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The Shadow Bodies of Mice: Invisible Work in Translational Medicine

Carrie Friese

Abstract

The clinician-scientist is often viewed as the crucial nexus in the translational processes that turn scientific research into medical technologies, including but not limited to pharmaceuticals. To create a point of contrast, and to consider the theme of invisible labor, this paper foregrounds an alternative actant who has also been deemed a vital nexus in translational medicine within Science and Technology Studies: the laboratory animal as model organism. Based on observational research conducted in an animal facility that was caring for laboratory mice as well as the immunological laboratory that was conducting research regarding ageing and vaccine uptake using those mice, this paper explores how mouse bodies and animal technicians' knowledge of those mouse bodies are rendered invisible through the everyday flows of translation. I draw on Balka and Star's concept of "shadow bodies" to consider variations in how mouse bodies are understood across the translational process and probe the consequences this has for what knowledge is legitimately produced and by whom. By making the invisible work of mice and of technicians visible, I argue that the organizational filters of translational medicine may inadvertently make the work

Department of Sociology, London School of Economics and Political Science, London, UK

Corresponding Author:
Carrie Friese, Department of Sociology, London School of Economics and Political Science, London, UK.
Email: c.friese@lse.ac.uk

of animal technicians all the harder, in a manner that reproduces social inequalities.

Keywords
Translational medicine, animal technicians, invisible work, sociology of ignorance, shadow bodies

As the editors of this *Science, Technology & Human Values* Special Issue note, the clinician-scientist is often viewed as the crucial nexus in the translational processes that turn scientific research into medical technologies, including but not limited to pharmaceuticals. The prominence of this actor is abundantly clear in public discussions regarding the development of vaccines for COVID-19. To create a point of contrast, and to consider the theme of invisible labor, this paper foregrounds an alternative actant who has also been deemed a vital nexus in translational medicine within Science and Technology Studies: the laboratory animal as model organism (Ankeny et al. 2014; Creager 2002; Davies 2010; Lewis et al. 2013; Nelson 2012; Shostak 2007, 425). The invisibility of the laboratory animal in vaccine production has been stark in public discussions regarding vaccines for COVID-19.[1] This paper is based on observational research conducted in an animal facility that was caring for laboratory mice, as well as in the immunological laboratory that was researching age and vaccine uptake using those mice. I explore how the biologies of mice, as well as technicians' knowledge regarding those biologies, is rendered invisible through the flows of translation. I analyze here both the epistemic and the political economic consequences of the "shadow bodies" (Balka and Star 2015) of laboratory mice.

The productivity of looking to animal models for understanding translational medicine has been well-established. In his now canonical work, Michael Lynch (1989) showed that scientific research using animals requires both a distinction and a relationship between what he calls the "naturalistic" and the "analytic" animal. The naturalistic animal refers to the whole animal that is part of the common-sense life world, and is the animal that technicians and veterinarians are concerned with. The analytic animal is, by contrast, a tissue sample, an electron micrograph, or a statistic based on the naturalistic animal body. Lynch contends that sacrifice is a pivotal moment in the transition from naturalistic to analytic animal, and so animals have to die in specific and well-orchestrated ways for an analytic animal to result—or for the tissues that make up the animal's body to become valuable data points in an experiment (see also Shostak 2007; Svendsen and Koch 2013).

Much social science research has since explored the varied ways in which naturalistic and analytic animals are related in the practices of biomedical and bioscientific research. Historians have shown how the rise of laboratory animal science has sought to standardize the naturalistic animal to improve the science and translatability of the analytic animal (Druglitro 2017; Kirk 2010, 2014, 2008, 2016). Geographers have shown that the animal facility is a social environment, one that shapes both animal bodies and the resulting biological knowledge (Davies 2012, 2013, 2010). The fact that laboratory animal and human health are deeply entangled as a consequence of translational medicine has been a key argument (Dam and Svendsen 2018; Friese and Latimer 2019; Svendsen 2022; Svendsen and Koch 2013). But Eva Haifa Giraud (2019) has cautioned that this more general move toward entanglements in science studies eclipses the ways and the reasons why people and others withdraw from a set of relations. I take from Giraud (2024) a need to also focus on gaps, where distance is required to do politics, as seen for example in the need for the animal rights activist to remain distant from the life scientist or the animal technician as their practices of care are incommensurable. This paper takes up Giraud's focus on incommensurabilities, here emphasizing how the gaps in the translational process are linked with more general inequalities, and are as such a site of everyday politics.[2]

