4 PREPARING SCIENCE

A fossil emergency, so to speak, offers a revealing example of how research workers prepare their sense of what science is through their everyday work. This episode illustrates how workers differentiate themselves into professional groups that they believe are united by a common purpose: science. (Chapter 5 follows how research workers prepare a conception of science for the public through museum exhibits, as opposed to within the fossil community.) One afternoon, a collection management assistant at the Southern Museum telephoned the prep lab and asked preparator Jay to come immediately to the long rows of metal shelves that house the museum's fossils. Jay stopped what he was doing and hurried, with me in pursuit, to a small room surrounded by specimen cabinets and with a tense, funereal atmosphere. Grave-faced scientists and collection management workers were crowded around a three-foot-long fossil skull. The skull belonged to a phytosaur, an extinct semiaquatic reptile that resembled crocodiles. Jay and I had moved it from its shelf to that room a few days earlier so that a visiting researcher could study it. Preparator Kevin followed us in and asked Jay, "How bad is it?" Jay answered, staring at the skull, "Pretty bad. Three breaks and crumbs." The skull was disastrously split about halfway down its length, where it narrowed into a long snout (figure 4.1). The "crumbs" of fragile bone meant that the fossil was disintegrating along the breaks and thus the skull's pieces would not fit together cleanly when repaired. This severe damage was surprising because the skull was in a custom-made plaster clamshell jacket, which has two sides to allow the

Figure 4.1
The broken phytosaur skull lies in its plaster jacket with a long crack through its snout.

specimen to be turned over while supported inside the jacket. The workers did not have to say that the jacket should have prevented this damage; they all knew it. Only Jay touched the broken skull, while the others asked him subdued questions about how it may have broken and how to fix it. A collection manager, for instance, offered an idea as a question to Jay: "Flip it out [of the jacket] into the sandbox? Would that work?" Jay said shortly, "Uh-uh," meaning "no," and the collection manager did not question Jay's rejection. Mostly the staff members stared at the fossil, with long moments of shocked silence.

When the visiting researcher came in, the silence turned accusatory. With remorse, she explained that the skull must have broken when she and the collection assistant had turned it over, which, she swore, they had done with the clamshell jacket. Researcher Henry suggested that perhaps the jacket did not fit well and so had not protected the skull during turning. Jay checked the jacket and rejected that possibility: "There's contact on both sides. . . . There's not a lot of movement in here." Again no one argued. Jay's judgment was the end of the conversation. Jay told the assembled mourners that he would line the empty half of the jacket with plastic wrap, turn the skull over into that half, and then lift out the bone crumbs to reattach them as best as possible. No one questioned his plan or approved it, or said anything at all. They understood that the skull would never be quite the same. Jay left the room to report the broken specimen to researcher Maurice, telling him that he suspected that the visiting researcher had tried to lift the fragile skull out of the jacket to study it. Maurice asked, "Well, there isn't any other way to break it, right?" He had faith in the jacket, which a preparator had made, and assumed that such destruction could only result from mishandling.

The scientists and collection staff did not know how to fix the fossil; they knew only to call a preparator. Then Jay was in control. The only conversation was in the form of questions to him, and his judgments were the deciding ones. Maurice's trust in the clamshell jacket further reflects scientists' confidence in preparators' expertise in specimen protection. This crisis made the distinctiveness of preparators' and researchers' skills as well as jurisdiction (Abbott 1988) strikingly clear. Which group has power in which situations reflects how these groups perceive their differences and, crucially, their shared purpose and raison d'être: science.

This chapter investigates the social roles and power structure between the two groups of research workers whose tasks are the most interdependent: scientists and preparators. Preparators' jobs rely on scientists' requests, and scientists' ability to study specimens relies on preparators' work. (This coreliance is not as significant for conservators or collection managers, who are concerned with specimen collections regardless of whether the objects are prepared or studied.) Sociologist Pierre Bourdieu characterizes people who do similar work and share entry criteria as a "field," which is a helpful framework for categorizing groups of research workers. These groups of workers have various combinations of "capital" (i.e., experiences and skills), "habitus" (i.e., work practices), and "doxa" (i.e., beliefs), thereby designating them as separate fields (Bourdieu and Wacquant 1992, sec. II; Bourdieu 1993, chap. 9). Sociologist Aaron Panofsky (2011) has shown how field theory can illuminate how interdisciplinary communities exchange different kinds of capital; here, I apply it to multidisciplinary communities to analyze how separate fields work in parallel and coordination, yet with autonomy and distinct identities.

My aim is not to study demarcations between so-called scientific and technical work, which oversimplifies the divisions between research workers. Instead, I describe the fields that scientists and preparators enact for themselves and each other. This approach offers insights into how members of different fields collaborate in research communities, and how that collaboration reveals and helps define how these groups understand what it means to do science. Members of multidisciplinary research communities are united by their pursuit of a common vision of science, which they work to achieve while also advocating for their field's values. Specifically, scientists and preparators all want a researchable fossil. Preparators focus on making the fossil stable, protected, and undamaged, while scientists concentrate on gleaning the most and highest-quality data from it. Together, these priorities inform preparators' work in ways that satisfy both groups. This chapter studies how practitioners from separate fields prepare that common vision by enacting their divided labor, protesting when one group violates another's jurisdiction, and discussing their interrelated work to align it with each other's values.

Power in Context

Workers in vertebrate paleontology labs perceive science as a conglomeration of separate fields. This view has potential epistemic benefits, such as reducing theory-laden observation by distancing scientists from the preparation of evidence (chapter 3; Wylie 2019a, 2019b). It also justifies scientists' omission of fossil preparation work from publications because that work belongs to a different field. As a result, scientists don't pay much attention to how preparators make fossils researchable and thus preparators have de facto autonomy over their work. Scientific recognition—and the lack thereof—is a crucial mechanism of defining group identities and preparing a local conception of science as the goal that a research community works toward together. Like the preparation of evidence, communities, and technologies, the preparation of science is iterative, ongoing, and context dependent.

Less obvious, perhaps, are the social benefits for technicians of creating distinct spaces, responsibilities, and kinds of expertise for a research community's workers. By granting technicians (as well as scientists) autonomy over their work, this separation empowers all practitioners to develop their skills, train novices, choose and design techniques, and decide their own conceptions of good work and workers (i.e., to prepare their community, technologies, and evidence). This "craft control" (Keefe and Potosky 1997) encourages technicians' commitment to their field and institution, unlike demoralized workers who feel unappreciated. For example, one scientist told Barley and coauthors (2016, 143), "I have seen lab directors ruin their lab by giving orders to a technician. . . . A month later, the tech is looking for a new job and the director is left holding the bag." Control over techniques is a sign of expertise and respect, and receiving instructions from people in other fields can be interpreted as an insult.

Defining skill and identity relative to other groups is common in research communities. Doing (2009) describes a separation between physicists and "operators" based on their definitions of expertise. The physicists portray their expertise as abstract and theoretical, and operators perceive their expertise as manual and experience based, demonstrated by making lab machinery run effectively (Doing 2009, 58–59). Doing argues that these disparate beliefs allow each group to claim power over their own work, despite the formal status differential and the groups' de facto interdependence. While preparators' view of their expertise—as skillful and creative—matches abilities traditionally ascribed to high-status artists and scientists (chapter 1; Wylie 2015), Doing's operators present an opposite conception of expertise from that of their researcher-bosses. Both groups are trying to define themselves, but with different reference groups: for preparators, against the stereotype of protocol-following, low-status technicians, and for operators, against the high-status, theory-focused scientists who are—according to the operators—incompetent at using lab machines. Thus technicians may be less interested in authorship or useful objects than they are in the power to direct their own work.

