Published version: Wylie, C.D. (2020). Glass-boxing science: Laboratory work on display in museums. *Science, Technology, and Human Values, 45(4),* 618-635.
https://doi.org/10.1177/0162243919871101

Glass-boxing science: laboratory work on display in museums

Caitlin D. Wylie (wylie@virginia.edu)

ABSTRACT: Museum displays tend to black-box science, by displaying scientific facts without explanations of how those facts were made. A recent trend in exhibit design upends this omission by putting scientists to work in glass-walled laboratories, just a window away from visitors. How is science being conceived, portrayed, and performed in glass-walled laboratories? Interviews and participant observation in several "fishbowl" paleontology laboratories reveal that glass walls alter lab workers' typical tasks and behavior. Despite glass-walled labs' incomplete and edited enactment of scientific work, displaying an active workplace challenges visitors' assumptions that science is passive and that museums are home only to facts and dead things. Thus, glass-walled labs do not destroy the black box that obscures scientific practice for non-scientists. Instead, they exemplify a *glass box*, a kind of black box that contains a performance of scientific work. Glass-boxing describes a common way in which museums present scientific practice—i.e., by making it observable but incompletely so—by inviting the public to construct a rich understanding of science as human work.

Keywords: museums, display, black box, paleontology, laboratories, performance

Black boxes contain unknown, unquestioned processes that transform inputs into outputs (Latour 1987). From the perspectives of non-scientists, science itself is a black box: Nature goes in and knowledge comes out. Museums tend to perpetuate the mystery of doing science by displaying only the products of scientific work, such as specimens and facts. The processes of how these objects are studied and these facts are made are largely missing from exhibits, and so are the people who do this work. However, a recent trend in exhibit styles focuses instead on the inside of science's black box, by displaying live scientific practice. Glass-walled laboratories in museums put scientific workspaces, workers, and work directly before visitors' eyes (figure 1).

Some of these labs are demonstration spaces for staged experiments and reenactments. Most, though, house everyday research work. These "real" laboratory tasks tend to be edited or adapted for a public audience, and they tend to be unexplained or incomprehensible to visitors. What then is on display in these "fishbowl" labs, as their inhabitants fondly call them? This paper investigates what glass-walled labs portray as science and what that portrayal tells us about how the black box around science can be made transparent.

There are many possible reasons why museums omit scientific work and workers from exhibits. Staff may consider those aspects boring, overly complicated, irrelevant to the finished facts, or too subjective and messy to be shown as the foundation of stable, solid scientific knowledge. Strauss and coauthors (1985) refer to the everyday tasks of doing science, such as managing the spaces, people, and materials that make research possible, as "articulation work." These tasks articulate—i.e., bring together—the components that constitute science, but they aren't mentioned in publications or exhibits. Other low-status kinds of work and workers are similarly overlooked. Shapin (1989) argues that omitting the name and work of "the invisible technician" from 17th-century research records and publications promoted the objectivity of knowledge claims, by obscuring the subjective, skillful, human work of conducting successful experiments. This omission of work and workers helps form the black box around science, in Latour's (1987) term. A laboratory is a black box in the same sense; data sources (e.g., specimens, experimental materials) and publications are relatively familiar to non-scientists compared with the mysteries of laboratory work. A laboratory with glass walls permits the public to watch people doing scientific work, which should arguably—and admirably—destroy the black box around science.

Science as performance

Glass-walled labs are an example of how museums are broadening exhibits beyond specimens and informational placards. Nineteenth- and twentieth-century museums presented natural history behind glass, as preserved organisms and recreated still-lifes of environments, explained to the public by authoritative text panels (Nyhart 2004; Kohlstedt 2005; Alberti 2008). How museums altered their displays and institutional identities in the twentieth century reflects changes in funding, scientific disciplines, beliefs about public education, and debates about the role of specimen collections in research (Rader and Cain 2014). More recent strategies for public