This paper develops analytically through a juxtaposition with Anja Jensen and Mette Svendsen's (2020) notion of "collaborative intimacies" through which medical and other professionals learn to work together in new ways by using animal models as part of translational medicine. Also highlighting questions of work and labor, Jensen and Svendsen show that the work they observed, where pigs served as models of humans, allowed for traditional medical hierarchies to be reworked in practice: students conduct surgery while doctors clean surgical equipment; medics learn how to care for pigs before and after surgery; grief becomes expressible for clinicians when there aren't patients or families who must be prioritized. Through collaborative intimacies, Jensen and Svendsen articulate the productivity and potentiality of working closely, intimately, with other professionals through working with other-than-human species. Relatedly, Dam, Sangild and Svendsen (2018) describe the research pig as a boundary object in the collaborations that cross disciplines and fields and which make up translational medicine. The porosity of species that is a hallmark of animal models creates important sites of occupational porosity and, hence, entanglements.

Where Svendsen and her colleagues draw upon "boundary objects" (Star and Griesemer 1989) to explore the clinician–researcher interface in the work practices of translational medicine, where the animal model is a nexus, this paper builds upon another of Susan Leigh Star's foundational concepts—invisible work (Star and Strauss 1999). I use invisible work to explore the *disjuncture* between animal technicians and researchers in the translational process. Star developed her scholarship on invisible work in collaboration with and by extending Anselm Strauss's research on invisible work in hospitals. Building on their shared pragmatist theoretical tradition, Star and Strauss (1999, 9) emphasized that what counts as work in a particular milieu is inseparable from its in/visibility: "No work is inherently either visible or invisible. We always 'see' work through a selection of indicators." This paper sees the work of translation through the laboratory mouse, as an indicator of the marginalized work involved in translation. This is consistent with Star's approach to studying "the work behind work" (Timmermans 2015), where mice work by "just existing" (Star and Strauss 1999, 357) through the paid work of animal technicians. Through the concept of invisible work, I probe the barriers that are created in translational medicine, which Svendsen and her colleagues note are always also necessary in sites where the human and nonhuman animal are intimately entangled (Jensen and Svendsen 2020; see also Latimer and Lopez Gomez 2019a, 2019b).

It should be emphasized that there is already extensive research showing that animal technicians do invisible work (Birke, Arluke and Michael 2007; Sharp 2019), and even dirty work (Sanders 2010; Tallberg and Jordan 2022). Animal care is practiced as a service to other life sciences, and so knowledge about animal welfare is produced within a power-laden hierarchy (Greenhough and Roe 2019). Scientists thus have epistemic authority when compared with animal technicians. Lesley Sharp (2019, 139–140, 147–148) locates the marginalization of laboratory animal science in the credentialed expertise of scientists versus the tacit knowledge of technicians gained through time spent with animals. In other words, the invisible work of animal technicians is rooted in the hierarchization of universal versus "local" knowledge (Raffles 2002). This hierarchy results, according to Sharp (2019), in the continuance of "the technicians' burden" (Birke, Arluke and Michael 2007), creating high levels of social isolation and compassion fatigue. This paper seeks to contribute to this body of scholarship by probing the consequences of the marginalization and invisibility of technicians' knowledge for science itself.

Nicole Nelson (2018, chapter 4) has explored the epistemic consequences of the hierarchies of science involving laboratory animals. Nelson develops the concept of "epistemic by-products" to denote the hierarchy of genetic versus environmental knowledge regarding mice and their behaviors, based on ethnographic research of behavioral genetics. Nelson (2018, 114) defines epistemic by-products as "management work…extrafactual work that takes place before and alongside the production of scientific facts, and that has consequences for the stability of those facts and of long-term research programs." She gives the example of a set of experiments that asked whether the genetics of heavy drinking was correlated with alcohol metabolism. Nelson notes that this study had to generate a significant amount of knowledge about individual mice—knowledge that was necessary but was never intended for publication. Nelson also notes that there is a great deal of social distance between researchers and animal technicians in this context. The links between tacit knowledge and the sociology of ignorance are identified in Nelson's conceptualization of epistemic by-products, a scholarly convergence that this paper seeks to further engage in by asking what kinds of knowledge don't travel.