Low or high status in research publications and institutional hierarchies has a major influence on research work, but as a shifting, local, context-dependent practice rather than a predetermined status quo. A more accurate indicator of groups' relative power is context-based (in)visibility, which can confer control in unexpected ways. For example, museums' so-called scientific staff (i.e., scientists) and support staff (i.e., everyone else) have different expertises, but institutions tend to value research expertise over all other kinds. A similar distinction exists between factory managers and "unskilled" workers, because managers consider "unskilled" work inferior and yet don't actually know how to do that work (Kusterer 1978, 14). As a result, the supposedly unskilled workers control their work by choosing how to complete tasks and train novices (Kusterer 1978, 42–44), as preparators do. Preserving this knowledge separation "added to the workers' autonomy and decreased their alienation," thereby improving their job satisfaction despite their low institutional status (Kusterer 1978, 14). Barley (1996, 429) similarly observed that "our data are inconsistent with the view that a technician's knowledge is a proper subset of what another occupation knows. . . . A more accurate image would be that of intersecting sets." All fossil researchers and preparators, for instance, can distinguish fossil from rock, but in general only researchers know the unique characteristics of different species, and only preparators know how to remove matrix safely and effectively. Both groups need each other's expertise in order to prepare fossils to serve as evidence.

Likewise, biology research workers consider their expertises separate but equally important: "The technicians possessed most of the contextual knowledge of empirical matters whereas scientists were masters of formal representations. Because scientific productivity required both forms of knowing, scientists and technicians considered themselves to be *mutually interdependent*" (Barley and Bechky 1994, 119, original emphasis). Contextual knowledge means knowing how to use experiments and equipment to achieve desirable results. The embodied, adaptive craft of preparing evidence is a form of contextual knowledge. These biologists and technicians recognize their need for each other's knowledge, yet the technicians nonetheless have low institutional status. This situation "reflected a disjuncture between institutional and everyday evaluations of the importance of contextual and formal knowledge" (Barley and Bechky 1994, 116).

This disjuncture appears in preparation labs too, and may be common in research communities.

Differences in research workers' power can also be explained by differences in their goals. Technicians report that they work because they "love" and enjoy their jobs (Zabusky and Barley 1996, 197)—sentiments that preparators express frequently and paleontologists articulate less often, perhaps for fear of sounding too emotional and not purely rational. Sociologist John Law (1994, 123) found that synchrotron technicians named pay as their motivator, but acted as though pride was their aim by valuing autonomy and good work. In comparison, physicists told Law that success in their field was their goal, and acted accordingly by valuing respected experiments and publications. As a result of these disparate stated goals, physicists assumed that technicians were "passive, uncreative, and unskilled" and treated them that way, such as by giving them instructions rather than allowing independent work (Law 1994, 123). De Solla Price (1965) similarly argues that scientists write as many papers as possible for personal glory and to add to the "eternal archive" of knowledge, but they rarely read papers. In comparison, "technologists" rarely write papers but often read them, preferring to update their knowledge over sharing it and to measure their expertise by the production of objects or processes, not papers (de Solla Price 1965). Communities distinguish among fields in many ways, suggesting that workers' skills, motivations, and tasks are important indicators of social order as well as the more formal measures of job title, credentials, and pay.

HOW SCIENTISTS AND PREPARATORS DEFINE SCIENCE BY DEFINING THEMSELVES

There are social and epistemic benefits to dividing research communities into fields, despite these fields' interdependent expertises. Conflicts arise, however, when these fields do not have equal institutional status and thus their power dynamics depend on context. For example, as in the case of the phytosaur skull, preparators are in charge in situations of broken fossils. In comparison, scientists choose which specimens to be prepared. Other contexts, such as setting deadlines for preparation work, require negotiation and shared contributions. In addition to different responsibilities, scientists and preparators enact different social norms (a form of habitus), such as their language and sense of humor. Understanding how these groups differ and how they work together sheds light on how they perceive their work, and thus what they understand science to be.

Prioritizing Specimens

Researchers request the preparation of what they deem the most scientifically significant specimens. That judgment is not inherent to particular fossils or researchers; rather, it changes based on what preparators reveal and what other projects might arise. Like many researchers, Preston monitors preparators' progress to inform the kinds of data he prioritizes: "As things are being prepared, you make decisions on what you particularly want to see." These ongoing decisions are crucial because of the long time frame of preparation work. Preston explained that he had asked a preparator to leave one fossil half embedded in matrix because "I could get all the information I pretty much needed from that level of prep, so taking it out further would simply have just cost a lot more prep time without necessarily too much research benefit." Maximizing research output involves minimizing preparation time, such as by prioritizing the most interesting aspects of the most scientifically valuable fossils based on dynamic assessments of the ongoing preparation work. Preston portrays preparators in a way reminiscent of Taylorism, in the sense of optimizing workflow as though the lab were a factory. But he doesn't suggest streamlining preparators' work. Instead, he adapts his requests to them in order to maximize his research benefit. Preston, as a researcher, seems to perceive how preparators manage their time and assignments as black boxed or irrelevant.

Because preparation reveals new information that can change researchers' priorities, workflows require communication. Preparator Bill's work depends on researcher Frank's priorities: "We always need to keep in touch with [Frank], as to asking him questions. 'Is this where you want us to work? Is this on the front burner now or is *this* on the front burner?' Things are always changing in our projects." Moving specimens to the front burner

Figure 4.2
Specimens in progress are carefully arranged as a physical to-do list on a table in a preparation lab. They are stored in various boxes, specimen drawers, field jackets, and plastic cups, and surrounded by written notes, specimen labels, sandbags, and foam pads.

means Frank wants to study them soon and so they need immediate preparation attention. Likewise, for preparator and conservator Laura, researchers set her projects, but she plans her work: "We get given a list of things for the year, and we talk to the curators and see which are urgent. We'll have ongoing projects as well, so they're the ones that will get put on the back burner." This recurring burner metaphor captures the flexibility of paleontology work environments in that researchers promote and demote specimens' priority levels depending on changing information (figure 4.2).

Preparators accept this system of dynamic assignments, mostly without complaint. Preparator Max, for example, works on fossils according to researchers' changing requests:

> I've had some pretty amazing projects put on hold for years because something cooler comes up. One year you'll start digging up some really neat sauropod and you'll get part way through preparing that, and you go out in the

> field and you dig up a really neat theropod or you find a mammal skull, and all of a sudden that takes priority. I don't have a whole lot of choice over that, and sometimes that sucks, but most of the time . . . we're on the same page, "Yeah, this is exciting stuff, let's do it."

Researchers' changing priorities can be frustrating for preparators, but being on the same page suggests that preparators understand the reasons for researchers' sometimes erratic to-do lists. In comparison, preparator Steve pointed out that *not* having researcher-determined work assignments would be inefficient: "If I was allowed to go select what I was going to prepare, I'd have a fantastic [lab] bench full of oddities. But it possibly might coincide with none of the researchers' studies. . . . You can't have these prepared fossils just sitting waiting for the next twenty-five years, because somebody's paid me to do that." While Steve would love to work on fossils of his choice, he justifies researchers' power over his assignments as more economical for the museum. Note that he does not explain this system as preparators following the orders of a higher-status boss. Instead, like most research workers, he portrays the processes of preparation and research as separate, implying a division of labor between experts of equal status in different fields.

Setting Deadlines

Deadlines can be contentious for researchers and preparators due to different priorities along with disparate expectations of preparation time. One preparator's workplace plight was infamous among preparators for being an extreme example of researchers forcing faster work: "We were so pushed by our boss to get a particular project done that it led to huge tensions. In fact, we went over his head to his supervisor and said, 'Look, this is unhealthy, it's bad for us, it's bad for the fossils.'" The boss viewed preparation as a roadblock to research and therefore a task to finish quickly, while the preparators saw it as a process requiring skill, time, and patience. This difference in values led to conflict, which was intensified by the groups' unequal institutional statuses. The preparators' appeal for the well-being of the specimens ("It's bad for the fossils") reflects their own concern as well as perhaps an assumption that the boss and supervisor might be more likely to slow the work pace for the *fossils'* sake than for the preparators'.

