Beaver Dams, Spider Webs, and the Sticky Wicket
An Investigation On What Counts As Technology and What Counts As Knowledge

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Thesis submitted to the faculty of the Virginia Polytechnic Institute and State University
in partial fulfillment of the requirements for the degree of

Master of Science
In
Science & Technology Studies

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May 9, 2007
Blacksburg, Virginia

Keywords: epistemology of technology, natural technologies, non-human engineering, philosophy of technology, non-human-built things

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ABSTRACT

Philosophers of technology have often considered only the tools and processes used and conducted by humans, but natural structures and man-made structures are not always easily discernable from one another. The complexity of a spider web is not matched by many human-made technologies. Beaver dams, beehives, and ant hills are great creations made by non-human animals. Davis Baird has argued that our scientific instruments bear knowledge in important ways,[1] and the idea of technological knowledge bears interestingly on discussions of natural artifacts. Baird thinks his argument for instruments bearing knowledge can be extended, but how far can it be taken? Do 'natural' technologies, like spider webs, bear technological knowledge of some sort?

This move to consider whether natural artifacts might bear knowledge rubs interestingly against current definitions of technology which include human agency or progression as important. If we find that some natural artifacts seem to bear knowledge in the way Baird describes, technological knowledge would not be the exclusive domain of humans. Our current definitions of technology seem incongruent with our view of knowledge and our knowledge of natural artifacts. The purpose of this paper is to sort out the inconsistencies between current philosophical literature on knowledge and on technology.

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[1] Baird, D. 2004. *Thing Knowledge: A Philosophy of Scientific Instruments*. Berkeley: University of California Press.

In sorting out the inconsistencies we find, I recommend a spectrum approach with regard to technology based on the epistemological status of the artifact. Using observations from anthropology and biology, I suggest a scale with regard to technological behavior, tool use, and technology.

ACKNOWLEDGEMENTS

My thesis director and readers have played a large part in shaping my ideas with regard to how to approach my topic. Though the idea for the topic was my own, these three scholars have taken my thoughts in new directions and steered me to literature that would challenge my assumptions. Without the biological and anthropological concerns of Laura Perini and Matthew Goodrum, this thesis would not have taken the shape it does, and, without the clever counter-examples Joe Pitt posed to me, my thinking and writing would be considerably less clear. Specifically, Matthew Goodrum suggested a spectrum for what I was trying to say with a step-type model that would have been less accurate for what I was envisioning. His rather simple suggestion now plays a key role in how see this work. Laura Perini clued me into the design/function issues between biology and engineering. Initially, I had intended to spend much more time looking at engineering literature to the exclusion of biological concerns and literature, but I've found the biological concerns (and related anthropological concerns) to be more fundamental to this project. Joe Pitt, as director of all my academic projects, continued to bring up confounding issues and push for better philosophical analysis. Any remaining lack of clarity, lack of explanation about specifics, or lack of proper grammar and spelling in this thesis is the product of my own failings and frustrations and does not stem from a lack of prodding on the part of my committee. I sincerely thank Drs. Perini, Goodrum, and Pitt for their great help in this project.

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Chapter I: Introduction and Definitional Issues

Technology is not a monolith, nor is it proper to speak of technology in the singular, as we usually mean tool or device. Indeed, speaking of technology usually entails talking about technologies. This thesis aims to make the plurality of technology even more complicated because there is more to consider than has been previously investigated. This thesis is aimed at sorting out what we mean and how we can talk about technology as it relates to other tool-use and technological behavior. When it comes to speaking about the knowledge embedded in technology, our initial reaction is to limit our thoughts to those things that we know come from knowledge of the world, our (human) technological instrumentation, but I would like for us to toy with the idea of instinctual knowledge of the technical and of how spider webs and beaver dams can look like impressive engineering feats.

The purpose of this thesis is to argue that natural artifacts (as lease some of them) ought to be regarded as epistemically equal to human-built technologies. To argue this, I extend the work of Davis Baird on ‘thing knowledge’ to observations from biology, anthropology, and engineering. Ultimately, I conclude that we might regard technologies as existing in a spectrum with regard to the instantiation of knowledge.

The subtitle of this thesis is “An Investigation Into What Counts As Technology and What Counts As Knowledge.” In this first chapter, I will lay out different definitions of technology and examine how some of these definitions are at odds with some intuitions we might have about created artifacts (Part A), describe ways in which we may think about technology and knowledge (Part B), and explain the understandings of two fields which will contribute to our understanding (Part C), and, finally conclude by trying to bring together these pieces to set up the problem philosophers of technology face (Part D). Our definitions of technology are going to be extremely difficult to maintain in the face of natural artifacts and literature on design. The distinctions between natural and artificial, between tool and object, seem artificial. Indeed, it seems that tools can be more or less complex, more or less useful, more or less necessary than others. Considering spider webs and beaver dams will lead us to gradations of technologies, a spectrum of possibility, rather than an either/or distinction between being a technology or not.

Part A: Defining Technology

Carl Mitcham and Robert Mackey, in the introduction to *Philosophy and Technology*, explain three basic ways in which we might take the definition of 'technology': epistemological, anthropological, and sociological.[2] Defining technology might be an epistemological project; it might also be a question of the role of humanity in the world; or, it might be a "characteristic of thought and action in modern society."[3] The definitions at which we will look will take the basic approaches that Mitcham and Mackey suggest or combine them in interesting ways. In the end, I think that we must pay attention to all three sorts of categories for a proper definition of technology.

Melvin Kranzberg and Carroll W. Pursell, Jr., prominent historians of technology, explain that technology involves "man's attempts to satisfy his wants by human action on

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[2] Mitchan and Mackey 1972

[3] Ibid., page 2

physical objects."[4] Kranzberg and Pursell explain anthropology as discovering that *homo faber* (man the maker) cannot be distinguished from *homo sapiens* (man the knower), and they say: "Man made the tools; but tools made man as well."[5] Perhaps obviously, Kranzberg and Pursell fall into the anthropological approach to defining technology. Man is a tool-user, and the tools have made man what he is. I'll discuss a challenge to this view in Chapter 3 in my discussion on tool-use among non-human animals.

Don Idhe, in *Philosophy of Technology*, explains technology "anthropologically and philosophically." He says that technology involves humans "relating to their environment." Non-human animals, of course, modify their environments, but, with humans, modification is magnified such that the power of humans over the environment is an important characteristic.[6] Idhe emphasizes the non-neutral power of humans with technology to transform, and Idhe identifies his view as anthropological.

Frederick Ferré, in *Philosophy of Technology*, defines technology as the 'practical implementations of intelligence."[7] Ferré notes that this definition does not restrict technology to humanity (though he rules out those phenomena which are based on pure instinct) and does not restrict technologies to modern times. But, this definition does restrict technologies to "something embodied in artifacts."[8] Ferré's definition is anthropological and epistemological, in that intelligence – or perhaps knowledge – must be implemented and that we might need to look at anthropological information to say

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[4] Kranzberg and Pursell 1967, page 7

[5] Ibid., page 8

[6] Idhe 1993, page 51

[7] Ferré 1988, page 26

[8] Ibid.

whether something is technology or not – whether the artifact was created by instinct or intelligence. This seems to be a more advanced anthropological approach than Kranzberg and Pursell and Idhe suggest, one that allows for creatures other than humans to create and implement technologies. But, Ferré also limits technology in a way that other philosophers do not. Ferré makes technology something that has to be embodied in some sort of artifact, some sort of physical object. Philosophers, like Joseph C. Pitt would resist this limitation that Ferré sets.

Pitt, in *Thinking About Technology*, defines technology as 'humanity at work,' which he claims leads to a view of technology where an input/output transformation takes place with the use of some feedback loop or mechanism to evaluate and improve technologies. In this way, Pitt allows for a court system to be as much a technology as a telescope.[9] Both the court system and a telescope can be improved over time; both have feedback loop type mechanism in their improvement over time (the appeals courts and better designs). Pitt's approach seems to be a sociological one. We make technologies and improve them over time through our interactions. Technology is defined by what we do, rather than what we are (as in the case with anthropological accounts). Pitt's account of technology reflects a larger change in philosophy of science. The creation of knowledge, among other things, is now taken as a social process.

Spurred on by the publication of *The Structure of Scientific Revolutions* by Thomas Kuhn in 1962[10] and by criticisms of the philosophy of science arising out of sociological programs, philosophers of science were directed to examine the history of

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[9] Pitt 2000

[10] Kuhn 1962

science in a new way. Namely, social factors and pressures often played a major role in the development, the acceptance, and the use of scientific theories.[11] Contemporary philosophers of technology, like Andrew Feenberg and Joseph Pitt, make a similar move, insisting on the importance of social discourse and influence on the history of technology (Feenberg) and in the making of technologies (Pitt).[12]

Part B: Technology & Knowledge

The importation of ideas from philosophy of science to philosophy of technology makes sense when presented with the development of the history of technology as a field and work done by historians of technology. Edwin T. Layton, Jr., has written extensively about the relationship between science and technology using metaphors gathered from Lewis Carroll's *Through the Looking Glass*. Layton talks about science and technology as "mirror-image twins," addressing the "scientific revolution in technology" of the 19th Century.[13] Layton argues that scientists help found the formal discipline of engineering as we know it today, but that the basic endeavors of science and engineering differed in methodology and in constraints, which led to a difference in language and in values. By 1900, Layton tells us that science and technology appeared as mirror-image twins – with "subtle and irreconcilable difference."[14] Even though one resembles his mirror twin, the images are not the same; they are different in important ways. Furthermore, to understand

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[11] Shapen and Schaffer 1985; Longino 1990; Latour and Woolgar 1986; Knorr-Cetina 1981; Pickering 1984.

