Published as: Wylie, C.D. (2015). "The artist's piece is already in the stone": Constructing creativity in paleontology laboratories. *Social Studies of Science*, *45(1),* 31-55. https://doi.org/10.1177%2F0306312714549794

'The artist's piece is already in the stone': Constructing creativity in paleontology laboratories

Caitlin Donahue Wylie

New Jersey Institute of Technology, Newark, NJ, USA

Abstract

Laboratory technicians are typically portrayed as manual workers following routine procedures to produce scientific data. However, technicians in vertebrate paleontology laboratories often describe their work in terms of creativity and artistry. Fossil specimens undergo extensive preparation – including rock removal, damage repair, and reconstruction of missing parts – to become accessible to researchers. Technicians called fossil preparators choose, apply, and sometimes invent these preparation methods. They have no formal training, no standard protocols, and few publications to consult on techniques. Despite the resulting diversity of people and practices, preparators and their work are usually absent from research publications, making them 'invisible technicians' in Steven Shapin's sense. But preparators reject the view of their work as predictable or simple; in particular, many preparators value art training, the aesthetics of prepared fossils, and the process of creative problem-solving in their work. Based on interviews and participant observation and drawing from literature in science studies, sociology of work and anthropology of craft, I ask why these technicians compare themselves with artists and how this portrayal affects scientific practice and social order in laboratories. I argue that associating artistry and creativity with their work distances preparators from ideas of

unskilled technical work and technicians' low status, thus improving their social role in the lab community and preserving their power over lab practices.

Keywords:

laboratory studies, technicians, expertise, creativity, paleontology, fossils

Corresponding author:

Program in Science, Technology and Society, Department of Humanities, Cullimore Hall, New Jersey Institute of Technology, University Heights, Newark, NJ 07102, USA

Email: wylie@njit.edu

In addition to fossilized bones, a typical vertebrate paleontology laboratory also contains many scattered paper cups of dental scrapers, paintbrushes, plaster, glue, broken fossils – or this morning's coffee. Pneumatic engravers, delicate handheld jackhammers designed for writing on metal, are plugged into air lines at every workstation. Fossils wait for attention in various cardboard boxes (some emblazoned with food labels or shoe brands) or cushioned on sandbags made of burlap, old jeans, or recycled socks. Sandblasting equipment, often housed inside a homemade chamber of clear plastic with holes cut to admit the technician's hands, may occupy one table. These striking collections of objects – obtained from 'Dumpster diving' expeditions and dentists' donations as well as from science supply companies – give the impression of a place that is simultaneously a hardware store, a tinkerer's workshop, and an artist's studio. Of course, this place is defined by its native inhabitants as a science laboratory, though those inhabitants walk by in plaster-coated jeans and dusty Star Trek or dinosaur-themed t-shirts, with white lab coats nowhere in sight.

Who are the technicians who build, use, and adapt this environment as their workspace? They are fossil preparators, whose work of removing rock matrix from fossils, repairing breaks, and reconstructing missing pieces is at once physical, dirty, delicate and precise. This manual labor may seem like only the prerequisite for the more interesting and difficult work of science, such as identifying specimens, describing species and interpreting large-scale patterns to form conclusions about evolution and Earth history. But the work of collecting and analyzing data happens throughout the life of a specimen, from its collection, transport, preservation and preparation for study to its measurement, description, comparison and interpretation. These tasks are done by many knowledge workers, including field collectors, lab technicians, collection managers and conservators, as well as researchers. In vertebrate paleontology, these workers all come together in the lab, which is preparators' domain.

How these workers negotiate notions of acceptable methods, division of labor, status and expertise crucially depends on their conception of creativity. 'Creativity' is an ability and an activity typically reserved for scientists, more than for technicians or other knowledge workers. But in the paleontology lab, I argue, notions of creativity serve to delineate areas of control for all groups of experts, not just researchers. One preparator, at a large American natural history museum that I'll call Midwest Museum, echoed many preparators in her explanation of why she likes her job: 'I get to use my hands and be artistic and work in advanced science in an exciting environment and a creative environment.'[1] Her portrayal of technicians as 'artistic' and a laboratory as 'creative' rejects the common perception of lab technicians' work as following routine protocols. In a review of ethnographic studies of technicians across several fields, Stephen Barley (1996: 409) points out that in the nineteenth century 'technician … implied a competent practitioner with no artistic gift'. Thus the term was an insult when applied to artists.

This concept arguably shaped the post-World War II meaning of a technician, as someone who works with tools in science or technology. Technicians in both senses were not expected to be creative, either because they were incapable or because it was not part of their job. But, during my ethnographic investigations of vertebrate paleontology labs, many preparators described their work to each other and to me in terms of 'art' and 'creativity'. I suggest that preparators may employ these concepts in order to distance themselves from an image of protocol-bound technicians whose routinized work values following directions.

Despite preparators' critical role in making fossils accessible for research, their work is typically not described in research publications, thus making them 'invisible' to the scientific community, to use Steven Shapin's term (1989, 1994). Preparators have no formal training, no standard protocols, and few publications on techniques; the lack of textual descriptions further obscures what they do and who they are. Preparators' perception of their work as 'artistic' and 'creative' – which they present as opposite qualities to 'technical' and 'routine' – sheds light on the impact of technicians' work on scientific research as well as their identity and role in today's laboratory communities. I argue that preparators' claims to art and creativity are best understood as a justification for their diverse and individualized problem-solving practices, thereby asserting preparators' power over their work and thus their status as experts in the lab, despite their lack of formal training.

Technicians have been largely overlooked in sociological studies, as well as in scientific publications (e.g., Collins, 1985; Fujimura, 1996; Knorr Cetina, 1999) Latour, 1987; Lynch, 1985; Traweek, 1988) This omission results in part from a failure to realize that technicians often have principles and goals for their work that are independent of those of researchers. In the few studies that do mention technicians, they are portrayed as manual workers with varying levels of

skill and creativity. For example, Max Charlesworth and his coauthors describe an immunology lab's all-female technicians as 'support staff' who do routine protocols and only occasionally participate in research (1989: 82-9). Michael Lynch and his coauthors found in forensic labs that 'in highly routinized work, the lowest-grade technicians are required to act with machine-like regularity, keeping thought and creative variation to a minimum' (2008: 89-90). On the other hand, these researchers appreciated skillful technicians who did not need instructions to produce desirable data, and who were therefore allowed to work unsupervised. Researchers thus distinguish between technicians based on the ability to achieve researchers' aims. This ability is rewarded with more independence, namely the opportunity to choose and create lab methods.

Preparators, in comparison, have decision-making power based on their job status rather than necessarily on past performance. They are responsible for choosing and even designing practices, because their work is considered separate from researchers' knowledge construction rather than as a protocol-driven component of research (Wylie, 2013). Kenneth Kusterer's study of 'unskilled' work suggests that this distinction exists among factory workers too, in part because foremen consider that work inferior and in part because foremen don't actually know how to do that work (1978: 14). As a result, the supposedly unskilled workers control their sphere of work, particularly by choosing how to complete tasks and train novices (Kusterer, 1978: 42-4). Kusterer argues that preserving this knowledge separation 'added to the workers' autonomy and decreased their alienation', thus improving their job satisfaction despite their low institutional status (1978: 14). Likewise, preparators are tacitly empowered to control tasks that involve their skills. Park Doing's ethnography of a synchrotron lab describes a similar division of labor and power between technicians and researcher-bosses. He argues that 'operators' – technicians – define their knowledge as learned from interacting with machines, while

researchers define operators' knowledge as a result of their innately skilled 'lab hands' (2009: 58-9). Doing argues that these conceptions of knowledge allow each group to claim power over their own type of work. However, even these rich studies of workers' skill and culture emphasize their 'hands' and on-the-job experience, rather than their creativity, as sources of expertise.

The few studies of artistry in lab work have found that practitioners view it as undesirable, due to its subjective and tacit nature. Alberto Cambrosio and Peter Keating observe that researchers in bioengineering labs believe that new techniques rely on experimenters' 'art', meaning individuals' skill and judgment (1988: 248). But researchers assume that as techniques gain acceptance, their standardization and reliability increase. Thus *removing* individuals' subjective 'art' from lab work is the goal, particularly for biotechnology industries (1988: 256-7). Cambrosio and Keating do not report technicians' view of standardization. Stephen Barley and Beth Bechky found that both technicians and researchers in biology labs refer to the 'art' of technicians' work (1994: 118). However, their informants use the term 'art' to refer to tacit knowledge – or what Barley and Bechky (1994: 116) call 'contextual knowledge' – which is learned through experience and rarely articulated. Learning by doing is not necessarily the same as adapting or inventing practices, which is the basis of preparators' notion of their creativity. For preparators, their work on fossils relies on both art (as tacit knowledge) and creativity (as purposeful adaptation of practices).

