SOCIO-FUNCTIONAL FOUNDATIONS IN SCIENCE:

THE CASE OF MEASUREMENT

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*Abstract*: We present a novel kind of “socio-functional"foundationalism rooted in the division of scientific labor. Our foundationalism is social in that it involves a socio-epistemic phenomenon we dub *epistemic outsourcing*, whereby claims from one group of scientists provide epistemological foundations for another group of scientists. We argue that: (1) epistemic outsourcing results in a legitimate form of epistemic foundationalism, (2) this sort of foundationalism can be used to shed light on the epistemology of measurement; and (3) epistemic outsourcing is a distinctively collective epistemic phenomenon.

# **Introduction**

Scientific knowledge is typically the result of collective efforts. Collaboration is the norm, with different specialists pooling their resources in organized ways. We will argue that this profoundly affects the structure of justification, yielding a novel kind of *Socio-Functional Foundationalism* rooted in the division of scientific labor. Our foundationalism is social because it involves a socio-epistemic process we dub *epistemic outsourcing*, whereby claims from one group of scientists provide epistemological foundations for another group of scientists. Our aims in this paper are threefold: first, to argue that epistemic outsourcing results in a bona fide form of epistemic foundationalism; second, to argue that this sort of foundationalism can be used to shed light on the epistemology of measurement; and third, to make the case that this is a distinctively collective epistemic phenomenon. Throughout, we illustrate our points with a case study involving social behaviors in mice.

# **Epistemic Outsourcing**

We are interested in social processes whereby members of one scientific community employ the results of another scientific community. For our purposes, scientific communities include any collection of scientists who can be seen to be working together in research, whether as members of a particular research team, as fellow scientists within a given subfield (solid state physics, molecular biology), or as members of a given discipline (entomology, biochemistry, physics, etc.). Additionally, we will construe ‘results’ broadly, to include scientific claims about measurements, experiments, instruments, models, and theories (among others).

**2.1 Epistemic outsourcing and socio-functional foundations**

Our proposal rests upon a core analogy between one scientific community’s epistemic reliance on another for its results, and an audience’s epistemic reliance on a speaker’s testimony for what she believes. Consequently, communities, rather than individuals, stand in the relations of epistemic reliance that we will discuss.

Let *epistemic outsourcing* be the phenomenon whereby results taken as basic or given in one scientific field are justified owing to the intellectual efforts, evidence, and methods in another scientific field. In such cases, the results that are justified by one field or community—the ‘outsourced’ field or community—serve as what we will call *socio*-*functional foundations* for members of the other field or community—the ‘reliant’ field or community. These foundations reflect the fact that a single statement (of a result) can function as epistemically basic for the reliant community even as it is non-basic for the outsourced community. More precisely:

A reliant community CRel *epistemically outsources* the justification for result R to an outsourced community COut if and only if:

1. Members of CRel are entitled to use R as a premise in their reasoning without having non-basic justification for R;
2. R is justified in COut (so that COut has evidence that justifies R); and
3. The entitlement in (1) is the result of a reliable social (paradigmatically testimonial) process by which (the informational content of) R is communicated from COut to (members of) CRel.

In such a case, Rwill be a *socio-functional foundation* for the reliant community.

* 1. **Example: measuring mouse social behaviors**

We believe that epistemic outsourcing and socio-functional foundations provide important contributions to the philosophy of science. In this section we illustrate this by appeal to Hong et al.’s (2015) automated assessment of social behaviors in mice.

Hong et al.’s measurement process begins with a side-view camera, a top-view camera, and a depth sensor set up around a mouse cage. The outputs of the two cameras and the depth sensor are then coordinated to form a three-dimensional map of the cage. A single male mouse serves as the “resident” of a given cage, and an “intruder” mouse (male or female) is then introduced. The mice are allowed to interact freely for 15-30 minutes before the intruder is removed. Using the video data, algorithms track the mice’s poses, movements, and ultimately classify three kinds of social behaviors (attack, mounting, and close investigation) using a machine learning (ML) algorithm. The ML algorithm underwent supervised learning in which the “ground truth” data—roughly, the “standard” by which the ML algorithm was evaluated—were generated by two humans observing the same video data of the mice as the ML algorithm and classifying the mouse behaviors using the same three categories.[[1]](#endnote-1)

 Next, Hong et al. evaluated the algorithm’s agreement with the human observers’ judgments (Table 1). The ML algorithm performed admirably. For instance, its precision and recall in identifying attacks lasting longer than three seconds was in 100% agreement with the human observers’ judgments.

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| --- | --- |
| **Criterion of metrological evaluation** | **Definition** |
| *Precision* | True Positives/ (True Positives + False Positives) |
| *Recall* | True Positives/ (True Positive + False Negatives) |
| *Accuracy* | (True Positives + True Negatives)/ (True Positives + True Negatives + False Positives + False Negatives) |
| *Fallout*  | False Positives/ (False Positives + True Negatives) |
| *Miss* | False Negatives/ (False Negatives + True Positives) |

Table 1

Criteria used by Hong et al. (2015, p. E5355) to evaluate ML algorithm for measuring mouse social behaviors

Additionally, they further bolstered the algorithm’s acceptability through two “use-cases.” In use-cases, a newer measurement procedure replaces one of its predecessors in an experimental context with a well-known result. To the extent that the new measurement procedure coheres with that result, this further justifies the measurement procedure.

