Introduction

There is a tendency to see making as primarily a material practice and to underestimate the role of signifying practices and conceptual work. This is, in fact, one reason why the term 'critical making' creates (for some) a kind of cognitive dissonance. There is a common-place understanding that 'critique' is a conceptual, language-based activity whereas 'making' is often understood as physical and material. In order to develop critical making, we have to overcome simplistic understandings both in terms of a perceived aporia between language and the physical world and, an associated linkage between language and critique. On one hand, we need to be clear that material engagements can both support traditional process of critique and critical thinking and, at the same time, constitute forms of critique in and of themselves. There is a tendency, particularly by critical scholars themselves, to underestimate the ways direct engagement with materials themselves can provide resources for critical insight and, instead, to rely heavily on linguistic description and appropriation as the proper vehicle for critical work. On the other hand, we should not fall into realist material determinisms, naive materialisms or vitalistic perspectives where it is assumed that materials speak for and by themselves in ways that are more 'true' than our linguistic representations. The power of material-based critiques disseminated through art and design exhibitions or tactical media interventions has been demonstrated by critical designers (Dunne and Raby) critical engineers (Julian Oliver), artists (Jerimijenko, Hertz) and tactical media practioners more generally (Barbie Liberation Organization, Critical ARt Ensemble, YesMen, RTMark, etc) But my work here is somewhat different. I am not trying to incorporate a reductive version of art or design material practices into processes of academic critique – replacing the academic article, say, with a differently material

insubstantiation. We must be careful not to fetishize the physical object and the manual process despite an inclination to do so. Matthew Crawford (2010) has written eloquently about his own return to the material object (motorcycles) after a decade of advanced academic work in political science. Among other things, he sees his own return and the current focus on making more generally as a specific response to the alienation of the current conception of 'knowledge worker', including that of the academic. However, a purely romantic return to material production reifies problematic separations between the work we do when we represent the world in language and the world itself, and therefore buys into claims regarding the ontological primacy of the material world that are, in fact, part of the problem critical making is intended to address.

This chapter addresses the linguistic appropriation and the realist materialism issues described above using the concept of 'material-semiotic' as a starting point. As we will see, the term provides an entry into the issues, but does not, in and of itself, resolve the problem. Instead, a deeper analysis reveals the limits of positions associated with this term. Critiques of what has been termed a 'representationalist bias' (Barad) serve as points of departure for the development of critical making as a mode of engagement that engages with language and representational work more generally, but remains cognizant of its limits.   [Matt Ratto, 2013-08-29 12:50 PM need more transition here]

From Technology to Technoscience

One potential outcome of the critical unmaking process you experienced (Ch 1) is a new sensitization to the difficulties in separating 'materiality' as a pure, objective, ontologically grounded phenomenon, and subjective and interpretive meanings. As analysts of the complex relationship between technologies and social life, we often struggle with these kinds of separations, wanting to define what is truly 'of' or 'in' the technology as opposed to the meanings that we and others ascribe to them. Is it tempting to impose a clear division between human interpretation and objective description, but in practice it remains difficult to keep symbolic understanding and material aspects of technology separate. In fact, we might go so far as to say that instantiating this divide in a particular way is what marks material expertise within professional and academic contexts such as archaeology, cultural history, and museums.[1] Critical making, if it is to have any purchase at all, must come to terms with this problem. But it must do so not by erasing the issue through a nomothetic frame that merely arranges symbolic meaning and material attributes into appropriate categories. Nor should it simply notes their interfiliations. Instead, we need to develop a practice and mode of engagement that notes the entanglements as a key resource for insight and understanding.

A starting point for any form of making that includes the word 'critical' must be the critical theory that finds its origins in the theories and perspectives developed within classic philosophy of technology. Among other things, these critical scholars argued that technological developments inhibit human action, 'technicizing the life-world' and causing the diversity of human behaviors to be reduced to the ordered circuits and pathways of some sort of gigantic machine. (e.g. Marcuse 1941, 1964; Ellul 1964). As has been noted by

scholars such as Feenberg and Leo Marx, these critical theorists end up essentializing technology as an independent force , defining it as oppositional to human drives and desires, and locating its power in forms of instrumental rationality that are intrinsic and objective aspects of technology. (Feenberg, 1991; 1999; Smith and Marx, 1994). The power of this critique is obvious, given how often most of us feel subject to the seemingly inhuman strictures of technologic systems. But as you experienced in the critical unmaking process that proceeded this section, it is inaccurate to define technologies as purely the result of objective material attributes. Therefore, while we should take on a critical perspective, we must immediately discard essentializing theories of the technological that describe it as purely instrumental and autonomous. Equally, it is important to not reduce technologies to neutral vehicles for human intentionality. Our starting point is therefore Kranzberg's law, "technology is neither good nor bad nor neutral" (1986). By agreeing with this claim, we move our focus from the 'technological' to what Bachelard (1953) described as 'technoscience' or organizational theorists of technology call 'the sociotechnical'. These terms both highlight the complex interfiliation of the social and the material in the formation of knowledge, describing the world as 'co-constructed'. (CF Bijker, Hughes, and Pinch, 1987) These theories and perspectives which we will call 'material semiotic' borrowing language from Haraway (1990), start from the assumption that the symbolic and the material aspects of technologies are co-constructed and do not exist in linear uni-directional relationships. In other words, for these scholars, the symbolic aspects of the technology of the automobile (for example) is not merely a form of social meaning laid on top of a core physical functionality, nor is the use, function, and physical characteristics of the auto manifested primarily through our linguistic expressions and conceptual meaning-

making processes. Instead, technologies are hybrid semiotic and material objects and are not understandable without analysis of their conjoined nature.