engagement include staging demonstrations of experiments (Sibum 2000)[i], providing docents to answer visitors' questions, and encouraging visitor participation, such as through citizen science programs (Ballard et al. 2017) and social media (Drotner and Schroder 2013). Making museums' storerooms visible through glass is another powerful way to display previously private spaces and inspire visitors to wonder about behind-the-scenes practices and labor (Brusius and Singh 2018; Delbourgo 2018; Reeves 2018; Bond 2018). Increasing nonscientists' participation in research aligns with rising demands for "open" science, which also encompasses open-access publications, open-source data, and transparent research administration (Fecher and Friesike 2014). Glass-walled labs offer a powerful way to make scientific work open, by enabling the public to watch lab workers in action. Meyer (2011) argues convincingly that, unlike traditional exhibits, glass-walled labs in museums are valuable for raising questions rather than delivering answers, and for portraying science as in-progress rather than pre-existing. Accordingly, Gavigan (2009) found that fossil preparation labs on display inspire so many questions from visitors that some institutions have purposefully removed ways for visitors to talk to lab workers; otherwise, the workers are too busy answering questions to prepare fossils. Noble (2016) suggests that including a glass-walled lab as part of a fossil exhibit provided legitimacy for the fossils and facts on display, by showing where both came from. These studies investigate display labs as methods of public communication and education; this paper asks how being on display influences lab workers and the specimens and knowledge that they produce. Together, these approaches shed light on what science means to lab workers and the public.

Bennett (1988) argues that the "exhibitionary complex" of public cultural institutions makes visitors themselves part of the display, thereby implicitly enforcing behavioral norms while explicitly teaching a specific worldview of how to order specimens and people. This complex is therefore a powerful mechanism of social control, resembling Foucault's (1975) notion of instilling discipline through surveillance. Specifically, observing exhibits invites visitors to judge and thereby legitimize knowledge of natural order for themselves while also subjecting them to other visitors' (and workers') surveillance. Crucially, the exhibitionary complex does not consider exhibits that *look back* at visitors, as in the case of glass-boxed laboratory workers. Noble's (2016) specimen-spectacle complex suggests that a worker interacting with a specimen lends that specimen life and liveliness, creating a spectacle that is worth watching.

A display lab resembles a theater, in that the actors and audience occupy separate spaces, the actors work (more or less) for the audience's entertainment and education, and the audience can see the well-lit actors much better than the actors can see them. A key difference is that the stage's imaginary "fourth wall" exists as a physical—though transparent—barrier between a display lab's actors and the audience (Heimlich 2013, 132). This wall blocks sound and physical contact, but the lab workers remain well aware of their audience. Also, the lab doesn't exist entirely for the audience, as a theater does. Even when no visitors are present, lab workers continue their tasks. Their work is rarely artificial, even though it contains elements of performance.

Goffman (1956) considers all human behavior a performance, whether on stage or at work. He differentiates frontstage behavior, i.e., how we perform for others when we want to make a good impression, from backstage behavior, i.e., how we unselfconsciously prepare to perform for others. Frontstage for scientists includes publications, talks, and museum exhibits. Their backstage is the work of preparing these products, which is usually done in offices and labs. Are glass-walled labs supposed to provide rare views backstage, or do they act as a frontstage where workers perform scientific work as they want it to be seen by the public? I suggest that these labs are simultaneously backstage and frontstage, because they offer views of authentic scientific work while also changing that work for public consumption. This overlap of backstage and frontstage has utility, as a compromise between workers' privacy and visitors' access. Crucially, it illustrates that black-boxing can be incomplete, such as lab work that workers make visible for public view while also altering it to become frontstage behavior.

To find out what happens behind the glass, I conducted interviews and participant observation in glass-walled fossil preparation labs in six natural history museums in the United States (Wylie 2009, 2015, 2016, 2018, 2019).[ii] In my experience, fossil preparation is the most common type of display labs in museums. Less-common topics include other kinds of specimen preparation (such as for botany, zoology, and entomology), artifact conservation (such as pottery and art), and DNA analysis. Lab workers prepare fossils for study and display by removing rock and repairing broken bones. This is delicate and precise work, done by technicians called preparators who learn their skills on-the-job. Staff preparators also train volunteers to prepare fossils; these volunteers make up the majority of workers in many fishbowl labs. As part of a larger study on the work and world of fossil preparation, I spent six weeks each at two natural

history museums with glass-walled fossil labs and visited four others for 1-3 days. I sat beside staff and volunteers in the lab, conducting informal interviews about their experiences while witnessing what it's like to be on display. Ironically, my study added extra surveillance to these already-observed workers.

Based on these data, I suggest that a fishbowl lab offers public views of unfamiliar scientific work, including tools, unfinished specimens, and, crucially, humans interacting with these objects in pursuit of research. These actions are missing from typical exhibits, and fishbowl labs make them observable. But even a display lab remains an exclusive box, not an accessible public space. In that sense, glass-enclosed labs adhere to museums' tradition of displaying pieces of nature, history, and technology behind glass. Glass enclosures—for traditional exhibits and for labs—imply that objects should be admired while also protected from the admirer. Thus, rather than destroying the black box around how science is done, display labs enclose it in a new box, a glass box, which makes scientific practice visible but not necessarily comprehensible to the public. I suggest glass-boxing is a category along a spectrum between "fully black-boxed" and "revealing the construction of scientific facts." Other examples of glass-boxing besides glass-walled labs include behind-the-scenes tours and videos of science facilities, demonstrations of experiments and facts in schools and museums, and other activities that make scientific work visible but not understandable or complete for non-scientists.