 In their first use-case, NZB/B1NJ (“New Zealand Black”) were previously found to be a more aggressive strain of mouse than C57BL/6N (“Black 6N”) (Guillot & Chapouthier, 1996). In different trials, each was used as the resident mouse and exposed to a BALB/c (“albino”) intruder. The algorithm correctly tracked the New Zealand Black mice as spending more time attacking these intruders and less time engaging in non-aggressive behaviors (such as close investigation.) They also attacked with greater frequency than Black 6N’s.

 In their second use-case, BTBR T+tf/J (“Black and Tan Brachyury”) mice are known to display more autism-like behavioral phenotypes (such as reduced social interactions) than Black 6N’s (Silverman, Yang, Lord, & Crawley, 2010). As before, these two strains were treated as residents and exposed to a BALB/c intruder. As predicted, the algorithm correctly tracked the Black and Tan mice as spending less time investigating intruders than Black 6N’s, and to do so with less frequency.

 Finally, Hong et al. suggest ways that their algorithm is epistemically superior to human observation. The key is the latter’s limitations: “human observers may fail to detect behavioral events due to fatigue or flagging attention, miss events that are too quick or too slow, or exhibit inconsistencies between different observers in manually scoring the same videos” (Hong et al. 2015, E5357-E5358).

 We submit that this episode of scientific justification can be illuminated by treating the background information—information which is taken for granted in the use of this technology—as among the research team’s socio-functional foundations. Consider the following claims contributing to the justification of this measurement procedure:

1. Various video cameras, MATLAB programs, and algorithms designed by other scientists and engineers function as described;
2. The previous studies on which the use-cases are based are accurate and well-designed;
3. The strains of mice are NZB/B1NJ (from Jackson Laboratory), BTBR T+tf/J (also from Jackson Laboratory), and BALB/c (from Charles River Laboratory).

We submit that claims (a)-(c) constitute socio-functional foundations for the scientists using the technology. This idea can be defended by reflecting both on what justifies these claims, and on Hong et al.’s relative ignorance of the justifying materials.

To begin, while the justification of these claims may derive in part from their cohering with measurements of social behaviors in mice, their justification involves much more besides. For instance, MATLAB is a matrix-based programming language used by scientists and engineers; the claim that MATLAB works as described is justified by highly general mathematical and computational considerations, but not by mouse antics. Nor do (a)-(c) appear to be justified in other ways by those who employ these technologies in the measurement of mouse behaviors. For instance, the reliability of a video camera is not rooted in perception, memory, or *a priori* reflection. Our proposal is that these claims serve as socio-functional foundations.

We will use the last of these claims, (c), as an illustration.

In our example, Hong et al. are entitled to take it as given that the mice in their experiments are New Zealand Black, Black 6N, and albino. Given that the mice were purchased from reputable laboratories, only exceptional circumstances—consistently surprising results that could not be attributed to other sources, for example—would occasion reason to doubt that the mice are from the indicated strains.[[2]](#endnote-2) Thus, this example satisfies condition (EO1): members of the reliant community are entitled to use the claim in question as a premise in their reasoning without having non-basic justification for that claim.

Turn to (EO2), according to which R is justified in COut (so that COut has evidence that justifies R). As suggested above, coherence with the results produced by the ML algorithm does not justify claims about mouse strains. Rather, claims about mouse strains are justified by specific breeding protocols in the laboratories from which the mice originate. It appears that none of the authors are expert mouse breeders, and the protocols involved in preserving the purity of a mouse strain are surprisingly complex. A bank of frozen embryos taken from an initial or “foundation stock” is incrementally built up. The frozen stock is then used to re-establish the foundation stock about every five generations of mice, from which a new bank of embryos is built up, and so on, with parallel efforts to expand the foundation stock through exogenous means, such as from other suppliers (Jackson Laboratory 2007, 11). However, for Hong et al., it suffices to know that the mice are from the Jackson and Charles River Laboratories. Any further justification concerning frozen mouse embryos, the foundation stock, etc. can be outsourced to these laboratories. Note that the laboratories have materials that provide non-basic justification for claims about mouse strains—materials that might draw on a combination of coherence considerations, reliable perceptual foundations, and their own set of socio-functional foundations, e.g., about the cryogenic technologies involved in freezing the mouse embryos. Hence, (EO2) is satisfied as well.

Finally, consider (EO3), which requires that the reliant community’s entitlement to the claim be the result of a reliable social (paradigmatically testimonial) process. To bring out that this condition is met, we note that the mice were *purchased* from these laboratories, and there is a norm of selling as advertised. Since these laboratories consistently deliver the mouse strains they promise, this transaction is reliable.[[3]](#endnote-3) Thus, the example satisfies (EO3).

With this, we see that the claim that the strains of mice are NZB/B1NJ, BTBR T+tf/J, and BALB/c is a socio-functional foundation for Hong et al. We submit that the other supporting claims—(a) and (b) above—are also socio-functional foundations. If our example of mouse behavior is representative, then many scientific claims are justified via epistemic outsourcing.

# **Socio-Functional Foundations**

We have appealed to the measurement of mouse behaviors as part of our case for thinking that epistemic outsourcing is a key part of the cognitive division of labor in science, and we have suggested (in 2.1) that the epistemological dimension of such outsourcing can be understood by postulating the existence of socio-functional foundations. In this section we reinforce the claim that socio-functional foundations are *foundations* in the epistemologist’s sense. (Our account’s foundationalist credentials will loom large in our account of the epistemology of measurement in Section 4.)

