Thing Knowledge
– Function and Truth

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Thing knowledge

Elsewhere I have argued for a materialist epistemology that I call "thing knowledge." This is an epistemology where the things we make bear our knowledge of the world, on a par with the words we speak. It is an epistemology opposed to the notion that the things we make are only instrumental to the articulation and justification of knowledge expressed in words or equations. Our things do this, but they do more. They bear knowledge themselves, and frequently enough the words we speak serve instrumentally in the articulation and justification of knowledge borne by things.

Figure 1. A model of Davenport's motor, that was patented in 1837. (Davenport 1929 p. 144)

Making is different from saying and made things bear a different kind of knowledge than expressed sentences. Thomas Davenport, a Vermont blacksmith with little schooling and no training in electromagnetism, made a rotary electromagnetic motor after seeing a demonstration of Joseph Henry's electromagnet. Patenting his motor in 1837, Davenport is a claimant to being the first to make such a thing. Davenport's motor worked well enough to power a printing press. One major obstacle to making a commercial success of his invention was the lack of good batteries or other sources of electric power. Davenport's intellectual achievement was a commercial failure. See *Figure 1*.

The invention bears some of Davenport's knowledge of electromagnetism. Certain aspects of the relations between electricity and magnetism can be expressed in literary terms with words and equations. Other aspects can be expressed in material terms with wire, iron and wood. This was Davenport's way. Davenport was able to see relationships in the material terms in which they were presented in Henry's electromagnet. He could manipulate these relationships in his mind's eye and ultimately manually to make something new. He was not working with equations or propositions. He was working with materials. What he learned from Henry's electromagnet he learned from the material object. He then worked with what he learned, with his hands and his blacksmith shop's materials, to produce his motor. This was his contribution to our knowledge of electromagnetism. It was a material contribution, not a theoretical contribution.

The problem of truth

I claim that material products such as Davenport's motor bear knowledge and that the knowledge they bear is (typically) different from knowledge borne by theories. But this claim raises several pressing questions. The concept of knowledge is tied to other concepts. A well-worn road in epistemology speaks of justified true belief. My project is one of expanding the domain of knowledge and doing this requires expanding the concepts with which we analyze knowledge.

Clearly I have abandoned belief. Whatever Davenport's motor may be, it is not a belief. For me, however, belief, has never seemed essential to knowledge. I've always been more attracted to objectivist theories such as Karl Popper's (1972).

Theories and hypotheses, the kind of things that can be spelled out with propositions, and ideally sentences on paper (or computer screen), always have struck me as more appropriate epistemological objects. So I freely abandon belief.

I am less happy to jettison justification and truth. I have never been wedded to a literal use of truth in the analysis of knowledge. Here again my roots in Popper's and Lakatos's philosophy show (Lakatos and Musgrave 1970; Hacking 1981). "Every theory is born refuted." But there is something about truth that is important. Below, in section 5, I am going to spell out just what I take this something to be. From my point of view, the appropriate extension of the concept of knowledge from the domain of propositions to the domain of artifacts demands an extension of this something-about-truth from propositions to artifacts. This is the problem I am concerned with in this paper.

My proposal: function for truth

I solve this problem of truth with the concept of function. Roughly speaking, I claim that an artifact bears knowledge when it successfully accomplishes a function. This claim requires elaboration, most particularly with respect to the concept of function itself. The concept I employ is relatively thin, stripped of any heavy load of intentional baggage, and focused on the reliable, regular predictable performance of the artifact. It might best be characterized in terms of mathematical functions instead of biological or more broadly teleological functions.

Before I elaborate the sense of function I want to use, I first examine a hint of linguistic evidence for my proposal. Then I canvas the ways that truth is important for the analysis of knowledge borne in propositions. I argue that functions can serve these same functions (!) when we analyze knowledge borne in artifacts. After presenting the case for functions serving for truth in general terms, I return to a more careful consideration of what I mean by function. A function, for me, is a crafted and controlled phenomenon.