Scientific practice is glass-boxed in two ways in glass-walled labs. First, the lab's work is rarely effectively explained. Many labs don't allow the public to talk to workers and I haven't seen any displays that invite the public to participate in the lab's work. Lab workers put up text panels and homemade signs around the lab to inform visitors, but making sense of these signs is left to the visitors. Second, the lab's work is performed, meaning that it is edited, selected, and otherwise changed from how the same tasks would be done behind the scenes. Fishbowl lab workers do not act out scientific work purely for the public; they conduct legitimate, authentic specimen preparation. But this work is intended for public witnessing, such as by presenting workers as skillful and professional and by hiding tasks workers deem risky. Thus, the public can see and attempt to understand scientific work inside glass-walled labs, but that work is still enclosed, exclusive, and somewhat mysterious. A glass box, then, is more penetrable than a black box, while still preserving the longstanding social, epistemic, and physical barriers

between science and the public. Barriers to public understanding of science, then, can range from full to minimal obfuscation, from black walls to transparent walls to, perhaps, no walls at all.

Seeing without understanding

Science is glass-boxed when non-scientists witness it without understanding its work, workers, or products. People can watch a phenomenon or activity without necessarily knowing what is happening. For example, watching cooks in a windowed restaurant kitchen, construction workers through safety fences, and even caged zoo animals is entertaining, but requires preexisting knowledge to understand the observed actions and the implicit goals. Without that knowledge, boredom can result, as reflected by a news article's tongue-in-cheek title to describe an opportunity for visitors to watch art conservators preserve paintings as part of a museum exhibit: "Watching Varnish Dry" (Carvajal 2016). Some observers already have the background knowledge or receive it during their observation, from workers, text panels, or fellow observers. People without this knowledge will make sense of what they see based on their prior experiences. This process resembles scientific thinking—i.e., gathering sensory data and drawing conclusions from it—and is part of what makes glass-walled labs engaging.

However, this lack of explanation can lead to conceptions of science that differ from scientists' and other lab workers'. For example, I saw a woman with a child approach a glass-walled fossil preparation lab with excitement. She pointed at the man inside the walls, who was spreading plaster-soaked burlap strips over an unfinished storage container for a fossil, and exclaimed to the child, "Look! People making fossils!" It did look like this lab worker was "making fossils" out of the materials strewn around him, including plaster, cloth, wood, a level, scissors, and rubber gloves. In a flipped reality of typical museum exhibits, there were no fossils in sight and a live human on display. No lab worker or institution wants to portray fossil preparation as fossil creation, because that portrayal is inaccurate and scientists want to protect paleontology from accusations of fraud. After all, preparation reveals a fossil rather than sculpts it. But the fabrication of fossils was a logical interpretation for the tableau this visitor saw. Even knowledgeable observers can misinterpret display labs. Based on surveys, visitors to one glass-walled fossil-preparation lab "understood the lab's purpose," which they defined as "to educate them about paleontology, allow them to see paleontologists at work, or offer them a chance to talk to a paleontologist" (Gavigan 2009, 16). However, workers in preparation labs are very

rarely paleontologists; they self-identify as preparators and volunteers. These visitors' understanding of the lab probably did not match the lab workers' intended messages after all.

Similarly, visitors' beliefs about the purposes of lab work can be diverse. One volunteer told me that a child watched him delicately separate tiny fossils from a pile of gravel and then asked, "Are you being punished?" To this observer, the volunteer's focus on small rocks seemed so tedious that it must be a punishment. The volunteer loved retelling this story, as self-deprecating evidence that people who prepare fossils have unusual focus and tolerance for boredom. His story is also evidence that the work of preparing fossils is not intuitive to non-experts.