These firsthand stories are rare, however. Most preparators told me stories about other preparators' forced deadlines because they personally hadn't had this problem. Stories like these make Marc grateful for his sympathetic bosses, because "some people have pretty scary bosses who want shit done fast." Luckily, negotiating deadlines typically involves both groups' empathy for each other's goals. Steve, like most preparators, fears that obeying researchers' demand for speed entails destroying data:

> If I'm preparing something and I find a little tooth next to a bone, there's some interesting taphonomy there. Has that tooth washed in, or is that where something bit that bone and the tooth fell out? It's not for me to decide, but I need to leave that tooth there, whereas someone else might say, "Oh, bloody tooth in the way, take that off. Now there's a nice clean bone so I can see all the faces."

Researchers' need for quick preparation of the specific parts they want to study, which enables quick publication, can be at odds with preparators' goals of careful work and the long-term conservation of specimens. Steve's distinction between explaining an unexpected find and preserving that find captures the division between researchers' and preparators' perceived responsibilities, respectively. Balancing these responsibilities arguably helps produce a more complete fossil that can inspire more interesting interpretations.

When I emailed the PrepList to ask its members about using cyanoacrylate versus reversible adhesives, their answers were much broader in scope than just choosing glues. Specifically, they made rousing statements about preparators' role in counteracting researchers' potentially destructive impatience. For instance, preparator Bill responded to the list, "One of the most controversial issues we face is the continuing tension between the aim of preparators . . . to do the least harm to a specimen and preserve it as well as possible into the future, and the frequent need/desire/preference of researchers to have specimens prepared quickly, reassembled, and cast" (Wylie 2009, 10). This perception of preparators as protectors of specimens becomes problematic when preparators, as support staff, are asked to prepare specimens quickly. Another respondent, Pete, used militaristic language to emphasize preparators' duty: "Preparators have the responsibility to speak for the long-view conservation of specimens to their administrative superiors. We are the first line of defense" (Wylie 2009, 11). Balancing preparators' and researchers' priorities is a major source of discussion and sometimes discord.

Preparators tend to portray researchers as impatient or pushy. Researchers define this characteristic more positively as, in Preston's words, "result oriented." Researchers' focus on papers and technicians' stress on objects has been long noted (de Solla Price 1965), and in paleontology labs, workers recognize these differences and try to compromise. For example, Marc finds deadlines in his lab to be negotiable: "Sometimes we prep to a deadline, but . . . my bosses have also appreciated the importance of slowing down. If I go to them and say, 'You're not going to get this on this date because of reasons X, Y, and Z, like, something's cropped up, this area's really smashed, we can't clean it up really rapidly,' they listen. In general."

Discussion between preparators and researchers allows both groups to share their goals and values, such as quick access to a prepared fossil versus allowing time for careful preparation and dealing with unexpected complications. After all, neither researchers nor preparators want damaged or badly prepared fossils. Allowing preparators to set their own pace prevents poor work and thus protects fossils. This system also benefits social relations: giving preparators input into their schedules makes them feel empowered, responsible, and respected, as opposed to low-status workers who are pushed to produce such as on factory assembly lines. Thus even though scientists set the deadlines, technicians can challenge those deadlines based on issues that they identify, such as surprise discoveries or the need for conservation. Furthermore, scientists rely on preparators' expert assessment to produce the best-possible specimens, making the power to revise deadlines more like a collaboration than a low-status worker begging a boss for more time.

Choosing Techniques

In some research communities, technicians have similar training and tasks as scientists; in others, scientists value technicians for their mastery of skills that scientists themselves lack. Scientists and engineers who analyze structures for earthquake resilience, for example, are grateful for the lab technicians' expertise in construction, which is crucial for building test structures that yield reliable research results (Sims 1999). Scientists and graduate students even learn their basic knowledge about constructing test structures from the technicians. Likewise, preparators are the experts on how to remove matrix, repair breaks, and mold and cast fossils as well as, crucially, how to prepare technologies for these tasks. Preparators and scientists agree that most scientists don't know how to design, select, or even apply preparation techniques. For instance, Carla said that researcher Luke does not tell her which techniques or tools to use on a specimen "because he wouldn't know." Carla surmised that if she asked for his guidance, Luke would say something like, "You're hired to do this. You're the expert. I leave it to you." According to Carla, her expertise—and job—centers on choosing methods, so of course a researcher would not tell her how to prepare fossils.

Preparators relish the power derived from having knowledge that the scientists need. As Steve said,

> One of the joys of being a preparator is the fact that nobody can tell you how to do it. . . . The researcher or the people on [the] exhibition [team] will just say what they want the thing to look like, or what they want to see on that specimen. How I actually go about giving them that information is entirely up to me, so I can use air pens, I can use grinders, I can dissolve the rock away using acid.

Deciding what they want the thing to look like is the domain of the end users, namely researchers or exhibit designers, while choosing ways of accessing that information is preparators' domain. Preparator Erica was shocked and a little insulted by the idea that researchers would choose preparation methods:

> **Caitlin**: So would [researcher Frank] tell you to do things in a certain way?

Erica: No, no, no, no. No. We're all sophisticated here enough and good at what we do enough to know what we have to do. . . . Unless it's otherwise not feasible to get it done, then we'll tell him, "That's not possible."

Preparators' commitment to selecting and adapting their methods, as discussed in chapters 1 and 3, is evident in Erica's adamant "no" response. She, like many preparators, claims responsibility for judging the feasibility of researchers' requests and, if necessary, rejecting them. Kevin finds himself in that position often: "Our experience is to overrule the curators" when choosing techniques. Researchers are not expected to know about preparation methods; hence preparators can "overrule" researchers' requests thanks to their expertise, despite researchers' higher status. Researchers agree that preparators should select methods. As Maurice humbly put it, "I have a lot of respect for what [preparators] have to do with the materials and for the fact that I know I can't do it."

Moreover, Preston thinks that fossils benefit from the separation between researchers and preparation work: "In the case of most scientists, it's probably not a good idea to have them do prep. . . . We focus more on what the scientific results might be, and less on the concern for doing it right and getting the specimen stable." This researcher agrees that separating researchers' and preparators' fields could protect fossils from rushed researchers. Distancing scientists from evidence production could also promote objectivity by preventing scientists' assumptions from influencing the evidence, as discussed in chapter 3 with regard to CT images. Yet paleontologists do not articulate this reason of epistemic defense; rather, they subtly dismiss preparation as merely manual work. Preston continued, "I trust [preparators'] judgment. They have the better knowledge of the particular adhesives. . . . That level of decision on it is not normally something I take part in." As his tone of voice implied, that "level of decision" means a lower-status level that is not important enough to merit his high-status paleontological expertise. Ironically, scientists' disinterest in preparation decisions empowers preparators to choose their techniques and to identify as experts and, in some cases, defenders of the specimens against the scientists. But, of course, scientists and preparators both claim that their priority is to serve science by preparing good evidence.

Talking as Scientific Practice

To align their respective goals, researchers and preparators regularly discuss and negotiate. Maurice said that he frequently goes to the prep lab with an unprepared fossil and "specific questions. 'So if I want to see this, this, and this, is it possible?'" Checking in with preparators is important to Maurice because "if we're not conversing about it, then what [the preparators] might want to do may impact something I want to do later with the specimen." Discussing both groups' priorities and limitations is necessary in part because there are so many options for preparation techniques. Laura considers meeting researchers' needs as a way to protect specimens, not just a case of following instructions from a boss: "We always try and consult the curator to see how often [a fossil] is used and what it's going to be used for. I mean for simple things, like which side up should the crocodile jaw be stored, because are you interested in the eye sockets or the mandible? . . . To reduce the amount that it's going to be handled and shifted and turned over." Tailoring specimen storage to researchers' needs minimizes fossil handling and thus damage, which reduces future repair work for preparators. Communication is considered so key that it sometimes delays preparation work, which frustrates Steve: "If I need the researcher to come down to look at something before I can continue forward because they need to say, 'Yes, you can remove that bone' or 'No, I need that left there,' if they don't come down for a week or two, then that's a week or two that I've lost, and I can't undo it." Despite his aversion to losing time—an interest keenly shared by researchers—Steve values knowing researchers' priorities enough to wait. It is not always preparation, then, that slows down research; researchers and preparators also consider information exchange worth waiting for. A communication failure can cause wasted time, overdue specimens, and prepared fossils that don't reveal the features that the scientists want to study.

