

The Plurality of Assumptions about Fossils and Time  
Caitlin D. Wylie (wylie@virginia.edu)

**ABSTRACT:** A research community must share assumptions, such as about accepted knowledge, appropriate research practices, and good evidence. However, community members also hold some divergent assumptions, which they—and we, as analysts of science—tend to overlook. Communities with different assumed values, knowledge, and goals must negotiate to achieve compromises that make their conflicting goals complementary. This negotiation guards against the extremes of each group’s desired outcomes, which, if achieved, would make other groups’ goals impossible. I argue that this diversity, as a form of value pluralism, regularly influences scientific practice and can thereby make scientific evidence and knowledge more useful and more reliable. As an example, I examine vertebrate paleontology laboratories, which house a variety of workers with different training and priorities, particularly about the meaning of time. Specifically, scientists want to study fully prepared fossils immediately, conservators want to preserve fossils for future use (such as by not preparing them), and preparators mediate between the other groups’ conflicting goals. After all, one cannot study a fossil encased in rock, and one cannot remove that rock without removing information from that specimen. In response, these coworkers articulate their assumptions in everyday deliberations about how scientific evidence should be made and used. I argue that this exchange of assumptions is crucial for achieving mutually beneficial compromises which in turn benefit current and future knowledge construction.

A research community shares many assumptions, such as about accepted knowledge, appropriate research practices, and good evidence. Community members—as well as those of us who study them—tend to focus on these shared characteristics to define these communities and how they construct knowledge. However, we often overlook the *divergent* assumptions that communities hold. I suggest that this diversity, as a form of value pluralism, is widespread among research communities and has important implications for knowledge construction practices. A research community, in this paper, refers to coworkers who rely on each other’s expertise and labor, though they may belong to separate disciplines and/or professions. This is a broader notion than similar ideas of an epistemic community (Meyer and Molyneux-Hodgson 2010) or an epistemic culture (Knorr Cetina 1999) which focus on shared knowledge, while also a more specific notion because it refers to a single workplace of people who interact regularly, as opposed to a diffuse, inter-institutional group. A community of members who hold different assumed values, knowledge, and goals must negotiate to achieve compromises that make their

conflicting goals complementary. This process guards against the extremes of each group's desired outcomes which, if achieved, would make other groups' goals impossible.

To illustrate the potential usefulness of a plurality of assumptions in scientific workplaces, a revealing example is the vertebrate paleontology community, which includes people who identify with a variety of separate fields yet who work together in one institution and often even in a single laboratory.<sup>1</sup> In Pierre Bourdieu's (1993) definition, a field is a group of people with shared skills, practices, and beliefs (in his terms, capital, habitus, and doxa, respectively). This paper focuses on the three fields who are most involved in fossil research, as opposed to collections or display: scientists, preparators, and conservators. These groups agree that fossils are important research objects; however, they disagree about how fossils should be prepared, stored, and studied. Scientists want to convert fossils into publications quickly, which entails asking preparators to chisel away the rock matrix around the bones and glue broken bones together; conservators want to preserve fossils, such as by protecting them from the data loss and damage risk inherent in removing matrix; and preparators walk the boundary between these groups, in that they work for scientists but, like conservators, consider themselves responsible for fossils' well-being. These assumptions vary by professional group, as a tacit system of checks and balances that, through everyday negotiation, achieves a compromise of seemingly contradictory values. As a result, the vertebrate paleontology community conducts research while also protecting specimens. Central to these divergent assumptions is groups' conceptions of *time*, i.e., relative to the breathless pace of publish-or-perish scientific careers or the potentially centuries-long lifespan of museums, universities, and specimens, an achievement that benefits all groups. (Ironically, these conceptions all seem rather immediate relative to the deep geological time that fossils represent.)

This plurality of co-existing assumptions in a single research community, I argue, produces better evidence and better overall research through compromise. For example, research communities study fossils *and* preserve them for the future, rather than strictly one or the other

---

<sup>1</sup> Other workers include collection managers, exhibit designers, and institutional administrators, all of whom deserve future attention but are beyond this paper's scope. Vertebrate paleontology involves closer interaction between members of separate professions than do similar disciplines, such as invertebrate paleontology and paleoanthropology (which lack preparators because the scientists typically prepare the fossils), making it an especially illustrative example of inter-field collaboration. However, most sciences include a variety of people who manage collections, data, equipment, and/or institutions and who provide the kind of plurality that this paper traces.

as scientists and conservators, respectively, might fantasize. Complete pluralism of values and goals could threaten the social and epistemological coherence of a research community, but limited pluralism, such as disagreements about whether evidence should be useful in the short or long term, can be good for science. When groups have to compromise to allow seemingly contradictory goals to co-exist, they produce evidence and knowledge that is more flexible and less tied to the extremes of any group's assumptions. Accordingly, the resulting evidence and knowledge claims that such communities produce are shaped by workers' shared *and* divergent beliefs.

Assumptions are typically unspoken, unwritten, and sometimes unconscious. How then can we study them? This paper analyzes interviews and participant observation from several vertebrate paleontology laboratories in the United States and the United Kingdom.<sup>2</sup> Because these communities rely on multiple kinds of workers, people from different Bourdieusian fields regularly interact. These discussions require workers to become aware of their own and others' assumptions and to defend them in cases of disagreement. Thanks to this practical need and cultural norm of articulating assumptions, pluralistic communities offer rich sites for studying usually-tacit knowledge, norms, practices, and values.

This paper investigates the epistemic effects of limited pluralism of assumptions in research communities. Multiple fields can co-exist and collaborate in a single laboratory, and the interactions between fields' members' disparate training, work practices, and assumptions makes their collective work more useful and reliable. To demonstrate this claim, I first compare and contrast three fields in vertebrate paleontology laboratories. Next, I discuss how the negotiated alignment of different assumptions in research can benefit the production of scientific evidence and knowledge. I finish with a methodological reflection about how we as historians, philosophers, and social scientists might study the assumptions of groups to which we do not belong.

### Separate Fields, Shared Repertoires

A single research community can be home to a variety of workers. Bourdieu's notion of "fields" can help us understand the divisions among them. Members of a single field share

---

<sup>2</sup> For methodological details, see the section of this paper titled "How to study assumptions."