If Jensen and Svendsen (2020) push on the social porosities that emerge with species porosities as part of the work of translation, this paper pushes on the social boundaries sustained through the infrastructures of scientific work. Building on Ellen Balka and Susan Leigh Star's (2015) concept of "shadow bodies," I probe how epistemic by-products and invisible work are interconnected in ways that are politically and economically consequential. Balka and Star (2015, 418) define shadow bodies:

> In contrast to "the body multiple" (Mol 2003) that is not fragmented, but rather in its multiplicity hangs together (and in which differing versions of the body have to be workably complementary with the others), shadow bodies are the fragments which do not hang together in their multiplicity, but rather exist, in clouds of indicators, waiting to be woven together in meaningful ways. Shadow bodies are both created by the fragments that are measured, and by the unaccounted for and invisible spaces left in between.

Where Balka and Star used shadow bodies to consider the variations and uncertainties in how bodies are understood across healthcare institutions, I explore the variations and uncertainties in how mouse bodies are understood across the translational process. Where Balka and Star were interested in the consequences of these uncertainties for lived experience, I am interested in the consequences of these gaps for what knowledge is legitimately produced and by whom. The question of what knowledge is produced and by whom is linked to more general social hierarchies that are re-enacted in the workplaces of science. And like the sociology of ignorance, the concept of shadow bodies emphasizes that "it is not always deemed appropriate to hand over all existing information in a chart…in the care chain" (Balka and Star 2015, 425). I further develop this element of the shadow bodies concept by emphasizing the practices and technologies involved in filtering, broadly defined.

Materials and Methods

This paper draws upon ethnographic fieldwork conducted in 2015–17 at a large life sciences research institute in the UK. This independent research institute gains much of its funding from research councils funded by the state. It is affiliated with a nearby and highly esteemed university in training PhD students, but it is independent from the university. Much of the research conducted at this institute is "basic" science with a focus on aging, epigenetics and immunology among other areas of biomedical science. However, some researchers do collaborate with pharmaceutical and biotechnology companies in doing more "applied" research. The animal facility, which is part of this research institute, houses primarily mice but also rats, and is quite large as animal facilities go. One veterinarian told me that, at any given time, there are up to 30,000 mice in the facility. This facility services not only the research institute, but also pharmaceutical and biotechnology companies by breeding, rearing and caring for mice and rats. The facility maintains itself in part through these contracts with industry. I could not, however, gain entrée into this part of the facility.

I conducted this research alongside another ethnographer. We both gained access after attending several meetings at the institute (Friese and Latimer 2019). Through these meetings, we introduced our research and discussed how we would undertake a study of how the Institute models aging in its research. Over the next year-and-half we conducted ethnographic research by shadowing animal technicians, laboratory heads, postdoctoral and post-graduate research scientists, and a veterinarian. Given the nature of the site, we could never become "part of the furniture" in the way that the ethnographer strives for. The animal facility is biosecure, and so entry was highly controlled, which I discuss below. In this sense, we as researchers had ourselves a shadow-like presence and were never woven into the institute. The fieldnotes presented in this paper come from observations I conducted in the aged mouse colony in the animal facility, and in an immunology laboratory that was using those mice in its research.

Notes were taken while conducting participant observation in the laboratories. Notes based on time spent in the animal facility were taken afterward because I could not bring a notebook with me into the biosecure facility. Rather than code these fieldnotes, I wrote the fieldnotes into vignettes to bring the spaces and interactions to life in a manner that put the reader in my shoes, and that was reflexive of my own role (Humphreys 2005). This paper is based specifically upon this research, which juxtaposes a vignette from the laboratory with a vignette from the animal facility that I found to be connected. These vignettes are written in the auto-ethnographic tradition of Science and Technology Studies, and a focus on granular studies of embodied practices (see for example Akrich and Rabeharisoa 2016; Myers 2008; Puig de la Bellacasa 2009).

I conducted this ethnographic research as one sub-project within a larger research program, which asked how much and why scientists in the UK think that animal care is important to scientific knowledge production, how this value is practiced, and where this idea comes from. This was in response to earlier social science scholarship on laboratory animals, which positioned animal care as something that animal technicians did and that was separate from scientists' work (Birke, Arluke and Michael 2007; Lynch 1989). The other two work packages included a survey of UK-based scientists that included follow up qualitative interviews (Friese, Nuyts and Pardo-Guerra 2019; Nuyts and Friese 2023) and historical research (Holmes and Friese 2023, 2020).