A hint of linguistic evidence: a true wheel

As philosophers, we are accustomed to think of truth in terms of propositions or sentences, and so we ignore turns of phrase such as, "a true wheel." A golfer has spoken to me of a "true drive down the fairway." Amongst the more philosophically common senses of “true” the dictionary also includes, “9. Accurately shaped or fitted: *a true wheel.* 10. Accurately placed, delivered, or thrown” (Anonymous 1993, p. 1450). But a “true wheel” is not true simply because it properly conforms to a particular form; a true wheel spins properly, dependably, regularly. A wheel that is “out-of-true” wobbles and is not dependable. Ultimately it will fail. This sense of “truth” picks out those contrived constellations of materials that we can depend on. A public, regular, reliable phenomenon over which we have material mastery bears a kind of “working knowledge” of the world and “runs true” in this material sense of truth.

The need for the wheel to spin properly to be true immediately intertwines this material sense of truth with the notion of function. Barring aberrant contexts, the basic function of a wheel is to spin, smoothly, regularly and reliably. Of course we may deploy such a function as a component serving the broader purpose of some device. Bicycle wheels spin to move the bicycle. But it is because a bicycle maker can depend on the spinning function of the wheel that the maker can deploy this function to serve the broader goal of locomotion.

Knowledge, expressed in propositions, provides fodder for further theoretical reflection. These resources—sentences with content—are manipulated linguistically, logically and mathematically. Theoreticians are “concept-smiths” if you will, connecting, juxtaposing, generalizing and deriving new propositional material from given propositional material. In the material world, functions are manipulated. In a spectrograph, photographic film is used to record spectral lines. An analyst, then, determines elemental concentrations from the intensities of the lines on photographic film. In a direct reading spectrometer, photo-multiplier tubes replace photographic film; condenser electronics replaces the analyst. These are functional substitutions. One material truth is substituted for another that serves the same function. Photo-multiplier tubes, instead of photographic film, perform the function of intensity recording. Condenser electronics performs the function of determining elemental concentrations. “Instrumenticians” are “function-smiths,” developing, replacing, expanding and connecting new instrumental functions from given functions.

What does truth do for us?

If I want some information about plutonium I can look it up in an encyclopedia:

> Plutonium. Actinide radioactive metal, group 3 of the periodic table. Atomic number 94. Symbol Pu. This element does not occur in nature except in minute quantities as a result of the thermal neutron capture and subsequent beta decay of ^{238}U; all isotopes are radioactive; atomic weight tables list the atomic weight as [242]; the mass number of the second most stable isotope ($t_{1/2}$ = 3.8 _ 10^5 years). The most stable isotope is ^{244}Pu ($t_{1/2}$ = 7.6 _ 10^7 years). Electronic configuration … (Considine 1983, p. 2262).

I do not have to read about Glenn Seaborg's discovery of the element in 1940 through the deuteron bombardment of uranium in UC Berkeley's 60-inch cyclotron. Nor do I have to read about all of the various ways that the information above has been ascertained and justified. This information has been detached from its context of discovery and can be used elsewhere without reference to its discovery which, I note, is lacking in this encyclopedia entry.

This is a feature of "scientific truth" that is of signal importance. Truths can detach from their context of discovery to be used elsewhere. They come with a kind of guarantee that, when they are used appropriately, they can be depended upon. They are efficacious in this respect. Finally their guarantee insures a kind of longevity. Scientific truths are not fashionable whims.

Saying this flies in the face of much recent science studies scholarship. An appreciation of the history of science shows us that knowledge changes. Propositions held true today will be abandoned in future years. Propositions discovered in one context cannot be assumed to hold in other contexts. The efficacy of a proposition depends as much on what our other resources are for doing what we desire to do, as it does on the proposition itself.