These two cases also portray perceptions of technical work as serving social purposes. Cambrosio and Keating argue that scientists' various views on 'the opposition between art and routine' serve to distinguish between academic and industrial researchers (1988: 257). Barley and Bechky explain technicians' low institutional status by their work's perceived connection with 'art' or contextual knowledge: 'Cultural schemes associated with contextual knowledge

continue to elicit images of artisanal or craft work and, hence, attributions of lower status' (1994: 120). However, I argue that preparators consider art and creativity to be indicators of expertise and thus claims to higher status. Without standard training or credentials, preparators need another way to highlight their skill and knowledge, and thus assert authority over their work. Jeffrey Keefe and Denise Potosky (1997) describe a mismatch in technicians' perceived skill and status, resulting in lower job satisfaction than skilled tradespeople and professionals (e.g., researchers) in a pharmaceutical company. Keefe and Potosky explain this trend by technicians' lack of independence from their bosses: 'Technicians do not control their occupational knowledge or skill system, nor do they control the entry, education, or formal training of new recruits. In this sense, *they are craftworkers without craft control*' (1997: 79, original emphasis). Similarly, preparators consider themselves skilled, despite their low institutional status, and, like many technicians, they feel frustrated by low pay and insufficient respect (Barley, 1996: 432). Without control over their training, preparators instead claim power – both decisive and creative – over their techniques.

To access the roles of these 'invisible' technicians and their undocumented work in fossil research, I conducted participant observation, interviews and survey research in several paleontology labs in American and British museums and universities in 2010-2011.[2] Preparators' mentions of art and creativity came as a surprise to me, as did the fact that many preparators have art training. These artist-preparators compare their work to art more often than other preparators do, though the majority of interviewees mentioned creativity with regards to their work. Preparators describe their work as 'artistic' or 'creative' in three main categories: discussing skills relevant to preparation in terms of art training, how aesthetic goals shape their decisions and the necessity of 'creative problem-solving' and innovation. For these practitioners,

'art' means the skill and processes of physically making fossils fulfill researchers' needs as well as preparators' priorities, including aesthetics; 'creativity' means choosing or designing methods. I use these actors' categories to analyze how lab workers construct notions of social status through the ways in which they perceive and present their practices. Whether preparators *are* artistic and creative is less relevant to this topic; rather, I focus on how and why they define these concepts.

Preparators challenge the notion of technicians as standardized and thus replaceable by invoking the individual-based abilities of artistry and creativity. Problem-solving, after all, requires in-depth comprehension of a task, including the acceptable amounts of methodological variation and risk. In addition to this enculturation in a field, problem-solvers need an imagination. Building from their conceptions of good practice and of researchers' goals, technicians generate new approaches in response to the wide variety of data sources, research questions and methods in lab work. Thus preparators' constructions and assertions of artistry and creativity are, I argue, best understood as a method of defining their expertise and thus asserting control over their work.

Preparators' conceptions of 'art' and 'creativity'

Art training

Preparators believe that they share a variety of skills with artists, including visual perception, attention to detail and manual dexterity. Many preparators first learn these skills through making art: six of the 48 paleontology lab workers who responded to my survey (13%) reported having

a bachelor's degree in fine arts. Of the twenty-six preparators I interviewed, at least six (23%) have art training. In their ethnography of astronomical imaging, Michael Lynch and Samuel Edgerton (1988: 192) also found that two of the lab's seven astronomers exhibited their own artwork, separate from their jobs constructing and studying digital images. These astronomers identified 'a firm distinction between "scientific" and "artistic" uses of image processing technology' (Lynch and Edgerton, 1988: 192). In contrast, preparators with art training specifically state that they rely on skills learned through making art to prepare fossils. For them, art and preparation are complementary, although, like the astronomers, preparators avoid conflating them, perhaps to protect the credibility of the resulting data.

Shared skills and tasks are the primary unifying factor of the preparator community, in place of the more typical unifiers such as formal training, shared methods and printed communication methods, e.g., journals (Wylie, 2013). Preparators have become increasingly connected through preparation-specific presentation sessions and a Preparators' Committee at Society of Vertebrate Paleontology (SVP) conferences, an annual Fossil Preparation and Collections Symposium and the PrepList email forum. Despite more meetings and communication, preparators' efforts to establish standard training, credentials and best practices for their community have so far failed. Robert Faulkner and Howard Becker's (2009) study of jazz musicians captures the complexity of the 'shared' but actually highly variable skills and knowledge required to carry out communal tasks, such as playing in a band. The 'standard' repertoire of professional jazz musicians varies, Faulkner and Becker (2009) show, by individual. Analysis of musicians' pre-performance negotiations reveals the contextualized and dynamic construction of what is 'standard' or shared among all the musicians in that particular group. Despite this variation, Faulkner and Becker argue that the *concept* of standard repertoire

and musicians' ability to discuss it, learn it and adapt to it is what defines the community – and identity – of professional musicians (2009: 31, 82-3). For example, these musicians rely primarily on their knowledge of scales and chords, rather than on written music or memorized songs. This knowledge is required to 'improvise' – to innovate effectively within a community of practice defined by their 'standard' knowledge (Faulkner and Becker, 2009: 28-30). Similarly, preparators' knowledge is primarily learned through experience and is not codified. Preparators share certain skills and knowledge, such as how to handle fragile heavy objects, the properties of chemical adhesives and the design and use of tools. Though there is no formalized, universal preparation rulebook, there is a repertoire of skills that the community considers necessary both for doing good work and for innovating effectively. Many of these skills overlap with – and, for some preparators, are learned from – making art.

Preparators with art training believe that they share a common outlook on their work; art-inspired skills and approach may therefore be a significant unifying factor for the preparator community more generally. John, an artist-preparator at a large American natural history museum I'll call Eastern Museum, believes that artist-preparators understand each other:

> I have a very big art background. And so I tend to use a lot of that in my prep. And that falls in line with [Anne] [a coworker], you know, [Anne] has a huge art – sculpting background .... So we kind of vibe on that same aspect of things. So for us – well, for me specifically, it's kind of like art, you know. The longer you take, the more detail comes out in the piece. That same is true of prep, you know, the slower you go at it, the more time you take on it, the more detail you can get out of a certain piece.

Revealingly, John used the same word – a 'piece' – to refer to an artwork and a specimen. Artist-preparators' common 'vibe' or shared worldview can contribute to community-building and collaboration. Frank, a researcher at a midsize private American university I'll call Midwest University, studied both fine arts and biology as an undergraduate, before his graduate degrees in geological sciences. For Frank, 'the visual is extremely strong in paleontology', such as in preparation and fieldwork. Based on this belief, he hired two artists as preparators, Erica and Tim. Erica agrees with Frank that the visual skills she learned from drawing, painting and sculpting apply to working with fossils:

> As artists, most of us conceivably are very spatial-oriented and we can understand perspectives and we can understand – you know, we can see things that may not be there. And I think as a preparator you kind of have to feel that way.

For Erica, artistic skills extend beyond hand-eye coordination to include visual perspective and imagination. For example, she believes all preparators must be able to 'see things that may not be there', such as a fossil beneath rock. Tim also believes that preparators develop an artistic perspective regardless of art training, because it is integral to preparation skill: 'I think most preparators have a little bit of that kind of artistic sense where they can make things with their hands. You know, just by virtue of preparing you're kind of creating something.' For Tim, 'creating something' as a preparator relies on manual dexterity and visual judgment, like making art. Because this action is considered a fundamental part of preparators' skill, it may serve as a source of unity – and perhaps even shared identity – for the preparator community.

It may seem that this emphasis on art is specific to the labs that contain artist-preparators. For example, graduate student Sam, who had done research with Frank and at Eastern Museum, said of preparation: 'It's art, and it's patience, and it's skill.' Sam had tried to prepare fossils but found that preparation is 'not a great skill of mine. I'm not very artistic'. Perhaps Sam believes artistic ability is necessary for preparators because he was trained in labs where artist-preparators work. However, all preparators value manual dexterity, visual perception and being detail-oriented, even if not all of them credit art training for developing these skills. Asserting these skills as foundational for their work may benefit them not only by defining themselves as a unified group but also by equating themselves with artists, as skillful and high-status workers.