“capital” (i.e., experiences and skills), “habitus” (i.e., work practices and social norms), and “doxa” (i.e., assumptions) (Bourdieu and Wacquant 1992; Bourdieu 1993, 72-73; also see Panofsky 2011). The types of workers who make fossil research possible—e.g., scientists, preparators, conservators—self-identify as separate fields, and they believe that their fields contribute to broader fields, such as paleontology. Even if a worker has some overlap with another field, for example in habitus (e.g., a preparator who does conservation work or a scientist who prepares fossils), if they lack other requisite components of field membership, such as capital or doxa, then they don’t self-identify with or belong to that field. Inter-field collaboration is typical in today’s scientific workplaces (Panofsky 2011); it is therefore important to understand how it is achieved and how it shapes knowledge construction.

One way in which people work across fields is by developing what Leonelli and Ankeny call a “repertoire,” i.e., the social, technical, and epistemic infrastructure of a project that is shared by scientists and non-scientists from different fields (Leonelli and Ankeny 2015, Ankeny and Leonelli 2016). These collaborators strive to “align” their diverse goals, practices, and assumptions, thereby establishing a repertoire that enables them to construct mutually-satisfactory knowledge together (Ankeny and Leonelli 2016, 25). To do so, they acquire what Collins and Evans (2007) call interactional expertise in their coworkers’ fields, such as a scientist knowing that a preparator has a choice of glues for fossils or a conservator putting extra care into the protection of skulls because they know scientists are more interested in that bone than any other. These fields understand each other’s assumptions enough to communicate and help achieve others’ goals as well as their own.

Repertoires are more flexible, dynamic, and informal than fields, which are typically well-established and institutionalized. For example, repertoires begin as small-scale projects and can grow into long-term collaborations and even new fields. Like fields, repertoires focus on what practitioners share, such as values and practices. But, unlike fields, repertoires have less rigid definitions and few formal gatekeeping criteria, such as specific credentials as indicators of capital. As a result, practitioners can move among repertoires more easily than among fields. Furthermore, they generally “need familiarity and engagement with more than one repertoire” to attract funding and attention for their research (Leonelli and Ankeny 2015, 4). While fields and repertoires are defined by what practitioners share, I argue that what practitioners disagree about is also crucial to how they work together and interpret the world. This section presents the

capital, habitus, and doxa of three fields of lab workers in vertebrate paleontology to illustrate how a degree of pluralism of assumptions influences how a community produces evidence and knowledge (see Table 1).

To become physically stable and epistemically reliable enough to study, artifacts and specimens undergo significant processing. Once collected, these objects are cleaned, repaired/reassembled, and given a label, a storage container, and a database entry (Holtorf 2002; Edgeworth 2006; Leonelli 2008; Alberti 2009, 2011; Brusius and Singh 2018). This work shapes how objects look and thus how scientists interpret them.

In particular, how lab workers prepare, preserve, organize, and study vertebrate fossils is based on their assumptions about time. These assumptions encourage practices that range from patient, long-term planning (inspired by fossils' incomprehensibly old age and by practitioners' desire to do the best possible work) to frantic urgency (driven by scientists' need to publish to assert their intellectual claim to new knowledge and thereby protect their jobs). Whitney (2019, 268) defines this "temporal orientation" as the "time-based perspectives and epistemological commitments" that various scientific fields bring to interdisciplinary collaborations, such as environmental conservation. For example, past-focused field biologists and future-focused population modelers struggle to align their knowledge and priorities to agree on policies for species conservation, in part because they do not explain their different temporal orientations to each other (Whitney 2019, 281-4). Likewise, doctors and patients perceive time in different ways with regards to illness, which creates a barrier to their communication (Toombs 1990). I suspect that it is common for participants in multi-field scientific communities to tacitly hold a plurality of temporal orientations, which all of which shape their practices and interactions. These assumptions can prevent fields' cooperation, as Whitney (2019) and Toombs (1990) noted; however, they can also encourage the construction of evidence and knowledge that are less tied to one particular worldview and therefore more flexible and useful.

Likewise, fossil scientists, conservators, and preparators hold different and tacit temporal orientations from each other, which strongly influence their expectations of "good" specimens and therefore the practices they deploy to construct such specimens. Specifically, conservators strive to prevent change in objects, which guides their choices of adhesives and storage materials (i.e., ones that don't degrade) and interventions (i.e., minimal, to reduce risk of introducing new sources of degradation). They perceive objects as valuable in themselves as well as sources for

current and future research. In comparison, scientists understand fossils as a means to an end, i.e., publications. They believe that the papers endure, not necessarily the fragile fossils. Preparators have traditionally followed scientists' short deadlines, which has meant using instant, chemically unstable glues (which set quickly but degrade in a few decades) and removing all the rock around fossils (making them visible but physically weak).<sup>3</sup> More preparators have begun to adopt conservators' values, such as by choosing chemically-stable adhesives (though they set more slowly) and by removing rock only from the scientifically important parts of fossils (which saves time and leaves more physical support for the fossils). These disagreements shape how these groups work with and understand fossils. As a result, practitioners' notions of time shape their and our conceptions of extinct organisms and environments.

### *Scientists Who Publish or Perish*

Scientists who study vertebrate fossils vary in their disciplinary identities, such as paleontology, paleobiology, and geology, but their capital, habitus, and doxa are similar enough that, I argue, they constitute a single field. They hold PhDs in their disciplines, which means they share training in academic subjects and professional skills, such as interpreting fossils, reading scientific papers, and conducting fieldwork. They share the experience of socialization into a specific academic research community, in which they learned a sense of hierarchy (with scientists at the top and technicians, students, and other workers as lower-status), the importance of publications, and a sense of urgency, stemming from competition with peers and other research groups (Traweek 1988; Delamont and Atkinson 2001; Kaiser 2005). Beyond their shared field of vertebrate fossil research, these scientists also participate in a variety of repertoires surrounding specific research areas, such as the study of fossil species' phylogeny or behavior; the composition of paleoenvironments; geological and evolutionary trends in narrow or broad time periods; or the application of certain research techniques, such as CT scanning, histology, or chemical analyses.