[12] Pitt 2000; Feenberg 1999

[13] Layton 1971

[14] Ibid.

the image one needs to do some work in translating the image into the 'correct' direction, just as work in science or engineering had to be translated for the other. In engineering, there are principles of design; science has laws of nature. Engineers have design; scientists have law or theory. Engineers focus on practicality or workability, while scientists are concerned with truth.[15]

Technology was once widely considered 'applied science,' but Layton and others, like Barry Barnes, John Staudenmeier, Alexander Keller, Paul T. Durbin, Joseph C. Pitt, have overturned this idea by studying more carefully the interplay of science and technology through history.[16] Layton moves us to a view of science and technology where technology might also be considered a valid form of knowledge. Technology is no longer subordinate to science, but creates and involves knowledge of a particular sort.[17] Layton uses the work of A. Rupert Hall, holding that "technological knowledge is knowledge of doing or making things; the sciences are a more general form of knowing."[18] For Layton, technological knowledge is 'know-how.' Layton explains that technological knowledge is involved in design, and he divides technological knowledge into three 'compartments': technological theory, design, and technique. Layton also takes the design process and goal as the important hallmark of technology.[19]

Part C: Biology and Engineering on Design

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[15] Ibid.

[16] Layton 1987; Pitt 2000

[17] Ibid.

[18] Hall 1978

[19] Layton 1987

This role of design is crucial in our consideration of natural artifacts, and it comes with complications from literature in biology and in engineering. There is a great tension between the biological and the engineering use of ‘design,’ and, if technology involves design as a crucial component (as Layton says it does), the tension between the usages of this term could easily lead to confusion. Biological literature often uses the term ‘function’ or ‘design’. Biological function involves how a thing does what it does. Biological literature might say that spider webs are *designed* to catch the spider’s prey or that the function of the beaver’s teeth is to aid in felling trees. One might also use the teleological notion of function when speaking of evolution and the designedness [20] The difference between function in engineering and biology is perhaps more striking than design. Function, for a biologist, involves some property of an organism. Function, for an engineer, is the purpose for which something is used.

Function and design are employed in their usage in similar manners with slightly different meanings in engineering literature than in biological literature. ‘Design’ is loaded with more intention and more concreteness in engineering. One can be instructed to place the designs for a particular building into the proper file without confusion. But, design means much more than that. Henry Petroski, in *To Engineer is Human*, explains:

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[20] For more on this, see *The Stanford Encyclopedia of Philosophy* entry on ‘Teleological Notions in Biology.’ Available: http://plato.stanford.edu/entries/teleology-biology/. This question of whether a structure deploys evidence of design also brings us into issues of intelligence versus naturalism, but I will not be exploring this topic within this particular thesis.

> The idea of design – of making something that has not existed before – is central to engineering, and I take design and engineering to be virtually synonymous for the purposes of my development.[21]

Petroski goes on to say that failure is crucial to understanding engineering because engineering design is meant to “obviate failure.” Failures of design advance engineering knowledge.[22] The act of making a technology, in Ferré’s sense – of designing, in Petroski’s sense – leads to the augmentation of knowledge that helps us design and build in the future.

The problem, as some see it, is that these notions of design in biology and engineering overlap. In *The Extended Phenotype,* Richard Dawkins considers the web of a spider to be “a temporary functional extension of her body, a huge extension of the effective catchment area of her predatory organs.”[23] Dawkins goes on:

> … individual spiders have consistent idiosyncrasies which are repeated web after web…. [O]ur belief that spiders’ webs have evolved their efficient shape through natural selection necessarily commits us to a belief that, at least in the past, web variation must have been under genetic influence… From the viewpoint of this book an animal artifact, like any other phenotypic product whose variation is influence by a gene, can be regarded as a phenotypic tool by which that gene could potentially lever itself into the next generation.[24]

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[21] Petroski 1985, preface

[22] Ibid.

[23] Dawkins 1982, page 198

[24] Ibid., page 199

Dawkins makes the case that spider webs are part of the spider's phenotype, tools that allow for the extension and flourishing of spider predatory activity. But, why is all this of interest?

Part D: The Set-Up

Discussing definitions earlier, I explained how Kranzberg and Pursell wanted to anthropologically define technology in terms of the tool-making ability. It seems that, in the same way that 'man made tools, and tools made the man,' spiders make webs (tools), and webs (tools) make the spider. Our anthropological distinctions, here, seem inadequate to accomplish what was hoped, to easily distinguish between something which is a technology and something which is not. Our social definitions may, too, be at risk. While we have the improvement of technologies over time with subsequent failures and designs, we might also see evolutionary mechanisms as performing the same role in non-human-made creations. "Failures of design" in natural artifacts can cause creatures to be unable to make it into the next generation. If a spider is unable to catch prey because of some inability to make a proper web, the genes for the making of this inadequate web will be lost. The survival value of the tools of non-human animals – their webs, their dams, their anthills, their nests, etc. – leads to the 'right' genetics to be passed on. The role of social mechanisms in definitions of technology could easily be replaced in the animal kingdom with notions of evolutionary selection, and, in fact, we may apply evolutionary mechanisms in our descriptions of technology. If 'tools made the man,' the tools would be regarded in Dawkins' scheme as part of our extended phenotype. Tools are modified and improved over time with feedback mechanisms (failure, redesign, or natural selection). Or, if a tool fits its task well, the feedback mechanisms will lead to the tool remaining how it is for some period of time. The rate of improvement over time has not yet been a part of social definitions of technology, but we can think of human-made tools which have remained in basically the same form for eons (like knives, bowls, and nets), so it seems as this would not be a worthwhile addition. We are left with some sort of epistemological or combined approach to defining technology.

By examining technologies with knowledge in mind, we may reach a definition of technology that satisfies concerns we might have about our technologies as they are related to natural artifacts that also seem useful to their ‘owners.’ If we examine our technologies as embodying or presenting knowledge, we can come to some very interesting conclusions because we can see the similarities between what non-human animals build and what we build. These similarities are already present in the way we think about beaver dams and spider webs; we admire their creations, their skill. But why should we? Currently, there are tensions between and within our ideas about technology and natural artifacts in the world; we see ourselves as so far detached from the ‘natural’ world and think of our technologies as making us who we are. This thesis will move toward gathering together some of the pieces we need to make sense of this mess. In the remaining chapters, we will find that our notions of technological knowledge and technological artifact are at odds, and so we must reconsider technology. I will recommend a spectrum approach which coheres better with how we think of, how we use, and how we speak about technology.

Chapter II: Technological Knowledge

In this chapter, I explain how natural artifacts can bear knowledge and that this claim about natural technologies does not entail the agency of artifacts. First, I will explain Davis Baird's idea in *Thing Knowledge* of 'thing knowledge' and evaluate it by looking at what might count as knowledge-bearing under his philosophy (Part A). Second, I will look at the work of Joseph C. Pitt in *Thinking About Technology* and discuss how his 'feedback loops' might speak against the move toward regarding natural artifacts as technologies (Part B). Third, I will evaluate Baird's 'thing knowledge' through Helen Longino's types of knowledge discussed in *The Fate of Knowledge*; Baird's types of 'thing knowledge' seem to synthesize several of her types of knowledge (Part C). Fourth, I will discuss how Actor-Network Theory (ANT) contrasts with what I suggest about the extension of 'thing knowledge' to non-human-built objects (Part D). I will conclude that we can regard 'natural technologies' as epistemically equal to the objects made by humans, but this conclusion does not necessarily entail support for Actor-Network Theory.

Part A. Baird's 'Thing Knowledge'

In his 2004 book *Thing Knowledge*, David Baird rethinks the classification of scientific instrumentation in epistemology. Scientific instruments are more than just instrumental in our dealings with the world. Rather, instruments bear knowledge that is the epistemological equal of the knowledge we express verbally. Baird explains in the beginning of his book:

> Along with theories, the material products of science and technology constitute knowledge. I focus on scientific instruments, such as cyclotrons and spectrometers, but I would include recombinant DNA enzymes, “wonder” drugs and robots, among other things, as other material products of science and technology that constitute our knowledge. These material products are constitutive of scientific knowledge in a manner different from theory, and not simply “instrumental to” theory.[25]

Scientific instruments, for Baird, constitute knowledge in a way that may not be as easily expressed through words, but, nonetheless, should count as knowledge. Baird offers three types of ‘thing knowledge,’ each corresponding to a different type of scientific instrument. He explains that there is no one way to treat knowledge and argues for a pluralist view by showing how different kinds of things “constitute knowledge in fundamentally different ways.”[26] Baird’s three types of ‘thing knowledge’ help to demonstrate how knowledge can be encapsulated in different ways.

The first type of ‘thing knowledge’ with which Baird deals is the knowledge of models. Working in a way that most closely resembles theory, physical models of the solar system, miniature water wheels, and the ball-and-stick DNA models all encapsulate some sort of understanding about the world. Baird calls this kind of knowledge a ‘material mode of representation.’ Models explain some part of the world in ways that may not even be able to be expressed verbally or that may not be as easy to express

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[25] Baird 2004, page 1

[26] Baird 2004, page 12

verbally. Models help us work things out and allow knowledge to be rendered more clearly.