Aesthetics

Aesthetic goals feature in preparators' decisions about how to prepare research specimens as well as their decisions about *who* will prepare them. In Lynch and Edgerton's study of image-making, astronomers reported that 'aesthetics', such as adding colors to images, are irrelevant for research and useful only for making 'pretty pictures' for the public (1988: 192-6). However, the authors observed astronomers altering research images in similar ways as they altered public images. Astronomers justified these changes in terms of making research images look more 'real', meaning more like the astronomical objects they represent (1988: 202). Lynch and Edgerton suggest that researchers' credibility depends on images' authenticity; hence researchers' claim that processing research images is *not* aesthetically motivated. Fossil researchers can also encounter this dichotomy of specimens as natural objects and as products of preparators' decisions and work. However, because fossil preparation is not described in publications, researchers do not focus on it. The reliability of fossil-based knowledge claims is

rarely questioned on the basis of preparation work.[3] Nonetheless, preparators perceive a fine line between including aesthetics in their preparation goals and – advertently or not – sculpting fossils to the point that they could be considered forgeries.

Conceptions of 'beauty' and 'ugliness' serve social functions in science, as shown by studies of images and specimens in which aesthetic terms can denote the quality and comprehensibility of data (especially for non-expert audiences) and advertise a knowledge claim as visible and therefore credible (e.g., Cambrosio et al., 1993; Frow, 2014; Kessler, 2007; Law and Lynch, 1988; Lynch and Edgerton, 1988; Tauber, 1997). In paleontology labs, these labels further indicate distinctions between groups, judgments of specimens' preparation difficulty and workers' skill levels. Marc, a preparator, believes that preparators and researchers have different aesthetic criteria:

> We love the beauty of fossils, at least I think there's a very strong appreciation for the beauty of fossils, and I'm not saying that researchers don't have that, but they want to get in and look at specific parts, and they don't necessarily look at, like, the whole of a mount.

Marc defined the two groups' interests based on what they consider beautiful, i.e., specific research-relevant details versus a specimen's full appearance. Amanda, a preparator at Midwest Museum, described a case in which her aesthetic judgment differed from a researcher's. She said of an endothiodon jaw that she was preparing, 'I think it's super ugly' because 'there's no order to it', i.e., the teeth are in an irregular arrangement. However, she said that the researcher 'thinks it's beautiful', because he is interested in that species. Thus preparators and researchers – and

presumedly other groups, including collections managers, conservators and the public – have different criteria for fossils' aesthetics, depending on their uses for specimens. Using aesthetic terms to indicate diverse context-based priorities is a kind of 'skilled vision', as Cristina Grasseni describes breeders' conceptions of 'beauty' in cows (2004). These community-specific designations assess the desirability of an object (a cow or a fossil) as well as indicating a judge's expertise. As a reflection of practitioners' skill, aesthetic criteria are also a matter of personal pride. A volunteer preparator considered aesthetics intrinsic to standards of good work and thus to his task of making plaster storage jackets for fossils: 'I like [the jacket] to be as nice-looking as I can get it. It's going to go back in the basement, you know, beauty is not critical. I just like to.'

Aesthetic descriptors have a practical use among preparators: to indicate specimens' preparation difficulty and accordingly who should work on them. For example, in Amanda's lab, a volunteer who had just joined the lab 'got [a] somewhat non-descriptive bone because he's a new guy'. Ugly fossils can be uninformative, and thus can serve as training projects for novice preparators. However, if ugly fossils are scientifically valuable, then they are challenging to prepare. For example, Amanda said that another endothiodon skull she was working on is 'ugly, but cool' because it has unusual teeth, unlike the other, purely 'super ugly' jaw. 'Ugly' here refers to fossils that lack well-defined morphology, regardless of whether they are scientifically important. Preparators believe that fossils without clear structures are difficult to prepare, because their atypical shapes are unpredictable and thus easy to damage during matrix removal. As a result, Amanda said, 'I have [a] tendency to get specimens [to prepare] that are kind of smushed … because I'm chief'. As chief preparator, Amanda is responsible for assigning specimens to staff and volunteer preparators. She usually takes the 'smushed' but informative

specimens ‘because I can be happy with anything’, while many preparators dislike working on these misshapen ‘ugly specimens’. In Amanda’s experience, ‘appealing specimens are more fun to work on’ and ‘definite shapes are more exciting’ than indeterminate-looking specimens such as bone fragments, which ‘you get bored’ preparing.

Aesthetic descriptors can also indicate a specimen’s usefulness. Preparators believe that their work can change specimens’ aesthetic categories, and in a sense they strive to improve specimens’ beauty. Bob, a volunteer in Amanda’s lab, said one specimen ‘looked horrible’ because it was broken into several pieces. But after he reconstructed it, he said, ‘That looks good!’ By giving it order and the appearance of a whole bone rather than fragments, Bob thought he had changed the fossil’s aesthetic status. A complete fossil is typically more scientifically informative and safer from damage than loose fragments, so Bob’s concept of attractiveness may in part describe the achievement of the basic preparation goals of research access and conservation. These terms are thus not intended to judge an object for beauty’s sake; instead, they serve as informative and pragmatic labels for preparators’ assessments of difficulty, project assignment and goals. Using group-specific jargon for these purposes may emphasize preparators’ expert judgment of specimens’ potential preparation difficulty – their acquired ‘skilled vision’ – because understanding what it means for a specimen to be ‘ugly’ requires enculturation in the preparator community. This language could be a way to block outsiders from accessing preparators’ ‘invisible’, unwritten and uncredentialed knowledge.

The use of aesthetic words in particular may be of historical origin. Nineteenth-century fossilists commonly prepared fossils to sell, and strove to make specimens attractive-looking to appeal to customers (Wylie, 2009). Steve, a preparator at a large British natural history museum, prepared several specimens that had been prepared first in the nineteenth century. He warned of

differences between past and current beliefs: 'You have to take everything with a pinch of salt that was done in Victorian times because it was done on the beauty of it, the interest you get could from it.' For example, a valuable, beautiful specimen would be complete, so people preparing fossils often replaced specimens' missing parts with bones taken from other specimens or carved from plaster. Kirk, a collections manager at an American university's natural history museum I'll call Northern University Museum, has also encountered evidence of changing ideas about how prepared fossils should look:

> People used to go to great lengths to make [plaster replicas of missing bones] the same color as the bone, even to the point of, like, painting the bone and painting the plaster with the same paint …. Their reason was, you know, it'll confuse people if they can see that some of that's real and some of it isn't …. We don't think today that that's an ethical thing to do.

The Victorians' legacy of beautifying fossils persists, although in less interventionist ways than camouflaging artificial bones. Sheila, preparator and conservator at a British university's geological museum, admitted sheepishly that she smoothes the matrix around finished specimens, to remove tool marks and 'make it look appealing'. She sounded sheepish because she thinks it is unnecessary for research objects to have smooth matrix. But Sheila is not alone – many preparators mention the importance of aesthetics in their work. Historically, it was common for workers such as taxidermists to remove signs of their work, as Samuel Alberti points out: 'After the labour of manufacture [of a taxidermied specimen], still further efforts are expended to conceal this work. It is ironed out, silenced, deleted' (2008: 81). Alberti argues that

this convention served to present specimens as 'real' and thus as reliable research objects, rather than as products of artistry: 'For if objects are to act as data, they need to be impartial – their constructedness needs to be hidden by those whose credibility depends upon them' (2008: 81). The implication is that research would lose its credibility if researchers acknowledge that decisions and work – and thus subjectivity – shape specimens. Today's preparators do not explain their tidying-up of specimens in this way, but their aesthetic descriptors may inadvertently fulfill this longstanding function of abstracting technical work.

Far from abstracting their influence on natural objects, several preparators spoke about their work in terms of making art, implying the intentional use of their individual judgment. For example, John appreciates his coworker's ability to prepare fossils so that they look beautiful, like 'pieces' of art:

> If you look at some of [Anne's] pieces, they literally look like artwork. Just the way that they're in the block or, you know, the way that she's removed certain things but kept others. It's like a really really artistic way of looking at it and it looks beautiful.