Their shared academic training informs fossil researchers' habitus, or ways of working. These scientists work in museums or universities, with job titles such as "curator" ("keeper" in

---

<sup>3</sup> Preparators rarely publish and there is no widely-used manual about their techniques. However, a group of preparators collected the existing publications about preparation into an online bibliography (Bibliography 2019). In comparison, many conservators publish about their techniques and there are textbooks and manuals about conserving natural history specimens (see Reference Books 2019).

the UK), “professor,” or “research scientist.” Their primary responsibility is research, which entails studying specimens and writing papers, managing a preparation lab and its workers, and, for many scientists, collecting fossils in the field. Thanks to their graduate training, fossil researchers are well-educated in a large set of research methods, such as comparative anatomical measurements, histology, chemical dating analysis, and fossil imaging techniques. As “methodological omnivores” (Currie 2015), they are open-minded about methods and willing to try a variety in combination. Common other duties include education (e.g., public engagement in museums, course instruction in universities), collection care, and institutional administration.

One area in which scientists share a *lack* of expertise is fossil preparation and conservation. A few scientists pick up basic preparation skills informally as graduate students, such as if their funding does not include pay for a preparator. As scientist Maurice 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.”<sup>4</sup> This “respect” stems from Maurice’s own inexpertise and thus his reliance on preparators’ work. Similarly, scientists value conservation in the sense that their research requires well-cared-for specimens, but they rarely know how to prevent or remediate fossils’ long-term degradation. They consider that habitus to belong to conservators. Scientist Preston had once interviewed for a job at a museum that does conservation and not preparation. The conservators told Preston that they would not prepare new specimens he might collect in the field because they disapprove of preparation as destructive. Preston was baffled by the idea of doing vertebrate paleontology research in an institution that opposes preparation.

Like all fields, scientists’ capital and habitus shape their doxa (and vice versa). Fossil scientists’ most important values are quantity and quality of research output and, accordingly, efficient use of time and money. This value reflects the general perception of time as accelerated in late capitalism, as people experience time as driven by faster technology and demands for ever more efficiency (Wajcman and Dodd 2016). Preston described this assumption as a reason to separate preparation work from research:

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.

---

<sup>4</sup> I refer to participants with pseudonyms.

Scientists want “stable,” long-lasting specimens, but that is not their primary priority. As a result, Preston portrays preparators as protection against scientists’ short-term interest in results. Similarly, preparators criticize scientists’ relative disinterest in conservation. Gary complained, “Scientists in charge of the collection, ... some of them don’t like the idea of conservation at all. To them it’s like a four-letter word, it’s something that’s to be avoided at all costs because it’ll slow down their research, it’ll cost money, it’s just a nuisance.” He knew of preparators who were trying to integrate conservation into preparation and collection care and “meeting great resistance [from scientists], which is really terrible.” This conflict suggests that scientists value spending resources to collect, prepare, and study fossils more than to conserve them, which they don’t consider their responsibility.

One conflict illustrated scientists’ rush vs. preparators’ precision and the worst possible outcome of impatience. Scientist Tom told me, “Every time before I’ve saved [preparator Jane] weeks’ worth of work by chopping a slab down ... [Today] I did it and I broke the fossil. [laughs] So I apologized and kind of crawled out of there.” Jane’s version of the story was that Tom wanted to thin a plate-sized, two-inch-thick rock slab containing 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,” such as with a pneumatic engraving pen that vibrates small pieces of rock loose with precision. Jane said that she warned Tom that the matrix grains are “tight” and thus would not split as he expected. But Tom insisted and hammered the knife tip against the slab. The fossil fractured into three pieces (figure 1). Jane felt she had won a battle because she had warned Tom that the fossil would break: “Score one for me in a way. Fish lost, but I won.” Despite this victory, Jane was shaken by the episode, which “took the wind out of my sails.” The callous fracturing of a specimen that Jane had been meticulously preparing depressed her. She left work early that day. Tom didn’t mean to break the fossil or to offend Jane; nonetheless, to him, his desire to minimize the time before he could study the fossil justified a risky preparation technique and a power play over a disapproving technician.



*Figure 1: A scientist broke this fossil by using a preparation technique rejected by the preparator. The preparator then had to repair it and feared the scientist's continued interference, as seen in the warning notes.*

### *Conservators for the Future*

Conservators think in terms of centuries. Their professional society, the American Institute for Conservation of Historic and Artistic Works (2018), defines their work as “the long-term preservation of cultural property,” such as paper, glass, buildings, and natural history specimens, by monitoring how objects change over time and sometimes intervening to prevent their degradation. Their capital comes from a master’s degree in conservation, a credential that most conservator jobs require.

This shared training embeds an ethos of minimalist practices. Conservators interpret “long-term preservation” to mean doing the fewest possible “treatments,” i.e., interventions that change objects (e.g., adding adhesives), and designing necessary treatments to be as “reversible” (i.e., impermanent) as possible. However, every conservator I interviewed pointed out that “reversibility is a myth,” as Carter put it, because it is impossible to fully remove the effects of most treatments, particularly adhesives. Conservator Kate explained, “You should not be doing things [that] we can’t have any sense of what the outcome might be and what that might do down the road.” Conservators fear that their interventions may do more harm than good because past well-intentioned techniques have proven destructive, such as using nails (which rust), plaster (which crumbles), and animal glues (which decompose) to stabilize fossils (Cruickshank 1994,

Author 2009). Their work focuses on documenting objects' status and trying to prevent changes, such as controlling environmental conditions (e.g., minimizing exposure to humidity, insects, or even oxygen), using storage containers made of chemically stable materials, and administering treatments (e.g., repairs). Conservators are experts on the scientific processes of chemical and physical deterioration. Accordingly, many conservators do research and publish papers on materials and methods.

Conservators collect meticulous data about objects' condition. For example, conservator Kate assessed several fossil skeletons on display in the museum where she works, with a team of graduate students. They observed each specimen by filling out a standardized form, and then a formula converted those data into a numerical score representing each specimen's physical and chemical stability. The museum's preparators complained that these practices demanded more data and work than necessary to generate useful conclusions. Likewise, Kate complained about the preparators' lack of records about their methods: "If you make the decision to do something [to a specimen], one thing we do in conservation which is not always done in preparation is to document it with exquisite thoroughness." These differences in habitus inspired both groups to voice mild disdain for each other, despite their ongoing collaboration. The preparators were also frustrated with the conservation team's lack of expertise about fossils. For example, the team telephoned preparator Jay often during their study to ask him to look at things that they diagnosed as deterioration indicators, such as "efflorescence" (when salts crystallize onto an object's surface, indicating the breakdown of internal chemicals). Jay usually deemed these apparent indicators harmless, such as plaster dust rather than salt crystals. As a result of these differences of opinion, Jay thinks Kate's data—presented in several graphs and tables in a 34-page report with an additional five appendices—are overstated. However, he agrees with Kate's conclusion that many of the specimens are in poor condition.