Despite their frequent conversations, preparators and researchers use language differently. This is a powerful indicator of separate Bourdieusian fields. After all, knowing a group's "practice language" indicates membership and belonging in that group (Collins 2011). Because researchers' and preparators' tasks are interdependent, we might assume that they share a practice language. However, examples of preparator-specific terms and, revealingly, humor suggest that these groups have distinct practice languages. This difference could be problematic because knowledge cannot simply be "transferred" among occupational groups by shared words; it must be "transformed" to match each group's ways of thinking and working (Bechky 2003). Bechky (2003) observed that technicians act as transformers of knowledge between engineers and assemblers in a factory: the technicians participate in engineers' abstract communication style with reference to design drawings as well as in assemblers' concrete communication style with reference to the objects they build. To communicate, then, researchers and preparators must either use a "pidgin" language to allow simplified interfield conversations (Galison 1997, 832) or understand enough about each other's field to be able to discuss it, which means achieving interactional expertise (Collins 2011, 282–283). Interactional expertise resembles these workers' discussions about fossils because both groups typically understand each other's perspectives. Yet these discussions also involve transforming knowledge so that it makes sense for the other group. Sometimes preparators don't bother to transform their knowledge for scientists, and vice versa. Reserving one's knowledge for one's field can be a way to assert power.

Not all preparators know all techniques and materials, but they are much less likely to confuse or mispronounce preparation-relevant words than researchers are. For example, after I interviewed Kirk, a researcher and collection manager, I mentioned that I had worked as a preparator. He replied that if he had known that, "I would have used the long words instead of the short words, like 'Butvar' and 'resin.'" He meant that he would have spoken preparator language with me, such as by using adhesive names. Kirk actually revealed himself as a *non*preparator, however, by mispronouncing Butvar (a brand name for the adhesive polyvinyl butyral).[1]

Workers use discourse style as an indicator of who belongs to their field and a way to exclude nonmembers. For instance, preparators use scientific terms such as species names when talking with scientists. Technicians generally are proficient in the practice language of their bosses, though that proficiency is not always reciprocal (Barley et al. 2016, 136). Preparators rarely use scientific terms among themselves, such as by nicknaming specimens instead of using species names. Several preparators call *Priscacara* fish fossils "Priskies," for example, and the Southern Museum preparators refer to specific specimens of stegosaur, camptosaur, and fossil frog as "Steggy," "Campty," and "Froggy," respectively. These diminutive names suggest fondness and informality, perhaps reflecting preparators' affection for specimens from spending many hours preparing them—a long-term familiarity that scientists may lack. These nicknames are not intended to serve as a secret language since they are not difficult to decode. Rather, this subtle avoidance of scientific terms may serve to assert preparators' identity as proudly separate from that of scientists.[2]

Separate Humor

A joke highlights a linguistic and cultural divide between preparators and researchers, while also pointing out preparators' power over scientific evidence and knowledge. I first heard it from preparator Mary, who told me that she and a coworker joke about the pressure to provide what researchers want to see in a specimen. For instance, if a researcher expects to find a foramen—a naturally occurring hole in a bone that blood vessels and nerves pass through (plural: foramina)—in a certain bone, then, Mary joked, she might reply, "You want a foramina [*sic*] there? OK." The implication that Mary would purposefully bore a hole through a fossil to create a feature that a researcher expects is unthinkable—and therefore laughable—to preparators. It violates their primary priority of revealing data while conserving fossils. This joke thereby makes this priority explicit. Also, using "foramina" instead of the grammatically correct "foramen" shows that Mary knows scientific terms but imperfectly, suggesting that she is a preparator rather than a researcher.

Preparators use the same joke to describe accidentally making holes. Marc worries about unconsciously making a fossil look as he expects it to, which illustrates that technicians' observations are, of course, also theory laden. Thus his goal is to "follow the fossil, and not try to put too much of my ideas about what it should look like into it, because I think that's where mistakes come from, in a lot of cases. You know, you want a fenestra to be someplace and so you put it there [*laughs*]." A fenestra is a natural opening in a bone that muscles pass through, similar to a foramen. Presenting a mistake—such as a preparator-made hole—as a natural feature is a joke so often told among preparators that it is rather formulaic. Preparators' low institutional status somewhat restricts them from pointing out their necessity to scientific endeavors; instead, they use humor to subtly remind scientists that the coveted fossil evidence is literally in preparators' hands.

This joke depends on the use of scientific terms too, such as foramen and fenestra, to emphasize the jarring misalignment of scientific rhetoric and human work. Mulkay and Gilbert (1982, 592; see also Gilbert and Mulkay 1984, chap. 8) claim that humor is a result of scientists' mixing of ways of describing science: "Participants regularly create the incongruity essential to humour by bringing together two distinct interpretative repertoires . . . which are normally kept separate." Calling a hole made by a preparator a foramen or fenestra is funny both because it is not a natural hole, and foramina and fenestrae cannot be "made," and because the formal scientific terms do not fit the stressful, messy situation of a preparation mistake (or fraud). Normally, such a mistake would belong to the less formal "contingent" repertoire used for everyday lab conversation as opposed to the dry, publication-style "empiricist" repertoire that includes scientific terms (Gilbert and Mulkay 1984, chap. 3). Preparators' infrequent use of empiricist language accentuates the misalignment and therefore the humor.

Humor is important for building relationships among members of a community. Zookeepers, for example, use humor to create social bonds as well as provide distraction from boring, unpleasant work, such as by telling each other poop jokes while they clean animals' habitats (Grazian 2015, 100–101). Humor also denotes members—and outsiders—of a field. Strikingly, only preparators laugh at the foramina joke. This became clear when I witnessed the joke told to an audience of researchers. Henry, a researcher at the Southern Museum, had done more preparation—and thus spent more time with preparators—in graduate school than most researchers do. His immersion in preparator culture may explain why he was in on the joke, which he told to me in an interview: "We always joke about, you know, making foramina! [*laughs*]. . . . I'm currently studying a specimen that was first exposed by a volunteer at another museum, fortunately not ours, and when the volunteer uncovered the specimen, he made a couple of really nice big holes in it [*laughs*]." A few weeks later, Henry presented this specimen as a new dinosaur species at a conference. Preparation is rarely mentioned in research talks and is not mentioned in Henry's published abstract, but he explained in the talk, with a laugh, that a volunteer preparator "added some foramina" to the specimen's snout. The stakes of this damage were high because as a new species, no one knew whether the animal had foramina there.[3] In his talk, Henry likened the holes to extant animals' "foramen of Winchester"—the bullet hole in zoological specimens' skulls from collectors' Winchester guns. Bullet holes are obviously not a natural feature of animals' skulls and so it is ironic to call them—and the holes made by the volunteer preparator—foramina. But hardly anyone in the large auditorium laughed at Henry's comment about the human-made foramina. It was not clear whether the audience of researchers understood that a preparator had damaged the skull.[4] This lack of reaction suggests that the joke belongs to the community of preparators.