John values his coworker's choice to make prepared fossils 'beautiful', such as by planning a composition of bones in matrix by extracting some while leaving others. Some researchers also appreciate preparators' ability to make fossils look real. Graduate student Sam credits preparators with the responsibility to 'bring this stuff alive, bring it out of the rock'. Luke, a researcher at Midwest Museum, agrees:

> Since I'm interested in evolution, I have to look at [fossils] as animals…. I need really really good preparation, because I'm used to working with living material so I want the fossils to look just about as good as the living material. And these preparators here are capable of doing that.

Luke studies extant organisms alongside their fossil relatives, and he expects the bone and fossil skeletons to look equally 'good', meaning complete, accurate, and visible. 'Good' here is an aesthetic descriptor, used to communicate how the specimen should look. When I then asked Luke what made these preparators 'capable' of doing such high-quality work, he cited their creativity alongside their knowledge and experience:

> They've been working for picky people like me for so long that they've become highly skilled, and they know the material they're working with, and they know all the newest techniques. They're innovative, they invent new techniques, so it's a really good group.

Luke values preparators' ability to innovate as part of their expertise at making fossils into 'good' specimens. He also, revealingly, claims credit for helping develop their skills by being a demanding supervisor.

Several preparators compared preparation to sculpting, highlighting the process of judging how to reveal a hidden object. John said:

> There's a quote that I think that Michelangelo said about, you know, the piece being already in the rock, it's just the artist's responsibility to get it out… Like 'the artist's

> piece is already in the stone'. Or something like that. And so I see this in that same way, in that the piece is already there, you know, I mean it's inside of that block of rock. And, you know, it's really your job to get the piece out.

John considers his preparation work artistic and sculptural but 'the piece is already there'. It is striking that the claim attributed to Michelangelo is about objectivity, in that the statue exists independently of the sculptor and is just waiting to be uncovered; here, sculptors are objective revealers, rather than subjective designers. Erica spoke independently of the same claim:

> It's like the same thing that, you know, Michelangelo said when he sculpted David… that he's revealing it out of the rock. Like it's already there and he can see it and he's just pulling it out, rather than taking the rock away, he's – you know, he's exposing it, like he can already see it. And I think preparators have to think that way too, that, like, you've got this solid piece, there's something inside you just have to – you have to find it and know where it's going and try to understand it.

Planning ahead and 'understand[ing]' fossils can help prevent damage; therefore Erica thinks that preparators, like Michelangelo, should have a mental image of invisible objects while 'exposing' them. In this view, preparation requires imagination and not just manual dexterity to reveal the 'solid piece' hidden inside a rock. Comparing lab work with art thus also connotes individual responsibility, skill, and appreciation for the specimen, the 'piece'.

Based on their imagined view of a piece within a stone, preparators' and sculptors' decisions about what to remove define their finished product. Peter Galison captures this idea in

terms of ‘laboratory judgment’, which is used to select and reject data by, like a sculptor, ‘carving away the background’ of noise that surrounds experimental results:

> Michelangelo was once asked how he had carved his marble masterpiece. The sculptor apocryphally responded that nothing could be simpler; all one needed was to remove everything that was not *David*. In this respect the laboratory is not so different from the studio. As the artistic tale suggests, the task of removing the background is not ancillary to identifying the foreground – *the two tasks are one and the same*. (Galison, 1987: 256, original emphasis)

The decisions of rejecting ‘background’ define what is ‘foreground’, and vice versa, both in art and science. These judgments require knowledge of what to look for, as well as the sacrifice of some material in the interest of revealing other material. The fact that two lab technicians and a sociologist of science all cited Michelangelo’s apocryphal statement suggests its relevance to the complex and dynamic act of deciding what is – and is not – intrinsic to the sought-after product, be it a fossil or *David*.

Sculpture, however, can be a controversial depiction of scientific work. Researchers may oppose likening fossils to sculptures because it highlights the people who shape data, potentially diminishing the naturalness of specimens. Opponents of current paleontological knowledge, such as creationists, may use this idea to undermine fossil-based interpretations about past life. But John and Erica did not mean that they are inventing fossils’ shapes. They meant that by sculpting the matrix around fossils, they reveal objects that had been invisible, like Michelangelo’s description of making a statue appear where there had been rock. When I told Tim what his

coworker Erica had said about Michelangelo, he agreed with regards to a fossil hadrosaur skeleton with preserved skin impressions:

> That's kind of what I thought in exposing the skin that I've done over the last few days, that like the skin was in there, it was under several inches of sandstone… and luckily if you find it then you can follow it and not break that skin barrier, and then you're exposing it, and you could almost imagine just kind of making it up as you went along and using the tool to make a skin pattern on sandstone and just kind of sculpt the skin, you know, which I guess in fossil forgeries that's done quite a bit, you know, where the things that are for sale on the black market and parts that are missing are just kind of carved out of matrix to look like the fossil. So it definitely is done, I would say, by unscrupulous people for the wrong reasons, but that's not what I'm doing. [laughs]

Tim named similarities between sculpting and preparing, but he laughed at the idea that they are actually the same. Sculpting fossils is done 'by unscrupulous people', while revealing skin impressions – though it may resemble sculpting – is good preparation practice that makes visible a scientifically valuable aspect of a specimen.

A fear of outsiders misinterpreting the roles of creativity and aesthetics in fossil preparation sometimes makes preparators cautious about directly comparing their efforts with art. Preparator Mary, who previously worked as an artist, revised her definition of 'creative' during my visit to her lab at Northern University Museum. First, she said, 'Preparation is creative problem-solving'. Later she said, 'Preparation's not creative – or it shouldn't be', and laughed. Then she said, 'Preparation is creative problem-solving but it's not *create*-ive – or it shouldn't

be', and laughed. Like Tim, Mary insists that inventing aspects of fossils is obviously bad practice, to the point that the idea is laughable.

The distinction between applying artistic skills and aesthetic concerns to preparation work and committing fossil fraud is not obvious and is difficult to formalize. For example, research on scientific fraud in history shows that notions of authenticity are context-dependent (e.g., Spary, 2003). This indistinct boundary worries preparators enough that they usually laugh at anything that suggests their work is subjective, which I interpret as a sign of discomfort or nervousness. For example, Rick, a volunteer at a large American natural history museum I'll call Southern Museum, asked staff preparator Jay for help reattaching a fragment to a fossil. Jay moved the fragment around in different orientations, trying to find where it fit, and then said, 'It can go in how we want it'. His tone was joking and his remark was possibly for my benefit, if he felt self-conscious about having a spectator. Regardless of why he made the comment, Jay followed it up by gluing the fragment in place. Rick, laughing, commented, 'I'm not sure if I'm cleaning it or sculpting it!' Even volunteers are conscious of the usefulness of artistic skills and attention to aesthetics, but also of the dangers of using them in ways that alter fossils unethically. Judging the limits of acceptable practice is a crucial aspect of technicians' expertise, and examining how these limits apply to aesthetically motivated decisions highlights both the complexity and the significance of defining reliability in data preparation.

Creative problem-solving

The most common way preparators refer to 'creativity' in preparation work is as 'creative problem-solving'. As artist-preparator Anne put it, 'What I like about fossil prep is it's problem-solving, and, you know, I'm just being creative'. Science as creative, adaptive, context-

dependent problem-solving is a common and useful way of understanding science as a social process. Thomas Kuhn even defines 'puzzle-solving' as a crucial component of science, such that a scientist's main motivation is 'the conviction that, if he is skillful enough, he will succeed in solving a puzzle that no one before has solved or solved so well' (1996: 38). Problem-solving in ways acceptable to a field and its paradigm therefore can be an indicator of skill, knowledge and membership in that particular field.

Rarely is this ability to apply acceptable practices to identify and solve problems valued for or even attributed to technicians by scientists. John Law found that physics lab workers distinguish between researchers and technicians in terms of creativity: 'The physicists perform a version of vocational stories of hierarchy, stories about the distinction between creative puzzle-solvers on the one hand, and those who are passive, uncreative, and unskilled on the other' (1994: 123). The 'creative puzzle-solvers' strive to 'excel' personally in and promote their fields, while 'technicians tell of other quite different kinds of desires' to do their work, such as pay (Law, 1994: 125, 129, 132). Technicians are often defined as doing work that lacks innovation and skill. As a result, researchers 'tend, in particular, to delete the work of subordinates: to assume that technical or low-status work gets done "automatically", as if people were programmable devices' (Law, 1994: 131). Treating technicians as 'passive, uncreative, and unskilled' and assuming their goals are only monetary justifies 'deleting' their work. In Law's case, solving problems serves as a status-defining ability and is reserved for researchers.