This disagreement about how to determine objects' well-being reflects the two fields' conflicting doxa about time. Conservators frame their work as preventing or reducing objects' degradation, which assumes long time periods. As Kate put it, "Everything rots ... But preventive conservation is about slowing the rate at which time does the inevitable." Thus, the investment in collecting data to monitor specimens' condition is worthwhile, because those check-ups can prolong objects' shelf-life. Kate names temporality as the cause of the differences between conservators' and preparators' values:

The primary purpose of preparation is to make the specimen useable for a specific use at a specific time. It's not necessarily about, what are we doing to preserve the specimen for the most likely uses over time.

The latter value, of course, belongs to Kate's field of conservation. Conservator Laura explained, "We're into minimal intervention. If it's stable in the matrix, we leave it in the matrix." She criticized people who want all rock removed from fossils: "It's very arrogant to cause any destruction because in the future there may be better methods for extracting information." She wants to prevent changing an object—even by removing rock—for as long as possible to make more data available for potential future research techniques, such as, for example, DNA extraction from fossils. Many conservators share this optimistic view of future technological progress, following the "planned hindsight" mindset that geneticists and conservationists use to explain the importance of preserving frozen biological samples for imagined future uses (Radin 2015). Planning for future research in the present can arguably preserve multiple possible purposes and meanings for preserved specimens, while also shaping their future users' potential questions, techniques, and evidence through current decisions about what is preserved and how. For specimen conservators, one wonders how they decide when exactly that progress is sufficient and new techniques should be carried out.

Scientists, in comparison, prefer to conduct research now than to wait for potentially better future research methods. Turner (2016, 64-67) argues that scientists must make predictions about future research questions, methods, and evidence, and that it is better for the success of current and future knowledge construction to make these "epistemic bets" than to adopt a "no-betting policy" by acting as though everything will stay the same, an assumption that Turner deems "too cautious." However, a more productive policy than patiently betting on the future is carrying out all the research that is currently possible, such as by fully preparing all fossils and dousing them in strong glue, even if it is chemically unstable and permanent. A goal of achieving maximum research in minimum time could lead to a slash-and-burn approach to specimens. Conservators, on the other hand, regularly place the optimistic epistemic bet that the future will yield more useful research techniques than the present, perhaps to the detriment of current research but in the interest of maximizing the quantity and quality of knowledge output over the long term.

Conservators see any kind of interaction with objects as a potential “loss of data,” in Carter’s words. For example, collecting a fossil removes it from its context and threatens its stability, so conservators strive to minimize any further data loss. Like fieldwork, preparation also removes context (i.e., rock matrix) and can damage fossils. Conservators’ aversion to change in an object can seem extreme to preparators. Preparator Gary attended a workshop in which “[Carter] pointed out, much to my dismay but I recognized the truth of it, he said all preparation is destructive.” Destroying information seems antithetical to preparators’—and scientists’—goals. For Carter and most conservators, the original location and matrix are irreplaceable parts of a specimen, while scientists believe that careful documentation of a specimen’s locale and geological context can substitute for these information sources. As a result of this disagreement about the very definition of a specimen, Gary emphasized the need to balance the two fields’ conflicting but important doxa:

When we prepare fossils, our goal is to reveal data. And conservators’ goal is to preserve data ... So the ultimate conservation is not to collect, and the ultimate preparation is to prepare it completely. We’ve got to find the middle ground that satisfies our immediate needs, looks to future needs, future capabilities, and also gives the fossil its due respect. This “middle ground,” I argue, is better for all three fields because it allows immediate research (which justifies keeping collections) *and* protects specimens from maximum matrix removal and rushed preparation, thereby making those specimens useful for future research.

### *Preparators Serve Scientists or Fossils?*

Preparators work for scientists yet value protecting fossils. They therefore fall between scientists and conservators in their perception of time, and they often mediate between the other groups’ priorities. Preparators accumulate capital through on-the-job learning, often as volunteers. There are no educational prerequisites, training courses, or standard protocols for fossil preparation. Due to their lack of specific credentials, preparators are often classified as lower-status job ranks, such as “support staff.” While some preparators oppose this subordinate role, they all consider it normal. Preparator Bill thinks that because the money for fossil fieldwork, preparation, research, and storage comes from scientists’ grants, their satisfaction is paramount: “If the curator’s happy with how it’s done, that’s the bottom line.” This view reflects most institutions’ formal hierarchy, but in everyday interactions scientists and preparators tend to

negotiate and collaborate more than act solely as instruction-giving bosses and instruction-following employees. Furthermore, low institutional status does not mean that scientists consider support staff unimportant. For example, scientist Maurice thought his department needed two preparators for each curator but at the time there were only two preparators shared among three curators, which Maurice called “a terrible staffing problem.” Preparators can be a limiting factor to research, which is a significant kind of power despite their low institutional status.

Preparators participate in scientists’ Society of Vertebrate Paleontology (SVP) and have their own professional society, the Association of Materials and Methods in Paleontology (AMMP), but neither group credentials preparators or standardizes techniques. The only document that aims to define preparators’ professional identity is a list of “essential competencies” written by a group of preparators (Brown et al. 2012). The authors were inspired to write this list by the American Institute for Conservation’s report about conservators’ “essential competencies” (Perkinson et al. 2003), a document that the preparators used as a model. The preparators’ list is posted on the AMMP and SVP websites (AMMP 2018; “Preparators’ Resources” 2016). It names general characteristics preparators should have, such as “critical thinking” and an “understanding” of fossils, tools, materials, conservation, and fieldwork. This portrayal is vague compared with the specific degrees and practices required for conservators. Preparators might structure their capital and habitus in similar ways to conservators in the future, as the list’s first author Matthew Brown (2009) has recommended. As a sign of potential movement in this direction, the list of essential competencies includes desired practices that are not currently widespread, such as “the preparator keeps records of all tools, techniques, and materials used to prepare or house the specimen” (Brown et al. 2012). This is standard practice for conservators, and Brown and coauthors want to make it standard for preparators too.