Call an epistemology *foundationalist* if it distinguishes two types of epistemic justification, basic and non-basic. A claim (statement; proposition; belief)[[4]](#endnote-4) enjoys *basic* justification just in case (i) it is justified and (ii) its status as justified does not derive from its relations to any other justified claim (statement; proposition; belief). We assume that basic justification is defeasible, and that claims enjoying basic justification are fallible. All other justified claims (statements; propositions; beliefs) enjoy *non-basic* justification.

We provide two defenses that socio-functional foundations satisfy these conditions. First, as our example of mouse strains illustrates, when reliant community CRel inherits a result R from outsourced community COut, members of CRel themselves need not, and typically will not, be in possession of the evidence that justifies R. Rather, members of CRel treat R as foundational—as something they can take for granted and on which they can further build in their inquiries. The point is that R counts as *prima facie* justified within CRel. R has this status in virtue of the fact that *it is* *a result developed in a scientifically respectable way by a scientific subcommunity (COut) on which CRel* *is properly relying*. The scientists in CRel themselves may be unaware that R has this property, still less must they have justified beliefs to this effect. It suffices that R has this property, that the individuals employing R are members of CRel, and that as a matter of fact the communication of R from COut to CRel is a reliable one. When these conditions are satisfied, R is *prima facie* justified (among members of CRel), and in the absence of relevant reasons for doubt, R is justified *simpliciter* for the members of CRel. In this way, R has a foundational status for members of CRel.

Some epistemologists might resist this proposal. Non-reliabilists will see it as too reliabilist in nature; others may resist the idea that evidence one *doesn’t* have can ever play a justificatory role in what one accepts or believes. But there are reasons to endorse our proposal and significant costs to rejecting it. For one thing, if the epistemic assessment of scientific belief or acceptance is restricted to evidence in the possession of individual scientist herself, we will be unable to capture the various types of epistemic dependence in science—and so will fail to appreciate the systematic ways in which science is a social endeavor. Of course, science is not merely social, but *collective*: it is not merely that individual scientists depend on one another, but one group of scientists can depend on another group for their results. We submit that the model above provides a plausible way to capture such relations. We will be developing the case for this model in what follows, but it is worth noting that the burden is on those who would reject our model: absent an alternative, they will fail to illuminate the collective nature of epistemic dependence in science.

The analogy mentioned above provides a further advantage to these non-reliablist and individualist alternatives. *Anti-individualism* (AI) about testimony provides an important precursor to and motivation for the idea that results that have been justified by one community can serve as epistemic foundations for another community (Goldberg, 2007, 2014; Kallestrup & Pritchard, 2012; Levy & Alfano, 2019; Palermos, 2020). While such a view is not uncontroversial, AI holds that an audience need not justify her reliance on another’s say-so: the absence of defeaters suffices for her to be entitled to accept that say-so.[[5]](#endnote-5) However, AI also entails that justification of audiences’ resulting beliefs depends (not only on the absence of defeaters, but also) on the epistemic credentials of the testimony itself.[[6]](#endnote-6) The result is that testimonial beliefs on this picture manifest a kind of epistemic reliance akin to epistemic outsourcing. They are *foundational* in the sense that an audience does not need positive reasons to accept a speaker’s claim: in the absence of reasons for doubt, the audience is entitled to do so. But at the same time the justification of the audience’s belief depends on more than the mere absence of relevant defeaters. According to AI, testimonial beliefs also depend for their justification on epistemic work done by the speaker (or someone still further upstream in the chain of communication). It is here, of course, that our core analogy emerges: our suggestion is that the epistemic outsourcing in play in science, as characterized in conditions (EO1)-(EO3), can be seen as yet another version of the sort of epistemic reliance that takes place in cases of testimonial belief, as these are understood by AI.[[7]](#endnote-7)

We offer a second defense of the idea that socio-functional foundations *really are* epistemic foundations. One rationale for foundationalist epistemologies is their solution to regress-of-reasons problems. If a justified belief is a belief based on good reasons, and if reasons themselves are beliefs (so that a ‘good’ reason is itself a justified belief), we appear to be facing an infinite regress. Foundationalist responses to this threat of a regress hold that some beliefs (reasons) are epistemically good, where their goodness does not require vindication by appeal to still other reasons. The challenge facing foundationalists is to specify the properties a reason must have to enjoy this status. But assuming this question enjoys a motivated answer, there is a class of beliefs such that citing a belief in this class is (in the absence of positive reasons for doubt) adequate to stop the regress. We submit that this is precisely what one would see in connection with our postulated socio-functional foundations: scientists in CRel who are challenged to defend their claims can stop the regress by citing a result that, within her community, is rightfully taken for granted (owing to the epistemic outsourcing in play).[[8]](#endnote-8) If there are positive reasons for doubting this result, of course, then these reasons must be addressed; but in the absence of any such reasons, the appeal to this result stops the regress. This is further evidence that socio-functional foundations really are epistemic foundations.

Having secured our position’s foundationalist credentials, we now advertise four of its initial attractions as a foundationalist epistemology. First, as mentioned above, our position highlights the role of foundationalism in the epistemic division of scientific labor. It makes clear that scientists within CRel may not be able to provide the evidence that justifies the results they are taking for granted. In addition, our account highlights the sort of property that scientific claims must have to enjoy this status: the property of *being a result developed in a scientifically respectable way by a scientific subcommunity (COut) on which CRel* *is properly relying*.