The public also interprets the workers themselves in ways the workers disagree with. Lab workers often told me that the public thinks they're mannequins. Surprisingly, workers consider this a rational conclusion; one volunteer told me, "They think we're fake because they can't see what we're doing when we're working on tiny areas." This idea makes sense in the context of the glass cases of immobile, nonliving things surrounding the lab: visitors do not expect to see people in a museum case (Noble 2016, 255-6). The labs' appearance, typically with darkness on the public side and bright lights inside, resembles spotlighted display cases or theaters. This feature may further support visitors' impression that the labs are somehow artificial. Sometimes even the workers' movement does not convince visitors that they're alive; I overheard several debates among visitors about whether the lab workers were robots. These misconceptions result from the museum providing views without accessible explanations, i.e., glass-boxing. Glass-walled labs invite the public to think like scientists by generating conclusions about what they see. It seems to be less important to staff whether these conclusions match their own, since glass-walled labs provide few facts through text panels or conversation with experts.

Even if fishbowl labs don't reliably convey scientific knowledge, they have powerful potential to portray science as accessible and participatory. Specifically, most workers in fossil labs are staff preparators and volunteers, who don't do research or necessarily have science degrees. Yet they actively contribute to research by preparing fossils. Few labs explain this variety of workers. I imagine that many visitors don't know that anyone can volunteer to work on fossils; fishbowl labs would be a valuable advertisement for potential volunteers as well as evidence that people without science degrees can do scientific work. Not describing the workers may be an overlooked opportunity for recruitment and education. It may also be a purposeful

omission, because many museums have too many volunteers who want to work with fossils. Regardless of an institution's potential need for new recruits, informing visitors about the workers in the lab, including their status as staff or volunteers and their educational and career backgrounds, can valuably broaden visitors' understanding of who does science.

The most targeted way to provide explanations is for visitors to ask lab workers questions, to clarify their existing knowledge and address what they'd like to know. Heimlich (2013, 137) calls for museums to devise ways to increase visitor/lab worker interactions, particularly to encourage visitors to share their expertise with workers as well as vice versa. Gavigan (2009, 16) found that visitors who spoke to a lab worker reported experiencing more learning and more fun than visitors who did not speak to workers. Miller and coauthors (2013, 54-5) similarly noticed that visitors spent more time in front of a glass-walled lab when docents were there to talk to them. Some labs include ways for visitors to speak with workers, such as telephones and open windows, to make the labs into spaces of discussion and learning alongside research (Meyer 2011; Gavigan 2009).

Other display laboratories purposefully prevent this possibility, such as by building labs on separate floor levels from visitors (Meyer 2011, 265) or removing communication devices (Gavigan 2009, 16-7; Noble 2016, 256-7). Most of the labs I studied had planned for workers to interact with visitors, but in practice found it to be too time-consuming and disruptive to delicate preparation work. In response, labs sealed sliding windows and disconnected through-the-glass telephones. Instead, they encouraged staff and volunteers to step outside the lab to talk to the public occasionally. Some institutions schedule once-a-day conversation times between the public and lab workers (Noble 2016, 256-7). The lab's roles as a workplace and an educational space are brought into conflict by workers' direct interaction with visitors. Many labs therefore choose to protect the workplace by limiting interaction to only the visual, which arguably distracts lab workers less and contributes less to visitors' understanding.

The many glass-walled labs that limit visitor-worker communication use text panels to explain to visitors what they're seeing. But these panels are usually small, in dark spaces, and not very informative or engaging. Sometimes the text panels are misleading, such as by referring to lab workers as "scientists" though few preparators—and even fewer volunteers—self-identify as scientists. Some lab workers write their own temporary text for visitors, using whiteboards or printouts. These signs often list facts about the specimens they're working on but without

explanations of how they're working on them, which one might expect to be the purpose of a display laboratory. In museums' defense, people must experience some aspects of scientific practice to understand them, such as embodied skills and tacit knowledge. And, of course, many visitors find watching people to be more interesting than reading text. Making science observable but not necessarily comprehensible is one category of glass-boxing, by providing partial access to knowledge-making. Another category is altering knowledge-making for public consumption.