Baird uses the "DDI" account of R.I.G. Hughes[27] concerning the semantic view of theories to help explain what it is that models do for us.[28] "DDI" stands for 'denote, demonstrate, interpret.' Models represent or signify some aspect of the world; they denote. However, it is not necessary that a model resemble what it denotes, just as illustrations look more like illustrations than what they were meant to depict.[29] But, often models do look something like what they are supposed to represent, like the model for DNA that Baird discusses.[30]

To understand a model, one must understand what it is being denoted or symbolized by each component. After one has that understanding, one can work on the second step of the "DDI" explanation: demonstration. Models can be used to demonstrate how the world is, as with a mechanical model of the solar system, or how something could be done, as with the miniature waterwheel that Baird discusses.[31] A model's power of demonstration allows for explanation and prediction. Physical models can mimic the way in which we use mathematical and conceptual models,[32] so this type of 'thing knowledge' seems rather uncontroversial. So, too, the third leg of the "DDI," interpretation, can be performed with a well-designed model. Models can help us come to

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[27] Hughes 1997

[28] Baird 2004, pages 37-39

[29] Ibid.

[30] Ibid.

[31] Ibid.

[32] Ibid.

interpretations or approximation that are often also demonstrated mathematically or through laboratory data, as in the case of what Watson and Crick figured out by working with the physical models for possible formations of DNA.[33]

Baird offers a second type of material knowledge in the form of what he calls "working knowledge."[34] Working knowledge might be commonly referred to as 'know-how' that is demonstrated or instantiated by the construction of a device. Baird explains:

> Subjectively, a person who has "a working knowledge" has knowledge sufficient to do something. Objectively, a device that bears working knowledge works regularly. It presents a phenomenon, which might be used to accomplish something. This form of material knowledge, in contrast to model knowledge, is not representational, but rather appeals to pragmatist notions of knowledge as effective action.[35]

Baird gives examples of the pulse glass of Benjamin Franklin, Michael Faraday's electromechanical motor, and the air pump of Robert Boyle, and cyclotrons in explanation of his idea of 'working knowledge.' Baird, once again, analogizes this form of knowledge to knowledge that can be expressed verbally. "Much as we control concepts through the exercise of our literary skills, we control material agency through the exercise of our making skills."[36] 'Working knowledge' is in the man-made devices which allow us to control a phenomenon. This type of 'thing knowledge' relies on success, not representation of the world.

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[33] Ibid.

[34] Baird 2004, page 41

[35] Ibid., page 45

[36] Ibid., page 47

Success involves proper and steady operation. Oftentimes, these scientific instruments become increasingly complex. In this way, scientific instruments that create phenomena meet pragmatic standards of knowledge. Baird goes so far as to say that, for working knowledge, "objective knowledge is in the instruments and the materially instantiated techniques that constitute instruments and make their construction and reliable operation possible."[37] Baird describes instruction manuals and journals about instruments as mere records of techniques for getting what you want; they provide mere descriptions of working knowledge, and are not themselves bearers of knowledge in the way the scientific instruments that bear working knowledge are.[38]

Baird allows for a third type of 'thing knowledge' in the form of 'instrumentally-encapsulated knowledge,' or scientific instruments for measuring. Baird borrows from his two earlier notions of 'thing knowledge' – model knowledge and working knowledge – to use in characterizing his third type. Though measuring instruments are not models, they represent the possibilities in outcome in a way similar to models. And though measuring instruments are not cases of working knowledge, measuring instruments need reliability much like the devices that bear working knowledge. Baird uses direct-read spectrometers as his main example of instrumentally encapsulated knowledge.[39] Working knowledge and model knowledge are built into the workings of this final type of knowledge-bearing scientific instrument.[40]

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[37] Ibid., page 66

[38] Ibid.

[39] Ibid., page 69

[40] Ibid., page 70

People involved in science and technology studies talk about the ‘theory-ladeness of observation,’ the idea that, when we observe something, we have some set of theories in the background that works in our explanation of what we observe. Importing Baird’s instrumentally encapsulated knowledge, we might say we also talk about the theory-ladeness of our measuring instruments. Baird explains how good instruments “de-skill” a process, like reading the lines from a spectrograph. The direct-read spectrometer provided a substitute for the need for humans to read the lines of the spectrograph.[41]

Baird goes on to explain how analyzing how the parts of a measuring instruments work is not a sufficient explanation of the epistemic workings of an instrument because the parts cannot be properly account for the knowledge that the instrument bears.[42] Measuring instruments work in a way that uses all the parts, or, as Baird puts it, “presents an epistemic synthesis, seamlessly joining representation and action to render information.”[43] Building an instrument which bears encapsulated knowledge in the way Baird describes relies on overcoming many difficulties to successful operation. The instrument itself becomes skilled in the process of its development. Measuring instruments often work “synthesizing working knowledge, model knowledge, theoretical knowledge, and functional equivalents to skill knowledge.”[44] These types of instruments join material and idea and behave in ways unique to this union. Knowledge in these instruments involves more than just theory, but also the reality of materials by which the instrument is constructed for its proper analysis and use.

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[41] Ibid.

[42] Ibid.

[43] Ibid.

[44] Ibid., page 88

Baird's three types of 'thing knowledge' allow for many different types of scientific instruments to bear knowledge. Baird moves his classifications of knowledge to the idea of truth. One standard philosophical definition of knowledge is 'justified true belief,' but Baird lets go of the 'belief' part in favor of talking about knowledge in instruments as 'ringing' true. [45] Baird explains:

> 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.[46]

Just as we talk about something 'ringing' true, Baird explains the knowledge that successfully functioning instruments bear as having that sense of truth. For Baird, material truth involves success. We can speak about 'a true wheel' and mean that the wheel works properly and dependably, in addition to its correspondence to some form of wheel.[47]

Baird discusses five ideals for knowledge to demonstrate how instruments count as bearing knowledge with the idea of functions in mind. His five ideals include:

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[45] Baird 2002

[46] Ibid., emphasis added to quotation

[47] Baird 2004, page 122

detachment, efficacy, longevity, connection, and objectivity.[48] ‘Thing knowledge’ is constituted by instruments that can be detached and used in other places, are effective for their purposes (succeed in bringing about some goal), work reliably in the future, make a connection between the world and us (in this case a very material connection), and provide an objective way to judge the world within the context of our connection to it.

Baird describes his three types of thing knowledge, but we must inquire as to how the wonder drugs and robots he mentioned in the beginning fit into his scheme. Certainly science uses the types of thing knowledge suggested by Baird, but does Baird’s layout of thing knowledge apply to technologies and objects not from science? Baird has helped us in moving the idea of knowledge to technologies, but how far does this extend?

Baird’s five ideals (detachment, efficacy, longevity, connection, and objectivity) do not speak against the inclusion of natural objects as knowledge-bearers. While spider webs and beaver dams cannot be detached from their surrounding, some instruments, like complex, large, industrial microscopes, are just as difficult to move. Moving may cause damage that will need to be repaired and needs to be done very carefully. Moreover, spider webs and beaver dams can be constructed elsewhere; the idea of a spider web does not change from place to place, so the knowledge involved seems as if it can be detached and moved. Spider webs are also very effective for their purposes: spiders are able to catch food to survive thanks to their web-spinning abilities. Though the longevity of a spider web may be questioned, in the right environment, spider webs will remain, be used, and continue to work, and be built upon by a spider. Spider webs also present a connection between the spider and the larger material world. Spider webs also must

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[48] Ibid., page 120

conform to the world and its standards; spider webs must be built within the world and its constraints, so it meets the ideal of objectivity as well as a large microscope does. Baird discusses how these ideals are met by scientific instruments, though not always perfectly, as in the case of longevity. Instruments wear out sometimes, but we still trust them to work for some amount of time.[49]

But, what type of thing knowledge do spider webs and beaver dams use? I suggest that working knowledge is involved in spider webs and beaver dams. Working knowledge allows for the control of some phenomenon. Spider webs and beaver dams still require some skilled use to be effective, so they do not quite meet the standards of instrumental encapsulation. And, a spider web or beaver dam hardly seems to represent something in the world, so it seems as if they don't qualify as model knowledge. Baird, because he writes about scientific instruments, does not provide for all possibilities of 'thing knowledge,' so, though spider webs and beaver dams may not fit perfectly into working knowledge, it seems the best category. Working knowledge involves pragmatist ideas about effective action. Spider webs and beaver dams work regularly and work well for their suited purposes. Given that they meet the five ideas of knowledge as well as scientific instruments do, I see no reason why to exclude these natural artifacts from consideration as a technology from an epistemological standpoint, though that ruling cannot yet be made. But, at least from an epistemic point of view, we have reason to believe that natural artifacts are candidates for bearers of technological knowledge of some sort.