We can acknowledge all this but still hold that a legitimate and important distinction can be drawn between scientific truths and personal opinions. Scientific truths may never live up to the ideals I articulate:

(1) Detachment: We can use them without reference to their "context of discovery."
(2) Efficacy: We can depend on them as we use them.
(3) Longevity: We can depend on them indefinitely into the future.

But we have reason to take them to be more dependable in these respects than personal opinions. We know that when a scientific truth has failed in respect to one of these ideals, something substantial has happened, something that requires significant examination and evidence. Every theory may be born refuted, but the refutation of an accepted theory demands reasons. This is not the place to sustain a detailed argument for this conception of scientific truth. For this paper I assume that these three ideals are central to what "truth does for us."

To these three ideals, I add two others. The first is obvious, but important for my subsequent discussion. Scientific truth establishes a relationship between humans and the world. We may assert a fact or develop a detailed picture of "how we think things are." Scientific truth serves to connect our thinking with the world—either the world is or it isn't as we think.

But not any old connection will do. Scientific truths stand in a special relationship between an individual and the world, where the world's voice has a kind of priority. I may have wished that Al Gore won the popular vote in the State of Florida. But my wishing it were so, won't make it so. The votes make its so. "The votes" stand as impartial arbiters between camps with conflicting wishes. They provide an objective standard independent of subjective wishes

I use the Florida election pointedly, for it was a flawed election that revealed the difficulty with the idea of the world's voice having priority. How is the world's voice "translated?" There are moves and counter-moves. The wishes of the various camps direct the reading of the chads on the ballots. Some are tempted to conclude that that world has no voice. There are only the voices of the warring camps, each enlisting features of a mute world to support their projection of its voice. If one accepts this, one cannot be dismayed by the manner in which the election was brought to closure, through legal action and the more easily counted votes of nine Supreme Court justices. I am happier to accept as an ideal the view that one of Al Gore and George Bush did receive more votes in Florida, but unfortunately our methods of ascertaining this scientific truth, this objective fact, were not up to the task. Objectivity, like the other features I have identified, is an ideal.

These five features can be expressed in terms that speak of knowledge and not truth. This is how to expand the core value of truth for knowledge to a conception of knowledge not tied to propositions.

(1) Detachment: Scientific knowledge can detach from its context of discovery.
(2) Efficacy: Scientific knowledge can be depended upon to accomplish appropriate ends.
(3) Longevity: Scientific knowledge can be depended upon into the indefinite future.
(4) Connection: Scientific knowledge establishes a relationship between the world and us.
(5) Objectivity: "The world's voice" has priority in the relationship between the world and us.

These are ideals. As ideals we don't expect any specific claim to scientific knowledge to live up to these ideals without controversy and struggle. But also as ideals they tell us why truth is important, why we should demand truth of scientific knowledge. We can see how the concept of function also aims at these ideals. This is how function serves for truth.

Functions serve these functions

Each of these five ideals describes important central features to the functions we develop and deploy in our artifacts. There is an important sense in which we can better understand these ideals as ideals when we see them in operation with functions and material artifacts. The corruptibility and imperfection of our material terrestrial world has always been with us. We know nothing works forever—although John Harrison's wooden-geared clock built in the 17^{th} century continues to tell time (Sobel 1995). Indeed, in some cases we can profitably quantify the degree to which our artifacts measure up to these ideals. We can trade off cost against material perfection. Such trade-offs occur with theoretical knowledge too—why else is Newton still around, if not to trade difficulty of use off against accuracy—but they are easier to see, understand and accept when we examine our material artifacts.

Efficacy falls out almost by definition. When we build an artifact to accomplish some goal, we depend on the efficacy of our material contrivance to accomplish the goal. If it fails to accomplish the goal—if it fails to function—we have to keep at it or abandon the project and/or goal. The point of a material function is to accomplish something, to be efficacious.