Altered reality behind glass

Displaying nature requires changing nature. Questions of authenticity have a long history in museums, which strive to show "real" nature to the public while being indoors and usually far from specimens' original location (e.g., Nyhart 2004; Kohlstedt 2005; Rader and Cain 2014). For example, scholars refer to mounted dinosaur skeletons—amalgamations of fossil, plaster, and metal—as "mixed-media sculptures" (Rieppel 2012) and taxidermied animals that workers modify over time as "active assemblages" (Patchett and Foster 2008). Alberti (2008) examines this gray line between "specimen" and "artefact" in natural history museums, arguing that the objects on display can be categorized both as natural and as products of human work through collection, preparation, and preservation. Similarly, Grazian (2015) names zoos' "stagecraft" of simulated reality "nature-making," which incorporates live animals into purpose-built, stage-like habitats. Like displaying fossils and scientific work, nature-making strives to keep visitors and specimens safe, present authentic-seeming settings to encourage visitors to suspend their disbelief, and provide entertainment and education. Grazian (2015, chapter 1) argues that visitors expect this kind of performance, which in zoos includes natural-looking enclosures that zookeepers carefully empty of all shocking and unappealing aspects of nature, such as excrement, death, fighting, sex, and, for some visitors, mentions of evolution. What institutions choose to make visible and invisible about nature (extinct as well as extant) reflects their assumptions about visitors' desires and values, including learning and being entertained but not being offended at a zoo or museum. The same ideas apply to exhibiting humans at work.

Changing typical practices and behaviors in response to an audience, whether intentionally or not, is another category of glass-boxing. One common cause of difference between fossil preparation on display and behind-the-scenes is glass-walled labs' location in exhibit spaces that were not designed as lab spaces. As a result, some fishbowl preparation labs

lack room or electrical power for typical equipment, such as air compressors for pneumatic tools or ventilation systems to remove rock dust. Also, these tools make too much noise for un-soundproofed exhibit spaces. With limited tools, lab workers can only prepare certain kinds of fossils, such as those embedded in soft rock. This, then, is a selective performance of preparation work.

Humans behave differently when they are being watched, a phenomenon known as the Hawthorne effect (Adair 1985), such as when being observed at work causes people to feign working hard (i.e., "make-work" [Goffman 1956, 68-9]). The possibility of being observed, even if no one is present, can be enough to enforce "good," desirable behavior (Foucault 1975). This holds true for museum visitors who are observing each other, according to Bennett's (1988) exhibitionary complex, and, I argue, for workers in glass-walled labs who are both surveilling and being surveilled while working in a public panopticon. For example, lab workers change their behavior in response to visitors' behavior, such as "kids beating on the glass and making faces" and "kids doing gymnastics" on the exterior railing, which can shake the lab's worktables. Workers in one lab tell and retell a story of a male preparator who looked up to see two women pressing their breasts against the glass. Lab workers react to this story by laughing and shaking their heads in disbelief at visitors' disrespectful behavior.[iii] These stories show that visitors and workers modify their behavior in response to each other's presence. Also, glass walls permit vibrations as well as visibility, thus allowing more interaction between the public and lab workers than mutual surveillance alone.

The delicate and precise nature of fossil preparators' work creates a particular problem with observation-induced behavior changes. Visitors' glass-knocking startles workers and outside activity shakes lab tables, both of which can cause workers to inadvertently damage a fossil. In response, lab workers develop strategies to mitigate these problems, such as distancing visitors from the glass by moving railings further away, posting signs begging visitors not to touch the glass, developing a "sixth sense" to anticipate when someone outside will knock or shake the lab, listening to "aggressive" music to vent their frustration, and preparing fossils under a microscope, which helps workers forget about visitors because they can't see them. Arguably, these deviations are epistemically insignificant from how workers prepare fossils out of public view, in that they probably don't change how the prepared fossils look and are studied. However, the worry about outside surprises changes how workers think about their tasks and

causes a distraction in itself. What visitors see, then, differs from typical backstage lab tasks and behavior.

On the other hand, some staff and volunteers consider working in a glass box irrelevant to their work, or they believe that it adds fun and educational significance to their work. One volunteer explained that "I don't even know [the public] is there, [because] nothing else matters" when he's preparing, because for him it is an all-consuming task. As another volunteer put it half-jokingly, "What people?" The workers who don't notice their audience perhaps alter their practices less than those who feel unnerved by it. Some staff and volunteers even prefer working in a glass-walled lab. A staff preparator told me that working in public is "fun" because "you feel like you're in a museum," unlike working in a secluded backstage lab. A group of three volunteers agreed, explaining collectively that in a glass-walled lab, "you get a sense of what's going on in the museum," meaning a "vibe" for visitors' experience. Wanting to be near the public suggests that these workers like performing, perhaps because they feel more social and included in the museum community while on display. One volunteer explained that "it's fun" to prepare with a video camera on her microscope, projecting images of her hands and the fossil on a screen, because "people love it." In comparison, some lab workers avoid the camera because it reduces the light that reaches the fossil, making it tougher to prepare. Volunteers who enjoy performing for the public may be more likely to keep volunteering. Workers in fishbowl labs are, after all, self-selecting; those who don't like the public exposure quit. Most workers take short retreats to backstage spaces as a break from being on display, a habit that Meyer also observed among scientists working in an exhibit lab (Meyer 2011, 267). Working on display affects workers' experience, causing responses ranging from frustration and stress to enjoyment and a sense of public service.