Second, Socio-Functional Foundationalism illuminates a novel source of the justification enjoyed by those beliefs that are alleged to enjoy basic (foundational) justification. On our view, that justification is inherited from the reliant community. When CRel inherits result R from COut, members of COut are the source of the evidence supporting R, and so members of COut are the source of the justification for R. To be sure, we can ask further questions about COut’s evidence and how it justifies R; but that is another matter. When it comes to the members of CRel (the reliant community), R’s justification is basic.

Third, Socio-Functional Foundationalism mitigates the problem of showing how beliefs that enjoy basic (foundational) justification can be used to generate justification for the other beliefs or claims in the system. Many traditional accounts of foundational belief foundered on this problem: the foundational beliefs they postulated had contents that made it difficult to see how they could serve as the foundation for other beliefs or claims with more substantial content. (Here we have in mind the sense-data foundationalism that ran through the mid-20th Century.) Happily, Socio-Functional Foundationalism solves this problem decisively and directly. Insofar as the socio-functional foundational beliefs or claims are those results inherited from another scientific subcommunity, *they can be as substantial as any of the results of that subcommunity*—that a mouse is BALB/c, that E=mc2, that species evolve, and so on.

Fourth, our account makes clear that in scientific settings foundationalism itself might be given a distinctly communitarian gloss: what is foundational for one scientific community can be non-foundational for another. Furthermore, it underscores that any socio-functional foundation R in science requires some (outsourced) community for whom R is not foundational. One’s justified starting point, *qua* scientist, depends on the community in which one is working, and the state of the field at the time (both in one’s own community as well as in other scientific communities). But if science is developing properly, there will always be some community relative to which the results one takes as a starting point are not (for them) foundational. In this way results remain “in touch” with the evidence that justifies them.

We conclude, then, that Socio-Functional Foundationalism is not misnamed: it is a version of epistemic foundationalism properly so-called.

# Coherence, Collectivity, and Measurement

We have argued that epistemic outsourcing motivates a species of (socio-functional) foundationalist epistemology. We also claimed that socio-functional foundations figure in scientific measurements of mouse behaviors. Taken together, these two claims entail the epistemology of measurement has a foundationalist dimension. However, this picture of the epistemology of measurement faces an important challenge: there is a growing consensus in the philosophy of science that coherentism provides the most plausible epistemology of measurement (e.g., Bokulich, 2020; Chang, 2004; Crasnow, 2020; Tal, 2016, 2019; van Fraassen, 2008). In section 4.1 we present this challenge in detail, and in sections 4.2 through 4.4 we offer our reply.

## **A coherentist challenge**

The challenge that we shall consider alleges that coherentism is the only defensible response to something we call the *circle of measurement:*

CM1. Any acceptable process for measuring a quantity requires an empirically successful model of how that quantity is measured.

CM2. Any empirically successful model of how a quantity is measured requires an acceptable process for measuring that quantity.

More precisely, we take the challenge to be that coherentism, which is required for addressing the circle of measurement, renders socio-functional foundations unnecessary for the epistemology of measurement. Before answering that challenge, we unpack some of CM1 and CM2’s key terms.

 Following Tal (2017), we take a method of measurement to consist of a *process* and a *model* of that process. A measurement process is a set of physical interactions between the object of interest, the relevant instruments, and the environment. Measurement processes’ final states are *indications.* Examples include a speedometer needle’s position and Hong et al.’s ML algorithm outputting “attack” on a screen. As these descriptions suggest, indications are not yet interpreted as quantities (in these examples, as velocity and mouse aggression, respectively). Such interpretation requires a model that recruits theoretical and statistical assumptions about the measurement process. Measurement models tell us how the object of study, the instruments, and the environment interact so that a measurement outcome can be inferred from an indication. Here, a *measurement outcome* is a knowledge claim describing the object of interest as possessing the relevant measurable quantity. For instance, a speedometer’s measurement outcomes include the claim that (at a particular moment in time) a given car is moving at 102 kilometers per hour. Hong et al.’s measurement outcomes include that one mouse has attacked another.

We shall say that a measurement method is *acceptable* if scientists can use a measurement process’s indications and relevant background knowledge to cogently infer measurement outcomes, paradigmatically for the purposes of advancing experiment, prediction, explanation, and other scientific practices. Different “Measurement Coherentists,” as we shall call them, emphasize different criteria of acceptability or “epistemic virtues,” including precision, accuracy, consistency, scope, simplicity, fruitfulness, reliability, validity, and unification (Bokulich, 2020, p. 432; Chang, 2004, p. 227; Crasnow, 2020, p. 1208; Tal, 2017, pp. 43-44). Finally, we shall say that a measurement model is *empirically successful* if its measurement outcomes predict which indications will result under different variations of the measurement process.

With the circle of measurement’s key terms elucidated, coherentists’ domestication of this circle becomes straightforward. Their key move is recognizing that the measurement process in CM1 should differ from the one in CM2. Indeed, as measurement practices mature, multiple independent methods of measurement converge, so that vicious circularity becomes virtuous coherence. Insofar as claims about the acceptability of a measurement method are justified by considerations of coherence, coherentism appears to take center stage in the epistemology of measurement. We take coherentism to be the doctrine that a statement or belief is justified (at least in part) by its inferential and explanatory connections to other statements or propositions in a network. Measurement Coherentism is the more specific position that certain statements pertaining to measurement are justified by these connections.