Knowing and Caring in the Workplace

The Institute was marked by a highly structured and policed boundary between the Biological Services Unit (BSU) where the mice used in the laboratory research were bred, reared and ultimately killed—and the laboratories. To enter the BSU, one had to enter through two sets of doors that required entry clearance embodied by a swipe identity card issued to BSU staff. I always entered the BSU with a staff member as a guide. After passing through the two sets of doors, everyone then had to change into scrubs with issued socks and shoes either before taking a dry shower or after taking a wet shower. These showers were commonly commented upon as a deterrent to scientists' entering the animal facility, because the process was time-consuming. When I first visited the BSU, I was given a tour by CCTV as a result, and was told that we would need to schedule specified and full days for me to visit the inside of the animal facility. This was thus a situation in which there was little space for the kind of collaborative intimacy between animal technicians and scientists described by Jensen and Svendsen (2020). But like Dam, Sangild and Svendsen (2018), contamination was here also understood as both material and epistemic.

Vignette I

I am spending the day with Adam, a postdoctoral researcher conducting a series of experiments that all ask why older people respond less well to vaccines when compared to younger people. Adam is using the aged mouse colony to answer this question. He explains to me that it is known that older people do not uptake immunizations as well as younger people do, but the mechanism for this is not known. These experiments aim to understand those mechanisms better. Immunizations were given to mice of 12 weeks of age and to mice of 90-plus weeks of age. Seven older and seven younger mice were then culled at each of the following timepoints after the immunization was given: 7, 10, 18 and 21 days. I am watching the last experiment, using the seven young and seven old mice culled at day 21 after the immunization. This laboratory is collaborating with a pharmaceutical company, and this research with mouse-derived tissue is being conducted alongside research using tissue derived from humans.

This is a repeat experiment; the lab has done this experiment once before and so they are now checking for validity. Adam has therefore done this experiment many times. When I arrive he is well underway with the experiments, having already taken lymph nodes from the fourteen mice. He is mashing the lymph nodes in a very fine mesh sieve, held over a Petri dish, using saline solution. Adam then adds more saline to each Petri dish, and puts the Petri dish against a little motor that runs in circles to stir the lymph node particles and saline together. Adam then puts the Petri dishes in a centrifuge and adds a culture. He puts the cells in the incubator for about 20 min.

While the cells were incubating Adam has me watch a PhD student, Sandra, whose research is aimed at building a mathematical model for immunological response. Sandra has the legs from the same fourteen mice that were the subjects of today's experiments, and is removing the bone marrow. Under a hood, in a separate part of the lab, Sandra is taking away all the tissue and skin from the legs. She takes a needle-full or syringe-full of saline solution to get the bone marrow out from the bones and into test tubes. In both Adam's and Sandra's work, I am watching the animal body and its parts disappear—and using Michael Lynch's (1989) categories, the naturalistic animal is becoming an analytic animal.

Throughout the day I watch cells be cleaned, spun in a centrifuge, put into incubators and solutions be made. We spend a lot of time "waiting for culture" as Adam puts it. Adam and I therefore have time to talk about a range of different topics. He tells me about how he likes to organize his weeks, in terms of experimental work and data analysis. We talk about being non-British academics in the UK and how Brexit puts up new uncertainties to our careers. We talk with his lab partners about everything from politics to exercise routines. Because of the division of labor in science, everyone I spend time with, in this laboratory that is studying aging, is significantly younger than me. They are working hard to carve out a future for themselves in scientific research, while being concerned about and cognizant of how uncertain global geopolitics will impact them. These were often informal conversations, where humor often played a role in a marked casualness that was entirely different from how they talked about their experiments. These conversations were a way to pleasantly pass the time.

During one of these "waiting for culture" conversations, I asked Adam if he culled and dissected the mice at the different time points, or if he had the animal technicians in the BSU do this for him. Adam responded that the BSU culled the mice because that's what they do: they're better at it and they're faster at it. But Adam continued to explain that he preferred to remove the organs himself. He liked to see the individual animal, to be able to assess the organ of interest in relation to the whole animal. He said that was a personal choice, not everyone did this, but it was something that he felt was important—to dissect the animal himself.