The foramina joke is self-deprecatory when preparators tell it, but it can sound reproachful coming from an outsider. Henry could have been understood to be criticizing the volunteer for clumsy work. Yet he had a lighthearted tone while talking about the false foramina, and at the end he thanked a staff preparator for her "excellent" work on the specimen—an uncommon practice in research talks that shows Henry's respect for preparators. Thus he told the foramina joke as a preparator would—as a humorous way to point out the difficult and important work that preparators do. When I told a group of preparators what Henry had said in his talk, they all laughed. They had apparently already heard and probably told jokes about making foramina. Perhaps preparators poke fun at the potential epistemic significance of their mistakes to lighten the mood around stressful preparation work as well as to assert their power over scientific evidence.

TASK TERRITORIALITY

Preparators Doing Research

The separation and resulting autonomy of researchers' and preparators' fields creates space for them to respect each other's work and skill. This respect's dependence on separateness is made clear when a practitioner conducts another field's habitus, provoking an assault of indignant sanctions from that field's members. This problem is particularly acute when scientists pull rank over technicians, as Barley and coauthors (2016, 152) documented among medical and science technicians: "It was only when superiors wielded the power of their positional authority without concern for the technician's substantive expertise that the web of collegial relations—and the 'trust' they inspired—unraveled." Such conflicts reveal technicians' preference for valuing expertise over institutional hierarchy. Of course, technicians and scientists both act as gatekeepers to defend their respective areas of work (Merton 1973), but their methods differ because scientists are typically preparators' bosses.

The ire that some preparators have faced when conducting paleontological research indicates some researchers' strong opposition to nonresearchers studying fossils. For example, one preparator told me that his researcher-boss "was getting upset that I was doing research on fossils. So I stopped, and I started doing a lot of research into plastics [i.e., adhesives] . . . [as] things that were directly related to preparation." This researcher considered testing materials to be acceptable work for a preparator, unlike publishing fossil research. In another case, a researcher judged it inappropriate for preparators to do any research, including on materials. A preparator therefore faced "a really hard environment" when he and another preparator began testing materials: "We started doing experimentation on adhesives. . . . That was too scientific, too much like research for our boss and he put the kibosh on it. In fact, he stole our glues! . . . Anything that was not simply removing rock from bones and sticking things back together and putting them on a shelf was frowned on by our boss." This strict enforcement of the researcher's perceived division of labor between researchers and preparators apparently defines all experimentation as researchers' domain and only a narrow list of tasks as suitable for preparators. This preparator felt oppressed by the order to stop doing research, which he perceived as a way for the researcher to unfairly assert power over him.

Researchers' negative reactions to preparators doing research reveal the social significance of fields' claims to certain kinds of work. The addition of unequal formal power complicates this territoriality because researchers can punish technicians in ways that technicians cannot punish them. Gary sympathizes with preparators who do not feel valued by researchers: "I've always had the respect of my boss . . . but there are bosses . . . [who] don't have a lot of respect for the professionalism that we all have, the dedication we have to do them no harm while we're preparing fossils." I understood Gary to mean "do *fossils* no harm," but his words could also be interpreted as "do *researchers* no harm." This seems like an obvious statement, but it implies that researchers can feel threatened by preparations' incursion into research and/or their reduced focus on the specific tasks that researchers rely on them to do. Overall, the fact that only a few preparators have personal experience feeling disrespected by researchers—although all preparators know stories about others feeling that way—suggests that researchers and preparators generally collaborate effectively and peacefully. Their conflicts reflect the closeness of their work and the resulting precarity of their fields' separateness, which they have to continually reassert through territorial disputes about responsibilities.

Researchers Doing Preparation

Researchers can likewise incur preparators' wrath by preparing fossils. Preparators, however, must express their disapproval more subtly than simply forbidding researchers from removing matrix. I happened to interview researcher Tom on a day when he had crossed the boundary between researchers' and preparators' domains of power: "I went down there [to the prep lab] today after a frustrating meeting. . . . Every time before I've saved [preparator Jane] weeks' worth of work by chopping a slab down. . . . This time I did it and I broke the fossil [*laughs*]. So I apologized and kind of crawled out of there" (figure 4.3; Wylie 2016). This explanation demonstrates researchers' characteristic interest in time efficiency. Also, Tom thought he had offended the preparator, which he indicated by apologizing and leaving in shame. (This reaction may also reflect Tom's

Figure 4.3
A scientist smashed this fish fossil with a preparation technique that its preparator disapproved of. After the preparator made initial repairs to reunite the fish's pieces, she lined the specimen box with notes to warn away the scientist while the specimen's glue dried.

regret at damaging the fossil that he so eagerly wanted to study.) His feeling of guilt suggests that he views the lab and the unprepared fossil as preparators' domain of power, which he knowingly invaded. Tom told me, "I try not to do much preparation, although every now and then I need some mindless thing to do, after a meeting or something, [so] I'll wander down and pick on a fossil. But preparators don't appreciate that." Preparation is a mindless escape from his own tasks such as attending meetings. He knows that preparators don't approve of him preparing fossils, and he often jokes about it. I overheard Jane tell Tom, for instance, that she had pointed him out as a famous paleontologist to a tour group visiting the lab, to which Tom joked that Jane must have actually said, "Here's that darn [Tom] in here screwing up the preparation." This lighthearted view of his visits to the lab is probably an attempt to downplay preparators' frustration with him. Nevertheless, the preparators quietly complained about his interference in their work and, as further insult, his refusal to use their preferred techniques.

After I interviewed Tom, I sought out Jane. She said that Tom wanted to thin the rock slab containing a specimen of a new fossil fish species using a hammer and a butter knife as a chisel. Jane rejects this method as hard to control and thus an unnecessary risk. She told me in a disgusted tone, "You don't need a butter knife. Take a little time to do it right." Jane said that she warned Tom that the matrix grains are "tight" and would not split as he expected. Tom insisted, and hammered the knife tip against the slab a few times. The fossil fractured into three pieces. Jane reported that Tom had said, "I'm sorry" and "You can call me an idiot," but that she had responded, "No, but I will say I told you so!" She appreciated his apology and felt she had won a battle: "Score one for me in a way. Fish lost, but I won" because she had warned Tom that the fossil would break. Jane hoped that her "win" over Tom in terms of judging techniques would keep him away from the lab. "I don't think he'll be sniffing around here tomorrow," she told a coworker. Despite this victory, Jane was rather shaken. The episode "took the wind out of my sails," and she left work early. Her dismay encompassed the damaged fish, her insulted sense of expertise, and the disrespect Tom's destruction showed for the hours of meticulous work she had already invested in the fossil.

As usual, hierarchy complicated the interactions between this researcher and preparator by making the discussion rely on differences of institutional power rather than expertise. Jane remarked to me that Tom is a researcher and her boss, "and he's [Tom]. He's going to do it anyway" despite Jane's warnings. "What can you do?" she said, smiling sadly, perhaps because she felt powerless to protect fossils from her boss. Another preparator said, "[Tom] used to drive me nuts" by preparing fossils—often poorly—in the lab when no one was around. "You'd be afraid to go to lunch" in case Tom came in. To protect fossils from Tom's preparation, this preparator had installed locks on the lab's specimen drawers. Preparators and other workers took advantage of the broken fish episode to enact some power over Tom by teasing him to his face as well as criticizing him behind his back. Denigrating researchers' incompetence at preparation celebrates preparators' skill in comparison.

The power dynamic also shaped Jane's assessment of the broken fossil when she and I were alone in the lab. She said that the fish had broken apart cleanly, meaning with edges that fit together closely, because she had already applied a weak adhesive over the entire fossil to strengthen it. By taking credit for the fossil's clean breaks, Jane asserted her expertise and claimed that she had done the "right" technique, just as she had advocated against Tom's "wrong" one. Jane was also confident that she would be able to reassemble the fish because of its clean breaks and scientific importance. Furthermore, "I think it'll be easier" to prepare the fossil now than before it was broken. Jane immediately realized what she had admitted, turned to me, and said adamantly, "Don't you dare tell [Tom] that! Caitlin, I will get you with my pin vise!" The threat, though of course not intended, communicates her fierce desire to not let Tom win by admitting that his preparation had perhaps had the effect he intended: to reduce the time Jane would spend preparing the fossil. The broken fish reveals a researcher's power to carry out a preparation technique despite a preparator's opposition. By complaining about the researcher's preparation work to coworkers, the preparator reinforced the idea that researchers and preparators have different expertises and should therefore stay out of each other's areas of power. This approach is not always effective, as shown by Tom's years of preparing fossils in the face of preparators' resentment. But clearly members of both fields know the agreed-on demarcations of their fields' jurisdictions, even if they don't always follow them.