The study of mouse social behaviors seems to fit naturally with Measurement Coherentism. As CM1 suggests, the process for measuring mouse social behaviors satisfies various epistemic virtues (see Table 1) and requires a model according to which mouse behaviors are detected by the various cameras, which in turn produce data that is processed by the ML algorithm, resulting in the indications. As the Measurement Coherentist interpretation of CM2 suggests, that model’s empirical success consists of coherence with a prior measurement procedure (human observations of mouse behavior) and the use-cases. Hence, it may seem that our Socio-Functional Foundationalism has no role to play in the epistemology of measurement.

## **Foundationalism in the epistemology of measurement**

How can we reconcile Section 2.2’s claim that socio-functional foundations play a role in measurement with Section 4.1’s argument that coherence alone is sufficient for the epistemology of measurement? While we ourselves embrace coherentist elements in the epistemology of measurement (see below), we deny that coherence considerations *alone* exhaust the epistemological story. To that end, we argue that the circle of measurement is compatible with an epistemology of measurement that includes some non-coherentist elements.

On this front, our argument is simple: only an extreme coherentist position—one that seems neither very plausible nor widely endorsed—would preclude our claim that metrological justification is a combination of coherentist and non-coherentist considerations. The sort of extreme coherentist position that is our target we dub ‘*Ambitious Coherentism*’:

(AC) All scientific claims are justified by coherence alone.

We will use AC as a foil by which to highlight how Socio-Functional Foundationalism contributes to the epistemology of measurement.

Importantly, most Measurement Coherentists are simply silent on the scope of their coherentism. Thus, they are more charitably interpreted as endorsing *Modest Measurement Coherentism*:

(MMC) Some central claims about measurementare justified by coherence.[[9]](#endnote-9)

Let ‘supporting claims’ denote those claims with which these central measurement claims must cohere. Then proponents of AC and MMC are likely to agree about how central claims are justified, but their burdens of proof shift substantially with respect to supporting claims’ justification. On this front, AC is restricted to justifying all supporting claims through coherence alone, whereas MMC is far more flexible, for it can recruit any epistemological tools appropriate for the job. As we shall argue below, this flexibility is a virtue, for Socio-Functional Foundationalism does important work regarding supporting claims in the epistemology of measurement.

 The current literature infrequently distinguishes AC from MMC.[[10]](#endnote-10) We suspect that this imprecision has contributed to the singular focus on coherentism and has made the non-coherentist elements of measurement less salient. Of course, MMC’s initial attractions would be overridden if there were conclusive arguments for AC. However, because Measurement Coherentists’ foremost arguments—their responses to the circle of measurement—only discuss the justification of central claims about measurement, they do not vindicate anything as bold as AC. As such, there is space for foundations to work alongside coherence in the epistemology of measurement.

It remains a live option, then, to supplement the sort of coherence involved in the epistemology of measurement with epistemological foundations. We develop this option by defending the following:

**The Measurement Claim**. The combination of Socio-Functional Foundationalism and Modest Measurement Coherentism (MMC) outperforms Ambitious Coherentism (AC) as an epistemology of measurement.

Our arguments for The Measurement Claim are twofold. First, relative to AC, the combined view better captures the communal dimensions of the epistemology of measurement, which in turn capture the varieties of justification found in scientific measurement (Section 4.3). Second, relative to AC, the combined view more capably captures the independence of metrological evidence (Section 4.4).

## **The argument from justificatory variety**

We will first argue that that the appeal to socio-functional foundations captures the communal dimensions of the epistemology of measurement in a way that the pure coherentism of AC cannot. Because of this, our view more capably captures the variety of metrological justification in scientific practice.

To appreciate how Socio-Functional Foundationalism captures the communal dimensions of the epistemology of measurement, we will discuss the three conditions, (EO1)-(EO3), whose joint satisfaction gives rise to socio-functional foundations.

 (EO1) states that the reliant community’s members treat erstwhile socio-functional foundations as basic statements. However, (EO1) is not merely a descriptive claim; it asserts that CRel’s members are *entitled* to treat socio-functional foundations as basic. Importantly, on pain of failing to satisfy (EO1), the reliant community’s members cannot “blindly” accept whatever results are conveyed to them by other scientific communities. On the contrary, if the conveyed results were to conflict with background information already in the reliant community, the members of that community would—or, at any rate, should—raise questions, either about the results themselves or about their background assumptions. This reflects both the fallibility and defeasibility of basic claims, and is fully consonant with anti-reductionism in the epistemology of testimony.

It is here, in connection with the conditions on the defeat of a basic claim,[[11]](#endnote-11) that we see one salient dimension of socio-functional foundations’ collective nature. We understand defeat here to be a matter of conflicting information already ‘in the reliant community’ (Goldberg & Khalifa, forthcoming). In this regard the reliant community is taken to be a collective which possesses background information. Two reasons support this contention. First, no single individual in the community possesses all the relevant information. Second, to play its role as a potential defeater, the background information must be taken to be a single body of information, individuated in some way by reference to information possessed by its members (over some period of time). While we will have a little more to say below about the nature of this collective, for now we will proceed on the assumption that defeat of socio-functional foundations is to be understood in collective terms.