Preparators’ primary habitus is removing rock from fossils. This work inevitably entails repair, as preparators uncover—and sometimes cause—broken fossils. Discussions among preparators about which glues to use—such as permanent, instantaneous “super” glues or the dissolvable, slower-setting glues used by conservators—are complex, ongoing, and sometimes viciously argued. These disagreements reflect preparators’ autonomy over their materials and methods, and their staunch desire to preserve that autonomy as a sign of their expertise and identity. There are many possible ways to prepare fossils, just as there are many ways to study them (Author 2019). A preparator is responsible for selecting which tool best matches a fossil’s

rock type, fragility, and size, as well as the institution's resources and the scientist's deadline for that finished fossil. This complex calculus of priorities shifts often, such as when a fossil proves more crumbly than expected, a tool produces more vibrations than a preparator's wrist can withstand, or a scientist loses interest in a half-prepared fossil and requests that a more promising one be prepared instead. Preparators' judgment is embodied, tacit, and a deciding factor for how a prepared fossil looks. As Steve put it, "One of the joys of being a preparator is the fact that nobody can tell you how to do it ... The researcher will just say what they want to see on that specimen. How I actually go about giving them that information is entirely up to me." Scientists decide which fossils to have prepared and then wait—sometimes impatiently—for the preparation work. Sometimes scientists check on fossils-in-progress and may change their requests accordingly, such as if preparators uncover unexpected morphological features.

Unlike scientists and conservators, preparators are not expected to conduct research. In some institutions, they are actively barred. One preparator published scientific articles until a scientist complained: "He was getting upset that I was doing research on fossils. So I stopped and I started doing a lot of research into plastics [adhesives] ... [as] things that were directly related to preparation." This scientist considered testing materials to be acceptable work for a preparator, unlike fossil research. Because the scientist outranked the preparator, his assumption about appropriate habitus took precedence. Most preparators, though, are not interested in doing fossil research; they see it as scientists' domain. Likewise, preparators rarely publish about techniques or materials, perhaps because, like many technicians, they consider themselves responsible for objects and not papers (de Solla Price 1965).

Preparators' role as specimen protectors becomes problematic when they, as support staff, are asked to prepare specimens quickly or using techniques they oppose. Preparator Bill explained,

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. (Author 2009, 10)

Balancing preparators' and scientists' priorities is a major source of discussion and sometimes discord. Preparators tend to portray scientists as impatient or pushy, a characteristic that scientists define more positively as, in Preston's words, "result-oriented." Scientists' focus on

papers and technicians' focus on objects has been long noted (de Solla Price 1965), but these values are usually complementary rather than contradictory. After all, research requires functional objects. Conflict arises only in cases in which doing research involves damaging objects.

Preparators vacillate between conservators' long-term view of specimens and scientists' interest in seeing a fossil quickly prepared. Negotiations about deadlines for prepared fossils make these disparate doxa clear. Preparator Max told me,

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—a scientist—viewed preparation as a roadblock to research and thus as a task to finish quickly, while the preparators saw it as a meticulous 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 an assumption that the boss and the supervisor prioritize protecting fossils over preparators and thus might reduce the work pace for the *fossils'* benefit.

Institutions hire preparators to provide access to fossils for scientists. As preparator Charles put it, "if you can't study them, what's the point? Right? You've got to make the specimen so you can get the scientific information from it, and that's why you're doing the preparation." But, like conservators, preparators feel a moral responsibility to preserve fossils for future research. Charles continued, "I think you ought to do it right the first time so that that specimen will be there for as long as possible, instead of using some quick-fix method just for the short term." Hence preparators' role as mediators between scientists' immediacy and conservators' vague and optimistic future. Conserving fossils aligns with scientists' interests, since many studies include analyses of already-prepared fossils. However, high-impact studies in vertebrate paleontology typically announce *new* specimens, which must be prepared before they can be studied. In these situations, scientists are more likely to sideline conservators' concerns and push preparators for quick work.

This collaboration involves naming each group's doxa, such as quick turnaround times, long shelf lives for specimens, and careful preparation work. Because no one wants badly

prepared fossils, preparators can leverage their need for unhurried concentration. They can also tailor their methods to scientists' deadlines, in some cases. For example, if a scientist wants to study just one bone in a rock-encased skeleton, a preparator can prepare only that bone but with care and conservation-approved materials, thus reducing prep time while also producing a stable specimen with minimal intervention. This negotiation is crucial for achieving research and specimen conservation together, thanks to the compromises of delaying research, allowing the loss of some matrix, and risking fossil damage (though reducing that risk by not rushing the preparator). Successful collaboration forces fields to recognize and articulate their doxa, such as about time, and then work together to devise a solution that respects a version of all groups' doxa. A successful balance of conflicting doxa then is valuable for achieving each field's primary goals and for constructing evidence and knowledge that are more useful to more fields.

The assumption that I suggest underlies how these fields work with fossils is their conception of time. Scientists see time as a ticking threat to their careers, reputation, and ownership of new discoveries and interpretations. Conservators similarly see time as a threat but to objects, not themselves. They strive to slow inevitable deterioration to preserve specimens for current study, potential future research, and for their own sake as a unique product of nature. Preparators argue scientists' and conservators' perspectives depending on the situation, thereby defining a practical middle ground of conservation-minded matrix removal and specimen reconstruction. They have one foot in the deep past as they protect fossils and one foot in the frantic present as they make fossils researchable for their bosses. Preparators tend to have the lowest institutional power, which may explain why they are more willing to compromise with scientists than conservators are. Understanding each field's foundational assumptions, then, is crucial for understanding how multi-field communities work together to produce evidence and knowledge.