Detachment, not quite as obvious as efficacy, is an equally central feature of the functions of our artifacts. Photo-multiplier tubes were developed in the late 1930s as part of a research program at RCA. These tubes use a special cathode that emits electrons when struck by light; they then amplify the electric current over 2 million times (Zworykin and Rajchman 1939; Rajchman and Synder 1940). See *Figure 2*. When these tubes were used in a direct reading spectrometer, their function to sense light was detached from their original context of development. While the quality control on the manufacture of the tubes was relatively loose—and individual tubes had to be individually checked for performance characteristics—once checked and approved, the tubes could be built into the spectrometer and relied upon to perform their function as expected into the foreseeable future. This is most clearly seen from the point of view of the users of the direct reading spectrometers. They may not have had a clue how the instrument sensed light signals. But they still were able to deploy this function in their fabrication of metal.

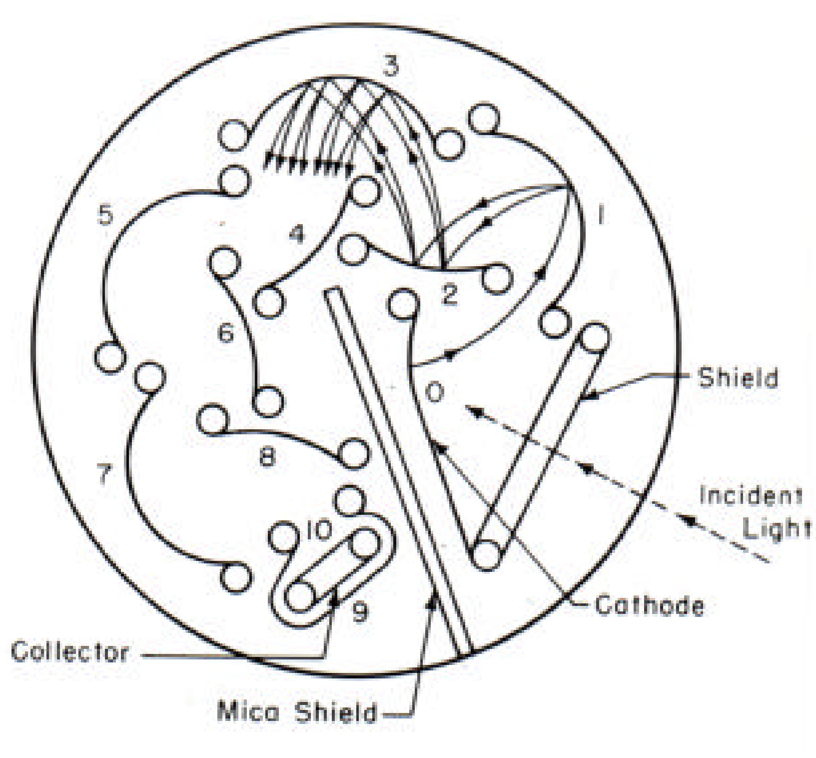

Figure 2. A schematic diagram of a photomultiplier. (Saunderson 1947 fig. 3).

"Into the foreseeable future" speaks of longevity. Material artifacts are perhaps more prone to wear and tear. They cannot be depended on to work forever. But if we couldn't depend on them to work for a reasonable—sometimes carefully quantified—amount of time, they wouldn't be of much use. Charles Sanders Peirce used these words to describe such a situation:

> When an experimentalist speaks of a *phenomenon*, such as "Hall's phenomenon," "Zeeman's phenomenon" … he does not mean any particular event that did happen to somebody in the dead past, but what *surely will* happen to everybody in the living future who shall fulfill certain conditions. The phenomenon consists in the fact that when an experimenter shall come to *act* according to a certain scheme that he has in mind, then will something else happen, and shatter the doubts of skeptics, like the celestial fire upon the altar of Elijah. (Pierce 1934, v. 5, paragraph 425).

Whatever else they are functions must have material forms that behave as the phenomena Peirce speaks of behave. Ideally a phenomenon has the striking and persuasive quality of the divine blaze by which Elijah embarrassed the 450 prophets of Baal, but it must also be constant and reliable, a permanent fixture of the living future.