Admittedly (EO1)’s appeal to the epistemic entitlements of members of a reliant community may seem curious. Specifically, the entitlement that figures in (EO1) differs from more familiar entitlements in epistemology—such as the entitlement to rely on one’s perceptual faculties, memory, or reasoning—in two ways. First, whereas the latter are entitlements to rely on *one’s own* cognitive processes, the former is an entitlement to rely on the results of other scientific groups, and it can seem strange that one can be entitled to rely on a social process. For another, whereas the more familiar entitlements are underwritten by e.g., the evolutionary function of cognitive processes (and their reliability when fulfilling their function in normal conditions), no such consideration can underwrite the entitlement postulated in (EO1).[[12]](#endnote-12) These differences can make the entitlement associated with socio-functional foundations seem odd: how can one be entitled to rely on the outsourced community for its justified results?

In response, we submit these differences reflect yet another communal dimension of socio-functional foundations. Recall the earlier parallel with anti-individualistic approaches to the epistemology of testimony (AI). AI already recognizes the phenomenon of epistemic reliance as characterizing the relation holding between audience and speaker in testimony cases. We have claimed that the phenomenon whereby reliant communities rely on outsourced communities in science is another instance of this same phenomenon. However, whereas in ordinary testimonial exchanges it is the audience who is responsible for monitoring the speaker for signs of unreliability,[[13]](#endnote-13) here it is *the reliant community as a whole* that is responsible. Individual scientists discharge this responsibility when they ensure that they accept no results that clash with their own background beliefs. Importantly, however, this responsibility is also discharged socially, as in practices of peer review and public criticism of scientific work—practices whose function is in part to screen for reliable information.[[14]](#endnote-14)

Crucially, while such social practices play the role of a ‘filter’ in communication between scientific communities, we have no need assume anything like collective subjects on this score. Thus, while (EO1) postulates an entitlement which links members of one community to the results of those of another community, the entitlement is one that is enjoyed by each of the members of the reliant community (rather than by the reliant community as a subject in its own right). The real collectivity in epistemic outsourcing, then, is seen in the fact that the members of this community depend on the *justified results* of the outsourced community.

To appreciate why this aspect of epistemic outsourcing must be understood in collective terms, we must proceed to (EO2), which requires that result R be justified in the outsourced community, so that this community, unlike the reliant community, have non-basic justification for R. This ensures that the epistemic buck stops somewhere. This requirement must be understood in collective terms—in terms of what it is for the outsourced community to be justified in endorsing the result at issue. Addressing this would require addressing one of the central questions of collective epistemology: the conditions on collective justification (Andersen & Wagenknecht, 2013; de Ridder, 2014; Lackey, 2021, 2014; Rolin, 2010; Tuomela, 2011). While we don’t have anything particularly original to say regarding these conditions, our view offers a case for thinking that such an account is positively required to make sense of epistemic outsourcing in the division of scientific labor.

(EO3) states that the reliant community’s entitlement to treat the target claim as a foundation is the result of a reliable social process. This process involves all the outsourced community’s intellectual and scientific work that justified result R; R then serves as a functional foundation for the reliant community. Obviously, some social processes that transmit information between scientific communities (e.g., interdepartmental gossip) will not produce justified basic statements for the reliant community. This caveat notwithstanding, the social processes that can legitimately underwrite epistemic outsourcing are quite varied, including citation, collaboration, and testimony.

While it is not obvious that (EO3) needs to be understood in collective terms, it is fruitfully characterized in this way. The point here concerns the nature of the communication itself. Here we might highlight that there are two dimensions of reliability in this communication: the members of the reliant community are *reliably apprised* of epistemically well-sourced (*reliable*) information. There is reason to think that collectives are involved in both dimensions of reliability.

Consider first the reliability with which members of the reliant community encounter the relevant results of the outsourced community. (We will designate this sort of reliability as ‘systematic reach’ in order to distinguish it from the reliability of the information communicated.) We speculate that the systematic reach of this sort of communication is underwritten by various social practices and institutions characteristic of organized science. These practices and institutions ensure systematic routes through which the members of one research community are kept informed of useful results from other research communities. A good deal of extant work in philosophy and sociology of science describes these processes[[15]](#endnote-15); the remaining task is to model how such practices and institutions subserve the systematic reach of the communication channels.

Consider next the reliability of the sources that are doing the communicating. As we noted above, testimony is the paradigmatic way in which information is communicated from the (members of the) outsourced community to the (members of the) reliant community. In some cases, the testimony itself should be seen as coming from the outsourced community as a collective, rather than from any specific individual within that community. As the mouse example above illustrated, the mice were purchased from well-known and highly respected laboratories, and the information communicated by the lab to the purchasing scientists can be thought of as testimony from the lab itself (as opposed to any particular individual in the lab). But even when the testimony itself is proffered by a particular individual within the outsourced community, that person in effect serves as a spokesperson for the outsourced community,[[16]](#endnote-16) as it is the collaborative justificatory work of the community that renders the testimony reliable (to the extent that it is reliable).