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[49] Ibid., page 121

Part B: Pitt's 'Feedback Loops'

Joseph C. Pitt, author of *Thinking About Technology*, would argue against the simple move made in Part A, though his work and Davis Baird's are not incompatible. Joseph Pitt gives a very broad definition of 'technology,' in his book *Thinking About Technology*. Technology, for Pitt, is "humanity at work."[50] Pitt explains that "[T]he tools themselves are not the technology; it is the use to which they have been put that marks out a technology, and it is people who do the putting to use for some purpose." Pitt argues that technology goes through a social process in its development. Pitt develops his idea of technology, or "humanity at work," and models technology as "an input/output transformation process."[51] Pitt wants to get us away from talking about technology as artifacts so that we may concentrate on the processes involved in technology. Specifically, Pitt says that work, in his definition of technology as 'humanity at work,' involves "*the deliberate design and manufacture of the means to manipulate the environment to meet humanity's changing needs and goals*."[52] We find the notion of design present in Pitt's account, just as it is in engineering literature. Pitt spends a great deal of time discussing the relation between science and technology. For him, what a scientist is for science, the engineer is for technology.[53] But, this focus on design leads us to further complications with the biological material on the subject, as noted in Chapter 1. Pitt's phrase 'deliberate design' may get him off the hook, though it leads to further problems. What counts as deliberate?

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[50] Pitt 2000, page 11

[51] Ibid., pages 11, 13

[52] Ibid., page 30-31

[53] Ibid., page 31

I use technologies every day without a lot of thought about the technology or the process. When I go to work in my garden, I grab a shovel and one of those thingies that I can beat up clumped up dirt with, but the technology is already designed, and my use of it, though manipulating my environment, does not involve any real thought about it.[54] And what about things which are not used for the purpose for which they were designed? Henry Petroski has a colorful anecdote in his book, *Small Things Considered*, where he discusses the "pizza saver."[55] Few people know the pizza saver by its name, but the description seems to 'click' with everyone. Pizza savers are those little plastic tripods that keep the cheese of your pizza from sticking to the lid of the pizza box. Petroski explains how the pizza saver is a great design because everyone recognizes it, and they have often been put to other uses. Listeners to a radio show that Petroski was on called and wrote about their uses for the plastic tripods. Pizza savers can be used to display spherical objects, stacked between palettes for paint storage, for holding eggs to be decorated for a holiday tree, etc.[56] I remember saving the plastic tripods from pizzas and using them as Barbie tables (no matter that they were horribly out of proportion to Barbies – imagination works). But, pizza savers were deliberately designed and manufactured for the purpose of keeping cheese off the roof of the pizza box. Pitt's definition here speaks against the uses of decorating and using these plastic tripods in other ways and having the use count as technology. This is a major problem with his view, and one that speaks against his very specialized view of technology as it relates to engineering and science.

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[54] This, of course, is not the construction of a technology, but its use, though I make a deliberate choice to use a particular technology. Later, in Chapter 3, I give examples where animals pick up an object to use as if it were a tool made for the purpose to which the animal puts it.

[55] Petroski 2003, page 3-16

[56] Ibid., page 6-8

But, Pitt's view is specific to the current sociohistorical context, and he admits as much, saying that much of what he has "to say about technology may not apply to earlier historical periods."[57] Given this, I think we might conclude by analogy that his thought may not apply to more primitive technologies, and so his philosophy does not necessarily speak against the inclusion of spider webs and beaver dams throughout time, but rather the inclusion of spider webs and beaver dams today. This is a weird sort of claim to make, but, if we take his view, we might take the fork and the wheel to not be technologies in the proper meaning today because their design was determined before the modern era. If this is what Pitt is after, then it seems as if we have no argument, in that Pitt would be neither for nor against the inclusion of spider webs and beaver dams in past concepts of technology. (And, since we are in this particular sociohistorical context, the question of inclusion in the past might not make sense.)

But, rather than get bogged down in problems coming from his modern day view of technology, let us focus on his use of input-output transformations as a feature of technological design. Though Baird's argument applies only to material things, Pitt's model of technology would allow us to include non-material things. The Supreme Court of the United States is even suggested in Pitt's book:

> Lest there be an objection to using the courts in the context of technology, I remind the reader that the judicial system is a tool for adjudicating social conflict, a technology if there ever was one![58]

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[57] Pitt 2000, page 28

[58] Pitt 2000, page 85

The creation of the courts has progressed from some level of simplicity to more complexity with precedents. And, as Pitt has pointed out, the courts are a tool.

The Supreme Court is not model knowledge in Baird's sense, though we might enlarge the idea to include the representation of non-physical ideals from which the court system is designed. Working knowledge might be our best candidate for a type of thing knowledge which the Supreme Court might bear. The courts have gotten more reliable in how evidence is processed and in how juries are selected, with women and minorities now being eligible for duty. Also, more complexity has been added in the system. As for instrumentally-encapsulated knowledge, the Supreme Court might be seen as an instrument of justice, though this is more abstract that Baird might want to allow. The inputs and outputs of the Court are verbal, not material, which makes it more difficult to analyze using Baird's framework. In the same way that Baird expands our notion of technological knowledge, Pitt is also concerned with the expansion of technology to non-material systems and processes. The Supreme Court seems just as thing-ish as the electron microscope. The legal system, as Pitt describes it, results from the evolution of mechanisms for conflict resolution in a society, with constant feedback and reevaluation of the decision-making process. In this way, the legal system seems to mimic the design mechanisms we see in place in the animal kingdom.

A natural artifact, like a spider web, involves some sort of input-output process with a feedback process. The web has a specific purpose for which it seems to be designed (if we accept a biological notion of design), and it, with the energy a spider puts into making it, they are able to get some output, dinner. And, web building became evolutionarily better over time.[59] The case for beaver dams makes for an even stronger case, perhaps because beavers are mammals, and we can recognize some of what they do as similar to some of what we do more easily. In *Romance of the Beaver*, A. Radclyffe Dugmore explains the purpose of a beaver dam.[60]

> The most conspicuous work, so far as visible results are concerned, is the dam; and the purpose it serves is not so much to make a swimming pool, as some people imagine, as to keep a body of water at a more or less constant level in order to ensure certain ends: (1) to conceal the entrances to the houses and so prevent the entrance of any land enemies, (2) to be a place for the safe storage of wood for food during the winter, (3) to render the transporting of this wood as simple as possible, and (4) to be a place of retreat in case of attack. [61]

So, beaver dam are put to work for several good purposes. Dugmore goes on:

> To better appreciate the value of the dam, it is necessary to understand the structure of the houses, for there are several types. The most primitive is simply a hole in a bank, with no surface work. This represents what is probably the original and primitive form of house… Then we have the next step in advancement: the hole in the bank with the living chamber coming to the surface, so that in order to make it more secure against marauders and render it drier, a rougly arranged pile of brush and stick,

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[59] Foelix 1996

[60] Dougmore 1914, pages 14-15

[61] Ibid.

> logs, and mud and grass is heaped over it. From this, it is but a step to the house which is entirely above ground…[62]

It seems as if beaver dams might qualify for the same improvements in design that we normally think about in terms of human improvements of technology. Beavers also seem to ‘plaster’ their lodges with mud, which hardens during the freezing temperatures of winter.[63] Beaver dams go so far as to rival the designs of the dwelling structures of some early humans and some bad campers. As far as the encapsulation of technological knowledge goes, this sophistication of design points toward some level of encapsulation of working knowledge since the structures seem to rival things we consider bearers of working knowledge. Because Baird allows that detachment is an ideal of technology, it seems natural that two structures that serve the same function would seem to bear similar degrees of knowledge. Function or design might be one dimension on which we can compare built artifacts. The emphasis on design and the use of transformation that we see in the philosophy of Joseph Pitt may actually help the case of the consideration of beaver dams and spider webs as technology. The social process with which Pitt is concerned might be substituted with some notion of an evolutionary process of design, which will be spelled out more clearly in Chapter 3.

Part C: Longino’s types of knowledge in the face of Baird’s ‘thing knowledge’

Helen Longino, in *The Fate of Knowledge*, gives us three senses of knowledge: knowledge as knowledge production, knowledge as knowing, and knowledge as

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[62] Ibid.

[63] Ibid., page 16

content.[64] Longino's senses in which we may take 'knowledge' differ widely and may help us understand Baird's 'thing knowledge.' The first sense of knowledge, knowledge-production, the process of making knowledge, involves two possible understandings, an empirical account and a normative account. The empirical account can be derived from social science literature while the normative account usually comes from philosophers. The philosophers are interested in the processes that justify a belief, while the social scientists are focused on the processes that generate particular beliefs and secure them in a community.[65]

We might be tempted to take scientific instrumentation as part of the process involved in knowledge production; the instruments do not bear knowledge themselves, but they aid in its creation. But, Baird's 'thing knowledge' speaks against this possibility. Though scientific instruments might also help in knowledge production, instruments carry knowledge themselves. Scientific instruments can teach us, as with model knowledge, and other instruments can help us explain without words, as with Faraday's electromechanical motor, an example of working knowledge. Those instruments that bear encapsulated knowledge, like cyclotrons, though they are involved in the process of the creation of knowledge, rely on and encapsulate several types of knowledge to work in the first place. So, though we may see a role for things in knowledge production, Baird does not seem to be talking about 'thing knowledge' as a type of knowledge production.

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[64] Longino 2002, page 77-85

[65] Ibid., page 79

Longino’s second sense of ‘knowledge’ is knowledge as knowing.[66] Knowing involves the state of having a justified true belief, truth. Knowing some justified piece of information involves a normative and an empirical perspective, as well. Knowing, empirically, involves the acceptance of a proposition which accords with the acceptance or standards of acceptance of the community – this is of interest to social scientists. Normatively, knowing involves accepting some proposition that is true and in accord with the process of justifying a belief – over which philosophers have traditionally shown more concern. Knowing involves having some sort of good reason for a belief, whether through community standards or some standards of logic and evidence that matter to the individual. We can speak of someone having knowledge of something, of knowing.