Addressing technology as both material and semiotic has become something of a defacto position for many recent scholars[2] within STS and related fields, though there remains a desire by some technologists and scientists to insist on positions of ontological purity. (See 'science wars.') But despite this common understanding, scholars address material/semiotic relations using a diversity of methods, sites, and temporalities of analysis. Scholars have chosen different starting points in different units of analysis with which to try to address the complexity of the sociotechnical and have developed a variety of techniques and methods that can unpack this complexity in ways that provide for pragmatic value. Interestingly, these starting points relate in some cases to different moments in a cycle of sociotechnical relations. For example, some scholars start at the moment of the production of a technological system or artifact, looking for how its context and origins have longer term effects on the way in which it evolves over time (e.g. Woolgar, configuring the user; Pinch and Bijker) or focusing on the kinds of work that are required to stabilize technological artifacts as 'matters of fact. (Latour, Callon.) Other scholars have looked at technologies at the point of consumption and use, examining the tensions, frictions, and appropriations that occur when objects and users meet. (Eglash, Law and Mol) Still others examine what happens to technologies when they are no longer useful, at least for the purposes for which they were originally designed. (Martin O'Brian, 2008, A Crisis of Waste)[rec by nic to gitelman, parikka, etc]

An important aspect of the material-semiotic position, generally speaking, is the way

in which it focuses our attention on the history of artifacts and their co-evolution with human society. First and foremost this historical positioning de-essentializes the technological as suis generis, and locates it as coming from somewhere and being made to fit particular social contexts and particular social groups. This move importantly widens the temporal line of technological analysis, noting that in order to understand technologies we have to go back to their origins and their histories, as well as examining them in use and in context. In doing so, the material-semiotic positioning overcomes a range of problems associated with the essentializing arguments of a previous generation of technology theorists (e.g. Marcuse, Ullul, Borgmann) while, potentially, still opening up the possibility for a critical analysis of the socio-technical. I say potentially here because the question remains whether or not the move to the material-semiotic has in fact encouraged or allowed for critical approaches. Some of the best known theories and methods associated with this approach have been heavily criticized for their seeming inability to engage in value judgements. Actor-Network theory, for instance, has been criticized as entailing a 'managerial' or 'winner-takes-all' approach to technological stabilization (cites). Similarly, the analytic frame of the Social Construction of Technology has been criticized for failing to incorporate certain kinds of technology shapers within the trajectory of development since it views these users as 'non-relevant social groups.' (Cites) Most broadly, Winner (1991) criticized 'social constructivist' approaches (footnote: rejection of this term by latour and others due to the way it stabilizes the social,) for failing to take evaluative stances as a point of methodological principle. Brey (1997) explores whether or not this is truly the case, noting that 'mild' social construction and 'strong' social construction approaches differ as to their capacities to take on political and normative stances. This being said, he ends by

concluding that "social constructivist politics, in its current form, is unsatisfactory."

Much water has passed under the bridge since 1997 when Brey published his overview. Certainly, many scholars now working in STS do take on particular standpoints and perspectives that extend on from the earlier work described above but address more explicitly political and normative viewpoints. (Cite examples here) However, more substantially, some scholars doubt whether work based on the theoretical framing of constructivism can actually address the material world.

For example, Brian Massumi has noted the ways the dominant ideas associated with constructivism hobbles the ability to engage with materiality itself out of "fear of attributing an ontological status to what lies outside of social and cultural constructs" (Masumi,PARRHESIA, 2009: 37). By 'constructivist', Massumi is specifically referring to post-Derridian scholars who emphasize the processes of social construction by which reality is constituted. The focus of constructivists has tended to be not on the construction or development of things per se, but has focused on the signifying structures, perspectives, and paradigms. Similar in some ways to the examples from archaeology that initiated this chapter, we can see a focus on signification rather than materiality as a response to the essentialized material positions that came before. Like the post-processualists who emphasized a need to better theorize materiality, the constructivists rejected the idea of a material world that was ontologically superior to the processes of meaning-making associated with human agents. However, because of this focus on signification the models used to explore co-construction tended to be drawn from

linguistics and rhetorical analysis Masumi notes "this telescoped becoming on to the human plane at the same time, it reduced the consumption of the human plane to the question of the human subject" (Massumi, ??) According to Masumi then, "constructivism does not have the resources to effectively articulate the issue of the nonhuman." (Ibid)

A similar critique can also be found in the recent work of a group initially known collectively as 'speculative realists'(footnote here). These philosophers reject what they have termed the 'corelationalism' of much modern philosophy and its belief in the inseparability of thinking and being. (Meillassoux, 2010). Material-semiotic approaches are seen by the speculative realists as co-relationist, since they highlight the entanglement of the material world and our semiotic engagements with it. Among other things, advocates of this position claim that current analyses do not give enough credit to the objects themselves and by doing so undervalue and under analyze the ways that technologies and things that we make get away from humans and their ability to define them. In other words, the claim here is it, by focusing too much on the social relations of objects and not enough on 'objects qua objects' we undervalue in under estimate the ways in which objects exist outside of our control.

From these comments, we can pull out one aspect of the material-semiotic relationship that seems to be creating the difficulty. For both the speculative realists and Massumi the issue has to do with the reliance on 'signifying structures' generated by the humans who stand in relation to the material world. For Meillassoux, such relations prevent analysts from seeing 'objects qua objects', objects as they exceed our ability to fully

determine and understand them. For Massumi, the issue is the way in which a focus on

signification (and the academic methods associated with analyzing its associated practices

and results,) place the human subject as central to any understanding of the world.

These critiques do hold water in regards to the constructivist position, at least the

1990's formations of it described by Massumi (cite). However, it may be that the ideas of

material-semiotics, at least in so far as they have been pursued under that name by scholars

such as Haraway, Latour, Law and others, do not fall easily in the trap of human relatedness

as argued above. The problem here has to do with an easy error to make regarding the

concept of material-semiotic - namely, the idea that these terms name apriori attributes of

things that require work to be put into relation. Understanding the material-semiotic divide

as itself produced through work (not merely put into relation) helps maintain the

importance of materiality and discourse without falling into either a material or a social

determinism. This is a clearer reading of the term as initially defined by Haraway and

serves us well (as we will see) in thinking and doing critical making. To more fully address

this term, I turn in the section that follows to issues of representation and, more

productively, to post-representational accounts of things as a site for exploring critical

making.