Although fossil researchers typically render preparators' work invisible, they may do so not because they consider it unskilled or 'automatic', but because they trust preparators to do good work without their supervision or perhaps because they do not know how to do preparators' work. For example, Henry, a researcher at Southern Museum, showed a rock slab containing tiny

mammal fossils to preparator Paul and asked him about the 'feasibility' of 'breaking this apart … to get little bones out'. This statement may seem like an expert researcher informing a lower-status technician of the scientifically significant aspects of a specimen, while assigning the specimen's preparation – work unworthy of a researcher's attention – to the technician. However, Henry asked Paul his *opinion* about feasibility. Only when Paul said that it was possible did Henry's question turn into a work request. Then Paul said thoughtfully, 'A little acid?' and went to try dissolving the slab's matrix with acid. Paul was thinking out loud rather than asking Henry for permission to acid-prepare the block, and Henry gave no instructions. Researchers may leave specimen processing to preparators as the perceived experts in removing rock from fossils, as demonstrated by their effective choices and uses of methods.

Some technicians, such as those who repair copy machines and refrigerators, are seen as problem solvers (Henning, 1998; Orr, 1996). In the ethnographies that Barley reviews, technicians report that the best training for their work is experience: 'Since, almost by definition, problems involved unanticipated troubles, technicians found they had to piece together most of the information necessary for resolution from the situation itself' (1996: 425). Preparator Gary described the priorities that shape his problem-solving work:

> You just look at the problem and say, 'Well, what's the best way to solve this without compromising the integrity of the fossil or short-cutting conservation principles?', and based on that understanding you just come up with a way to do it better.

Gary aims to find 'a way to do it better' within his parameters of fossil protection and 'conservation principles', which include using archival materials. Understanding the many goals

and limits that shape a task and acting accordingly are key to practice-based expertise. To illustrate the importance of justifying decisions, preparator Marc told a story to a group of preparators about a volunteer whose fossil was too large to fit under a microscope. To solve that problem, the volunteer picked up a hammer to break the fossil into smaller pieces. When Marc asked what he was doing, the volunteer was shocked at his own destructive plan. 'We all get lost in our heads sometimes', Marc rationalized with a smile.

Literature in sociology and anthropology investigates the concept of 'problem' in ways that contribute to understanding how technicians work with objects. 'Puzzle-solving', according to Tim Ingold, is not standardized, but rather 'is carried out within the context of involvement in a real world of persons, objects and relations' (2000: 292-3). Accordingly, Joan Fujimura (1996) argues that scientists' success relies on their ability to construct 'doable' problems and solutions, which are achievable and also fit existing techniques, questions and funders' interests. This construction relies not just on knowledge or skill but also 'articulation work: how to build and run laboratories, how to cultivate sponsors, how to manage and work with students and technicians, and how to negotiate with administrators' (Fujimura, 1996: 185). Articulation work, also referred to as 'housekeeping' (Garforth and Kerr, 2010: 8) and 'lab caretaking' (Knorr Cetina, 1999), is critical to the function of the lab community but it is low-status and therefore 'invisible', according to Fujimura (1996) and Susan Leigh Star and Anselm Strauss (1999). Star and Strauss argue that articulation work is not explicitly discussed, studied or taught to science students, despite its complexity and necessity. If we recognize that 'rational problem-solving' is not objective or universal but is instead specific to situation and culture (e.g., Lave, 1988: 169), then problem-solvers become empowered as expert judges of acceptable goals and practices.

Presenting themselves as problem-solvers as opposed to instruction-followers can thus promote preparators' expertise and elevate their status.

Preparators pride themselves on their improvisational ability, a resourcefulness forced by restrictive budgets while also functioning as an indicator of expertise. As a result, labs often look like workshops, full of potentially useful objects (e.g., various containers, scraps of lumber and metal) and purpose-built tools. A volunteer showed me how to use pliers to bend a paintbrush handle, to better apply liquid mold-making material to a fossil's vertical sides (figure 1). Paul found some thick canvas in his lab and made it into a protective apron. Other repurposed materials include magnifying goggles designed for welding that a few preparators wear and garnet sand (typically used for sandblasting, and less dusty than common silica sand) in some labs' specimen-holding sandboxes. The identification of factors as problems, such as inadequate vision and dusty sand, is just as variable and expertise-dependent as the solutions.

Figure 1: A preparator altered a paintbrush to better accomplish a task.

Researchers often value preparators' specimen-specific innovations. Researcher Frank described a raptor specimen preserved lying on its side, which preparators in Frank's lab prepared from both the top and bottom of the matrix slab. Along the way, they molded each layer to create replicas and thus preserve data about the bones' articulation. 'No other lab would have taken it so far', Frank said proudly, 'Taking it to the eleventh degree is what we like to do'. Frank does not want preparators in his lab to do 'boring', 'routine' work; instead he thinks they should understand each specimen's scientific importance and devise ways to access as much data

as possible, to tell ‘the most convincing scientific story’. As a researcher, Frank may encourage preparators to develop techniques in order to access more information than his competitor researchers. Bill, a preparator in Frank’s lab, is grateful that Frank encourages new ideas: ‘[Frank] provides the money and the fossil and the equipment and the place to do it, and lets us figure out how to do it.’ As a result of this freedom, Bill has developed many techniques that he thinks may be novel, such as mailing a delicate specimen inside a box of sand to provide support.

Many preparation innovations are not controversial and are welcomed. While preparing small, delicate fossils, Connie Van Beek developed specialized tool tips for a pin vise (a pen-like handle fitted to a carbide steel pin) (figure 2). Van Beek sharpens the pin’s tip into a ‘serrated blade’, ‘hook’, ‘cat claw’ and other shapes to best remove matrix in particular situations, a technique she designed, she said, based on ‘trial and error’ (Van Beek, 2011: 8). This method has become well known, and Van Beek is often invited to teach others about making task-specific tool tips. Preparators admire each other’s ability to adapt or invent techniques. For example, Southern Museum hired Ken to build plaster storage jackets because he had improved the design as a volunteer. Ken presented his technique at a conference, and Marc, who had previously made jackets at Southern Museum, was impressed:

> He’s done so many innovations …. His use of foam blocks for feet – you know, we were just taking gobs of fiberglass and balling them up, and it was all sort of slapdash and haphazard …. We all kind of had our own styles and things like that. Yeah, my jackets are not as pretty as the new guy’s, for sure. His are just awesome.

Marc praised Ken's jackets for being 'pretty', meaning carefully made and not 'slapdash'. When comparing his own jacket design with Ken's, Marc sounded admiring rather than jealous or competitive.