‘Thing knowledge’ is a material form of knowledge, something which Longino does not discuss in relation to knowledge as knowing. Longino focuses on propositional, a type of verbal, knowledge, which has traditionally been the concern of philosophers. Baird, however, gives us something more to consider here. Knowing propositional knowledge involves active agency in the knowing, but, for ‘thing knowledge,’ the instruments themselves do not decide upon a proposition and its testing, rather the material facts about the world matter in its proper functioning. ‘Knowledge Bearing’ does not necessarily entail knowing in the sense of conscious agency, but we may want to say that scientific instrumentation plays a part in the reasoning that led to the confirmation/testing of a proposition. But, more than this, we might suggest that conscious agency is not a necessary part of knowing. That instruments bear knowledge

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[66] Ibid., page 80

might involve some sort of knowing because the instrument is charged with the measuring or modeling or setting up of phenomena.

The third sense of ‘knowledge’ that Longino addresses is knowledge as content.[67] This type of knowledge involves a body of knowledge. We can speak of a chef as having culinary knowledge or an aeronautical engineer as having mechanical knowledge of some sort. We can specify bodies of knowledge found in books and journals; Longino also includes some of this knowledge as possibly being on tape or disk.[68] Longino also breaks this knowledge as content into the categories of normative and empirical. In the empirical sense, knowledge as content involves what is accepted in a given community. In the normative sense, knowledge as content involves some set of truths which can be known by a community or individual and used to make decisions.[69]

Knowledge as content seems to be part of the record of knowledge that Baird mentions as “instrument cookbooks” in reference to working knowledge.[70] Baird explains:

> The information in this book [Moore, Davis, & Coplan’s *Building Scientific Apparatus* (1983)] and others like it, and, more generally, in the practices that are passed from teacher to apprentice at laboratories such as the Berkeley Radiation Laboratory, constitutes an important resource for making instruments – making working knowledge.[71]

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[67] Ibid., page 82

[68] Ibid., page 83

[69] Ibid., page 84

[70] Baird 2004, page 64

[71] Ibid., page 65

Though these types of how-tos offer some part of Longino's knowledge of content, the record of working knowledge, they are not the knowledge that is encapsulated in the instrument. So, knowledge of content can play into the record of 'thing knowledge,' but knowledge as content does not perfectly capture 'thing knowledge' because the content Longino describes remains largely verbal in character, so it seems at first.

Longino perhaps arrives somewhere closer to Baird when she explains:

> Both knowledge production and knowing involve agents or subjects. Knowledge as content, though it has to have been produced by some agent(s) in some context, can be materially detached from particular agents or subjects. It exists in representations.[72]

In this way, we might more easily include model knowledge, one type of thing knowledge, within the description of knowledge as content. Model knowledge is representational in the way an illustration or mathematical representation might be. But, knowledge as content doesn't quite explain the idea of working knowledge, another type of Baird's 'thing knowledge,' knowledge involved in producing some phenomena in some device.

If conscious agency can be separate from knowing, which I am not sure Longino would allow, we can make sense of working knowledge in Longino's account. And, model knowledge can be taken as knowledge as content. Where does instrumentally encapsulated knowledge fit? Instrumentally encapsulated knowledge, that of complex measuring devices, involves theoretical knowledge (a type of knowledge as knowing or as content), working knowledge, model knowledge, and skill knowledge, according to

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[72] Longino 2002, page 149

Baird. Longino explains how her senses of knowledge are interdependent. We can take, then, instrumentally encapsulated knowledge as a synthetic type of knowledge instantiated in material form. If we accept a pluralism with regards to knowledge, as Longino advocates in her book, Baird's account of 'thing knowledge' seems quite reasonable. Longino and Baird both embrace plurality. Baird explains:

> A primary consequence of the epistemological picture I am presenting here is that no single unified account of knowledge will serve science and technology. In advancing a materialist account of epistemology – thing knowledge – I do not also argue negatively that propositional and/or mentalistic accounts of knowledge are wrong. On their own, however, they do not provide a sufficient framework for an adequate epistemology of technology and science.[73]

Though we can allow for a pluralist account of epistemology, can we allow for the newer view concerning technologies, namely their agency? My discussion of Actor-Network Theory will address this issue. The inclusion of material artifacts as knowledge does not necessarily speak toward the agency of these objects. The case for this is perhaps best made through the natural technologies that we encounter. Treating them as agents through this sort of framework would be to make additional assumptions not made by Baird and Pitt on epistemology and technology. To say that something bears knowledge does not entail saying that the object can act upon that knowledge.

Part D: Actor-Network Theory

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[73] Baird 2004, 11

If objects bear knowledge, some might be tempted to assign agency to these objects. In *Reassembling the Social*, Bruno Latour explains several features of an Actor-Network Theory.[74] First, the theory must grant the role of agent to non-humans, including "microbes, scallops, rocks, and ships."[75] Second, the theory must destabilize the state of the social world. Third, the theory must work to overcome deconstruction and division by "reassembling the social" in terms of new institutions and concepts.[76]

One of the major components of Actor-Network Theory involves the treatment of non-humans as "actors." Baird's work and my extension of 'thing knowledge' does not lead to Actor-Network Theory of any sort. To say that some object bears knowledge is not to say that the object acts upon the world. Latour would count microbes and as agents,[77] and we might be led so far as to say microbes bear knowledge about the world in some form, but these two ideas should not be reduced to the same idea as they are very different – on regards agency and the other regards knowledge. It is a great leap from the encapsulation of knowledge to agency in the philosophical sense. A commitment to beaver dams as bearing knowledge does not lead to the conclusion that beaver dams are agents.

Part E: Conclusions

In this section, I have shown how some pluralist accounts of knowledge might allow for non-human-made created objects to be regarded as encapsulating knowledge, much in the

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[74] Latour 2005

[75] Ibid., page 10

[76] Ibid., page 11

[77] Latour 1988

same way we might regard scientific instruments as bearers of knowledge. This idea might seem unbelievable, but, with some further investigation into the natural realm and further reflection on the engineering and biological literature, I believe that, if we accept a certain movement in philosophy of technology, this conclusion is inevitable. If someone well acquainted with humans but unacquainted with beavers were to come across the destruction caused by the beaver and to come across a beaver dam, he or she would easily conclude that someone has been chopping down trees to block a stream. By the same token, if someone unacquainted with the abilities of humans to change landscapes were to come across an artificial lake, he or she might conclude that the lake was simply formed there without the aid of humans. Our notions of technological, engineered, artificial, and natural should be more contested than they have been up until this point.

By looking at some of the definitions of technology and the notions of design and function in biological and engineering literature, there seems to be more friction, more problems than have been examined. By looking into the epistemic status of beaver dams, spider webs, and other non-human-made created things, I hope to cause more problems, but I propose a possible solution. In the end, I think we must recognize a spectrum of possibility with regard to technology and artificiality. One way of mediating these definitional divides is by careful examination of the philosophy within the context of created and natural things. As I continue, I provide further grounding from the fields of biology, anthropology, and engineering to help clarify the subject.

Chapter 3: Anthropological, Engineering, and Biological Considerations: Object Manipulation, Tool, Artifact, Technology

The project of this chapter is to show how anthropological considerations concerning tool use and technological behavior might lead us to reconsider or be more precise with our notions of technology than we currently are. We have good reason to consider tool use in non-human species (Part B), and the objects of non-human tool-use might be considered technological knowledge of some form (Part C). Additionally, we must consider how our new ideas about technological knowledge fit into what we understand concerning engineering knowledge (Part D). I will further develop the notion of technology as a spectrum as part of this analysis of non-human construction and technological behavior.

Part A: Anthropological Considerations

Nicholas Toth and Kathy D. Schick, in *Making Silent Stones Speak*, discuss the differences between tools and technology.[78] Toth and Schick explain that archaeologists have often defined tools as objects that "have been used, either modified or unmodified, by human beings (or ancestral protohumans)."[79] They claim that this concept is useful for the purposes of archeology for the most part, yet it is inadequate when trying to understand the bigger picture. So, Toth and Schick spend time on tool use in the animal world. They explain tools in their most simple form as some external object used to

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[78] Schick and Toth 1983, Chapter 2.

[79] Ibid., page 48.

achieve some goal.[80][81] Tools are modified or unmodified objects that are used to do something by a human or a non-human. Artifacts, a type of tool, are objects that have been modified by humans, but, even this definition may be problematic, in that chimpanzees modify their tools such that they might be considered artifacts.[82] Schick and Toth explain that technology is larger than a simple tool:

> [Technology] refers to the system of rules and procedures prescribing how tools are made and used. In a broader sense, this term can be used for the systems of tool-related behavior of non-human species as well.[83]

But, Toth and Schick are quick to note that "technological behaviors" in non-mammalians are often more instinctual, meaning that they are typical of a species and inflexible, "bound to a set of stimulus-response interactions," part of the animal's genetic constitution.[84] But, chimpanzees demonstrate learning and culture which play a role in technology, thus the non-human species of chimpanzees that demonstrate this might be said to use and create technology, as they learn by error and imitation, things that philosopher Joseph Pitt takes as key in our understanding of technology with his notion of input-output transformation with feedback loops.[85]

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[80] Ibid., page 48.

[81] This idea might be contested by some who might view the tools of some animals as part of their extended phenotype – spider webs being the example of this previously touched upon.