Functions must have a kind of objectivity too. I may wish that the Ethernet circuitry in my computer were not broken. I may even behave as if it were not broken, reloading software and replacing other components. But, at the end of the day, if it is broken and I want to connect to an ethernetwork with my computer, I am going to have to replace or substitute my Ethernet circuitry. Now reliability is not a black and white concept. Perhaps my Ethernet circuit has a "flaky" component that only works some of the time. It is not quite as good as Peirce's celestial fire, but not hopeless either.

I have saved what seems the simplest function of truth for last. Connection. Both scientific truth and engineered function connect human thought with the world. Truths connect how the world is with how we think it is. Functions connect how an artifact behaves with how we want it to behave. This obvious and fundamental feature of functions is the basis for the research program that the Dual Nature of Technical Artifacts program is concerned with. While it may seem the simplest function of functions, it is indeed deeply complex and problematic, and requires, finally, a closer examination.

Thick and thin functions

On my analysis a function couples the crafting of a phenomenon in Peirce's sense with purpose. A function is a purposeful phenomenon. But adding purposes adds problems. There are problems ascertaining purposes or intentions. Without access to a designer's mind or a design team's interactions, determining the intention behind some part of an instrument can be a difficult matter of reconstruction and interpretation. Reverse engineering is not an automatic process. There are problems with unintended uses. The designers of photo-multiplier tubes did not intend their tubes to be used for radar jamming; they were because of the "black current" they produced (Saunderson 1997). They were also used to check for defective fuses in grenades (White 1961, p. 143). There are problems with intended consequences based on mistaken understandings. M. S. Livingston focused his cyclotron's beam by adding metal shims to the magnet; he did so incorrectly thinking he was fixing irregularities in what he thought should be a homogeneous magnetic field (Livingston 1985, p. 259). There are problems of unintended consequences. In the early days of word processing, the idea was to decrease, not increase paper consumption. Football helmets were meant to decrease serious injury. Unfortunately, despite the best intentions, things frequently "bite back" (Tenner 1996).

Function also has a normative dimension, and this adds another set of difficulties. In certain respects, the direct reading spectrometer I have made passing reference to was better at determining elemental concentrations in samples of metal. It was quicker than photographic spectroscopy or wet chemical methods—enough to make a major difference in the manufacture of metal. Less human labor and judgment was necessary. It was more accurate for many important chemical elements, but not all. On the other hand, it was more expensive and less flexible; only certain pre-selected elements could be analyzed. It was bigger and it changed the role of the chemical analyst in metal manufacture. There never is a simple "worse/better" with the kind of normative judgments involved with functions. Trade-offs are an inescapable part of work in the material world. Consequently, it is difficult to determine how normative judgments were applied in making certain choices in the development artifact, and it is more difficult, if it is possible at all, to determine what normative judgments *should* be applied.

A full analysis of the role of function in design requires attention to all of these problems. Functional design, like theoretical representation, is a deeply intentional arena. This is not an arena I care to enter, for I fear these problems. For my purposes, I prefer a "thinner" notion of function. I acknowledge that at some level in some way functions are connected with intentions. But I sidestep a detailed analysis, and focus on Peirce's phenomena. The epistemological work I extract from function can be accomplished by our crafting such a phenomenon. Here we get the ideals of truth I spoke of above—detachment, efficacy, longevity, objectivity and connection. We do not need a detailed analysis of representation to have confidence that knowledge can be expressed theoretically. Indeed, part of the philosophical motivation behind an analysis of representation is to have a more clearly articulated understanding of this kind of knowledge. Here I am content to argue *that* knowledge is borne in our artifacts, and to thereby provide an epistemological justification for a more detailed analysis of a thicker, more fully intentional, notion of function.