Fishbowl lab workers want to show the public how fossils are prepared, but they do not want to reveal the dangerous, destructive, or embarrassing parts of that work. Therefore, they practice the art of omission. In one case, a volunteer had finished preparing one side of a fossil whale skull, which was large, heavy, and fragile. Early one morning, a staff preparator decided to turn the skull over so the volunteer could prepare the other side. I suggested that we wait until the museum opened, so that the public could watch the maneuver. The preparator answered emphatically that he does this kind of work *before* the public arrives. I then realized the implications that were obvious to him: damaging the skull would be terrible for science, and

damaging it with an audience would also be terrible for the lab's—and paleontology's—reputation. Of course, lab workers want to present themselves in a good light while "frontstage," e.g., as professional, skillful, and responsible. On the other hand, they are hiding integral components of preparation work from the public, such as specimen handling. Lab workers want to do good work for its own sake, and they also want to be seen doing good work.

As a result, lab workers on display generally obscure risky tasks and perform easier tasks. For example, one volunteer bragged that he'd been assigned an easy-to-prepare fossil, with "good color distinction" between the soft rock and hard bone. He said that he'd like to "save it" to prepare on Paleo Day, an annual event that attracts large crowds to the lab, "so people won't see me cursing and swearing" at a more difficult specimen. The comment was not serious, but his joke reveals lab workers' desire to not be perceived as frustrated or unskilled. This selective presentation of scientific work misleads viewers, by portraying fossil preparation as a safer and easier process than it is. At the same time, this favorable performance makes workers feel more comfortable and willing to work on display. Glass-boxing, therefore, presents a view of science that differs from backstage science: it is selective and self-conscious, and it can contribute to workers' personal satisfaction and motivation from their performance for the public alongside their work for science.

Conclusion: a spectrum of boxes

Glass-walled labs present science as an active process of work, but one that is somewhat incomprehensible and altered for public consumption. Visitors can watch scientific work, but usually they cannot speak to workers. The public assumes that fossil lab workers are robots or scientists when in fact they are technicians or volunteers, none of whom study the fossils they work with. The lack of interaction and effective text panels means that visitors' perceptions are primarily based on what they see rather than on what experts tell them. This approach invites visitors to observe carefully and think critically, but offers no ways to address their questions or misinformation.

Unbeknownst to visitors, the work done on display differs from work done behind the scenes. Doing science in public, like doing anything in public, is a performance. This means that workers strive to present themselves favorably. After all, the "fourth wall" that separates actors from their audience is transparent in fishbowl labs, admitting intentional observation as well as

unintended glass-banging and vibrations. All of these factors influence how lab workers think about and carry out their work, as well as how visitors interpret the workers and their work. Of course, all displays for non-experts offer selective, simplified versions of complex work and knowledge. Omitted aspects of laboratory practice include risky tasks, loud tools, techniques requiring ventilation or compressed-air systems if a lab lacks that infrastructure, and the status of the workers, i.e., the unexplained distinctions between volunteers, staff, and scientists. These omissions can make preparation appear easier for workers and safer for fossils than it is. No display can be comprehensive, due to constraints of money, space, and visitors' attention spans. Rather, what displays include and don't include reveals the values and beliefs of the workers who design and work in them.

The idea of a black box then is useful for thinking about what we as a society want the public to know about science. A true black box, in which the public knows only the inputs and outputs of science, seems to block too much information. The absence of a black box, i.e., full access to and understanding of scientific practice, seems desirable for the public. In practice, lab workers actively avoid a complete unpacking of the scientific process by controlling how they and their work are portrayed. Moreover, many aspects of knowledge construction happen outside a lab, such as reading, writing, and reviewing papers; giving presentations; applying for funding; training students, etc., and go unmentioned in exhibits, even those of live scientific work. So glass-walled labs do not fully open science's black box to reveal the inner workings of how people make knowledge. Instead, they offer a glass box, as a compromise that balances the public's desire to learn how science is done (and museums' desire to show them) with scientific workers' desire to display their work favorably. This compromise gives non-scientists a sense of how people transform specimens into data sources and then into scientific facts and display objects. It's important, though, not to mislead people into thinking that a glass box, such as a fishbowl lab, behind-the-scenes tour, or documentary film, provides a complete picture of how science is done.