[82] Ibid., page 49

[83] Ibid., page 49

[84] Ibid., page 51

[85] Pitt 2000

Toth and Schick go so far as to suggest that chimpanzees possess many of the hallmarks that we consider key in technology, including cultural behavior. They do retain limits, though, by setting tool use apart from technology. Curiously, they do talk about *technological behavior* in animals. If we can talk about technological behavior, it seems as if we might have room to talk about technological knowledge without insisting upon the items or actions in question to be technology proper. Certainly, beavers building dams, birds using twigs to get food, and others are performing tasks that appear technological in nature, if we consider tool-use a precursor to technology. Toth and Schick count "fewer than twenty" tool-using non-primates, but they do not consider spiders spinning web, ants building anthills and other more instinct-based behaviors.[86] In this way, though the considerations Toth and Schick bring up can easily move our discussions of technology to encompass at least chimpanzees in addition to humans, they do not move so far as to consider the creation and use of technology by non-humans widespread. Nonetheless, Toth and Schick provide us with interesting examples of technological behavior in animals and introduce us to an exciting new term: "technological behavior."

Part B: The Difference Between Webs and Dams

At this point, it might be worthwhile to consider the differences in those technological behaviors that arise in non-human creatures and to draw some distinctions. In Chapter 2, I discussed how we might extend the notion of 'thing knowledge' beyond its original domain of scientific instrumentation. Baird himself recognizes that the concept might be

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[86] Schick and Toth 1983, page 54

used for other material products of science.[87] To find out how far we might extend this notion, we need to be more meticulous about technological behaviors and the technological objects of this behavior, our candidates for ‘thing knowledge.’ To help in this endeavor, I will present several cases of possible technological behavior and proceed to analyze each in terms of knowledge.

“Cows use tools to preen,” read one ABC news headline.[88] According to animal behavior scientist Bob Kilgour, several breeds of cow spend three percent of their days grooming and will sometimes use upturned branches, trees, and fence posts to aid in their preening.[89] Kilgour suggest that the grooming procedures, common to the cows he observed and a type of bison he compared them with, suggest a survival advantage.[90] Additionally, the cows Kilgour witnessed seem to be using tools, but not in a way previously recognized. Specifically, tool use usually entails the manipulation of objects, which usually entails being able to pick the object up and grasp it.[91] Cows using upturned sticks and posts to preen themselves may be a great example of a use of a tool that is used, but not grasped or employed in an obvious sort of way. This type of tool use – the use of nearby or convenient objects to groom – seems most basic.

“Manufacture and use of hook-tools by New Caledonian crows.”[92] Ecologist Gavin Hunt describes two types of tools manufactured by a group of crows. They make

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[87] Baird 2004

[88] Skatssoon 2006.

[89] Ibid.

[90] Ibid.

[91] Ibid.

[92] Hunt 1996

and use types of tools to help catch prey, tools that Hunt calls a hooked-twig and a stepped-cute barbed pandanus leaf. Hunt observes three features of tool use: standardization, the definite making of a form in the shaping of the sticks, and hook-use, features which have only appeared in the tool-using cultures of early hominids.[93] Hunt reports that this "indicates that crows have achieved a considerable technical capability in their tool manufacture and use."[94] The crows observed by Hunt and his colleagues looked in different trees with the same shaped tool, transferred tools between their beaks and feet, and went back to pick up tools after putting them down. Additionally, the two tool types, which are quite different would seem to indicate that the tools are used for different purposes.[95]

"Dolphin mums teach daughters to sponge."[96] Michael Krutzen and his research group observed thirteen related dolphins (twelve female, one male) breaking off pieces of sponge in the shape of a cup while foraging for food to put over their noses to get fish to come off the sea floor.[97] The researchers could find no biological basis for the behavior, not before reported among the hunting tactics of dolphins, but the thirteen dolphins were found to be related. Researchers claim that this might indicate a shared material culture.[98] The cultural element of this story is most compelling. While it is common knowledge that dolphins are smart creatures, their use of sponges without prompting from humans and in

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[93] Ibid.

[94] Ibid.

[95] Ibid.

[96] Skatssoon 2005

[97] Ibid.

[98] Ibid.

their own wild habitats is quite remarkable. It seems that the dolphins in this particularly family are sharing strategies for catching fish. This cultural or sociological element to their use of this tool is worth noting.

More commonly observed, beavers build dams. The destruction caused by the building of and the construction of beaver dams is well known. To ecologists, beavers are sometimes referred to as "ecosystem engineers," as they change the habitats in which they live by participating in three types of "engineering activity": dam building, canal digging, and lodge building.[99] As a response to the sound of rushing water, beavers build dams which transform the habitats in which the beaver acts in order to get protection from predators. In the process, the water level in the area is increased, and, a pond is formed. Typically, beavers build their dams in the narrowest part of a stream where the sound of rushing water is at its most violent.

Web spiders spin webs. Rainer F. Foelix calls the ability to make silk threads is the "most characteristic feature of spiders."[100] These silk threads are stronger in terms of tensile strength many natural products, including bone and rubber, and about half the tensile strength of steel.[101] Each thread is amazingly complex, as are the spinning glands of spiders.[102] Only web spiders build webs while wandering spiders do not, though they both have the ability to produce silk. Orb webs are the most typical construction of webs, though some types of spiders build other types of webs. Orb webs are sometimes

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[99] Haemig 2006

[100] Foelix 1996, page 110.

[101] Ibid., page 111

[102] Ibid., page 111-119, with really creepy pictures of spider abdomens

considered the "evolutionary summit of web-building spiders."[103] Seen in two groups, arachnologists are unsure of the evolution of the web in the two species. There is speculation concerning how spider webs evolved at all, though some think that tripping threads may have been a precursor or that enlarged living spaces evolved into the spider web.[104] Web spiders seem to use their webs quite effectively, as the design has stabilized in the two orb web spinning groups and in other groups.[105, 106]

In captivity, Kanzi, a bonobo chimpanzee, was used to study early hominid tool making and use.[107] Kanzi's researcher friends showed him a stone flake used to cut a cord to open a box with a treat, and Kanzi learned to use the flakes to cut into other boxes.[108] And, he became effective at choosing the right sort of tool to cut with. Kanzi became skilled in how to flake his own stones and invented his own technique of throwing rocks on a hard tile floor in order to chip them, without the prompting of researchers.[109] He came up with his own method of doing the thing that the researchers were prompting him to do. The cultural element is important, but so is the ingenuity of this chimpanzee.

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[103] Ibid., page 145

[104] Ibid., page149

[105] As for wandering spiders, one type of Hawaiian spider is not a web spider, but dangles from a single silken thread and "impales small insects with the highly elongated tarsal claws of its front legs" (Foelix 1996). I'm not sure I'll be able to sleep tonight.

[106] In much the same why that Lara Tauritz explains how there is no one perfect design for a desk chair in here 2001 paper "Sitting Pretty," presented at the Society for the History of Technology meeting, we might say that there is no one perfect design for the spider web.

[107] Schick and Toth 1993, page 136

[108] Ibid.

[109] Ibid., page 137

We observe human technological behavior through archeological artifacts and more contemporary invention. We demonstrate technological behavior when we sit at our laptops writing our theses or when we use a bottle-opener to crack open a cold one. Moreover, we witness the technological behavior of others and are surrounded by objects coming from technological processes of all types. Here, in my office, I am in a room of carpet, cracking paint, a wooden door, ceiling tiles, the thingies that hold ceiling tiles, florescent lighting. There is nothing “natural” in here beside my flesh and the flesh of an apple rotting away in the trash. I sit in front of the stare of my computer with sticky notes on one side, books and articles and related debris on the other.

Though I have favored primates in my examples of technological behavior, giving one chimp example and two human ones,[110] I’ve also tried to give a couple accounts that give a nice range of possibilities in the discussion of technological behavior. From cows grooming themselves with sticks, to crows making what seem to be tools designed for particular purposes, to dolphins learning technological behavior from one another, to us humans working on writing papers and to those who have built useful things that last through time, the range of technological behavior is so large that it might make us ill at ease. Though humans in modern times might be the most immersed in such an array of technological behaviors, we are not the only species who demonstrates technological behavior in the way Toth and Schick use the notion.

Part C: Technological Knowledge and Technological Behavior

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[110] Here I assume that humans constructed the pyramids and choose to ignore the alien conspiracy theories.

While I take Baird's notion of 'thing knowledge' as a way of expressing the idea of technological knowledge, some may argue that the technological behaviors I've described do not necessarily require knowing of the sort with which we are familiar. Because I contend that there is a spectrum with regard to what we might classify as technology, I do not insist that every creature that demonstrates technological behavior (the use of some object or special material ability to alter the environment or one's ability in an environment for some purpose) has technology, nor does every creature create objects that encapsulate technological knowledge, nor does every created object or process constitute technology. But, there is a spectrum here. Furthermore, Baird's notion of 'thing knowledge' does not entail that everyone know or understand how a device works. In fact, some instruments that encapsulate thing knowledge de-skill a process. In the case of, say, a beaver dam, its construction is largely instinctual. Nonetheless, it may be considered a bearer of working knowledge that supports the five ideals of knowledge discussed in relation to Baird's philosophy discussed in Chapter 2. The demonstration of technological behavior points toward knowledge at work and objects bear working knowledge when they can demonstrate effective action in the world. Dams successfully function (as witnessed in the beaver's continued survival). Dams serve to make water levels rise so that beavers have an easier time hiding from predators and an easier time finding food in the winter without exposing themselves to predators. Though the awareness of the process might not be something a beaver can sketch out for us, we should not discount it. Knowledge is sometimes inexpressible in those terms for humans at times. Davis Baird gives the wonderful example of the Davenport motor to help show this.[111] According to Baird,

> 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... The invention bears some of Davenport's knowledge of electromagnetism.[112]

Without being able to articulate the theory or the engineering involved, Davenport could build a motor demonstrating those principles. I do not make a great leap in saying that a beaver dam demonstrates knowledge of something. Though this knowledge may be reduced to instinct or evolutionary mechanisms, it is still a feat to be able to build such a thing, a thing that bears knowledge about the situation of beavers in the world. If we accept Baird's argument concerning the material creations of science, the move to considering beaver dams and spider webs as bearers of knowledge is not a tricky one.