Biological and mathematical functions

There can be no doubt that the concept of function used in design is teleological, and, in this sense, is akin to the role function plays in biology. We have hearts *in order to* pump blood. The heart has this purpose or telos. This "thick" intentional concept is deeply problematic for the variety of reasons I mention. I have argued that all I need is a "thinner" concept that acknowledges, without further analysis, a connection with human intentions and purposes, but that attends to the reliability and predictability of our crafted artifact. This thinner concept draws on the concept of a function from a different discipline. Mathematical functions are a better way to think of my functions than are biological functions.

A mathematical function is an association of values, or to put it another way, a set of ordered pairs of values. We can think of how "the function produces" an "output" value for a given "input" value. We can think of a mathematical function in quasi-teleological terms: the x^2 function has the purpose of giving as output the square of a number given as input. But from a definitional, set-theoretic point of view, a function is a set of order pairs.

This is how to think about crafted material functions. What we want is a device—an artifact—that reliably associates inputs and outputs, a device that is, in a possible-world-kind-of-way, a set of order pairs of inputs and outputs.

Consider the work that went into crafting photo-multiplier tubes for use in a spectrometer. As it happens the tubes were sensitive to exactly where the light struck the initial cathode. They did not instantiate a univocal set of ordered pairs, for a given input of light intensity could be associated with a spectrum of possible outputs. The spectrometer designer did not know the reason for this. What to do? By inserting a quartz plate between the light source and the tube's cathode he "fuzzed" the light over the cathode. This produced a material kind of averaging, with the result that the outputs were more closely univocally tied to the inputs. See *Figure 3*. Curves (a) and (b) show how slight variations in where the tube's cathode received light resulted in large variations in the tube's output. Curve (c) from figure 3 was obtained when a ground quartz plate was used to "fuzz" the line over the cathode to produce stable average sensitivity. As with the other ideals I discussed earlier, material functions do not live up to their ideal mathematical counterparts. We do not have an absolutely straight horizontal line for curve (c) in *Figure 3*. But, this is clearly where the designer was aiming.