*Table 1: A simplified comparison of three fields in one research community*

	<b>Capital</b>	<b>Habitus</b>	<b>Doxa</b>
<b>Scientists</b>	<ul style="list-style-type: none"> <li>Graduate training (PhD in a fossil-related science)</li> </ul>	<ul style="list-style-type: none"> <li>Research</li> <li>Specimen collection</li> </ul>	<ul style="list-style-type: none"> <li>Research and papers are paramount and should happen quickly</li> <li>New specimens are more interesting than old specimens</li> </ul>

<b>Conservators</b>	<ul style="list-style-type: none"> <li>• Graduate training (MA/MS in conservation)</li> </ul>	<ul style="list-style-type: none"> <li>• Preventing structural change in objects</li> <li>• Documentation</li> <li>• Research</li> </ul>	<ul style="list-style-type: none"> <li>• Objects are valuable in themselves</li> <li>• Future scientists and conservators will have better techniques</li> <li>• Don't do treatments with permanent or unknown effects</li> </ul>
<b>Preparators</b>	<ul style="list-style-type: none"> <li>• Learning by doing</li> </ul>	<ul style="list-style-type: none"> <li>• Removing matrix</li> <li>• Reconstructing broken fossils</li> </ul>	<ul style="list-style-type: none"> <li>• Fossils should be both researchable and stable</li> <li>• Choosing techniques and materials is a preparator's privilege.</li> </ul>

### The Epistemic Benefits of Some Pluralism of Assumptions

Bourdieu (1975) believed that the scientific community exists as a single field composed of more specific and narrow fields. This paper shows how incommensurable doxa can coexist in research communities. Rather than impeding a community's collective knowledge construction and scientific authority, I suggest that this plurality of assumptions shapes *and improves* research practices and knowledge claims.

Longino (1990, 76-82) similarly argues that a multitude of assumptions and biases should come together to inform scientific work, such as through peer review. Scientists must adapt their work to satisfy this "intersubjective criticism" for that work to be considered objective. Furthermore, scientists' own "understanding is enhanced if they can defend their work against criticism" (Longino 1990, 78). Longino assumes that the criticizers are scientists and that they share social and epistemic "standards" with the scientists they critique. I suggest that this analysis extends usefully to non-scientists too, whose plurality of assumptions can similarly improve scientific knowledge. As an aside in a footnote, Longino comments insightfully,

A scientific community existing in a (utopian at this point) society characterized by thoroughgoing inclusivity and equality might indeed encourage the persistence of divergent points of view to ensure against blindness to its own assumptions. (1990, 82)

While acknowledging the need for shared assumptions, Longino suggests that preserving plurality can improve knowledge by forcing scientists to defend their claims against people with different perspectives. Longino's big-picture portrayal of the scientific community also describes the local microworld of science, such as a single laboratory, in that a plurality of assumptions can exist in smaller subsets of the scientific community. In addition, discussions to resolve workers' divergent assumptions can usefully shape the production of *evidence*, well before formal evaluations such as peer review.

The beneficial influence of a plurality of assumptions operates by 1) making practitioners aware of their own doxa by having to explain and justify them to members of other fields, 2) putting practitioners in regular contact with members of other fields, such that they gain a shallow understanding—and perhaps even appreciation—of other fields’ doxa, and 3) forcing workers to modify their doxa to align with collaborators’ in mutually beneficial compromises. For example, a conservator’s wish to preserve the rock around a fossil cannot co-exist with a scientist’s wish to see the fossil. By balancing these two wishes, such as by partially preparing a fossil or by keeping a sample of removed matrix, both fields’ goals can be achieved, even if imperfectly.

The co-existence of opposing fields in a community allows each field to argue for their ideal goals, even though they don’t expect to achieve them. Plurality may be polarizing. For example, collections exist to be studied. Conservators exist to protect them, but still arguably in the service of knowledge production. It’s possible that in the absence of conservators, scientists might moderate their own desire to quickly gather maximum amounts of data from a specimen. Of course, many fossil researchers have shown such restraint over history. But fossils have also been destructively hacked out of their matrix, doused with adhesives that later degrade and leave the specimens in pieces, and/or physically sliced to access interior views. It may be unfair to expect scientists to prioritize the future when they are under pressure to produce knowledge *now*, and likewise to expect conservators to consider current utility when they value future potential. Letting someone else make the opposing argument can simplify each group’s position. Then the resulting compromise is informed by both sides.

Lab workers in paleontology believe they *should* belong to separate fields with some separate assumptions. For example, as previously mentioned, scientist Preston thinks that scientists and preparators should do separate work *because of* their different and sometimes conflicting values. He fears that scientists’ eagerness to access research results can lead to quick and destructive preparation work, such as Tom’s hammer-and-butter-knife technique. One way to avoid that risk is to distance scientists from preparation and instead entrust it to preparators, whose goals include stabilizing specimens in addition to accessing data. Preparator Gary agrees that division of labor ensures compromise, or at least prevents one group’s takeover of power:

I think there should be a clear division of tasks and responsibilities and those should be inviolate. The curator shouldn’t [say], “No, don’t put Ethafoam [a conservation-grade

material] on the shelves, just put cardboard. I want to spend that money to go into the field.” And yet ultimately the curator is in charge of the collection and everything to do with it.

For Gary, a scientist/administrator deciding to spend the institution’s money on fieldwork—scientists’ priority—instead of specimen care—conservators’ and preparators’ priority—would be a damaging abuse of power. Involving multiple fields in such decisions would prevent the imposition of one group’s incompatible values over other groups.

Another reason to involve multiple fields in one research community is as a form of epistemic defense. For example, 20th-century physicists preferred to hire workers with no training in physics as bubble chamber operators, to prevent them from imagining—and thereby inventing—desirable results (Galison 1997, 199-200; Traweek 1988, 28-9). Many of these operators were women with little education but significant control over physicists’ data. Likewise, leaders of the Manhattan Project found, to their surprise, that women with high-school diplomas (or less) were more efficient and effective workers in uranium enrichment plants than Ph.D.-holding scientists (Kiernan 2013, 109-110). They believed that the women, who were not told what the plant was producing or why, followed instructions better than the scientists, who knew the end goals and deviated from instructions to try to improve the process. Thus, scientists sometimes perceive scientific knowledge as an obstacle to good data preparation. This belief can inspire scientists to outsource this work to people in other fields, who don’t know scientists’ preferred results and whose observations are arguably less theory-laden (or, more accurately, laden with different assumptions from scientists’).

Involving more fields and people in a research community can also lend credence to the community’s knowledge claims. For example, Ivan Pavlov’s physiology laboratory, which was active in the 1890s to 1920s, included assistants, attendants, and “praktikanty” (physicians doing research to earn a doctorate):

His constant references to “the laboratory’s view” and to the experiments of various praktikanty gave Pavlov’s conclusions greater authority, portraying them as the results of collective thinking and independent experimentation by numerous individuals on countless dogs. (Todes 2002, 103)

The diversity and number of workers gave Pavlov the credibility of multiple experimenters (and experiments) to support his lab community’s knowledge claims.