A 'Seductive Habit of Mind'

Karen Barad has noted the ways current academic discourse, despite '...the ubiquitous puns

on 'matter'' (Barad, 2003;pp) continues to underaddress the relations between materiality and signification. She asks 'how did language come to be more trust-worthy than matter?' and emphasizes that a representational focus "...supports social constructivist as well as traditional realist beliefs." (Ibid.) Such a focus is what Barad calls 'a seductive habit of mind' (Barad, 802). Importantly, Barad notes that the deeper problem is a kind of 'representationalism':

...the belief in the ontological distinction between representations and that which they purport to represent; in particular, that which is represented is held to be independent of all practices of representing. (804)

Barad addresses this belief in some detail, noting its origins and its 'taken for granted' status. Barad's work, and what we might term 'post-representationalist theories more generally provide useful alternatives to a representationalist ontological position, alternatives that can serve us well as critical makers. Before addressing these concepts in detail, I will first examine some issues regarding descriptive language that critical makers need to think through. These are, specifically, first, that language imposes a structuring influence that undermines the non-linearity and particular experiential nature of other forms; and second, that scientific language (more specifically) buttresses a kind of ontological sleight-of-hand that helps hide the subjectivity of scientists and experts. Both of these critiques focus our attention appropriately - emphasizing the need to engage in discursive work as part of critical making, but encouraging us to be wary of language's structuring influence as well as how particular types of language can work to

overdetermine the human's authority and right to speak regarding objects. Following an

analysis of these specific issues with representationalism, I will then return to alternative

ontological positions as potential responses and methodological guides for critical making.

Two frames will be reviewed, Actor-Network Theory and specifically the work of Bruno

Latour, and Karen Barad's Agential Realism. Both theories extend past material-semiotic

work, emphasizing the interfiliation of material and semiotic attributes and the role

played by things.[set up shift in discipline - back to art history/ Why?]

The neutrality of language

The neutrality of language

The first critique has been most fully addressed in discussions of ekphrasis within

art history. Ekphrasis, generally speaking, is the rhetorical process of describing one work

of art using another form and has a long history of being seen as suspect, starting from the

work of Plato. (Fort, Ekphrasis as Art Criticism, 58). The assumption that descriptive

language can act as a neutral vehicle for depicting visual material is typically seen as

problematic.[3] For example, in an edited collection with the main title 'Dealing with the

Visual', Van Eck and Winters bring together a range of authors who all share a criticism of

proponents of 'visual culture' as having developed not a theory of the visual but a theory of

a 'beholder that speaks' (introduction by van Eck and Winters). In this volume David

Corbett writes:

"what this operation requires is the external modelling of the object as a textual doppelganger, formed out of discursive rather than visual material, and open to exposition in language accordingly." (22) Corbett, D (2005) Visual Culture and the History of Art, in Eck, C. V., & Winters, E. (eds) Dealing With The Visual: Art History, Aesthetics And Visual Culture. Ashgate Pub Ltd. (pp. 17-36)

As an alternative, Corbett encourages a more inferential process, one that works against linear textual descriptions of the visual work, and instead focuses on the intentions of the author , contexts of experience, and other factors. Note that Corbett, like others in the edited collection described above, do not encourage one to discard language all together. In the introduction, Van Eck and Winter's specifically note that linguistic definitions of the visual are necessary in order to insert visuality as an important presence within discourses on the arts and sciences. However, "there is always a price to pay: the loss of the specifically visual." (4) They see the reason why the visual cannot be translated directly into language as due to the fact that the visual is essentially experiential – while language can describe experiences, these descriptions are not the experiential act itself. (5)

More specifically, Baxandall has noted descriptive language as a structural problem for the analysis of art, noting that "Language is not very well equipped to offer a notation of a particular picture. It is a generalizing tool... (Baxandall, 1987, 3 quoted in Fort)[4] In particular, Baxandall singles out the problems language has in describing the specificity of color and form within pictures, and the 'crude' and general mechanisms it deploys in order to do so. Importantly, Baxandall emphasizes the temporally linear nature of language and

the ways in which the notation process typically reworks pictures into a linear 'one after another' form:

there is an awkwardness, at least, about dealing with a simultaneously available field – which is what a picture is – in a medium as temporally linear as language: for instance, it is difficult to avoid tendentious reordering of the picture simply by mentioning one thing before another. (Ibid)

Here we can begin to see one way in which language can be said to 'matter', in the sense that the re-presentation of a visual field such as a picture through language changes the ways in which individuals encounter it. It is generally understood that re-presentation also always involves transformation (e.g. Lynch and Woolgar, 1990). Baxandall provides us with a specific example of such a transformation and details what we might call an 'affordance' (Gibson, 1979) regarding language itself. However, it is also obvious that such an affordance can be worked against. For example, typographic forms such as concrete poetry stimulate and emphasizes the visual nature of language and Van Eck and Winter highlight architecture as a discipline whose use of language emphasizes spatial and experiential elements that work against the simple affordance listed above. In fact, Van Eck and Winter locate the problem not in some essential characteristic of language itself, but it a framing and use of language that focuses on 'meaning'.[5] (8). As an alternative, they feel "appreciation" is a better framing, with the term intending to convey the perceptual as well as the linguistic experience of art, and its use as an object of enjoyment as well as for learning. (8)

From the above work, we can take the lesson that we must, as critical makers, stay focused on how and it what ways we use language to describe and communicate about the things we make. We can also agree with Van Eck and Winter that , like art historians, there remains a need for critical makers to use language in order to insert its processes and results within wider systems of discourse. While such linguistic articulations will never fully convey the experience of making, linguistic expressions have capacities that are not shared by the processes or material objects that result. It is difficult to share critical making processes themselves given their ephemerality and material objects, while durable (in some cases) instantiations, contain only traces of their development and creation. Language is therefore an essential part of critical making, particularly if it is to be effectual within current critical discourses and their associated institutions.