Adam is thus working with mice in a manner that "choreographs" (Thompson 2013, 2005) what Daniel Nicholson (2018) has labeled "the machine conception of the organism" with a more processual conception of the organism. We see a mechanistic metaphor in the idea of the individual mouse body as a composite of parts that includes lymph nodes, wherein the parts make up a whole. This mechanistic metaphor makes it possible for the structures of interest—the lymph node for Adam, the bone marrow for Sandra—to be separated from other parts of the body. Substance metaphysics could be said to underpin the experiment; lymph nodes are things with a determined set of properties that exist independently of their filtering activities. As a philosopher, Nicholson delineates the machine concept of the organism from the stream-of-life conception of the organism in order to argue for the latter. In contrast, as a sociologist, I seek to describe how this machine metaphor must be choreographed with more processual metaphors. Charis Thompson (2013, 2005) has shown that medicine does not simply objectify people during treatment, but instead choreographs a mechanistic view of human bodies with the person's subjectivity in treatment. So too do scientists, who choreograph more processual understandings with mechanistic conceptions of the organism they are working with. After all, Adam does dissect the mice in his experiment to see the structures of interest in relation to the body as a whole. Indeed, weeks later, Adam and I see one another through a glass window, when I am in the biosecure part of the BSU and he is in the dirty wing—doing a dissection to gain this more holistic knowledge.[3]

I also asked Adam if he thought it made any difference for his experiment that all the mice were female. He responded that he didn't know why that was the case, that the mice are all female. Adam, like most of the scientists I met while doing research at the Institute, has not spent much time in the BSU. It takes a substantial amount of time to enter the animal facility because one needs to change clothes completely and take either a dry or wet shower. The showers are a necessary feature of a biosecure facility, but also act as what Sophia Efstathiou (2019) has called a "technology of effacement." Efstathiou argues that science is made up of various technologies that work to promote the idea of the laboratory animal as an analytic animal (Lynch 1989), and to make it possible for people to approach animals "as if they were models" (Efstathiou 2019).

Having spent time in the BSU, I explained to Adam that males of this strain will fight and so they cannot be housed together for two to three years. The Institute did not believe it was right to singly house a mouse for that long, and so that is why he is working with female mice in his experiment. Adam sort of laughs and calls out to a colleague, "you know why we use female mice? Because the males fight too much." He laughs a bit and turns to me saying, "I didn't know that." And then he goes on with his work.[4]

The sociology of ignorance emphasizes that sites of non-knowledge, such as Adam's non-knowledge of why he is working with female mice, needs to be understood as a social achievement as opposed to a background failure (McGoey 2007; Rayner 2012). This is not to say that Adam can or should know everything about these mice; we all need filtering mechanisms in order to make sense of the world around us (Rayner 2012, 110–111). The point is to say that Adam's lack of knowledge regarding why he is using female mice needs to be understood as part of an organizational filter, which the shower helped to enact. To understand this organizational filtering, I trace the female mice Adam is working with back to the BSU. In the process, I show that it was not only the sex of these mice that had been filtered out. So too was the health status of these older, female mice.[5]

Vignette 2

Today I am shadowing Janet, who has been an animal technician for about 35 years. After having changed into issued scrubs and taking the air shower by myself—something I feel oddly proud of being allowed to do on my own—I meet Janet in the BSU. As I put on my hair net, gloves and face mask, she gives me a bit of history to the mice she will be working with, and I will be observing. Janet explains that the mice she looks after are for a lab that is interested in questions of aging and immunity (the lab that Adam works in). The BALB/c mouse is the primary strain used in immunological research. Janet explains that the problem with BALB/c mice is that males of this strain cannot be aged because they fight too much, even with litter mates; so aged, male BALB/c mice would have to be housed alone. Housing mice for up to three years alone in a cage is not something that the Institute considered ethical, the implication being that mice need community. Therefore the lab, in conjunction with the BSU, decided to try to age female BALB/c mice, who are considered quite docile, unlikely to fight with one another and so can be kept as a community.[6] This was the first time that females BALB/c mice had been aged by the BSU, and Janet says that it has been a big learning process for them.[7]