FROM PREPARATION TO FACT

A Fish's Tale

To illustrate how scientists' and preparators' work interlocks and reflects their shared notions of what science is, I analyze one fossil's journey from being freed from rock to being described in a publication. This process was surprisingly difficult for me to observe because the timeline for fossil-based knowledge preparation tends to be long and unpredictable, and because institutions' collection databases don't typically include information about specimens' preparation or publication. The methodological difficulty of accessing these apparently discontinuous processes may imply that preparation and research occur in separate times, spaces, and/or fields from each other, making them tough to correlate. But I don't think that's the case, even if record-keeping practices present them as unconnected. After all, researchers and preparators regularly peer over fossils together to discuss future plans. Rather, it seems to me that they have little interest in each other's work beyond what they need to achieve their own goals. When I asked a few preparators years later for publications about the specimens they'd prepared during my visits, they didn't know whether those specimens had been studied, didn't know how to find out, and didn't much care. I didn't think to record the accession numbers of the fossils I was watching under preparators' tools. This unfortunate oversight means that I can't search for papers that mention that accession number or ask scientists whether they have published about a particular fossil. Luckily for me, one preparator published a paper (Van Beek and Brown 2010) detailing how she prepared a particular fossil that a scientist later designated as a new species in a journal article (Grande and Hilton 2006). As a case study of how a research community prepares its beliefs about what science is, I draw from these publications and interviews with the fossil's primary preparator and researcher to shed light on how preparators and researchers understand their collective work.

Sometime in the late Cretaceous, in a bountiful, salty sea overlying the middle of what would become the United States, a 2.5-foot-long fish was sheltering in and perhaps snacking on the bloated carcass of a hadrosaur, a duck-billed herbivore dinosaur. Suddenly, "both animals were quickly and completely covered by sand, trapping and burying the fish" (Ancell, Harmon, and Horner 1998) and fossilizing it, ironically, inside its potential prey. Seventy-eight million years or so later, in the 1990s in central Montana, legendary paleontologist Jack Horner and the field crew of the Museum of the Rockies found what they called a "gar in a duck-bill" (Ancell, Harmon, and Horner 1998; Grande and Hilton 2006, 8). The crew "rough-prepared" the fish, identified it as a gar, and presented it in a poster at the 1998 SVP conference (Ancell, Harmon, and Horner 1998). A few years later, Lance Grande, a fish expert and curator at the Field Museum in Chicago, asked to borrow the specimen, which he identified from a photograph as a sturgeon, not a gar (Grande and Hilton 2006). In 2003, Horner mailed the fish to Grande. "After many months of additional fine preparation of the specimen, it revealed amazingly detailed information on the skeletal anatomy of this Cretaceous species" (Grande and Hilton 2006, 1). Based on that information, Grande and Eric Hilton (2006), a postdoctoral researcher, named the sturgeon the type specimen of a new genus and species.

The sturgeon's story is relatively clear, but how its fossil moved from a hadrosaur's belly to the pages of the *Journal of Paleontology* is not. To help fill this gap, Van Beek, the fish's preparator at the Field Museum, published a rare paper about preparation methods to explain her work on this unusually well-preserved fossil (Van Beek and Brown 2010). The paper drew from presentations that Van Beek gave at the 2005 SVP conference and the 2008 Fossil Preparation and Collections Symposium. Preparator Matthew Brown had brainstormed ways to prepare the sturgeon with Van Beek, and he encouraged her to publish about it. According to Brown, Van Beek emailed him her presentation slides and notes, and Brown wrote the manuscript. They both thought the story of her work to prepare the sturgeon served as a powerful example of "how great preparation helps the science," as Van Beek told me. How she imagined and achieved this great preparation shows how she conceptualizes the science that it contributes to. In an email to me, Brown explained his motivation: "I really wanted the story of the specimen told . . . to plant a flag contradicting the Grande and Hilton [2006] assertion that 'we [the authors] spent several months fine-preparing the specimen.'" Brown believed a paper would properly award the credit for the preparation to Van Beek instead of the scientists, while also documenting the complex preparation more accurately than the basic description that Grande and Hilton (2006) published.

The sentence that goaded Brown to publish appears in a section titled "Preparation Methods," a rare occurrence in paleontology publications. It consists of one paragraph explaining that "we" prepared, documented, and disassembled the fish's bones (Grande and Hilton 2006, 3). For example, the scientists wrote, "The matrix was a soft, loosely consolidated sandstone that we removed with sharpened needle pin vises under a microscope" (Grande and Hilton 2006, 3). But it was Van Beek, who is not an author on the paper and did not contribute to this paragraph about her methods, who removed the matrix with pin vise tips that she had designed specifically for this challenging task. The "we" seems at least inaccurate and at most, as Brown interpreted it, insulting.

I surmise that the scientists wrote a methods section in part to defend their unusual decision to disassemble (or "disarticulate") the bones of the fish's skull. Disassembling fossil skeletons is controversial because it destroys the bones' original positions relative to each other and risks damaging the bones while separating them. But it grants three-dimensional views of each individual bone, which enables scientists to describe them in detail and compare them more easily with other specimens' bones. The scientists justify this decision in the methods paragraph: "Because the specimen was unique, well articulated, and unusually complete, we dissected it in stages, and were careful to photograph and draw each stage of disassembly for documentation in this paper" (Grande and Hilton 2006, 3). (Like Van Beek, the individuals who photographed and drew multiple beautiful depictions of these bones are obscured by the authors' use of "we" and named only in a brief acknowledgments paragraph.) This serial image making is an attempt to reduce the information loss inherent to disassembly. Nonetheless, Grande told me that Horner, whose employer, the Museum of the Rockies, owned the sturgeon, did not hesitate to agree to the fossil's preparation and disarticulation. According to Grande, the Museum of the Rockies "got a good deal" because the fish "was a lump of nothing when they sent it to us . . . and now it's a holotype." He meant that the museum benefits from the prestige of the specimen's new scientific importance, made possible by Van Beek's preparation and Grande's analysis, which were free for the Museum of the Rockies. This portrayal of a win-win situation, though, omits the destruction of the skull bones' contextual information, and the risk of damage during the fish's preparation and transport.

Interestingly, the scientists did not intend to mislead or claim undue credit by using the word "we" to describe the fish's preparation and documentation. When I asked Grande if he had helped prepare the sturgeon, he said, "Yes, I work with the preparators." He explained that he tells preparators what to expect about a specimen, such as where certain bones are likely to be, their shape, their fragility, and so on. He continued, "They're not morphologists. They're artists in the sense they take such skill and care to extract bones out of the matrix. But [Eric and I] are people who know how sturgeons are built." Grande considers his morphological advice part of preparation, and he's right that preparators take this information into account while preparing. Preparators, on the other hand, do not consider morphological road maps to be preparation; for them, preparation is the hands-on work of making that morphology researchable.