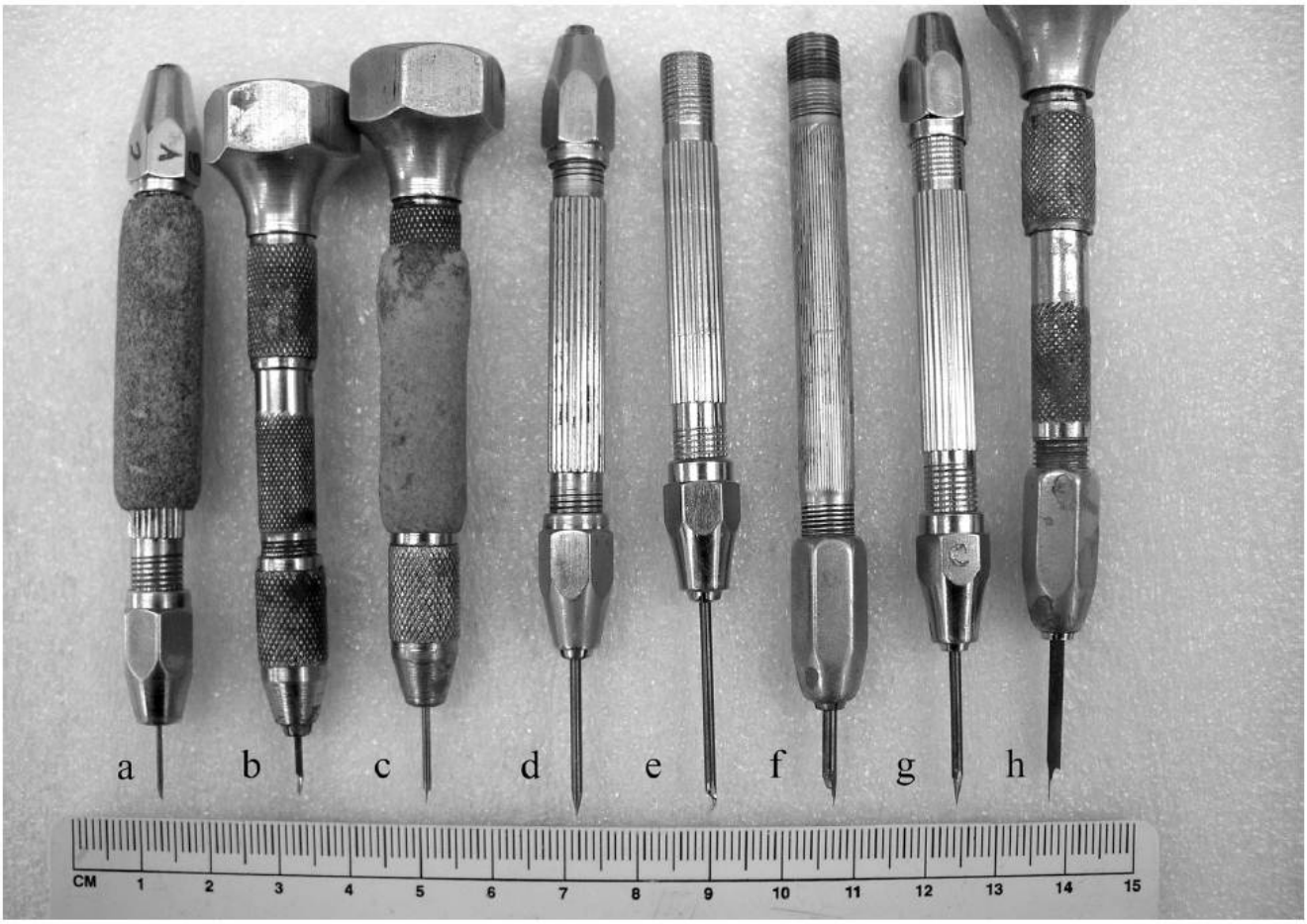

FIGURE 1. An array of modified pin vise tips, from left to right: a) serrated blade, b) scalpel, c) thin blade, d) pointed tip before modification, e) hook, f) cat claw, g) pointed chisel, and h) barb.

Figure 2: Van Beek's adapted pin vise tips (2011: 8)

Preparators expect each others' practices to vary, as Marc noted the many 'styles' of making jackets. As John put it,

> I have yet to meet a preparator that has the same technique as another one …. Every preparator I've met has a different way of doing things and even doing the same thing that you're doing. You know, like, there's no real one right way to do anything in preparation, I don't think. And so that leaves a lot of room for people to come up creatively with their own solutions for things.

For John, the lack of protocol allows – and perhaps requires – innovation. The variety of possible ways to prepare fossils means that new innovations are not always obvious. Tim described adapting existing techniques for molding and casting fossils: 'You can make a mold of anything a hundred different ways. So we had been doing it one way and I had other ideas from my previous experiences, so I brought those and changed it slightly.' Gary likewise described innovation as incremental: 'Most of our inventions or our creations are small. They're modifications of early established techniques that make it a little bit better.'

Preparators are aware that overlap is likely in a community of workers designing techniques. Steve even thinks that there are no new inventions: 'Everything comes round, everything's been invented before.' For example, he occasionally uses the centuries-old method of hammer and chisel because in some cases he finds it more effective than modern tools, such as for removing extremely dense matrix. After giving a conference talk describing a technique, Gary told me that 'inventions' are rarely new:

> The little bone bandage thing I was talking [about at the conference], reinforcing small surface area repairs by using a surfacial coating of paraloid and a little reinforcing

> veilcloth, it's not a new technique. I didn't invent it, but I guarantee that ninety percent of people in that room had never even heard of it.
>
> CDW: Where did you hear about it?
>
> Gary: I invented it. But I wasn't the first to invent it.

Gary blamed a lack of communication among preparators for allowing reinvention. He continued:

> We have enough creativity generally to invent things again, and again, and again, sometimes better than the original invention, sometimes not, and, being completely unaware of the original invention, we can invent things again. But it's kind of a waste of time.

Preparator Alan is also frustrated by re-invention: 'So many people spend so much time reinventing the same wheel over and over again.' In response, Alan organized a conference in 2008 to circulate techniques. He had found communication valuable while working on a team of preparators: 'There were eight of us at [Midwest Museum] … so you'd problem-solve and troubleshoot and just chat amongst one another …. We were able to do a lot of really neat innovating that way.' Innovation can come from people working together, but rarely do many preparators work in one lab. The average number of people preparing fossils in 69 survey respondents' labs was 5 (median 3, mode 1), and 59 respondents worked alongside fewer than ten preparators. As a result, preparators' innovation comes from individuals' 'creative problem-solving' more often than from collaboration.

Perhaps because of the low preparator population in most labs, many preparators value sharing techniques at conferences, on websites or via email on the PrepList. Tim, for example, promotes communication among preparators, and so does his researcher-boss:

> Over the years we've tried quite a few different things and experimented and modified our techniques. And I've tried to share those at SVP meetings and the Preparators' Symposiums. So that's been nice. I think [Frank] really appreciates that too, that we're showing what we're doing here and getting the word out about interesting spins on ideas.

Only one preparator mentioned competition and secrecy:

> I would like to be known in the world of paleontology as one of the best preparators that has ever been …. I'm sure we all have our own little secrets …. [If] a preparator wants to come and visit, I would gladly show them how to do other things. But mainly I don't really spread out too much of my little secrets.

Clearly preparators value the ability to design effective innovations – 'little secrets' – both to improve methods for the community's benefit as well as to demonstrate individual skill.

Andrew Abbott argues that professional groups' ability to assert control over certain tasks relies on 'the power of the professions' knowledge systems, their abstracting ability to define old problems in new ways' (1988: 30). Thus promoting their ability to adapt methods lends credence to preparators' call for control over their work. Claiming and successfully enacting control, or 'jurisdiction' in Abbott's term, over specific tasks legitimizes a professional group, by defining

the existence and scope of that group's power in the workplace and in society. Preparators may describe their work as innovative to highlight their expert decision-making and thus their jurisdiction over preparation work, thereby defining themselves as a professional group.

When creativity is 'bad'

Creativity as risky or inappropriate

When preparators say that they admire creativity and that it is crucial to preparation work, they mean only certain kinds of creativity. In some cases, creativity is considered risky and therefore discouraged. After all, if a new technique fails to solve a problem, consequences can include wasted time and materials, damaged fossils, and lost credibility.

Preparators laud their own and others' successful techniques, but these innovations are not risk-free. When Frank asked Erica to mold and cast a delicate ceratopsian skull, she was not sure it was possible without destroying the important specimen. She designed a method – a complex mold of detachable pieces – and tried it: 'Every day I was working with that thing, I was like, "Please work". Because you really don't know if it's ever going to, you just presume that it will.' Not knowing the results of a time-consuming and potentially destructive task like mold-making, which also requires expensive materials, means that Erica risked time and money as well as the fossil's safety in the hope of producing a mold and, from it, a cast. As a result of a conference talk Erica gave about this difficult project, Tom, a volunteer, decided not to learn molding and casting. He exclaimed to me, 'There were seventeen pieces to that mold!' Tom was impressed and intimidated by Erica's design – molds are typically two pieces and almost never

as many as seventeen – as well as her skill in successfully making the mold. Erica is proud of this unusual task: 'Not everybody does those kind of things, and not everybody takes on those kind of jobs, because it took me four months to mold it. You know, it was a lot of work.'

No preparators told me about ideas they tried that failed. Perhaps such attempts are forgotten because methods are rarely recorded, or perhaps preparators do not want to damage their pride or reputation by admitting failed attempts. But for every successful innovation, there are surely many more that are rejected.

Creativity as a status privilege

Power and hierarchy among lab workers are crucially shaped by who is permitted to innovate. Preparators believe the more experienced among them are more likely to be effectively creative, while those less experienced are more likely to invent unacceptable techniques. This distinction is emphasized for volunteers, who are expected to follow the staff's instructions and *not* adapt methods.