What they have learnt is that the female BALB/c mice develop cancer with age, particularly ovarian cancer and liver cancer. The technicians began finding bloody discharge in the bedding. The technicians became very concerned and called the vets in; they started looking at what was going on with the mice after they died. It was at this point that the veterinarians realized that it was cancer. However, they did not believe that the mice were experiencing any pain or suffering from the tumors, and so the research could continue. As such, the cancers were not deemed to affect the welfare of the mice or the immunological system, and this is presumably why Adam and his colleagues working at the bench did not know why they were working with female mice, or that the older female mice in their sample almost certainly had cancer. The technicians, however, remained concerned. They began to handle the individual aged BALB/c mice every day. This proved to be too excessive a form of care according to Janet, as the BALB/c mice are fragile and this level of surveillance was too stressful for the mice. So now the techs check the individual mice very carefully one time per week, and that is what I am going to watch Janet do for the day.

Janet starts by organizing the cages according to age, starting with the oldest mice first. All the cages with older mice have a red tag stating, "aging illness, bloody discharge." As we look at the cages lined up, each with this red tag, Janet tells me this is clearly an age-related disease; "look" she says to me, "there is bloody discharge in every cage with mice over one year old." These placards are the shadow bodies of the mouse lymph nodes and mouse bones I will see in the laboratory. Where cancer is invisible in the laboratory and in the work with mouse body parts, here in the BSU aging and cancer as a general condition is highlighted and illuminated with red tags. Both the mouse body parts and these red tags denoting blood and discharge are partial views and partial representation of the mice. Not all the mice in the cages necessarily have cancer, but at least one mouse in the cage does. The red tag denoting blood and discharge is the shadow body precisely because it falls from view over time: "Shadow bodies are constituted of data that fall from view because they are inconsistent with established understandings of bodies, don't fit into existing classification systems…yet somehow persist, precisely because they are rooted in lived experiences" (Balka and Star 2015, 425).

Janet goes about checking the mice in much the same way as I have observed others cleaning the cages. Janet puts eight cages on the trolley, and brings the trolley close to the hood that she is working at. She turns off the light on the hood; because the BALB/c mice are quite anxious, she does not want to have the light on. Janet follows up with further explanation: "because they're albino, it just feels like they should not have light directly on them." Janet puts a cage in the metal square used to open it, and looks at the different mice, watching their gait and how they are moving. She picks up one mouse at a time; she scuffs the mouse to look at the underside, palpates the stomach, checks for any hardness, and then looks at the teeth. Janet watches the mouse move around the cage, and holds each mouse in her hand, watching how the mouse comes off her hand in order to assess strength. If Janet notices anything wrong with a mouse she takes note.

I asked Janet if the BSU is reporting their experience with aged, female BALB/c mice. She says that she thinks the veterinarians reported this back to the mice supplier, in this case the company Charles River. She also thinks the veterinarians are going to write an article on this. When I follow up with one of the veterinarians, however, he seems rather unconcerned about the mice because they are not in pain and are not suffering. But he says that the other veterinarian may be writing something up on this.

The concern about cancer in aged, female BALB/c mice therefore seems to be held by technicians without circulating, and is filtered out through the built architecture embodied by the shower. This allows the analytic animal and corresponding mechanistic understanding of biology (e.g., the cancer is separate from the aspects of immunity under investigation) to come to the fore. Animal welfare (e.g., the mice are not suffering as a result of the cancer) works to legitimate this organizational filtering. Cancer in aged, female, BALB/c mice can be understood as an "epistemic by-product" (Nelson 2018) of studying immunity, but this epistemic by-product is not created through the logics of control and standardization as seen in Nelson's descriptions through which she develops the concept. Where in Nelson's case environmental knowledge is intentionally produced but is not considered scientifically important and is thus deemed a by-product, here cancer in aged, female mice is an unintended epistemic-by-product, one that is dismissed as insignificant both scientifically and ethically. Animal welfare aligns with the architecture of the BSU and the strategic placement of showers in order to separate out scientists from animal technicians, filtering "local" and "intimate" knowledge practices in the production of a universal science that can be embodied by a product like a vaccine.