This disagreement reflects the two fields' assumptions about what research and preparation are, and therefore what science is. Preparators value the specimens' stability, completeness, and beauty, in part because of scientists' interests in specimens and in part because they consider specimens to be inherently important objects. Preparators see current and future research as reasons to change pieces of nature to be accessible and preserved. This perspective explains their commitment to conservation-friendly techniques and materials as well as their willingness to compromise conservation in exchange for research access (e.g., disarticulating a unique skull to enable the detailed description of a new species). Researchers share preparators' assessment of specimens as a means to achieve new knowledge, but with arguably less appreciation for fossils' inherent value or potential future research. Their interest is more grounded in current research and intellectual contributions as activities that align with how their field measures success. The two groups' everyday interactions, then, are guided by these overlapping ideas about what it is they are doing together. Namely, for preparators, science is making fossils useful and then using them; for paleontologists, science is trying to understand a lineage, an ecosystem, the mechanisms of evolution, or other abstractions. These visions are essentially the same, just with different priorities that (ideally) complement each other to help achieve good science.

Preparing a Species

As a type specimen, the sturgeon is the defining example of its species (and genus, in this case). How this individual sturgeon looks is—and always will be—the gold standard for understanding how its species looked. Van Beek prepared the evidence from which the scientists prepared the knowledge claim that this sturgeon represents a previously unknown species (and genus). The scientists describe the preparation primarily as time intensive—"many months" (Grande and Hilton 2006, 1)—which is likely how they experienced it in their excitement to study this sturgeon. Van Beek, more precisely, reports that she worked on the sturgeon for about 750 hours (Van Beek and Brown 2010, 152), which, she told me, took about a year. How, then, did she transform the rock-encased skeleton into a fully visible, three-dimensional specimen with its individual skull bones separated?

Van Beek and Brown's paper details several tasks that the scientists don't mention. For example, before Van Beek started on Grande's request to remove matrix from the skeleton and dissect the skull, she decided to remove a thick layer of glue that a fieldworker or previous preparator had applied to the fossil, thereby obscuring the bones' surface details (figure 4.4). Van Beek told me that Grande "wanted to see every suture" (i.e., the thin ridges where skull bones meet). Grande, a biologist by training, integrates fossil fish into the evolutionary study of living fish; as a result, he said, "I need anatomical detail that is as close to an extant species as possible." That meant scraping away all the matrix—"every grain of sand," Van Beek emphasized—from the sturgeon. She interpreted this priority to also include removing the cloudy glue. She didn't ask Grande for permission nor about how to remove the glue. Instead, she got to work. Luckily, the glue was Vinac B-15, a reversible adhesive that can be dissolved by adding a solvent. So first Van Beek brushed on a solvent (acetone), but that only made the dense glue "gummy" (Van Beek and Brown 2010, 149). Next, she tried scraping the glue off with a pin vise, which, to her dismay, peeled away the bone surface along with the glue. As a result of this experimentation, she selected "continuous light brushing . . . with acetone" as the least destructive way to dissolve the glue, even though it left the exposed bones "extremely soft and fragile" (Van Beek and Brown 2010, 149). Van

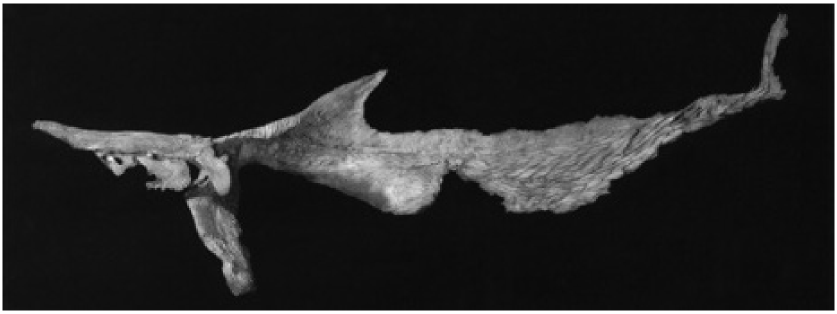

Figure 4.4
This photograph shows a side view of the beautifully preserved, three-dimensional sturgeon after delicate, innovative preparation work and before Van Beek took apart the skull bones (Grande and Hilten 2006, 6, reproduced with permission).

Beek's published description provides far more detail than the scientists' paper (and almost all scientists' papers), yet it still omits the frustration of counterproductive techniques and the patient labor of repeatedly brushing solvent over stubborn glue atop delicate bones. To address the newly glue-free but soft bones, Van Beek, counterintuitively, added more glue. But first she thinned the glue with solvent so that it would soak into the bones rather than solidifying on the surface (Van Beek and Brown 2010, 149). As a result of removing the original glue, "detailed features such as skull sutures, ornamentation and scale tubercles became visible," as Van Beek had hoped (Van Beek and Brown 2010, 150).

The experience of defining a goal, encountering challenges, and experimenting with possible solutions is repeated throughout Van Beek and Brown's paper. Van Beek employed particularly creative and diverse ways to reinforce the fragile bones, including at least three kinds of glue as well as external supports such as adding a coat of resin to serve as a transparent scaffold to hold up the fish's three-dimensional dorsal fin. Van Beek used a watchmaker's oiler (a miniature spatula) to apply the glue of her choice exactly where she wanted it on the fossil, much like how watchmakers lubricate miniscule components (Van Beek and Brown 2010, 150). This ingenious appropriation of another field's tool reflects her expert understanding of preparation problems and creativity to imagine potential solutions. Similarly, Van Beek (2011) is known among preparators for carving needle-like pin vise tips into purpose-specific shapes, as mentioned in chapter 1. She ground a pin vise tip into a thin, almost-invisible scalpel-like edge to "cut between the very tightly packed cranial elements" to disarticulate the sturgeon's skull (Van Beek and Brown 2010, 152). Before touching tool to fossil, Van Beek thought carefully about her and the scientists' goals, and then selected and altered tasks and technologies accordingly.

Van Beek also changed her plans based on the ongoing influx of in-the-moment information from the fossil. As she meticulously scraped sand grains from the fish, for instance, she came across minuscule double-pointed spikes—a surprise to her as well as the scientists. One of the many figures in Grande and Hilton's (2006, 34) paper (e.g., photographs, line drawings, a scanning electron microscope micrograph, and even an X-ray) shows these "tiny (i.e., < 0.5 mm), sharply pointed denticles . . . [that] were found scattered and loose in the matrix . . . and were mostly removed during preparation." Of course, it was Van Beek who found and, in her words, "saved" them. As a hypothesis for what these denticles are, Grande and Hilton (2006) liken them to spines in the skin of other fish. No mention is made of Van Beek's keen attention and skill to notice as well as preserve these unexpected and easy-to-miss spikes, which created the opportunity for Grande and Hilton to compare them with other species' features to inspire an explanation.

Another way in which Van Beek anticipated the scientists' needs, and thereby shaped the present and future specimen, is by designing a storage box to hold the small, delicate skull bones that she disassembled one by one. First, Van Beek traced a predisassembly photo of the skull onto a transparent sheet, creating a bone map. She then lined the storage box with this schematic as an easy indicator of where each bone had been on the skull, "making their identity far more obvious if the box were ever to be overturned or the elements were otherwise misplaced" (Van Beek and Brown 2010, 152). Then she segmented the box with foam to create a labeled compartment for each bone, preventing collisions between bones and confusion about which bone is which. Van Beek is so experienced with the common problems of collection storage and research, such as lost, unlabeled, or physically damaged specimens, that she actively engineers ways to prevent them.

Selective Recognition

This case demonstrates that the process of preparing evidence, communities, technologies, and conceptions of science is one and the same. How practitioners divvy up the responsibilities of separate fields reveals their values and social order as well as what they believe they are accomplishing together—that is, their conceptions of science. Their commitment to this underlying purpose guides their practices and interactions to pursue good science, such as communicating, compromising, and respecting each other's priorities for their mutual work.