The neutrality of the language user

Another particularly important critique regarding language and representation can be found in the work of STS scholars looking to decipher the acquisition of scientific authority and legitimacy. The primary example of this can be found in Shapin and Schaeffer's unpacking of the particular form of linguistic expression associated with scientific description. In 'The Levianthan and the Air Pump, they explore the development of modern science, using James Boyle's work on theories of gases and his creation of scientific apparatus such as the vacumm pump as an exemplar. A major claim of this work is that Boyle's innovations involved not just the material work of the air pump, but also included specific linguistic forms that created the possibility for 'virtual witnessing'. Shapin and

Schaffer described this form as the 'modest witness' noting that such forms, which include such attributes as the inclusion of circumstantial details and a modest or probablistic form of speech, work to construct a sense of objectivity in that being reported. Here, the particular form and mode of language is tied to the 'factness' of that being represented.

Language in this case is not a 'pure' representational vehicle but one that argues (often convincingly) for a specific view of the world but also works to instantiate the authority of those that speak for it. Haraway has taken up this particular aspect, noting the identity and its characteristics that entails and reinforces a kind of disembodied viewer as a key component. She notes:

...the modest witness is the legitimate and authorized ventriloquist for the object world, adding nothing from his mere opinions, from his biasing embodiment. And so he is endowed with the remarkable power to establish the facts. [Haraway, 24]

Shapin and Schaffer link the identity and power of the modest witness to a specific 'linguistic technology' - a genre of speech and writing that seeks to efface the subjectivity of he who experiences and writes. Haraway extends this analysis in important ways, surfacing the deeper power relations and 'lacunae' inherent in both the work of Boyle and in Shapin and Schaffer themselves. The seemingly inconsequential pronoun 'he' serves as a point of departure:

"They (Shapin and Schaffer) took his masculine gender for granted without much

comment. Like the stubbornly reproduced lacunae in the writing of many otherwise innovative science studies scholars, the gap in their analysis seems to depend on the unexamined assumption that gender is a preformed, functionalist category..." (Haraway, modest witness, 226)

Noting that Shapin and Schaffer were focused on different questions, Haraway says: "my focus in this chapter is to ask if gender with all its tangled knots with other systems of stratified relationships, was at stake in key reconfigurations of knowledge and practice that constituted modern science." (227). Referencing Elizabeth Potter's Gender and Boyle's Law of Gases (2001), Haraway demonstrates that gender was in fact at stake and that as the convention of scientific modesty stabilized, forms of masculinity work intertwined within it.

Pragmatically, we can take specific insights from the perspectives on language noted about and their linkages of authority and authorization to speak, truth claims, and legitimacy. Whereas the art history critiques emphasize the problematic transformations and losses in transforming non-linguistic objects into descriptive language, these analyses focus our attention on the systems of power and social discourses that are enacted through and by particular forms and uses of language. Not only do we need to stay cognizant of how language transforms our experiences and perspectives on critical making processes and results. We also need to stay aware of how our linguistic appropriations feature within and work to trouble or reify current systems and institutions of power. As we will see later in the book (ch. 7) this is particularly the case regarding the academic institution itself. Only

then do we have language use appropriate to critical forms of making.

But there is a deeper issue here that we need to address before moving on. This is namely, the relation between language and materiality and the reliance on pre-existing and ontologically firm divisions between them. Defining an alternative starting point[6] can help us better understand the need for critical making and, as well, parse the processes of engagement that are key to its value. This is the point where a better understanding of material-semiotic is required.

Moving beyond the 'word' and the 'thing': non-representational theories

Above, I noted more obvious problems associated with this conflation of language and materiality, highlighting in particular the problem of 'textual doppelgangers' (Corbett) and the 'modest witness' (Shapin and Shaeffer, Haraway). Both of these critiques describe what can occur when linguistic descriptions are simply taken for granted as representing of the material world, whether of a painting or of a scientific event or device. However, some scholars, notably Nigel Thrift (2007) have argued for conceptualizations of the world that do not parse it into 'word' and 'thing', but discard the primacy of either starting point. This may be the true 'seductive habit' - namely, a desire to maintain differences between the world and our signifying work as two separate entities. Haraway's term 'material-semiotic' names a desire to see world-sign as co-constituted. But what does this look like in practice? 'post-representational' accounts which I organize into two camps: 1) 'relational' accounts (e.g. Latour) that focus on the multiplicity and hybridity of technologies as made up of relations between entities and describe the critical task as

'unpacking' or opening up black boxes in order to denaturalize the seemingly homogeneous nature of objects. And 2) accounts that focus on incommensurable processes, phenomenon, or 'becomings' as the key attribute of objects. Barad serves as the primary example of this in the chapter due to the possibility of 'methodologizing' this ontological position, but other examples, such as Simondon and the New Materialists, specifically Bennett. Below I take both of these positions in turn after which I will reflect on how the theory/methods thus exposed can help specific and understand critical making.

Latour and ANT

Since the late 1980's, Bruno Latour and other theorists have explored a material semiotic theory predicated on a distinct vocabulary intended to reduce the ontological commitments that separate natural and social explanations. (Callon 1986; Latour 1996, 2005a; Law 2008; Law and Hassard 1999). ANT is markedly different from many theories of the socio-technical as it conceptualizes both humans and non- humans as actors, attempts to instantiate agency as a result of network-building, and focuses theorist attention on the 'building up' of power through the strategic formation of network relations. (Latour, 1988). ANT serves as a good example of a post-representationalist account of material semiotic relations due in part to the ways this work troubles simplistic linguistic accounts - including those of other academics.

Latour, in particular, has worked to overcome the limitations of the structuring of academic language and, to a lesser degree, the authority of the modest witness. Latour has

focused on allowing the objects themselves to have a voice – in ANT's principle of extended general symmetry (the agency of objects such as sea scallops and door closers) and in his participation in the ZKM, Center for Art and Media Technology, exhibition that culminated in the edited volume Making Things Public. In Aramis, for example, he makes the object of analysis – the aramis network itself - a character in the thread of the book that is constructed like a detective story:

I find your characters [the nonhuman things, the technological objects, as laid out in early specifications of the Aramis project] one-dimensional. They need to be animated: you have to make them move, give them depth and consistency. More than anything, they have to be autonomous; that's the whole secret. And instead they're so rigid! They'd pass for puppets. (Aramis,pg 55).