Modern science may therefore depend on interactions between a variety of workers, both to provide the relevant knowledge and skills and to strengthen scientific arguments. Galison credits the volume and complexity of scientific knowledge as a main cause of teamwork: “The composition of the experimental argument as a whole extends beyond what any individual or subgroup is capable of producing” (1987, 274-5). This heterogeneity improves scientific knowledge:

It is the *disorder* of the scientific community—the laminated, finite, partially independent strata supporting one another; it is the *disunification* of science—the intercalation of *different* patterns of argument—that is responsible for its strength and coherence.

(Galison 1997, 844, original emphasis)

Bringing different fields to a shared scientific question and making their diverse approaches commensurate means that knowledge is a compromise powerfully supported by a plurality of methods, assumptions, and experts.

### How to Study Assumptions

What do pluralist inter-field communities mean for us, as analysts of scientific practice and knowledge? One important methodological benefit is that assumptions are easier to study when they co-exist. As unspoken and unwritten beliefs, assumptions are difficult for outsiders to access. Luckily, practitioners tend to articulate their assumptions during interactions with people from different fields, including coworkers and social scientists, historians, and philosophers. This is why science studies has long focused on epistemic controversies, when groups must explain their beliefs to resolve a disagreement (e.g., Latour and Woolgar 1986, Collins 2004). As Ankeny and Leonelli (2016, 24) point out, repertoires that practitioners explicitly adopt are easier to study than tacit repertoires. Likewise, the everyday deliberations that workers held over partly-prepared fossils were my access point to learning what each field wanted from that object. I also asked practitioners directly, though they sometimes struggled to explain things that to them seemed obvious, such as conservators’ advocacy for reversible techniques and scientists’ shrugs when I asked them why they like to see entire fossils without matrix. It is difficult for us all to explain beliefs that, in our fields, seem like common sense.

As analysts of science, we recognize our own assumptions typically when we disagree with or are surprised by our participants. For example, when I asked a group of preparators

whether they worried that volunteers, who are the majority of workers in most preparation labs, could replace them by doing their work for free, they all laughed. Embarrassed and a little confused, I realized my assumption that volunteers and staff had the same level of expertise and did the same kinds of work. In comparison, scientists, preparators, and volunteers perceive a clear distinction between staff and volunteers' abilities and responsibilities. Thanks to my interviewees' feedback, I abandoned my assumption and began to pay attention to how staff and volunteers differentiate themselves in the lab, as a fascinating example of the ongoing construction of social status, skill, and division of labor. We have all experienced the confusion that reveals the conflicting assumptions underlying a conversation. Recognizing our assumptions does not necessarily require changing them, but it is valuable to be aware of them so that we understand how they influence our decisions as researchers.

More general assumptions that my ethnographic research made apparent and that perhaps other science studies scholars share include being impressed by the lab workers and their work, perceiving them as experts who are respected and somewhat autonomous, expecting them to agree on their collective goals, and believing that both their research and mine were important and worthwhile. First, I remember my awe when a preparator nonchalantly handed me a fossil for the first time while I wondered if I should be wearing gloves, as I would to hold an ancient book or an art object. Lab workers scoff at this novice bedazzlement, even though they completely understand it and, I suspect, still quietly experience it. But they have to get over this fascination in order to work with that otherworldly object, and I learned to do the same (or at least pretend). Accordingly, I assumed everyone who works with fossils must be an expert who makes their own decisions. The strict hierarchy of museums and universities did not always align with this belief. I also expected lab workers to work together towards the same goals, namely the study and display of fossils. This is not untrue, but there are many more steps and disagreements along the way to these big-picture goals than I had anticipated. Finally, I chose to study vertebrate paleontology communities because their work is the foundation of how we understand the history of life and is, therefore, important to understand. Lab workers share the former belief but not necessarily the latter, as shown by their mild suspicion about what I was doing and why, despite many discussions about it. Some participants thought I was an evaluator, judging the effectiveness of their work, volunteer programs, or exhibits. This mistaken idea limited what they were willing to tell me. Others thought I was a historian, so they recounted personal,

institutional, and pop culture versions of the history of paleontology. These stories were fun to hear, but the workers were then confused when I asked them about their choice of glues rather than about who led the lab in the 1980s. These mismatched assumptions and the difficulty of explaining and understanding both my own and theirs illustrate the power of our unexamined beliefs to shape our relationships, research questions and methods, and how we interpret the world.

#### Conclusion: The Epistemic Benefits of Compromise

Analyzing the various facts, techniques, values, and behaviors that scientists and non-scientists take for granted is a foundation of science studies. Thus, finding opportunities when these assumptions are exposed is a crucial component of research in history, philosophy, and social science. We might assume that a research community is united by capital, habitus, and doxa, but this approach overlooks the many fields that collaborate to produce scientific questions, evidence, and knowledge. It would be more accurate to recognize the diversity of fields and the plurality of their assumptions alongside the common ground they share, such as a repertoire. I suggest that a limited pluralism of assumptions can make scientific work serve more purposes (e.g., research *and* conservation) and be more convincing (thanks to the intersubjective, intercalated support of various fields' divergent practices and beliefs).

This phenomenon is well illustrated by the range of workers who collect, prepare, conserve, and study vertebrate fossils. Distinct fields do these tasks (habitus) and have different training (capital) and identities. Specifically, scientists have PhDs and value publishing new knowledge claims; conservators have master's degrees and value preventing long-term changes in objects through monitoring, interventions, and research on materials and methods; and preparators learn on-the-job to make fossils researchable as well as stable, thereby satisfying the divergent doxa of scientists and conservators. These workers know that they all rely on each other's work and expertise, even though they self-identify with only one of these three fields.

As a result of these fields' mutual dependence, they must regularly articulate their tacit values, beliefs, and priorities for their coworkers. This exchange of assumptions then encourages mutual understanding and interactional expertise, which can enable effective compromise. The co-existence and collaboration between groups with different assumptions empowers all the groups to communicate and justify their assumptions and to think carefully about how to align

each other's priorities to achieve mutually beneficial outcomes. These compromises produce evidence and knowledge claims that serve broader purposes and have already withstood criticism from various points of view, similar to Longino's idea of intersubjective objectivity.

