paper pointed out, though with no alarm, that "counterslab pieces of the right leg had been incorporated into the main slab in the position of the left leg [and] the tail is probably from the counterslab." These problems were repeated on a later page.

Sloan acknowledges that "in 20/20 hindsight, alarm bells should have gone off" when he read this. "But all those months ago, I probably read right over it and thought, Well, all those scientists don't seem to think anything is strange. I certainly didn't see any hint that the tail or anything else came from another critter."

On its fifth page the paper stated that the dromaeosaur-like tail on a birdlike creature suggested a previously unknown element in the evolution of birds from land-bound dinosaurs. In short, this was what Czerkas would tell NATIONAL GEOGRAPHIC was "a missing link."

Finally, the paper contained a hand-drawn figure of the skeleton, with the right leg and foot and tail shaded. The leg

and foot, the caption stated, "are counterslab elements that were cemented to the main slab. We believe the tail to have been cemented from the counterslab as well."

As the paper was winging its way to London, *Nature* senior editor Henry Gee was e-mailing an irate message to Barbara Moffet in the National Geographic Society's public affairs office. He told her he still had not received the paper and that there was no chance of having it peer reviewed in time to publish it, as planned, in September, ahead of the Society's scheduled October presentation to the media and the simultaneous publication of Sloan's article in the November magazine. Gee copied Rowe, Currie, and Xu, but not the Czerkases.

Unknown to Rowe's colleagues and to Sloan, on August 14, the day after the paper was mailed, Rowe responded to Gee with an e-mail. He'd been "sucked into" the project, Rowe wrote heatedly; he had "no idea of just how poorly the entire enterprise" had been conducted; and "the publicity circus that the Czerkas's [sic] have tried to orchestrate with [the National Geographic Society] has been driving way too much of the project, and that I just hope that it hasn't now completely [expletive] the scientific side." Still, he said, *Archaeoraptor* is "a very important specimen" and that was why he'd "signed on to this drowning party—and why I guess I'll put in a few more hours to try to straighten out the whole mess."

Sloan reacted with surprise when I read the message to him. "If Tim had given us even a sense of his outrage at that time, it would have made all the difference," he said.

On August 20, in a "Dear Dr. [sic] Czerkas" e-mail, Gee wrote, "We would not be prepared to consider this manuscript for possible publication in *Nature*." Gee gave no hint of the paper being inadequate or wrong, only blaming NATIONAL GEOGRAPHIC for refusing to hold off publication indefinitely to permit full peer review.

Shifting gears overnight, the scientists dashed off a subtly altered version of their paper to another journal, *Science*. *Science* farmed the paper out for peer review and then rejected it, saying it required more proof of *Archaeoraptor's* birdlike qualities. Another rewrite followed. Another rejection. Another red flag.

Currie and Czerkas continued to assure Sloan and Allen—even after the millions of yellow-bordered magazines began rolling off the presses—that the paper would be published somewhere, even if only by the Blanding museum. It never happened. Thus, the GEOGRAPHIC was out on its own limb, lacking the scientific backing it so badly wanted.

A dog-and-pony show for reporters on October 15, and the article itself, churned up the expected "missing link" publicity—and set the stage for the magazine to take a pratfall. Flaws began appearing almost immediately. At a meeting of the Society of Vertebrate Paleontology in Denver, October 20-23, some scientists in the holdout group that opposes the birds-from-dinosaurs theory used the forum to disparage the article. Rumors flew. Rowe presented a paper on CT scanning of fossils and, ironically, given his previous e-mail to Gee, stated: "I found myself as an author of a paper returned to us, saying the specimen had been doctored. I take exception to that, but now we have a tool to study it."

Storrs L. Olson, curator of birds at the Smithsonian Institution and a leading opponent of the theory, came down hard on *Archaeoraptor.* One of Olson's main concerns, but by no means his only one, was over the esoteric process of naming a fossil, a privilege normally granted the author of the scientific paper describing the specimen. In this case, since the only published use of the name *Archaeoraptor liaoningensis* appeared under Chris Sloan's byline in the GEOGRAPHIC, he won the dubious distinction by default. His surname is now appended to the full scientific moniker, *Archaeoraptor liaoningensis* Sloan. This further embarrassment could have been avoided if the article had simply referred to an "unnamed fossil," Sloan told me. But all this inside-paleontology quibbling soon deteriorated into a footnote.

On December 20, Xu Xing sent e-mails to his coauthors and to Sloan, bluntly smashing the missing link. "I am really sorry to tell you a bad news!" he began inauspiciously in strained English. A contact in Liaoning had shown him the counterslab of the *Archaeoraptor* tail—joined to a dromaeosaur body. Xu could see plainly (as I could when he showed it to me a month later in his Beijing lab) that the tail impression and a pair of flanking yellow iron oxide stains were perfect mirror images of the piece glued into *Archaeoraptor.* "I am 100% sure...," Xu wrote, "we have to admit that *Archaeoraptor* is a faked specimen."

The entire mess collapsed quickly:

NATIONAL GEOGRAPHIC published a cleaned-up version of Xu's letter in its March issue, at his request changing "faked" to "composite."

The Czerkases fell into despondency and then fought their way back, holding out hope against hope. They finally conceded defeat on April 4, when Stephen told a gathering of paleontologists in Washington that he and Sylvia had made "an idiot, bone-stupid mistake." At that meeting, organized by the National Geographic Society in an attempt to put an end to the fiasco, independent scientists for the first time examined *Archaeoraptor* and Xu's second fossil side by side. They concluded beyond all doubt that the tail belonged to the second fossil.

A shame-faced Philip Currie said getting involved in the *Archaeoraptor* saga was "the greatest mistake of my life."

Tim Rowe felt vindicated, claiming that his scans proved right from the start that the fossil was a fake.

Chris Sloan feared he did great damage to his credibility at the magazine. "I thought I was bringing in more than was expected, and it turns out I was dragging in a monster."

And Bill Allen says he's learned the wisdom of a saying scientists have long shared. "Extraordinary claims require extraordinary proof. We had an extraordinary claim, but very ordinary proof."