Animals (including humans) demonstrate technological sorts of behaviors when they use tools, from the cows who rub themselves on fence posts onward. Then, there are other animals, perhaps more advanced in terms of tool use who may actually be making objects that encapsulate some knowledge about how to get prey or how not to become prey; this further move on the spectrum would include spiders who make webs, beaver who make dams, and crows who make hooks. This further move on the spectrum does

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[111] Baird 2002

[112] Ibid.

not necessarily indicate that a species is more advanced than another, as some species may not be in environments such that they need to use tools or make tools for a survival advantage. Further over, when we consider objects that are made that we use within some process, we might consider things to be more built-up in terms of the amount of technological knowledge that it bears and the degree to which information must be culturally transferred or learnt.

Part D: Considerations from Engineering

Engineers are taken as the makers of technology in our contemporary society. We easily talk about how the items we use every day are 'designed' or engineered.[113] Henry Petroski, in *The Evolution of Useful Things* and *To Engineer is Human*, explains how failure furthers the design process.[114] When things fail – when bridges collapse, when shuttles explode, when breaks fail – we learn how to make those engineered objects better. Petroski explains:

> I believe that the concept of failure – mechanical and structural failure in the context of this discussion – is central to understanding engineering, for engineering design has at its first and foremost objective the obviation of failure. Thus the colossal disasters that do occur are ultimately failures of design, but the lessons learned from those disasters can do more to

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[113] The store Target™ mentions design about ten times in every commercial. They try to link being well designed with being better for us.

[114] Petroski 1992 and 1985

> advance engineering knowledge than all the successful machines and structures in the world.[115]

Failures of design and of implementation help us make better plans for the future. Our technologies improve as a result of failures. In a similar way, we might regard the constructed objects of non-human animals to go through a design process of sorts. Biological literature can talk about how spider webs are designed to catch prey. This design is not a conscious one for spiders. Webs are a product of the evolution of spiders. Before spiders used webs, a spider would have "a retreat with threads radiating from its opening."[116] Then, the catching plane of a web would have been enlarged, and so on until we got what we see today.[117] Given the fossil evidence, the 'invention' of the orb web had to be about 100 million years ago.[118] The evolution of the orb web conferred a survival advantage – web spiders spinning the webs could better cope with their environments, catching prey more efficiently to survive. Failure to cope in the environment would mean death. Failure in terms of biology and failure in terms of engineering seem to have a similar relationship to survival at times. Engineers and constructors who did not perform effectively would have to tweak designs such that they would not fail. In biology, organisms that did not adapt in such a way that they would fail would see the loss of their particular 'design' to the future.

Those who talk about technology as a sociological or anthropological feature of humanity are not wrong. But, when we expand technology with our notions of

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[115] Petroski 1985, page 2

[116] Foelix 1996, page 145

[117] Ibid.

[118] Ibid.

technological behavior and technological knowledge that come from our epistemological concerns, we might view the social and the anthropological differently. To help explain, I am going to be simplistic about the evolutionary process in order to talk about our new notion of social and anthropological. Over generations of spiders, new web and silk traits lead to better prey-catching for the spiders that get passed these traits. The ones that do not receive these traits die because they cannot compete with the ones who have the trait. A characteristic developed through trial-and-error in terms of evolution seems to point to some process over time between the spiders that results in something that looks a lot like an artifact with technological knowledge embedded in it (as well as moths). One spider passes the trait to its progency and on down. Though the trait is not learned by each spider, the instinct leads to the better construction of a web. This can be easily witnessed anthropologically; the spider develops this better capacity of its technological behavior in the world. But, in terms of a social process, spider generations improve over time through some sort of evolutionary mechanism in order to succeed in their particular situation. Though there is no interaction among the current generation, there is interaction through the generations such that the trait is conferred. This interaction might be taken as social/anthropological, and it is analogous to the human social process of improving technologies. We may be able to regard natural selection as some sort of cultural learning if we take generations of a particular species as a culture. We see some knowledge about the world, whether from the phenotype of the animal or from some social process, encapsulated in these tools and technological objects. Failure means modification to a design, just as failure of a particular web might mean that the design is not again repeated because of the death of the spiders that developed that web design.

In *The Evolution of Technology*, George Basalla explains that “any new thing that appears in the made world is based on some object already out there.”[119] In the same way that we can talk about evolution in the web designs of spiders we talk about our technologies, as Petroski does in *The Evolution of Useful Things*.[120] Petroski has a whole chapter describing the evolution of the fork in relation to the other silverware with which we eat. Describing the logistics of eating with just a knife, to two knives, to two-pronged forks for holding meat while cutting, to what we eat with today and how it is a function of what we eat and how we eat it, Petroski’s account could just as easily explain the evolution of the spider web and how it fits into an ecological niche for the web spider. Just as the development of chopsticks in the East developed parallel to knives in the West and the food follows from the use of the utensil, we can see by analogy that wandering spiders do not need webs and go further to catch prey (though often using silk and dangling), while web spiders stay in one area and wait for prey to be snared.[121] These two methods (for prey-catching in the case of spiders and for eating with in the case of humans) are equally good for their purposes, but the purposes are different, and so the ‘technologies’ are different.

There is no reason to regard the things made by spiders and beavers as vastly different in terms of epistemology from those things made by humans, such as a knife or a house. Walter Vincenti, in *What Engineers Know and How They Know*, describes the

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[119] Basalla 1988, page 45, as quoted in Petroski 1992, page 4

[120] Petroski 1992

[121] In Petroski 1992, he discusses the differences in Eastern and Western food-eating technologies. It provides great food for thought.

process of engineering as involving design, construction and operation.[122] Echoing Edwin Layton by taking design as a central element, he also discusses knowledge in terms of "knowledge of how to perform tasks" and "knowledge of fact."[123] Though he makes it clear that knowledge of very specific kinds is required for modern-day aeronautical engineering (his case study), he makes no claims as to whether the objects themselves bear knowledge. If we had to use his two categories of knowledge to describe the activities of spiders and beavers, we might speak of some sort of innate know-how, instinctual knowledge of how to build a web, the sort of knowledge we find in the material form of the web.

The literature on engineering considers design central, but, adding the biological notion of design, we are not limited to considering humans as fundamental in our definitions of technology. Rather, humans seem to have a larger amount of technology than Kanzi the chimpanzee. And, just as Kanzi might use technologies (the cement floor) that he does not understand, we use technologies everyday when we do not really have a good grasp of their construction. I understand in a basic sort of way how my laptop works, but, if you wanted me to make one, I would fail. My laptop bears knowledge such that I understand how to use it, but not how to make it. Spiders instinctively know how to use and make their webs, though you could not ask a spider to explain it to you. The knowledge that is encapsulated in a technology does not necessarily have to be

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[122] Vincenti 1990, page 6

[123] Ibid., page 13

understood in order for that object to encapsulate it, as Baird explained with his reference to the ideals of knowledge as discussed in Chapter 2.[124]

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[124] Baird 2004

Part IV: Conclusions: The Postive Project

Given the differentiation we can see through literature from biology, anthropology. and engineering, we have reason to conclude that technology, artifact, tool, and object are not clearly distinct, but seem rather like a spectrum of possibilities. Anthropologists Toth and Schick[125] helped highlight the differences between these categories, but these differences constitute relations between the concepts. In Part B of Chapter 3, I gave a brief description of different technological behaviors among a few different species. I take technological behavior to mean the use of tools to accomplish a task – behaviors that could at least lead to the belief that the one performing the behavior seemed to know what he/she/it was doing. More specifically, I take technological behavior to be what seems to be goal directed behavior that includes the use of found or made artifacts. In this way, ponds and rocks do not demonstrate any technological behavior, but beavers and monkeys do. I've also given a brief description of the relation between technological behavior (tool-use) and technological knowledge (encapsulated in the made tools).