Aramis speaks for all objects brought in to scientific language, chastising us for replacing their living qualities with static and quiescent replacements, making them puppets for human intentionality. Latour's alternative is to allow agency to be inherent in the objects of study not just in the humans that study them.

[Section in progress] review of ANT and objects as 'gatherings' (ref thing from german). Sources, mainly pandora's hope (ch2), Drawing things together. Others - Law, Mol. Attempts to address critiques (Star, Suchman) through topological transformation. Wide acceptance of theory - one reason, easy (though often incorrect) application. Listing of actants, examination of 'trials of strength', description of the 'winners.' Focus in on

relational quality if results - technoscience formed through the generation of networks of humans and non-humans. Latour focus on "the social does not explain, but must be explained." (Reassembling) Social as something that is built, something put together. Attemtping to overcome 'soft relativism" of recent social theory and constructionist and, as well, the hard (determinist) realism of classic social theory.

Texts to overview - irreductions, pandora's hope, drawing things together, reassembling the social, most recently, compositional manifesto.

Barad: posthuman intra action

Barad's articulation of what she terms 'agential intra-action' starts from the question of what damage is done when "materiality itself is always already figured within a linguistic domain as its condition of possibility" (Ibid.) This issue, of a pre-figured materiality constituted by and through language, shares much with Latour's critique of philosophers of science and, as well, Massumi's criticism of constructivism described previously. In my comments to follow, I use Barad's comments to fruitfully unpack both the assumptions of representationalism and to posit a material-semiotics (she uses the term material-discursive practices) that provides an alternative way to proceed. Barad's full theory of 'agential realism' requires more attention than I can give it here. Instead, I will single out three aspects of her work that provide an impetus towards critical making, namely, Barad's description regarding the contingency of representationalism, her notion of 'agential realism' as an alternative ontological position, and her description of 'posthuman

performativity'.

The contingency of representationalism

Barad begins her article "Posthumanist Performativity: Towards and Understanding of How Matter Comes to Matter." (2003), by noting an issue similar to those postulated by Meilleiseux and Massumi:

Language has been granted too much power. The linguistic turn, the semiotic turn, the interpretative turn, the cultural turn: it seems that at every turn lately every "thing"-- even materiality--is turned into a matter of language or some other form of cultural representation. (Barad, 2003:801)

Barad's goal in this work is not merely to critique but also to describe a 'performative understanding of discursive practices' (802) as a way to overcome representationalist accounts and to reinscribe the material as part and parcel of this work. In order to conceptualize what might constitute 'performativity' and 'discourse' in this idiom, Barad makes use of similar articulations by Butler, Foucault, and Haraway, among others. Importantly, she notes that these articulations help move the conversation from a representationalist emphasis on correspondence and accuracy, to "matters of practices/ doings/actions." (Ibid)

Barad starts by critiquing the ontological distinction inherent in representationalist accounts between representations and entities to be represented, including among these

accounts, tripartite versions that also add a 'knowing subject' into the mix.[7] She notes that this is a 'taken-for-granted' articulation of the world that is generative of most of the questions we typically think of regarding representation and mediational accounts of the world more generally. These include whether or not "language accurately represents its referent" and whether political representatives "accurately represent the interests of the people." (804). Such a connection between language and its referents and politics and subjects provides a way for Barad to connect Foucault and Butler to science studies critiques of representationalism by scholars including Hacking (1983) and Rouse (1996). She singles out Rouse as providing "the most sustained and thoroughgoing critique of representationalism" regarding scientific practices. She notes that Rouse's work highlights the ways both scientific realism and social constructivism share the same representationalist assumptions differing only in whether scientific knowledge represents real-world things (Nature) or the products of social work (Culture). Barad notes how Rouse demonstrates the linkage between Cartesian duality of 'internal'/'external' and the standard representationalist faith in an unfettered access to what we say about the world as opposed to the world itself:

The presumption that we can know what we mean, or what our verbal performances say, more readily than we can know the objects those sayings are about is a Cartesian legacy, a linguistic variation on Descartes' insistence that we have a direct and privileged access to the contents of our thoughts that we lack towards the "external" world. (Rouse, 1996: 209, quote in Barad, 2003: 806)

Barad uses these insights as proof of the contingency of representationalism as a dominant theory. Rather than being "a logical necessity", Barad understands it as "simply a Cartesian habit of mind." (Ibid.)

Agential Realism

Hacking also provides insight regarding the history of representationalist thinking, seeing its origins in the Democritean theory of atoms (Hacking, 1996: 142), cited in Barad, 2003: 806). Viewing the world as made up of aggregates of individual 'atoms' that collectively provide the 'appearance' of solidity creates a gap between 'real' and 'representation' that drives the issues noted above. According to this theory, all relations are preceded by relata - the individual parts that are held together through relations. From this theory derives the idea that the world is made up of individual objects with separately attributable properties which can be discovered through observation and measurement and represented through symbolic systems such as language.

Barad provides an alternative to the assumption of apriori relata, starting from physicist Neils Bohr's explanations for quantum effects he witnessed as part of his experiments. Bohr demonstrated that properties of an object that we might understand as intrinsic to it, such as its position or its momentum, are instead the result of relations between observed objects and 'agencies of observation.' For instance, the term 'position' only makes sense when an object is put in relation to a specific physical arrangement of measurement, such as a ruler or measuring tape. Equally, 'momentum' only makes sense when an object is put in relation to a physical arrangement requiring moving parts.