Glass-boxed scientific work offers the public a more accurate and detailed picture of how people do science than displays of specimens and facts alone can. For example, looking into a lab makes the public into observers, which is entertaining and educational because they must make sense of what they see, not unlike scientists' ways of thinking and knowing. That doesn't necessarily mean that visitors understand scientific work as lab workers or scientists understand

it. Nonetheless, perhaps museums should create more opportunities for visitors to use scientific skills like observation and interpretation, instead of directly delivering facts. Also, many things are visible in display labs that are usually kept out of public view. In fossil preparation labs, these behind-the-scenes sights include unprepared and partly-prepared fossils, tools, dirt, specimen storage containers, people at work, and typical workplace paraphernalia that visitors may not associate with doing science, e.g., coffee cups, lunch boxes, headphones, chatting, informal clothes, and dinosaur cartoons taped on lab walls. Stereotypical signs of doing science are also conspicuously missing in fossil labs, such as lab coats, computers, and unrecognizable machines and gadgets. Instead, relatively familiar objects fill the workbenches, such as dental tools, microscopes, paintbrushes, and boxes of sand (in which fossils rest while their glue dries). The lab's uses for these identifiable things may not be familiar, but familiar objects offer something for visitors to notice and then start to wonder about. All of these aspects arguably make science look more relatable, more social, and more human than any other kind of museum display.

Glass-boxing science, then, may be most valuable for putting the spotlight on the people who do scientific work. Viewing people preparing specimens can give more life, importance, and intriguing complexity to visitors' conceptions of both the specimens *and* the participants in today's scientific workforce. Crucially, it could potentially encourage more people to join that workforce, thanks to the engaging enactment of work they witness in glass-walled labs. While glass-walled labs don't open the black box around science, they offer a window into its workings. What that window displays—and doesn't—offers rich insights into how museums, scientific workers, and visitors understand scientific practice.

References

Adair, John G. 1984. “The Hawthorne Effect: A Reconsideration of the Methodological Artifact.” Journal of Applied Psychology 69 (2): 334–45.

Alberti, Samuel J. M. M. 2008. “Constructing Nature behind Glass.” Museum and Society 6 (2): 73–97.

Ballard, Heidi L., Lucy D. Robinson, Alison N. Young, Gregory B. Pauly, Lila M. Higgins, Rebecca F. Johnson, and John C. Tweddle. 2017. “Contributions to Conservation Outcomes by Natural History Museum-Led Citizen Science: Examining Evidence and next Steps.” Biological Conservation 208: 87–97.

Bennett, Tony. 1988. “The Exhibitionary Complex.” *New Formations* 4 (Spring): 73–102.

Bond, Sarah. 2018. “Serendipity, Transparency, and Wonder: The Value of Visitable Storage.” In *Museum Storage and Meaning: Tales from the Crypt*, edited by Mirjam Brusius and Kavita Singh, 64–82. New York: Routledge.

Carvajal, Doreen. 2016. “Showtime at the Musée D’ Orsay: Watching Varnish Dry.” New York Times, August 15. http://www.nytimes.com/2016/08/16/arts/design/showtime-at-the-musee-dorsay-watching-varnish-dry.html?_r=0.

Delbourgo, James. 2018. “Performances of Museum Storage.” In *Museum Storage and Meaning: Tales from the Crypt*, edited by Mirjam Brusius and Kavita Singh, 37–54. New York: Routledge.

Drotner, Kirsten, and Kim Christian Schroder, eds. 2013. Museum Communication and Social Media. New York: Routledge.

Fecher, Benedikt, and Sascha Friesike. 2014. “Open Science: One Term, Five Schools of Thought.” In Opening Science: The Evolving Guide on How the Internet Is Changing Research, Collaboration and Scholarly Publishing, edited by S. Bartling and Sascha Friesike, 17–47. Heidelberg: Springer International Publishing.

Foucault, Michel. 1975. Discipline and Punish. New York: Random House.

Friedman, Alan J. 2010. “The Evolution of the Science Museum.” *Physics Today* 63 (10): 45–51.

Gavigan, Annette M. 2009. “Working Fossil Laboratories as Public Exhibitions.” In Methods In Fossil Preparation: Proceedings of the First Annual Fossil Preparation and Collections Symposium, edited by M. A. Brown and W. G. Parker, 13–20.

Goffman, Erving. 1956. The Presentation of the Self in Everyday Life. Edinburgh: Universit of Edinburgh Social Sciences Research Centre.

Grazian, David. 2015. American Zoo: A Sociological Safari. Princeton, N.J.: Princeton University Press.