In my introduction, I borrowed the way in which Mitcham and Mackey[126] explain how our definitions of technology typically fall into three groups: epistemological, anthropological, and sociological, and I classified the definitions of historians and philosophers into these groups. The anthropology-based definitions of technology included those by Kranzberg and Pursell, Idhe, and Ferré.[127] Kranzberg and Pursell's approach to defining technology was the straight-forward definition of technology with which most people are most familiar: man is a tool-maker, and so technology is bound up

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[125] Schick and Toth 1993
[126] Mitcham and Mackey 1972
[127] Kranzberg and Pursell 1967; Idhe 1993; Ferré 1988

in being human.[128] Idhe sees technology in terms humans in relation to their environments.[129] Humanity is bound up in both these anthropological definitions of technology, and neither definition would give proper hearing to the evidence Toth and Schick give concerning the use of tools by chimpanzees.[130] Limiting our definition to humans seem arbitrary. Ferré's definition of technology involves the use of intelligence in the making of artifact, which bars instinctually created artifacts from counting as technology, thus ruling out the beaver's dam but including Kanzi the chimp making stone tools.[131] We cannot always distinguish works of intelligence from those of instinct. Many non-human animal behaviors are learned, such as dolphins coming up with techniques for catching prey.[132] While catching prey is instinctual, the means for the job can involve the use of created objects. These created objects bear the socially transferred knowledge of a good way to hunt. If we make a simple distinction based upon instinct and intelligence, it seems as if we cannot dismiss all cases of non-human animal tool-use as not fitting into the class of things that we will call technology. Further, it seems as though we cannot even make this instinct-intelligence criterion because instinct and intelligence often flow together for creative acts in the world, as in the case of the social learning of dolphins.

As for sociological definitions of technology, which now seem to be popular, these also have problems. Joseph C. Pitt and Andrew Feenberg, as well as others in the philosophy of technology community, advocate sociological definitions of technology. Technology is a social process of improvement over time. Technology includes a learning process. Pitt includes court systems as examples of technology because they

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[128] Kranzberg and Pursell 1967
[129] Idhe 1993
[130] Toth and Schick 1993
[131] Ferré 1988; Toth and Schick 1993
[132] Skatssoon 2005

have a system for improvement (appeals), they involve inputs moving to outputs, and they show human action at work. Pitt, Feenberg, and others think of technology in a particularly modern context where we humans are always amidst technological processes and objects. But, if we think of the hunting techniques of dolphins and their improvement with technological developments (and it seems as if Pitt would allow us to say other techniques besides those that use objects would count as technology) and the learning process involved, then it seems as if we have reason to conclude that, again, humans are not the exclusive class of things that use technology. Additionally, sociological definitions of technology point to social processes at work in technology, which might simply work very well as one way to talk about gradations of technology, rather than have a use in solely in defining technology. The necessity for a social process would mean that an isolated individual could invent some process or object for his own use, and it would not count as technology. This seems counter-intuitive.

We can define technology epistemologically. If we base our understanding of technology on some sort of epistemological framework, those who are isolated can create objects which bear knowledge, and we can embed social elements in part of the spectrum to recognize those things learned through social processes compared with those things that are evolutionarily or instinctually engrained. In Chapter 2, I focused on Davis Baird's 'thing knowledge' as a possible way of using epistemology to define technology. Epistemology is the study of knowledge, and, if we can reasonably talk about objects or processes encapsulating knowledge in some way, it seems reasonable that we can use this idea to talk about whether something counts as a technology. Like our definitions that rely on anthropology, a definition from epistemology could involve some demonstration of intelligence or some encapsulation of knowledge. Since the idea of technology encapsulating knowledge, and since the amount of knowledge can vary, it seems the best way to start setting up a definition of technology that recognizes the built-up-ness of technology for which sociological definitions of technology strive and that allows for the variety of technological behavior that we witness in the animal kingdom.

I suggest that we regard technology as a spectrum. There are some technological behaviors that seem instinctual, as in the case of spiders or beavers, but even these behaviors reflect encapsulated information about the way the world is from evolutionary processes. So, even at the low end of our spectrum, the technologies we will discuss are still fairly complex. Somewhere in the middle of the spectrum, we might have some sort of social learning process, within which dolphins and Kanzi can be accounted. These groups of artifacts on the spectrum demonstrate some sort of thing knowledge which Baird refers to as ‘working knowledge.’ And, perhaps on the far end of the spectrum, we’ll have the Great Pyramids and Google, things that require learned knowledge and an encapsulation of knowledge that involve Baird’s other types of knowledge of models and instruments and a larger degree of de-skilling. By looking at our problem of technology as an epistemological problem, we can make a more coherent definition of technology that allows us to talk about modern technology without insisting that humans are the only species capable of tool-use. This spectrum-of-possibility definition allows for a more coherent approach to philosophy of technology, as our definitions of technology have been so varied as to not make sense when you put them all together. We might have reason for setting a cut-off, and saying some parts of the spectrum are only tool-use, some involve instinct, and so on. We might have reason to say that only part of the spectrum is technology proper, and the rest of the spectrum is tool-use of varying degrees of complexity and of social learning. Nonetheless, this spectrum, based on the encapsulation of knowledge, has not yet been recognized in the philosophy of technology literature, and it is important to consider as we discuss what technology is, where it came from, and how we deal with it – questions that face the field of philosophy of technology. We see that technology did not arise out of nothing; we see that humans are not the only users of technology, perhaps only the ones with the most diverse and continually-changing set. We can see our place within the larger picture that comes from the study of anthropology and biology.

As a foundational move, this spectrum approach to tool use and technology is meant to allow for an easier dialogue among currently very different definitions of technology. Though my approach starts as an epistemological one, social, biological and anthropological elements are important to seeing the full range of possibilities. As we talk about engineering in relation to technology, our analogies to nature seem more justified. K. Eric Drexler, in his popular book on nanotechnology, *Engines of Creation*, explains the wonderful possibilities with references to the technological creations of non-human animals. In one part, he has us "imagine a network of graphite-fiber strands, a spinning spiderweb kilometers wide with gaps the size of football fields between the strands" to explain lightsail space technology.[133] Drexler wants us to use the idea of a web to help explain how a particular technology might work.

To those who would say that my spectrum definition is arbitrary, I would reply that my definition is no more arbitrary than any other, and, in fact, my spectrum approach is far more useful than many of our current definitions of technology which have no way

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[133] Drexler 1986

of talking to each other. My suggestion for a spectrum definition, in fact, mediates those conflicts. We can talk about where particular definitions of technology come into the technological spectrum and demarcate technology from tool and from technical instinct and behavior. Furthermore, my spectrum suggestion coheres with how we typically think about spider webs and beaver dams. We can admire the technological behaviors of ants hard at work building a hill, and we can admire the good use to which beaver dams are put. We can even emulate the 'technology' of the spider, studying its design to help us make stronger, more durable fibers. Our notions of design that come from engineering and from biology do not have to remain isolated from one another when we consider technology as a spectrum.

In *The Evolution of Technology*, Historian George Basalla brings organic evolution and technological evolution into contrast. He explains:

> Because there is an excess of technological novelty and consequently not a close fit between invention and wants or needs, a process of selection must take place in which some innovations are developed and incorporated into a culture while others are rejected. Those that are chosen will be replicated, join the stream of made things, and serve as antecedents for a new generation of variant artifacts. Rejected novelties have little chance of influencing the future shape of the made world…[134]

Basalla's use of evolutionary mechanism to describe the social process through which technology is put corresponds nicely to Pitt's feedback loops.[135] Furthermore, the description of the evolution of technology corresponds nicely to the type of evolutionary

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[134] Basalla 1988, page 135

[135] Pitt 2000

development of spider webs and beaver dams discussed in Chapter 3. The disconnect in the analogy is in the purposeful shapping that humans do, versus the less purposeful activities of those driven only by instinct.[136] But, if we pursue our subject with the encapsulation of knowledge (whether intended or not) in mind, we can make sense of these two types of evolution as existing in a technological spectrum.

In *Science in the Age of Sensibility*, Historian Jessica Riskin applies the idea of "sentimental empiricism" to describe the development of modern science.[137] This notion, though a concept she introduces, has great descriptive power that allows her to draw important ideas together in interesting ways to give a more coherent picture of the Enlightenment and its contributions to science.[138] In a similar vein, I suggest the epistemological spectrum approach to technology is a useful explanatory concept. Some people may object that this concept will force ideas on people and things that would not accept it, as we could not reasonably ask a spider what sort of knowledge it encapsulates in its web. But, as Riskin is able to employ a concept to bring back in time to use to help her describe the political climate of science, we too should be able to employ this concept of a spectrum of technology in order to describe the way in which technological instincts, tool-use, and social learning fit together. This approach is beneficial to our discussions, and it may get us around Pitt's concerns over placing things in their proper sociohistorical context that I raised in Chapter 2.

The usefulness of this project extends even further. Many critiques of modern technology lament the detached nature of technology. Pitt tries to re-evaluate technology

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[136] Basalla 1988, page 135
[137] Riskin 2002
[138] Ibid.

in terms of the social context which has gone unappreciated.[139] Feenberg would have us do better in examining the social roles for which technology is put.[140] Heidegger sees modern technology as a product of a scientific thinking which limits the way in which we can think about technology.[141] But, all these critiques of modern technology can be seen within the framework of a larger spectrum of technological activities. Social definitions of technology, even of the modern sort, can be accounted for, as well as their relations to other technologies and proto-technologies and technological behaviors in nature. We can understand social definitions of technology as identifying a portion of the spectrum as important. This reframing of the context in which we understand technology is an important shift to put us into a better relation to the natural world. This move is useful not only in making clearer the relation of our technology to the behaviors and creations of non-human animals, but it also gives room for the critiques of modern technology with which so many modern philosophers of technology are concerned. In addition to lending more coherence to definitional approaches to technology within philosophy, the spectrum recognizes key features of the nature of technology and tool-use that come from anthropology, biology, and engineering.

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[139] Pitt 2000

[140] Feenberg 1999

[141] Heidegger 1977

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