To describe relations between objects and physical arrangements of observation, Barad uses the term 'intra action' rather than interaction, since the prefix 'inter' presupposes the existence of two independent entities (relata) that precede their relationality. For Bohr and for Barad, the primary epistemological unit is therefore not an object with properties to be discovered and described, but is instead phenomena, "ontologically primitive relations - relations without preexisting relata." (815) There are no relata without relations. These notions, that of the primary nature of phenomena and the concept of relata-within-relations marks the ontological shift Barad describes as 'agential realism." Importantly, this ontology rejects the idea of separately occurring 'words' and 'things' noting that through this shift:

it is once again possible to acknowledge nature, the body, and materiality in the fullness of their becoming without resorting to the optics of transparency or opacity, the geometries of absolute exteriority or interiority, and the theorization of the human as either pure cause or pure effect while at the same time remaining resolutely accountable for the role "we" play in the intertwined practices of knowing and becoming. (8??)

Barad's theory, then provides a way to route around the errors of representationalism, allowing for a belief in a material world that is neither mirrored by (appropriately or not) representations in language nor a mirror for linguistic representation. It is not simply a matter of replacing the 'modest witness' with a different kind of interlocutor, one that recognizes and embraces the subjectivity of their position, nor

of getting the process of description 'right'. Instead, the focus shifts to the entanglements of intra acting agencies and the 'agential cuts' through which discrete individuals become determinate and meaningful. Understanding and addressing these entanglements and cuts requires a new focus on the material-discursive practices through which the world is produced.

Posthuman performativity

Having demonstrated the problems of representationalism and its contingency and scoped her alternative ontological position of 'agential realism', Barad proposes a 'posthuman notion of performativity" that builds on Foucault and Butler. She uses this notion of performativity to turn our attention from symbolic articulations used to represent a discrete material world to material-discursive practices, understood as intra actions through which divisions and boundaries - including those between words and things - are constituted.

The key insight articulated by Foucault was that political systems work to <u>produce</u> subjects rather than merely <u>represent</u> them. Both Butler and Haraway extended this central idea to note that such systems do not just produce subjects but also work to instantiate their material bodies as well. Butler specifically linked this to discourse, defining performativity as "that reiterative power of discourse to produce the phenomena that it regulates and constrains" (Butler 1993).

The concept of discourse is central to these accounts. Discourse describes "not what

is said" but "what counts as meaningful statements" (819). Discursive practices, in this

sense, sets the limits of what can meaningfully be articulated by enabling and constraining

disciplinary knowledge work. Further, discursive practices are not transcendent or abstract

laws but are 'historically situated social conditions" (819). Barad notes that neither

Foucault nor Butler offer an account of precisely how discursive practices and materiality

are linked together, saying of Foucault:

> For all Foucault' emphasis on the political anatomy of disciplinary power, he too fails
>
> to offer an account of the body's historicity in which its very materiality plays an <u>active</u> role
>
> in the workings of power. This implicit reinscription of matter's passivity is a mark of extant
>
> elements of representationalism that haunt his largely post- representationalist account.[8]
>
> (Barad, 2003:809)

This is an important linkage to make, between a passivity of materiality and aspects

of representationalism. Again, we can see connections here to the previous critiques of

constructivism noted by Massumi and Meillassoux. Importantly, this passivity has

ramifications for our understanding of the emergence and maintenance of social

formations. Barad cites Rosemary Hennessey's critique of Foucault which emphasizes what

is at stake:

> A rigorous materialist theory of the body cannot stop with the assertion that the
>
> body is always discursively constructed. It also needs to explain how the discursive
>
> construction of the body is related to nondiscursive practices in ways that vary widely from

one social formation to another. (1993:46, cited in Barad: 810)

As Hennessey points out, and Barad picks up, it is the relations between discursive and non-discursive work that matters here and, more importantly, the ways these relations differ from social formation to social formation. Such understandings also allow us to better address how disciplinary knowledge practices emerge and are constituted alongside the material-discursive practices that form the objects and subjects that are immanent to them. To turn Barad's theory to a programmatic drive for a new form of analysis, it is not a matter of tracing how the material world gets properly (or improperly) represented by semiotic systems or how the world is formed through practices of symbolic representation. Nor is it about picking apart the warps and wefts whereby the semiotic and material are woven together to form the world. Instead, Barad is advocating for understanding the world as based in:

"...<u>a causal relationship between specific exclusionary practices embodied as specific material configurations of the world</u> (i.e., discursive practices/(con)figurations rather than "words") <u>and specific material phenomena</u> (i.e., relations rather than "things.") (814)

To track back to the critical making experience that initiated our explorations in this chapter, we can begin to see how the divisions between 'description' - understood as the denotation of pure factual information about a material object - and 'deduction' - understood as subjective signifying (e.g. meaning-making) practice are maintained. Moreover, we can now view practices of ekphrasis as particular parsings of the divisions that work to produce what counts as painting and what counts as textual description, and

'modest witnessing' as the parsing of what counts as subjective insight and what should be considered "scientific fact'. From this we can now begin to understand how the maintenance of these divisions also works to construct and maintain particular social formations such as academic disciplines and institutions. Here we can begin to see a form of material-semiotic analysis that does credit to materiality and to language in ways that provide for critical analyses. As we will see later in this book, instantiating agential realism as a ontological position is in some ways easier to accomplish with critical approaches that engage in material forms of production.

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conclusion

Latour's assembly as main practice, barad's 'cut' - how do these differ? Latour's allows for posthoc analyses that 'reopen' black boxes'. Barad's cut, on the other hand, does not.