Assumptions shape scientific work, knowledge, and community, and a plurality of them can improve how knowledge is made.

## References

- Alberti SJMM (2009) *Nature and culture: Objects, disciplines and the Manchester Museum*. Manchester University Press, Manchester
- Alberti SJMM (ed) (2011) *The Afterlives of Animals: A Museum Menagerie*. University of Virginia Press, Charlottesville, VA
- Ankeny RA, Leonelli S (2016) Repertoires: A post-Kuhnian perspective on scientific change and collaborative research. *Stud Hist Philos Sci Part A* 60:18–28.
- Bibliography, The Paleontology Portal. In: *Am. Museum Nat. Hist.* <http://preparation.paleo.amnh.org/28/bibliography>. Accessed 3 Apr 2019
- Bourdieu P (1975) The specificity of the scientific field and the social conditions of the progress of reason. *Soc Sci Inf* 14:19–47.
- Bourdieu P (1993) *Sociology in question*. Sage Publications Ltd, London
- Bourdieu P, Wacquant LJD (1992) *An invitation to reflexive sociology*. University of Chicago Press, Chicago
- Brown MA (2009) Preliminary report on professional development in vertebrate fossil preparation. In: *Proceedings of the 15th Annual Tate Conference, Fossil Preparation and Collections Symposium June 5-7, Tate Geological Museum, Casper College, Casper, Wyoming*. pp 52–57
- Brown MA, Davidson A, Fox M, et al (2012) Defining the professional vertebrate fossil preparator: essential competencies
- Brusius M, Singh K (2018) Introduction. In: Brusius M, Singh K (eds) *Museum Storage and Meaning: Tales from the Crypt*. Routledge, New York, pp 1–33
- Collins H (2004) *Gravity's shadow: the search for gravitational waves*. University of Chicago Press, Chicago
- Collins H, Evans R (2007) *Rethinking expertise*. University of Chicago Press, Chicago
- Cruikshank ARI (1994) A Victorian fossil wholemound technique: a cautionary tale for our times. *Geol Curator* 6:17–22
- Currie A (2015) Marsupial lions and methodological omnivory: function, success and reconstruction in paleobiology. *Biol Philos* 30:187–209.
- de Solla Price DJ (1965) Is technology historically independent of science? A study in statistical historiography. *Technol Cult* 6:553–568
- Delamont S, Atkinson P (2001) Doctoring uncertainty: mastering craft knowledge. *Soc Stud Sci* 31:87–107.
- Edgeworth M (ed) (2006) *Ethnographies of archaeological practice: cultural encounters, material transformations*. AltaMira Press, Lanham, MD
- Galison P (1997) *Image and logic: a material culture of microphysics*. University of Chicago Press, Chicago
- Galison P (1987) *How experiments end*. University of Chicago Press, Chicago
- Holtorf C (2002) Notes on the life history of a pot sherd. *J Mater Cult* 7:49–71.
- Kaiser D (2005) *Drawing Theories Apart: The Dispersion of Feynman Diagrams in Postwar Physics*. University of Chicago Press, Chicago
- Kiernan D (2013) *The Girls of Atomic City*. Simon and Schuster, New York
- Knorr Cetina K (1999) *Epistemic cultures: how the sciences make knowledge*. Harvard University Press, Cambridge, Mass
- Latour B, Woolgar S (1986) *Laboratory life: the construction of scientific facts*, 2nd edn. Princeton University Press, Princeton, NJ

- Leonelli S (2008) Circulating Evidence Across Research Contexts: The Locality of Data and Claims in Model Organism Research. *Working Papers on The Nature of Evidence: How Well Do 'Facts' Travel?* London School of Economics: London
- Leonelli S, Ankeny RA (2015) Repertoires: How to Transform a Project into a Research Community. *Bioscience* 65:701–708.
- Longino H (1990) *Science as Social Knowledge: Values and Objectivity in Scientific Inquiry*. Princeton University Press, Princeton, NJ
- Meyer M, Molyneux-Hodgson S (2010) Introduction: The Dynamics of Epistemic Communities. *Sociol Res Online* 15:1–7.
- Panofsky AL (2011) Field Analysis and Interdisciplinary Science: Scientific Capital Exchange in Behavior Genetics. *Minerva* 49:295–316.
- Perkinson R, Bischoff J, Burke M, et al (2003) Defining the Conservator: Essential Competencies. American Institute for Conservation of Historic and Artistic Works
- Radin J (2015) Planned Hindsight. *J Cult Econ* 8:361–378.
- Reference books. In: Soc. Preserv. Nat. Hist. Collect. <http://www.spnhc.org/30>. Accessed 3 Apr 2019
- Todes DP (2002) Pavlov's physiology factory: experimentation, interpretation, laboratory enterprise. Johns Hopkins University Press, Baltimore, MD
- Toombs SK (1990) The temporality of illness: four levels of experience. *Theor Med* 11:227–241
- Traweek S (1988) *Beamtimes and lifetimes: the world of high energy physicists*. Harvard University Press, Cambridge, Mass
- Turner DD (2016) A second look at the colors of the dinosaurs. *Stud Hist Philos Sci Part A* 55:60–68.
- Wajcman J, Dodd N (eds) (2016) *The sociology of speed: Digital, organizational, and social temporalities*. Oxford University Press, Oxford
- Whitney K (2019) It's about Time: Adaptive Resource Management, Environmental Governance, and Science Studies. *Sci Technol Hum Values* 44:263–290.
- Wylie CD (2009) Preparation in action: paleontological skill and the role of the fossil preparator. In: Brown MA, Kane JF, Parker WG (eds) *Methods in Fossil Preparation: Proceedings of the First Annual Fossil Preparation and Collections Symposium*. pp 3–12
- Wylie CD (2019) Overcoming underdetermination. *Biol Philos* 34.
- (2016) Preparators' Resources. In: Soc. Vertebr. Paleontol. <http://vertpaleo.org/For-Members/Preparators-Resources.aspx>. Accessed 8 Oct 2016
- (2018) What is conservation? In: Am. Inst. Conserv. Hist. Artist. Work. <https://www.conservation-us.org/about-conservation#.WvXuSWaZOL4>. Accessed 11 May 2018
- (2018) Resources. In: Assoc. Mater. Methods Paleontol. <https://paleomethods.net/competencies/>. Accessed 11 May 2018