Heimlich, Joe E. 2013. “The Nature Research Center at the North Carolina Museum of Natural Sciences.” Curator: The Museum Journal 56 (1): 131–38.

Kohlstedt, Sally Gregory. 2005. “‘Thoughts in Things’ Modernity, History, and North American Museums.” Isis 96 (4): 586–601.

Latour, Bruno. 1987. Science in Action: How to Follow Scientists and Engineers through Society. Cambridge, Mass: Harvard University Press.

Meyer, Morgan. 2011. “Researchers on Display: Moving the Laboratory into the Museum.” Museum Management and Curatorship 26 (3): 261–72.

Miller, Renee, Kenneth G Johnson, Ali L Thomas, Lyndsey G Douglas, Nadia Santodomingo, Yoke Shum Broom, Therese Avedillo, Cassandra Murray, and Theresa Sadler. 2013. “V Factor: Volunteers as a Bridge between Museum Scientists and the Public.” Journal of Natural Science Collections 1: 48–58.

Noble, Brian. 2016. Articulating Dinosaurs: A Political Anthropology. Toronto: University of Toronto Press.
Nyhart, Lynn K. 2004. “Science, Art, and Authenticity in Natural History Displays.” In Models: The Third Dimension of Science, edited by Soraya De Chadarevian and Nick Hopwood, 307–35. Stanford, CA: Stanford University Press.
Patchett, Merle, and Kate Foster. 2008. “Repair Work: Surfacing the Geographies of Dead Animals.” Museum and Society 6 (2): 98–122.
Rader, Karen A., and Victoria E.M. Cain. 2014. *LIfe on Display: Revolutioning U.S. Museums of Science and Natural History in the 20th Century*. Chicago: University of Chicago Press.
Reeves, Nicky. 2018. “Visible Storage, Visible Labour?” In *Museum Storage and Meaning: Tales from the Crypt*, edited by Mirjam Brusius and Kavita Singh, 55–63. New York: Routledge.
Rieppel, Lukas. 2012. “Bringing Dinosaurs back to Life: Exhibiting Prehistory at the American Museum of Natural History.” *Isis* 103 (3): 460–90.
Shapin, Steven. 1989. “The Invisible Technician.” *American Scientist* 77 (6): 554–63.
Sibum, H. Otto. 2000. “Experimental History of Science.” In *Museums of Modern Science*, edited by Svante Lindqvist, 77–86. Canton, MA: Science History Publications.
Strauss, A., S. Fagerhaugh, B. Suczek, and C. Wiener. 1985. *The Social Organization of Medical Work*. Chicago: University of Chicago Press.
Wylie, Caitlin Donahue. 2009. “Preparation in Action: Paleontological Skill and the Role of the Fossil Preparator.” In *Methods in Fossil Preparation: Proceedings of the First Annual Fossil Preparation and Collections Symposium*, edited by Matthew A. Brown, John F. Kane, and William G. Parker, 3–12.
Wylie, Caitlin Donahue. 2015. “‘The Artist’s Piece Is Already in the Stone’: Constructing Creativity in Paleontology Laboratories.” *Social Studies of Science* 45 (1): 31–55.
Wylie, Caitlin Donahue. 2016. “Invisibility as a Mechanism of Social Ordering: Defining Groups among Laboratory Workers.” In *Invisible Labour*, edited by Jenny Bangham and Judith Kaplan. Berlin: Max Planck Institute for the History of Science. https://www.mpiwg-berlin.mpg.de/sites/default/files/migrated/book_invisibility_and_labour_in_the_human_sciences_preprint_.pdf.
Wylie, Caitlin Donahue. 2018. “Trust in Technicians in Paleontology Laboratories.” *Science Technology and Human Values* 43 (2): 324-348.
Wylie, Caitlin Donahue. 2019. “Overcoming Underdetermination.” *Biology and Philosophy*.

Figure 1: A museum visitor watches a volunteer fossil preparator at work in a glass-walled laboratory.

[i] Today's science centers embrace this approach by focusing on demonstrations and hands-on exhibits for visitors, often without natural history museums' defining purposes of holding collections and

conducting research alongside public education (Friedman 2010; Rader and Cain 2014, chapters 6 and 7). Here I focus on museums that include collections-based research; glass-boxing in other kinds of institutions deserves further research.

ii To protect participants, I do not name institutions or individuals.

[iii] I wonder if this instance was the visitors' experiment to see whether the preparator was a mannequin, robot, or human, in which case they may have been as embarrassed as he was when he looked up.