One case of volunteers not understanding this expectation led to conflict between volunteers and staff over who is allowed to be creative. In Southern Museum's glass-walled exhibit lab, volunteers Harry and Carl make plaster storage jackets for prepared fossils on Sundays. No staff preparators are there on weekends, and lab manager Amber said that Harry and Carl are proud of the 'creative problem-solving' that they feel forced to do without staff supervision. However, she explained, 'sometimes their creative problem-solving is excellent, and sometimes it's not'. Amber thinks that Harry and Carl have 'big egos' and 'perfectionist tendencies', and thus, combined with their pride in their problem-solving, they consider themselves independent. She surmised ironically, 'They wouldn't care if we [staff] were dead as

long as the bones kept coming' for them to work on. She believed that Harry in particular has 'a very strong sense of how things should be done'; he would often adapt techniques without getting permission from Amber or Jay, the staff preparator.

Jay sometimes disapproved of Harry and Carl's new techniques, such as when they emailed him to say they were going to wash matrix off mammoth bones with water. Jay sent Amber a strongly-worded email – using 'lots of exclamation marks', he said – warning that water would make the bones crack as they dried. He had intended for Amber to rephrase the email politely, but she forwarded it to Harry and Carl. This episode resulted in tense relations, even months later.

During my visit, Harry and Carl were jacketing the foot bones of a *T. rex* (figure 3). Their exchanges with Jay about this jacket reveal differences between volunteers' and staff's conceptions of innovation and power. For example, when Jay wanted to place the bones closer together in the jacket and to make a narrower top edge than the volunteers had planned, Amber cautioned that he should email the volunteers first to ask or they might feel offended. Amber said, 'It's a "who touched my cheese" situation. Or was it "who moved my cheese?"' Jay responded indignantly that it was 'more like they moved the cheese they borrowed from us!' Annoyed that, as he saw it, the volunteers were overstepping their decision-making power, Jay was asserting ownership of the museum's fossils. Harry disagreed with Jay's instructions for closer-spaced bones and a narrower jacket edge. Harry told me that he had said to Carl, 'We are masters of this project, we know more about this than Jay does'. He understood Jay's criticism as opposition to new techniques, not as opposition to *volunteers* creating new techniques; for him, expertise comes from being very familiar with a specific project rather than from being a staff member.

Figure 3: Harry plastering foam feet onto the jacket, with the fossils under plastic in the background

When I spent a Sunday with Harry in the lab (Carl was out of town), he proudly showed me his innovations, many of which he had not shared with Amber or Jay. His secrecy was not about competition, as it was for the preparator who guards his 'little secrets'; instead, Harry hid his innovations from his bosses to avoid punishment for disobeying instructions. When I asked what he and Carl do when they encounter a problem, Harry answered, 'We haven't come across a problem yet that we haven't been able to deal with one way or another'. When he pulled on two pairs of latex gloves instead of one, he explained, 'It's not something they teach, it just makes sense', because the fiberglass jacket material can pierce one layer. He said

disapprovingly, ‘Some people get set in their ways and don’t think about other ways to do things’. Harry said many times as he narrated his work to me, ‘You can do it any way. The objective is …’. He understood the goals of jacket-making as the staff had taught him, and he enjoyed coming up with new ways to achieve those goals. ‘Most of my life has been in trouble-shooting’, he said, naming as examples his experiences as an engineer, teacher, and parent. He felt capable of adapting methods according to his knowledge of the overall goals, as a staff preparator would. But Harry’s reluctance to tell the bosses about his innovations suggests that he sensed Amber and Jay’s disapproval. Amber and Jay perceived Harry’s innovations as a refusal to follow their instructions, implying both disrespect for staff and potential danger to specimens.

When confronted about his adapted techniques, Harry seemed to give in to hierarchical conventions. Before plastering a foam block onto the jacket, Harry poured liquid soap on it and said to me, ‘It’s a little bit unorthodox. It’s not been approved. But we haven’t asked.’ He explained that soap ‘breaks surface tension’ and therefore makes plaster stick better to foam. Amber witnessed him squirting soap on a second block:

Harry: This is unorthodox.

Amber: Does [Jay] know about it?

Harry: No.

Amber: You want to tell [Jay] about it? [No answer] Do you want me to tell [Jay] about it?

Harry: Tell him.

Amber: Thank you, [Harry].

Harry sounded proud of his technique, but he was also defensive as he told Amber that soap breaks water's surface tension. He claimed, 'I learned that in chemistry class in high school', making it sound obvious and thus justified as a technique for building jackets. Amber sounded accusatory and worried about what Jay would say about this 'unorthodox' practice. It is worth noting that Harry deemed the technique 'unorthodox', though staff preparators consistently told me that there are no standard methods or techniques. Because volunteers receive specific instructions, they might perceive those instructions as protocols or orthodox practices.

Preparators, and arguably workers in general, want to do their work well for many reasons, including pay, status, pride and enjoyment. For example, Harry's personal commitment to making the best possible jackets was clear when he said as he left the lab, 'I'll probably have nightmares about this tonight', worrying whether he 'should have tried this' or somehow done things better. Making good jackets is satisfying for Harry, but obeying the staff's notion of hierarchy is not. His enjoyment of inventing methods and his failure to ask permission suggest that he likes freedom from the staff's intervention, much as staff preparators appreciate the freedom to choose and design techniques with minimal input from their researcher-bosses. Personal satisfaction is clearly important for unpaid volunteers, but it is arguably also a significant motivator for staff technicians, who generally consider themselves underpaid and undervalued. These overlaps between volunteer and staff preparators could violate the staff's ideas of their separateness in authority. As a result, staff may resent volunteers who behave like staff, such as by adapting techniques, as a threat to the staff's position in the lab's hierarchy.

Defining skill and identity relative to others is common in lab communities, and in workplaces more generally. Derek de Solla Price (1965) argues that scientists and 'technologists' distinguish themselves through their goals: technologists rarely write papers – they are

'papyrophobic' – while 'papyrocentric' researchers' primary measure of success is publications. Doing (2004, 2009) similarly describes a separation between physicists and 'operators', based on their definitions of expertise. Operators perceive their expertise as manual, demonstrated by making lab machinery run effectively as well as by fixing their own cars. Perhaps operators emphasize their work as hands-on and experiential *because* their researcher-bosses view their own expertise as mind-based – abstract and theoretical. While preparators' view of their expertise – as artistic and creative – matches abilities traditionally ascribed to high-status, independent artists and scientists, Doing's operators present an opposite conception of expertise from 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 instead of publications or functional machinery, I argue that technicians can be motivated by independence and 'craft control' (Keefe and Potosky, 1997) as indicators of their expertise. They may be less interested in researchers' coveted authorship or useful objects than they are in the power to direct their own work, like artists and artisans.

Conclusion: Invisibility allows creativity

By drawing parallels with art – such as likening preparing fossils to carving sculptures – and by emphasizing creativity in solving problems, preparators present their work and their role as skillful, individualized and irreplaceable. Workplace hierarchies are generally both reflected and constructed by groups' levels of control over their work, on a spectrum from order-following

employees to order-giving bosses. But in paleontology labs, low-status and informally-trained technicians have significant control over choosing techniques. As a result, each preparator's artistic skill, aesthetic judgment and creative problem-solving affect prepared specimens' appearance and thus scientific interpretation. These characteristics also crucially define preparators' concept of expertise, their claimed area of jurisdiction and their community of practice. The many functions of preparators' conceptions of art and creativity in lab work call for a broader reconsideration of the role of technicians in terms of skill, work practices and social order.

Preparators may not be typical lab technicians. Unlike many technicians, particularly in experimental sciences, preparators lack standard training and credentials, and are not deemed authors on research publications. However, preparators resemble other technicians in significant ways: their typically low status in institutional hierarchy, their manual work to produce data sources that achieve researchers' goals and the fact that their bosses are often researchers who don't know how to do technicians' work. Also, arguably all knowledge workers practice some form of 'deleting' their work, whether to promote the objectivity of their work products or due to the limitations of verbalizing tacit knowledge. How technicians judge how to act, what practices to carry out and what to report to researchers reflects their preferred role and identity, e.g., preparators' choosing their own methods and thereby presenting themselves as independent experts. Thus this case highlights the need for analysis of all knowledge workers' actions and conceptual constructions in studies of laboratory life and its resulting knowledge production.

Choosing artistry and creativity as group-defining concepts portrays preparators as free-spirited and independent makers. As such, they view their field as the skillful, hands-on assessment and alteration of objects' characteristics, rooted in nonstandard ideas of good

practices and in the contexts of researchers' diverse purposes for prepared specimens. In their domain, most preparators have primary control, without protocols or methodological instructions from researchers. Furthermore, preparators themselves manage who enters their field without researchers' intervention, through informal local training of novices. It is that independence, I argue, that drives preparators' senses of personal identity and shared community.