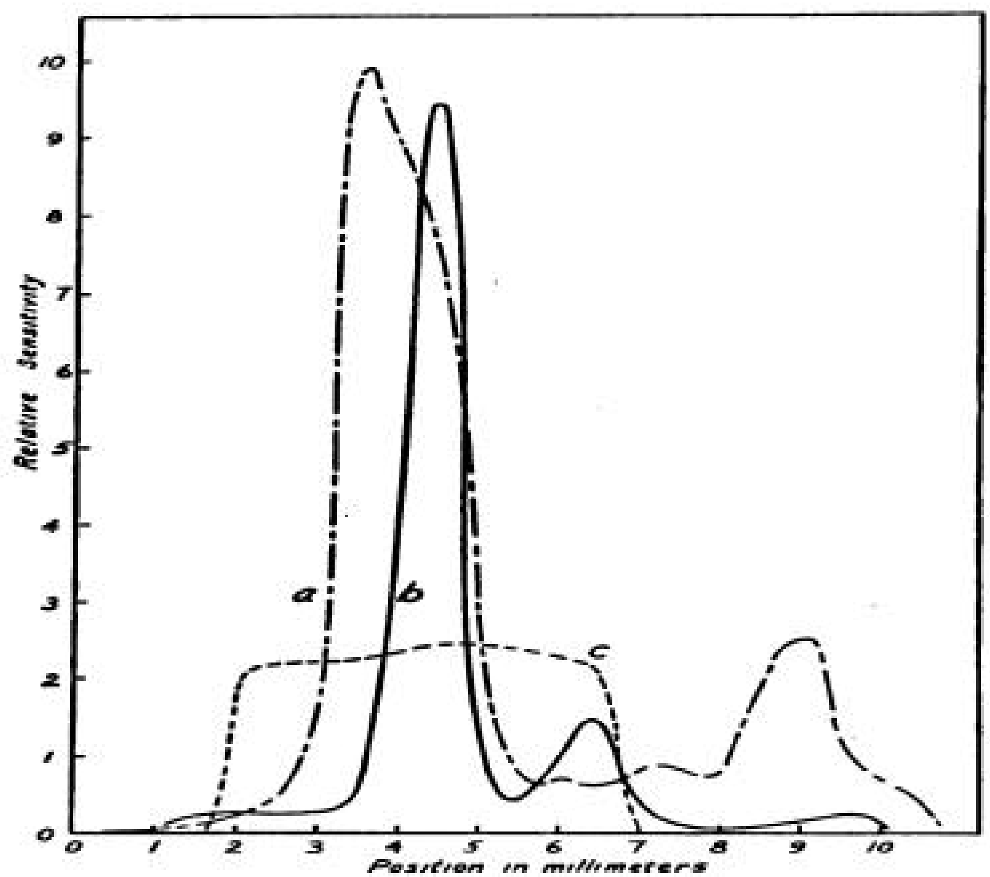

Figure 3. Outputs of three photomultipliers as a function of the place where the light strikes the initial cathode. (Saunderson, Caldecourt and Peterson 1945 fig. 4)

Functions: crafted phenomena, material truths

I close my paper raising a question: What is the role of human craft in the analysis of material knowledge? We can be reasonably comfortable extending the concept of knowledge to crafted artifacts. As crafted artifacts, we have built them with the "truth-ideals" of function—detachment, longevity, efficacy, objectivity and connection—in some manner in mind. Davenport's motor, as Davenport's creation, bore Davenport's knowledge of electromagnetism as surely as Oersted's speculations about electro-magnetism did. The motor presented a crafted phenomenon, a material truth.

The fact that Davenport crafted his motor reassures us that "he knew what he was doing." This fact, that he knew what he was doing, supports the notion that the motor bore his knowledge of electromagnetism, knowledge that he could not express in words. The crafting of the motor provides rhetorical mileage in pursuit of material knowledge. We also know that the functions Davenport developed and deployed were genuine connections between how Davenport wanted the world to behave and how he got it to behave.

But how important is this connection? Must an artifact be crafted to count as knowledge? And how clearly must those doing the crafting understand conceptually what they are doing? Our spectrometer maker did not know why photo-multiplier tube output was sensitive to precisely where light struck the tube's cathode. For whatever reason, it was, and with a quartz plate he "fuzzed" the light over the whole cathode and, through such material averaging, achieved dependable regular output from the tube. Livingston clearly misunderstood what he was doing in getting his early cyclotron to work. And then several of the early uses of photo-electric tubes relied on a different conceptualization of their function, namely that they produce "dark current," that is, current when no light is present and this dark current—or "noise" as the tube makers would have called it—was useful in the generation of radar jamming signals. What about the creations of evolution? Do spider webs bear knowledge of insect catching? Do naturally occurring phenomena bear knowledge? Does our solar system bear knowledge of gravity?

My distinction between thin and thick notions of function is connected to the distinction between an objective and a subjective concept of knowledge. Subjective knowledge is closely tied to subjects and draws on a thick, intention laden, notion of knowledge. As such, it is saddled with the host of problems of intention that I have spelled out. Objective knowledge divorces itself from subjects and requires only a thin notion of function. Popper's minimal criterion is that:

> in order to belong to the third world of objective knowledge, a book should—in principle, or virtually—be capable of being grasped (or deciphered, or understood, or 'known') by somebody. (Popper 1972, p. 116).

Extend such a view to material artifacts and we are led down the path that leads to spider webs and solar systems bearing knowledge.

For myself, I would trade off the problems of intention for the peculiarity of spider web and solar system knowledge tokens. But I acknowledge that my preferences here may be peculiar. How thin can we allow our concept of function? Perhaps at a minimum we should require human craft, without requiring any detailed conceptualization of this craft. This is not entirely satisfactory for the subjective beliefs and the objective knowledge that they interact with in the process of crafting can be—and many times are—incommensurable. Nonetheless, this seems the least problematic option to me.

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