Discussion and Conclusion

The animal facility in which I conducted research focused upon containment as a biosecure facility. This creates a contrast with piglets in translational research projects ethnographically studied by Mette Svendsen and her colleagues (Dam and Svendsen 2018; Dam, Sangild and Svendsen 2018; Jensen and Svendsen 2020; Svendsen and Koch 2013). Where the piglets enacted and enabled a kind of porosity between veterinary and biomedical science, human and animal health as well as basic and clinical researchers, the mice described here enable a reliable infrastructure for producing scientific knowledge in the form of mice as a model organism. Where the piglets became a site to engage with people and animals in ways that would not be otherwise possible, creating a productive contamination, the mouse infrastructure was made sustainable by selling itself not only to the academic researchers in the institute but also to pharmaceutical and biotechnology companies. The pigs were worked to make the work of bioscience and biomedicine explicit—work that is often filtered out when the focus is on a product such as a vaccine. The point here is that human and animal health are entangled in both sites, but the shape of the entanglement differs significantly.

In expanding upon Donald Rumsfeld's infamous delineation of known-knowns, known-unknowns and unknown-unknowns, Steve Rayner (2012) adds a fourth category: what we don't know we know. Rayner notes that the kind of tacit knowledge and experiential skill that is the hallmark of an animal technician's work often falls into this category. Rayner argues that this type of ignorance, what we don't know we know, is often uncomfortable knowledge for an organization in its attempt to get on with its work. Local knowledge needs to be filtered out to get on with the work of developing knowledge about immunity and aging to be packaged into a drug. Local knowledge is thus at odds with the bioeconomy.

It is important to emphasize that the sociology of ignorance does not argue that it is dysfunctional to forget, but rather that forgetting is crucial: "Without organizational filters we would not have information at all, only noise" (Rayner 2012, 110). Quite simply, all the variables of a mouse's life would create too much noise in an experiment that seeks to understand the mechanisms of aging and vaccine uptake. The sex of the mouse and the fact of cancer are potentially "uncomfortable knowledge" that no one is trying to actively conceal, but that is dismissed as insignificant. "Dismissal acknowledges the existence of information, and may involve some minimal engagement up to the point of rebutting it as erroneous or irrelevant" (Rayner 2012, 113).

But as Efsthathiou (2017) emphasizes, effacement is never complete. I carried the shadow bodies of the mice from the BSU into the laboratory, telling Adam a little bit about the life worlds of the mice whose body parts he was working with. A gendered stereotype became a quick-at-hand discursive resource that worked to minimize the importance of the sex of the mice as they moved from the BSU to the laboratory in the context of a porosity that my presence enacted. But this interactive mode of dismissal relied upon other, prior forms of organizational filtering that were rooted in codified knowledge. First, the mice are deemed to not be suffering from their cancers by the veterinarians. Because they are not suffering, they can continue to live and can thus be used in experiments (Dam and Svendsen 2018). Animal welfare and veterinary science play a key role in filtering tacit knowledge about mice in translational processes, making it possible for scientists to work with information from the mice rather than a mass of noise regarding mice biologies. The elusiveness of care thus shifts into the science of welfare through the professionalization of veterinary medicine. Second, the mouse cancers are understood as discrete from the mouse immune system that shapes vaccine uptake. The cancers are located in the reproductive organs of the aged female mice whereas the mouse's immunity is located the lymph nodes. Mechanistic models of biology are thus the other means of filtering tacit knowledge regarding mice in translational processes. What this means is that the ways in which the mice also model relationships between cancer and immunity were institutionally forgotten.

The invisible work of mice and animal technicians is thus made possible in part through the social construction of both knowledge and ignorance. Understanding biological mechanisms is part and parcel of making therapeutic mechanisms. There is a correspondence between the bench and the bedside through a shared focus on mechanisms that can be universalized, which means filtering out the laboratory animals with which that knowledge is produced. The sex of geriatric BALB/c mice and the fact that they get cancers are dismissed according to the mechanical models that dominate the life sciences. The work involved in making these mice work by simply living—the work of the animal technician—is thus invisible as well. The worries of animal technicians were addressed, but then downplayed and diminished. These organizational filters in knowledge mean that the emotionally hard work of doing animal research continues to be the technicians' burden (Sharp 2019). And it needs to be emphasized that these technicians are among the lower paid workers in the scientific workplace in the UK.[8]

It should be emphasized that mice work and are worked in bioscience, but they are not workers. Mice can only be worked through the work of animal technicians, who—as workers—are also rendered invisible in translational processes. Stefan Timmermans (2015, 3) has described Star's attention to nonhuman agency as follows: "Unlike Latour, Star focused on nonhuman agency in order to highlight how social life is recalibrated and restratified. Her goal was not to democratize the human-nonhuman divide but to analyze the powers of the nonhuman in reshaping a human world." Foregrounding the laboratory animal in translational medicine changes not only the way in which we think about this process (where animals are invisible) by highlighting work practices and corresponding knowledge practices that are also invisible (e.g., animal technicians).