Researchers well know that their fossil-based studies depend on preparators' work. But because many researchers do not know how to prepare fossils, they both save face and ensure good preparation by making this work invisible while also leaving it to the experts – the preparators. Researchers can justify granting preparators this craft control by leaving their work and names out of publications. Thus invisibility can benefit not only researchers who strive for 'objective' data but also technicians who strive for control of their work and community.

Acknowledgements

This research was made possible by the many generous participants who welcomed me into their labs and their lives. Jim Secord provided inspiring guidance in the 'preparation' of this paper and my Ph.D. thesis. Sophia Roosth, Derek Turner, and three reviewers offered invaluable attention and insight, and Sergio Sismondo contributed careful and thoughtful editing.

References

Abbott A (1988) *The system of professions: an essay on the division of expert labor*. Chicago, University of Chicago Press.

Alberti SJMM (2008) Constructing nature behind glass. *Museum and Society*, 6(2), 73–97.

Barley SR (1996) Technicians in the workplace: ethnographic evidence for bringing work into organizational studies. *Administrative Science Quarterly*, 41(3), 404–441.

Barley SR and Bechky BA (1994) In the backrooms of science: the work of technicians in science labs. *Work and Occupations*, 21(1), 85–126.

Cambrosio A and Keating P (1988) 'Going monoclonal': art, science, and magic in the day-to-day use of hybridoma technology. *Social Problems*, 35(3), 244–260.

Cambrosio A, Jacobi D and Keating P (1993) Ehrlich's 'beautiful pictures' and the controversial beginnings of immunological imagery. *Isis*, 84(4), 662–699.

Charig AJ, Greenaway F, Milner AC, Walker CA and Whybrow PJ. (1986) Archaeopteryx is not a forgery. *Science*, 232, 622–6.

Charlesworth M, Farrall L, Stokes T and Turnbull D. (1989) *Life among the scientists: an anthropological study of an Australian scientific community*. Oxford, Oxford University Press.

Collins H (1985) *Changing order: replication and induction in scientific practice*. London, Sage.

De Solla Price, DJ (1965) Is technology historically independent of science? A study in statistical historiography. *Technology and Culture*, *6*(4), 553–568.

Doing P (2004) 'Lab hands' and the 'Scarlet O': epistemic politics and (scientific) labor. *Social Studies of Science*, 34(3), 299–323.

Doing P (2009) *Velvet Revolution at the synchrotron*. Cambridge, Mass, MIT Press.

Faulkner RR and Becker HS (2009) *Do you know... ? The jazz repertoire in action*. Chicago, University of Chicago Press.

Frow EK (2014) In images we trust? representation and objectivity in the digital age. In: Coopmans C, Vertesi J, Lynch M and Woolgar S. (eds), *Representation in Scientific Practice Revisited*, Cambridge, Mass.: MIT Press, pp. 249–267.

Fujimura JH (1996) *Crafting science: a sociohistory of the quest for the genetics of cancer*. Cambridge, Mass., Harvard University Press.

Galison P (1987) *How experiments end*. Chicago, University of Chicago Press.

Garforth L and Kerr A (2010) Let's get organised: practicing and valuing scientific work inside and outside the laboratory. *Sociological Research Online*, 15(2), 1–15.

Grasseni C (2004) Skilled vision. An apprenticeship in breeding aesthetics. *Social Anthropology*, *12*(1), 41–55.

Henning PH (1998) Ways of learning: an ethnographic study of the work and situated learning of a group of refrigeration service technicians. *Journal of Contemporary Ethnography*, 27(1), 85–136.

Hoyle F and Wickramasinghe C (1986) *Archaeopteryx, the primordial bird: a case of fossil forgery*. Swansea, Christopher Davies Publishers.

Ingold T (2000) *Perception of the environment: essays on livelihood, dwelling and skill*. London, Routledge.

Keefe J and Potosky D (1997) Technical dissonance: conflicting portraits of technicians. In: Barley SR and Orr JE (eds), *Between craft and science: technical work in U.S. settings*, Ithaca and London, Cornell University Press, pp. 53–81.

Kessler EA (2007) Resolving the nebulae: the science and art of representing M51. *Studies in History and Philosophy of Science Part A*, 38(2), 477–491.

Knorr Cetina K (1999) *Epistemic cultures: how the sciences make knowledge*. Cambridge, Mass, Harvard University Press.

Kuhn TS (1996) *The structure of scientific revolutions*. 3rd ed. Chicago, University of Chicago Press.

Kusterer K (1978) *Know-how on the job: the important working knowledge of 'unskilled' workers*. Boulder, CO, Westview Press.

Latour B (1987) *Science in action: following scientists and engineers through society*. Cambridge, Mass., Harvard University Press.

Lave J (1988) *Cognition in practice: mind, mathematics and culture in everyday life*. Cambridge, Cambridge University Press.

Law J (1994) *Organizing modernity*. Cambridge, Mass, Blackwell.

Law J and Lynch M (1988) Lists, field guides, and the descriptive organization of seeing: birdwatching as an exemplary observational activity. In: Lynch M and Woolgar S (eds), *Representation in Scientific Practice*, Cambridge, Mass: MIT Press, pp. 267–299.

Lynch M (1985) *Art and artifact in laboratory science : a study of shop work and shop talk in a research laboratory*. London, Routledge & Kegan Paul.

Lynch M and Edgerton SY (1988) Aesthetics and digital image processing: representational craft in contemporary astronomy. In: Fyfe G and Law J (eds), *Picturing power: visual depiction and social relations*, London, Routledge, pp. 184–220.

Lynch M, Cole SA, McNally R and Jordan K (2008) *Truth machine: the contentious history of DNA fingerprinting*. Chicago, University of Chicago Press.

Orr J (1996) *Talking about machines: an ethnography of a modern job*. Ithaca, NY, Cornell University Press.

Shapin S (1994) *A social history of truth: civility and science in seventeenth-century England*. Chicago, University of Chicago Press.

Shapin S (1989) The invisible technician. *American Scientist*, 77(6), 554–563.

Spary EC (2003) Forging nature at the Republican Muséum. In: Daston L and Pomata G (eds), *The faces of nature in Enlightenment Europe*, Berlin, BWV – Berliner Wissenschafts-Verlag, pp. 163–180.

Star SL and Strauss A (1999) Layers of silence, arenas of voice: the ecology of visible and invisible work. *Computer Supported Cooperative Work*, 8, 9–30.

Tauber AI (ed.) (1997) *The elusive synthesis: aesthetics and science*. Dordrecht, Kluwer Academic Press.

Traweek S (1988) *Beamtimes and lifetimes: the world of high energy physicists*. Cambridge, Mass, Harvard University Press.

Van Beek C (2011) Putting a fine point on it... Advanced pin vise preparation techniques: materials and methods. *Brigham Young University Geology Studies*, 49B, 7–10.

Whybrow PJ (1986) Rare controversy. *New Scientist*, September, 62.

Wylie CD (2009) Preparation in action: paleontological skill and the role of the fossil preparator. In: Brown MA, Kane JF, and Parker WG (eds), *Methods in fossil preparation: Proceedings of the First Annual Fossil Preparation and Collections Symposium*, pp. 3–12.

Wylie CD (2013) Invisible technicians: a sociology of scientific work, workers, and specimens in paleontology laboratories. Unpublished doctoral thesis, University of Cambridge, Cambridge.

Author biography

Caitlin Donahue Wylie is a University Lecturer in the Program in Science, Technology and Society at the New Jersey Institute of Technology. At the University of Cambridge, her Ph.D. thesis investigated how workers in paleontology labs construct social structures, technical practices and fossil specimens. As a Postdoctoral Fellow at the Max Planck Institute for the History of Science, she studied the effects of CT scanning on paleontology lab communities. She has previously published on science education, medicine, and visual culture.

[1] Participants, universities and museums are identified by pseudonyms.
[2] I wrote and distributed an online survey to paleontology lab workers in 2010, regarding their demographics, training, work experiences and opinions about techniques.
[3] A notable exception was an accusation that preparators had created the holotype *Archaeopteryx* fossil (see Charig et al., 1986; Hoyle and Wickramasinghe, 1986; Whybrow, 1986).