These collective dimensions of epistemic outsourcing underwrite our first argument for The Measurement Claim—what we call the *argument from* *justificatory variety*. Metrological justification applies at different “social scales” which reflect different ways in which these communal dimensions of epistemic outsourcing can be realized. Our example suggests three such scales.[[17]](#endnote-17) First, Hong et al. (2015) are a *research team*. Second, although each member of that team is an *individual scientist*, each is also a member of one or more scientific *disciplines or fields* (Table 2).

|  |  |
| --- | --- |
| **Contributor** | **Field** |
| Hong | neuroscience of social interactions |
| Kennedy | theoretical neuroscience (neural computation, behavior) |
| Burgos-Artizzu and Perona | computer vision and machine learning |
| Zelikowsky | neural circuits underlying psychogenic stress |
| Navonne | electrical engineering (undergraduate) |
| Anderson | neurobiology of emotion |

Table 2. List of co-authors in Hong et al. (2015) and their fields

For a given measurement procedure, we can ask about its justificatory status at each of these scales, e.g.,

* Under what conditions is an individual scientist (Hong, Kennedy, etc.) justified in adopting the measurement procedure?
* Under what conditions is a research team (Hong et al., the Jackson Lab, etc.) justified in adopting the measurement procedure?
* Under what conditions is a scientific field (the fields of social neuroscience, theoretical neuroscience, computer vision, etc.) justified in adopting the measurement procedure?

An epistemology of measurement that incorporates socio-functional foundations capably delimits the different standards of justification needed to address these questions. Research teams and fields can be either reliant or outsourced communities, and individual scientists can be members of such communities.

Particularly in the case of research teams, these different scales interact in complex ways. Within the research team, one collaborator can epistemically outsource the justification of a claim to another collaborator. For instance, the neuroscientists in that team did not need to provide inferential justification concerning the coding behind new ML algorithms designed for the measurement procedure, but they did need to provide such justification about how the use-cases corroborated that measurement procedure. The converse would be true for the computer scientists in Hong’s team. However, the team as a whole has non-basic justification both for the new ML algorithms’ being properly coded and for how the use-cases corroborate the measurement procedure. We also saw that Hong’s team treated claims about mouse strains as socio-functional foundations, since they outsourced that justification to the Jackson and Charles River Laboratories. Thus, our approach is duly sensitive to how standards of justification vary across social scales and is well-positioned to solve the problem of justificatory variety.

 By contrast, Ambitious Coherentists have not said enough to capture justificatory variety at these different social scales. To see why, observe that most Measurement Coherentists write as if coherence is a relation between *propositions, models,* and *methods* (cn. 19). Call this *Abstract Measurement Coherentism.* To our knowledge, no Abstract Measurement Coherentist has provided an account of how these propositions, models, and the like are embodied in individual scientists, research teams, and fields.

Abstract Measurement Coherentists may allege that divisions between reliant and outsourced communities carry no epistemological weight. If that is so, then justificatory variety provides no genuine basis for endorsing socio-functional foundations in the epistemology of measurement. However, Abstract Measurement Coherentists will have difficulty putting the brakes on this bullet-biting maneuver. After all, the laboratories that provided the mouse strains have their own socio-functional foundations, concerning genetics, cryogenics, and other claims. But the geneticists, cryonicists, and so on will have their socio-functional foundations, and so we quickly see that the proposal to dismiss justificatory variety (to protect Abstract Measurement Coherentism) entails that the only “genuine” justification is coherence with the totality of science. While there may be merits to thinking about such an encompassing web, it is clearly an idealization rather starkly divorced from scientists’ justificatory practices. Furthermore, purveyors of this response are committed to this “mega-coherence” being the *only* kind of justification that figures in measurement—everything else is pretend, mere convenience, etc.[[18]](#endnote-18) This would implausibly suggest that most scientists are engaged in false consciousness when they adopt a measurement procedure. Such a construal is unfortunate. More to the point, it is unnecessary, since Measurement Coherentists can avoid it simply by embracing The Measurement Claim.

## **The argument from independent evidence**

Of course, historically, coherentists have sought to embody the coherence between propositions via *belief*.[[19]](#endnote-19) Call this *Doxastic Measurement Coherentism*.[[20]](#endnote-20) Such views are most at home in evaluating the beliefs of an individual scientist. For doxastic views to cover both research teams and fields, these social entities must be capable of having collective beliefs. However, it seems curious that metrological justification in science should hinge on a contentious social ontology. By contrast, our view assumes nothing more extravagant than scientists gathering evidence and interacting with each other.

 Moreover, even if teams and fields have collective beliefs, Doxastic Measurement Coherentists cannot replicate the second argument for The Measurement Claim—what we call the *argument from independent evidence*. Measurement Coherentism rests on the idea that justification accrues through the convergence of independently justified lines of evidence. Socio-functional foundations prove crucial in giving a line of evidence its independent justification. To see why, imagine two additional research teams with identical webs of belief to Hong et al. They differ with respect to things outside of their webs:

* *Team U* purchased their mice from some *unreliable* lab or through some *unreliable* social process.
* *Team A* simply *assumed* that the mice were New Zealand Black, Black 6N, etc. but these assumptions were not epistemically outsourced.