The two papers' similarities and differences illustrate where researchers' and preparators' doxa align and diverge. For example, Grande and Hilton (2006) focus on the fish's morphology relative to other species, while Van Beek and Brown (2010) consider how to enable researchers to study that morphology now and in the future. Both sides encountered surprises and problems, a few of which they documented in their papers. Both papers include some of the same photographs of the fossil. Both papers defend disarticulation by offering alternative ways of preserving information from the original articulated skull; specifically, the scientists credit the many photographs and drawings, and the preparators credit Van Beek's storage box. Clearly both sets of authors expected some criticism from their colleagues about disassembling such a complete, three-dimensional, beautiful skull. They differ in how they rationalize the disarticulation: the scientists omit themselves from consideration by arguing that the specimen's remarkable preservation and "unique" anatomy justify its dissection, while the preparators invoke the scientists' practices in that their "thorough description of an exceptionally well-preserved fossil sturgeon required nearly complete disarticulation" (Van Beek and Brown 2010, 149). Both papers express the authors' pride in the achievement of disarticulating the delicate skull. Interestingly, the scientists wrote their paper with the pronoun "we," even for tasks that they did not do themselves, and the preparators wrote their paper entirely in a passive voice, a style typical of scientific rhetoric. Thus the scientists implicitly took credit for all work leading to their knowledge claims about the fish, while the preparators eliminated themselves from their own description of their work. Even with the omission and self-effacement, both papers bestow more credit and documentation than preparators and preparation normally receive.

The preparators' paper documents the techniques with some misgivings as well as pride. They wrote with a regretful tone, "Reversibility was sacrificed in favor of greater strength several other times throughout the preparation of this specimen" (Van Beek and Brown 2010, 153). Van Beek, for example, mixed a familiar adhesive with loose matrix to create a filler for a small gap on one fin: "Elmer's Glue is also not recommended for use in fossil preparation, as it can become brittle, discolored, and insoluble over time" (Van Beek and Brown 2010, 153). The paper emphasizes the importance of conservation-friendly adhesives despite Van Beek's application of some nonreversible materials. This paper was published roughly six years after the preparation work, so Van Beek and Brown may be implying that beliefs about appropriate materials for fossils had changed in that time. Or they may have felt that they had no choice because, as they explain, "Justification was made based on research needs to sacrifice certain aspects of conservation principles in selection of non-reversible adhesives" (Van Beek and Brown 2010, 149).

But the preparators are not blaming the scientists for research needs that are best served with nonideal preparation techniques. They even express muted pride in the outcome of Van Beek's materials and methods: "The delicate specimen underwent frequent handling during photography, illustration, and study. However, it withstood such treatment admirably" (Van Beek and Brown 2010, 152). Van Beek's goal for the preparation, then, was to enable research in the safest way for the specimen's current stability. As a result, she risked the specimen's long-term stability by using some materials that degrade over time and cannot be removed (i.e., are not reversible). Rather than downplaying or apologizing for these decisions, she explains why she made them and how they achieved what she and the scientists wanted for the specimen. This justification can enrich future scientists' understanding of this fossil's appearance. It also serves as a model for other preparators for how to think about balancing research access with specimen conservation. By pointing out the choices that she considers imperfect or even regrettable, Van Beek calls attention to ways in which future preparators can learn from and improve on her techniques. As a technician, Van Beek didn't have the power to oppose the scientists' goals but could control how she achieved them. Namely, she devised a combination of reversible and nonreversible support systems for the fossil (such as the storage box and the dorsal fin's resin scaffold, respectively), and partially offset the loss of information from the destructive preparation (e.g., disarticulation and complete matrix removal) through meticulous documentation (e.g., detailed notes, photographs, and a methods paper).

Van Beek considers this sturgeon her favorite project of her twenty-year career because of the challenging process of making this extremely complete, delicate specimen visible and beautiful. Grande also praised the prepared sturgeon to me, though in less powerful terms that perhaps reflect the significantly less time he spent working with the fish: "This one came out particularly nice." Grande and Hilton (2006) named the fish's genus *Psammorhynchus*, after the sandstone that preserved the fossil (*psammos* means sand in Greek) and the fish's snout (*rhynchos*), whose large size characterizes sturgeon.[5] It seems ironic for scientists to name a fossil after its matrix, which they typically perceive as an impediment to research and which preparators labor to remove. Yet these scientists credit that soft matrix, along with the fish's holotype status and three-dimensional preservation, as reasons why they decided to disarticulate the skull (Grande and Hilton 2006, 6). Grande remarked to me with a laugh, "We named it after the preparation, of sorts."[6] The work on this fossil illustrates how researchers and preparators take different approaches to serve their shared scientific mission of making sense of nature based on preserved, useful, beautiful specimens.

CONCLUSION: SCIENCE AS A CONNECTOR

Research communities enact their conceptions of science in everyday interactions, such as scientists designating specimens for preparation, preparators selecting techniques, and both groups negotiating deadlines. These separate fields bring distinct priorities to science as their shared work and purpose. Aligning those priorities is a crucial mechanism of preparing a research community's social order as well as their vision of science. Preparing science also happens in more subtle ways, like when members of a field use language or make jokes in ways that assert power over other fields. Preparing science, then, is a foundational and often implicit component of how fields work together in a research community.

Perhaps their closely related work as well as their need for each other drives scientists and preparators to distinguish themselves by claiming separate expertises, responsibilities, and identities in the belief that good fences make good neighbors.[7] This social order exemplifies Bourdieusian fields, albeit closely interdependent ones, along with Bourdieu's (1993, chap. 9) idea that expertise, as a form of capital, is socially attributed. For instance, as Abbott (1988) points out, professional groups define themselves by fiercely defending the tasks for which they claim ownership from other professions' encroachment, thereby continuously defining each other's relative power in context. These processes of preparing notions of what a community does together are widespread and crucial for inspiring collaboration, communication, and compromise in service of a collective big-picture goal.

As evident in the case of the fossil sturgeon, fields may have different tacit conceptions of good practices and what they are striving to achieve. The scientist, for example, believed that he had contributed to the specimen's preparation, while the preparator laughed dismissively (to me) at the idea of the scientist helping her prepare the specimen. This disagreement arguably inspired the preparator to write a paper detailing her methods, however it did not affect the physical work or the specimen's finished appearance. In comparison, disarticulating the fish's skull forced the scientist and the preparator to articulate their priorities. The scientist was eager to study an entirely visible fish to glean the most comprehensive information and publish his interpretation of it as soon as possible. The preparator wanted the fish to be complete (e.g., by saving the surprise denticles), sturdy enough to be handled (e.g., by consolidating it with both internal chemicals and external supports), and accessible for future researchers (e.g., by storing it in a custom-made protective box that also serves as a bone map). These goals overlap and are not necessarily contradictory, although a disassembled fossil is more fragile than an assembled one and a more complete fossil takes longer to prepare than a less complete one. Thus these two fields' goals complement each other by preventing rushed, present-centric work while also informing the preparation of specimens that will be useful and interesting to researchers, both now and in the future.

Collaboration and compromise between fields can therefore promote better science by balancing out the extremes of each field's doxa (Wylie 2019b). Strict divisions between fields can also impede their shared work, such as the problematic chasm between scientists and nonscientists. For example, after the 1986 nuclear disaster in Chernobyl spread radioactive particles over British pastures, British sheep farmers and scientists failed to negotiate a response policy that aligned with both groups' priorities. Sociologist Brian Wynne (1989) explains this failure as a result of scientists' refusal to take farmers' expertise seriously because the scientists had higher social status and considered themselves more reliable sources of knowledge than farmers. Hierarchy can certainly impede the communication and interfield empathy that the preparation of knowledge relies on, as we've seen in situations of conflict between scientists and preparators. Hence another interpretation is that the British farmers and scientists failed to prepare a shared perception of what they wanted to accomplish together, such as protecting public health as well as farmers' financial success. Without this unifying purpose, the two fields struggled to align their capital, habitus, and doxa enough to work together. When various fields in a research community incorporate each other's priorities to inform their own work, then the ongoing, dynamic process of preparing science is succeeding. This success is crucial for preparing evidence, communities, technologies, and knowledge that suit everyone involved, including—as the next chapter discusses—the public.

Preparing Dinosaurs

The Work behind the Scenes

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