Focusing on the shadow bodies of mice, it becomes possible to see how knowledge could be made differently, or recalibrated. Aged, female BALB/c mice could model interfaces in the processes of aging, immunology, vaccines and cancer. This could be quite interesting and timely knowledge, and it might not be. It could help various actors, but it most certainly would not help all humans in the form of a vaccine due to inequalities between humans. Nor would it help any mice due to the persistence of species hierarchies. But asking the question does recalibrate social processes of translation because this requires knowing something about the work of mice and of animal technicians—work that had been in the shadows of the BALB/c mouse as a model of immunity. Making the invisible visible shows how existing organizational filters (embedded in technologies like an air shower) inadvertently may make the more marginalized work of marginalized people all the harder to do. Efstathiou (2019) argues that animal research is hard not only because it is physically and emotionally challenging but because this fact is routinely dismissed by various technologies that make the laboratory animal seem like a model. The shadow bodies of mice reveal inequalities between people that get reproduced in the workplaces of knowledge production, containment and dissemination.

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ORCID iD

Carrie Friese https://orcid.org/0000-0001-7144-8046

Notes

1. Annamaria Carusi has begun the work of mapping the rare moments of articulation, and thus the prominent absences, regarding animals in public discussions on COVID-19. See: https://carusi-annamaria.medium.com/we-are-all-animals-now-6707187caab4.
2. See also Efstathiou (2019) on disjunctures in animal research, which she emphasizes is an accomplishment made possible through "technologies of effacement."
3. I say that I saw Adam dissecting to emphasize that choreographing mechanistic with processual understandings of the organisms was not only something Adam said, which could be critiqued as part of the attitudinal fallacy of interviews and conversations in research (Jerolmack and Kahn 2014), but was also something he did in practice.
4. See also Greenhough and Roe (2019) on the importance of mouse strains for care practices, where they argue it is crucial to explore not only multispecies relations but also multistrain relations.
5. It is worth noting here a finding from the survey component of this research project. With the survey, we had hypothesized that women scientists would value animal care more than men because of the ways in which care work has been gendered and is gendering as "women's work." However, the survey did not support this finding (Friese, Nuyts, and Pardo-Guerra 2019). As such, I would caution against a generalized, gendered reading of the relations described between myself, Adam and the postdoc, and the animal technicians. I need to emphasize that, in the course of this study, I met plenty of animal technicians who were men who articulated and practiced their work in similar ways to Janet. I also met women scientists who articulated and practiced their work in similar ways to Adam.
6. As Greenhough and Roe (2019) note, these decisions are certainly about animal welfare, but they are also about cost. The expense of laboratory mice is normally determined by the cage rather than by the individual mouse. It would be considered prohibitively expensive to cage mice alone in a cage for 2-3 years.
7. This points to the ways in which (white) males have long stood as the standard by which universal, biomedical knowledge is produced—not only in clinical trials involving humans but also in preclinical trials involving animals. This universal has been challenged and reconfigured over the past thirty years in clinical research, through the "inclusion" paradigm (Epstein 2007). When and how this paradigm shift in clinical research has (and has not) filtered into preclinical research is worth exploring.
8. The starting salary for an animal technician in the UK is £17,000 per year, and an experienced animal technician will be paid £28,000 per year (https://

nationalcareers.service.gov.uk/job-profiles/animal-technician). The minimum salary for a PhD student in the UK is £17,668, noting this is payment for training and the person will be paid significantly more upon graduating. Laboratory cleaners earn more than either animal technicians or PhD students, with an annual salary of £22-34,000. See: https://www.glassdoor.co.uk/Salaries/preston-north-west-england-england-laboratory-cleaner-salary-SRCH_IL.0,34_KO35,53.htm.

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Author Biography

Carrie Friese is an Associate Professor in Sociology at the London School of Economics and Political Science. She is originally from the United States, and did her PhD at UC San Francisco, under the supervision of Adele Clarke.