Recall that the use-cases presuppose that the mice strains are as labeled. Then the use-cases do not provide further justification for the measurement procedure for either Team U or Team A. Team U is in a situation in which the justification for claims deriving from the use-cases is dramatically diminished, because their mice came from an unreliable source. (Compare an audience who accepts what in fact is unreliable testimony from a speaker, but where the content of the testimony happens to cohere with the audience’s background beliefs.) Team A is forced to justify its claims about mouse strains entirely by those claims’ ability to predict use-cases’ results. However, this entails that the use-cases are devoid of justificatory power. If the only justification for whether a mouse is, e.g., a New Zealand Black, is that the ML algorithm successfully predicted that it behaved more aggressively than some other mice, the use-case could not serve its function as an *independent* source of justification for the ML algorithm. By contrast, socio-functional foundations have no difficulty in accounting for the independent and reliable grounds for thinking that a mouse is, e.g., a New Zealand Black: it came from the Jackson Lab. This point generalizes.

 To summarize, we have highlighted two reasons that Modest Measurement Coherentists should add socio-functional foundations to their wheelhouses. First, socio-functional foundations more readily accommodate the different standards and structures of justification that arise at different social scales. Second, socio-functional foundations provide reliable independent grounds for accepting a measurement procedure—an essential ingredient of Measurement Coherentism.

# Conclusion

In this paper we have argued that epistemic outsourcing in science results in a legitimate form of epistemic foundationalism, that this sort of foundationalism highlights several distinctively collective dimensions to the division of cognitive labor in science, and that it can be used to shed light on the epistemology of measurement.

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1. Since Grant and Mackintosh’s (1963) pathbreaking study, human observation had long been the accepted method of detecting rodent social behaviors. [↑](#endnote-ref-1)
2. If such anomalies were to occur, this would be a case of incoherence defeating a functional foundation’s *prima facie* justification. We return to the matter of defeat below. [↑](#endnote-ref-2)
3. Of course, if this were false, this case would fail to instantiate socio-functional foundations. We return below to the conditions that underwrite the reliability of the social process involved. [↑](#endnote-ref-3)
4. Throughout the remainder of this paper we alternate, according to context, between speaking of *beliefs*, *propositions*, *statements*, and *claims* as the things that are justified. The standard way of talking in epistemology is to focus on beliefs or other doxastic states; in philosophy of science, on statements. Nothing hangs on our choice of wording. [↑](#endnote-ref-4)
5. This is the familiar thesis of anti-reductionism, which ascribes to testimony the status of innocent-until-proven-guilty (Burge, 1993; Coady, 1992). [↑](#endnote-ref-5)
6. This is AI’s distinctly ‘anti-individualistic’ aspect. Some think this requires S’s testimony to be knowledgeable; others, to merely be suitably reliable. We ignore these complications here. [↑](#endnote-ref-6)
7. In section 4 we will highlight how this difference points to one of the ways in which socio-functional foundations are a *collective* epistemological phenomenon. [↑](#endnote-ref-7)
8. See Greco (2020, p. Ch. 8) for an argument in the spirit of ours. Greco argues that even if scientists have reasons for believing that their sources are reliable, those reasons would not satisfy relevant scientific-epistemic norms for establishing the results being used. [↑](#endnote-ref-8)
9. The literature on the epistemology of measurement has not been particularly clear on whether the the claims in question are justified by coherence alone or justified only in part by coherence. Similarly, different Measurement Coherentists spell out which central claims about measurement are justified via coherence. Tal, for example, holds that all *measurement outcomes* are justified by coherence. We are happy to be flexible on these points, as our contention does not depend on any particular reading here. [↑](#endnote-ref-9)
10. Chang vacillates between AC (2004, 221) and MMC (2004, 159). However, his arguments only support MMC. Charity dictates that we treat him as endorsing MMC. [↑](#endnote-ref-10)
11. In speaking of the results of one community as ‘basic’ relative to another community, we do not mean to be denying that scientists in the latter (reliant) community often have reasons to trust those in the former community. Rather, our claim is that such reasons are not necessary for the justification of the results, or for the reliant community’s use of those results in its own reasoning. Compare: mature subjects may well have reasons to regard their perceptual faculties as reliable, but the justification of their perceptual beliefs does not depend on those reasons. [↑](#endnote-ref-11)
12. To be sure, there are other ways to capture entitlements not associated with our own on-board cognitive processes (e.g., Graham, 2012). These accounts are consistent with our point above. [↑](#endnote-ref-12)
13. Goldberg and Henderson (2006) discuss how a monitoring requirement and anti-reductionist epistemologies of testimony can be integrated. [↑](#endnote-ref-13)
14. This point has been noted by many others. See e.g. Longino (2002). [↑](#endnote-ref-14)
15. Zollman (2013) reviews some of the relevant literature. [↑](#endnote-ref-15)
16. For an interesting discussion of the social epistemology of spokespersons, see Lackey (2021). [↑](#endnote-ref-16)
17. Other social scales are possible, but this tripartite distinction already suffices to show that our view outperforms orthodox Measurement Coherentism. [↑](#endnote-ref-17)
18. See, e.g., Chang’s (2004, p. 224) passing remark that Duhem’s physician—who effectively treats the physics underlying his instruments as a functional foundation—is “get[ting] away with pretending that certain assumptions” are foundations. [↑](#endnote-ref-18)
19. Of the Measurement Coherentists cited in the introduction, only Chang (2004, 2007), Crasnow (2020); Tal (2016, 2019), and van Fraassen (2008) even suggest that coherence is a relation between beliefs, and often only in passing. The remainder are more plausibly interpreted as Abstract Measurement Coherentists. [↑](#endnote-ref-19)
20. We focus on beliefs, but the critiques of the doxastic approach apply to similar mental states, e.g., credences and acceptances. [↑](#endnote-ref-20)