This 'habit of mind' can also be seen in articulations of material-semiotic relations that start from strong separations between the material world and our semiotic understanding of it that must be re-related to each other through critical analysis. Latour himself, has been accused of falling into this trap. Lenoir has noted that hidden within Science in Action (1987) lies a potential return to concerns of realism and representation. He cites the definition of 'actant' as being 'behind the texts":

Behind the texts, behind the instruments inside the laboratory, we do not have Nature...What we have is an array allowing new extreme constraints to be imposed on `something.' (Latour, 1987:89, cited in Lenoir, Configurations, Vol.2 (1994): 119-136)

Similarly Lenoir cites Latour and Akrich as noting "...the key aspect of the semiotics of machines is its ability to move from signs to things and back." (Latour and Akrich, 1992:259, cited in Lenoir) In both these cases we can see a version of material-semiotics suffering from representationalism, though this is not to say that all of Latour's work suffers from this issue.[9]

Agential realism, and the concepts of material-discursive practice and relations-without-relata that serve as its most important aspects, instantiate a need for critical forms of analysis that do engage with material/technical work. From a purely constructivist or a depleted material-semiotic position one can view all moments in the life cycle of a technological object as equally in need of analysis and critique. With these approaches matter become passive (e.g. a Foucaultian discourse emphasis on signifying structures,) or is merely one element woven together with others (some linguistic some material). Initial creators and origins of objects have no particular authority since new meanings and new significance accrues and new networks are formed as the object moves through time and space. To a certain degree this remains true under agential realism since objects are not individuals that precede relations but instead are formed (and one supposes) reformed through engagements with other humans and non-humans. However, if we assume that objects do emerge from particular agential cuts, material-discursive practices that articulate what counts as matter and what as language, what counts as material fact and what as social construct, then there is reason to believe that these cuts have an obdurancy that lasts. Therefore, figuring out how these cuts are formed requires processes that engage

in work that involves cutting - material-discursive practices that provide insight regarding objects and not just objects themselves.

Critical Making 2: Blinky- Blinky

In the previous chapter, I addressed theories that highlight the 'material-semiotic' nature of technologies and the ways in which current academic work attempts to come to terms with this. I noted current criticisms involving the linguistic appropriation of the material world and the way in which this imposes a human subjectivity on the world that, for some scholars, delimits our ability to come to terms with objects in their own right. As noted in the previous chapter, the 'turn to things' has not necessarily engaged directly with material production itself. Two reasons have been given for this, one because of the aforementioned locating of co-construction within processes of signification and two, due to fears of falling into reductive theories of materiality.

The previous chapter also highlighted specific issues with the use of language to represent the material world and continuing problems related to 'representationalism'. Two specific 'post-representational' theory/methods were described - Latour (and many others) 'Actor-Network Theory' and Barad's 'agential realism' - both of which claim to move beyond the representational bias to provide differential access to the agential qualities of the material world. I raised the question of how and in what ways these two perspectives encourage engagements with the material world that connect with things themselves. I

noted that while both perspectives necessarily involve some direct contact with the

material world, Barad's agential realism appears to direct us towards more generative

'making' experiences, given the importance placed on the irreducibility of the performance

of 'cutting' as the moment when objects are produced.

Here in this chapter, I provide an alternative mode of comparison between ANT and

AR, using interactions with the Arduino microcontroller platform in order to expand and

try out a critical material practice that engages seriously with the material-discursive

practices and phenomena of the Arduino. This engagement therefore does two related

things; first, it provides a rough cut at a critical hybrid material-discursive experience that

links theory and practice; and second, it directs the reader towards some necessary

technical experience that will help in the more open-ended critical making experiences

detailed later in the book.

Critical Making 2- Blinky-Blinky

In my teaching and research I frequently make use of the arduino microcontroller

system for critical making, and the remaining examples in this book do likewise. By this

focus, I do not mean to imply that the arduino is inherently necessary for critical making. I

believe that critical making can engage with any material form but that, importantly, the

materials chosen should match the critical questions and domains being addressed. This

'matching' is an important component to critical making. Just as we choose insights and

theories that 'match' our conceptual needs, so too must we choose materials that provide

resources appropriate to our questions. Arbitrary theoretical choices reveal themselves by not providing guidance and help through our scholarly processes. Arbitrary material choices result in a similar lack, most obviously by not 'pushing back' on our conceptualizations in ways that encourage a deeper engagement with the materials and questions that are the focus of the work. The curation of material resources is an under-addressed aspect of research that engages materially with things, though, as we will see later in this chapter, examples from good work in this area can help us figure out ways forward.

As I briefly described in the introduction to this book and will address in more detail in the following chapters, my particular interest is on the increasing hybridity of our digital/material environment. The arduino is a good tool for exploring this hybridity because of its own conjoined nature, e.g. That it partakes of both digital (software) and material (hardware) components. Also, the arduino makes it possible for critical makers to construct hybrid objects that call attention to the critical domain we want to study. Equally, the open nature of the Arduino ecosystem means that source code and hardware examples proliferate and can be repurposed and transformed by critical makers. This is one way the maker movement[10] and free/libre open source software and hardware facilitates and supports critical making (Ratto, 2011, Open design now chapter.) As I will describe later in this chapter, the origins of the Maker Movement and its continuing relationship to art and design values and forms of expertise stand us in good stead for critical making.

In this critical making experience, I will walk you through the process of purchasing,

installing and developing using the arduino, focusing on a simple and ubiquitous example of blinking LEDS.

Our goal here is to use our engagement with the Arduino as a way to explore the importance of material choice and embodied experiences regarding critical making and to set the stage for a more detailed examination of how materials and experiences need to be considered as part of critical reflection.

Preparation

Obtain the following hardware;

> arduino microcontroller, (official, clone, compatible, or counterfeit)
>
> USB A-B cable (any length)
>
> Single color LED (preferably 5 MM)
>
> A PC running Windows or Linux, or MacOSX.

Find a workplace where you can concentrate for some time. Make sure you have power for your laptop or desktop computer, internet access (if you need to download the arduino software,) and adequate light for examining and using your arduino. If you have access to a magnifying glass , you may find it helpful for looking at the arduino.

Step 1: Arduino, definitions and descriptions

Originally developed by interaction designers looking for a less expensive way to

prototype digital/physical interactions, the arduino is a physical electronics board and accompanying software development environment that facilitates connections between the digital and the physical world. It allows developers to easily connect input components such as temperature sensors and buttons or output actuators like motors and lights and to program how these function using software code. The arduino can act as a stand-alone device or it can serve as an input/output device for a desktop or laptop computer. It has been widely adopted by artists and designers looking for simple ways to create interactive objects, spaces, and exhibitions, but also by engineers and scientists for prototyping and early development.

The arduino system is typically considered as having three main technical components; first the hardware board design that provides reliable power, a microcontroller chip, and a USB interface for programming and access; second, a software IDE or Integrated Development Environment, that provides a way to write and debug code and upload this code onto the arduino hardware; and third, software code running on the arduino hardware called a 'bootloader' that makes it possible for the IDE to program the arduino hardware. Importantly, the developers of the Arduino have licensed the electronic design of the arduino hardware as open source (Creative Commons CC-SA-BY License), the IDE software is licensed under the GPL and the bootloader under the LGPL free software licenses.

As many have noted, the arduino's technical capabilities are matched or exceeded by a range of alternatives. Before the arduino became popular, many computer science and

electronic engineering experimenters used the BASIC Stamp, a microcontroller and environment developed by Parallax, Inc. that provided many of the same capabilities as the arduino. Similarly, both the Lego Mindstorms (link) and the Phidgets (link) systems have been used for digital/physical experimentation. Explaining the arduino's popularity, despite these alternatives helps unpack it as more than simply the sum of its technical components.

There are a number of reasons for the popularity of the arduino platform and, not unrelated, my use of it for critical making. First, the hardware and software design make learning and use fairly easy - the hardware is mostly based on commodity parts and is inexpensive, all software is available online, and many tutorials are available to help beginners get started. Second, the focus by the original developers of the arduino was on encouraging adoption by designers rather than engineers. Therefore, early example code and the creation of the IDE itself focused on simple functions rather than technical sophistication. Third, the community of current users is very active and, due in part to the open source nature of arduino, many tutorials and sample projects, including wiring diagrams and code are online and available to be repurposed.

These aspects help explain the popularity of the platform but also reveals the 'arduino' as more than just a singular technical artifact. Instead, it can better be understood as the focal point of a number of technical, political, discursive and social moves, as a network, assemblage, or constellation. (Latour, Callon, Akrich) Actor-Network Theorists originally noted the multiplicity of objects and the ways in which they necessarily involve a

range of 'actants', including both human and non-human elements. Importantly, ANT scholars also highlighted the instability of objects and demonstrated the ongoing work that is required for them to cohere and maintain the semblance of durability. Latour, for example, initially described this process as a 'trial by strength' in which 'actor-networks' compete to 'enroll' others and thereby secure their own consistency as a 'fact' or 'artifact'. (Latour and Callon) Alternatively, from the viewpoint of agential realism described in the previous chapter (Barad, 2003) we might describe the arduino as a phenomena and its particular material instantiations as the result of material-discursive practices that work to 'cut' it in ways that highlight particular attributes.

There is, I believe, a strong recognition of the multiplicity/complexity of the arduino by its users. Few would claim that the arduino would be the arduino if licensed under a more restrictive license or without the strong community of developers and their willingness to share. Most recognize that the arduino is not simply what we might reductively consider its technical parts - electronic components and software code - but include social attributes as well. Reading the arduino through the lens of ANT or of agential realism is simplified by the public nature of the work involved in maintaining it as an object. Unlike many other technical systems which actively seek to hide the ongoing labor of their constructed nature, the work of managing the objectness of arduino and its appearance of consistency is done at open conferences, in public forums, and in fierce debates where motives, licenses, political discourse, and technical facts are deployed with little differentiation.

Here then we can see a fourth reason the arduino works well for critical making - it actively reveals what is equally true (but often hidden) in all technical artifacts, namely, their socio-technical nature. Importantly, the work that is carried out in order to manage and maintain the arduino as arduino is for the most part public work and available to us as scholars and critical makers. In fact, in choosing an arduino, you have already potentially participated in this process of managing the object.

If you went to a local or online electronics store you might have noted that there are many different arduinos, compatibles and clones made by a variety of different vendors. The original developers of the Arduino have licensed the electronic design of the arduino as open source (Creative Commons CC-SA-BY License) and made the actual design files available online. This has allowed many others to develop their own often customized versions. There are many such versions, developed and sold (often alongside the original arduinos) by various vendors. For example, Sparkfun electronics (http://www.sparkfun.com) sells approximately 16 different arduino and arduino compatible boards, including boards developed and manufactured by the official arduino developers as well as derivatives developed and made in house. Similarly, Adafruit (http://www.arduino.cc) sells both official arduinos and their own arduino compatible versions. Both are considered official distributors of arduino and are listed as such on the distributor page at http://arduino.cc/en/Main/Buy.

But the openness of the arduino electronic design files has also allowed a number of other companies to develop direct copies of the official Arduino boards. In a blog post titled

'send in the clones' from 2010, one of the original developers, Massimo Banzi distinguished

four different 'types' of arduino variations that are not an official arduino board, clones,

derivatives, compatibles and counterfeits. While encouraging the development of

derivatives such as the Sparkfun and Adafruit boards noted above, Banzi highlighted

problems with the three other variations. Banzi and the other developers have maintained

trademark control over the Arduino name, logo, and graphic design on the boards in an

attempt to differentiate the quality of their boards from others and to prevent pure clones

and counterfeits of their work. They specifically discourage others from reproducing the

graphics and logo in an attempt to pass clone boards off as originals and will leverage

trademark law in order to do so. Importantly, Banzi also described what constitutes an

actual arduino:

> An Arduino is a board which
>
> it's directly supported by the official Arduino IDE
>
> it follows the Arduino layout we have standardised
>
> it's properly documented on our website
>
> it's properly licensed to bear the Arduino name and logo
>
> it's made by authorized manufacturers (Banzi, 2010, http://blog.arduino.cc/

2013/07/10/send-in-the-clones/, accessed July 29,2013)

Here again we can see the public nature of the socio-technical work that stabilizes

arduino as arduino. For Banzi and the other developers, the arduino microcontroller is both

a technical object that follows a standardized arduino layout and utilizes official arduino

software, but is also named (by them), 'properly licensed', and made by manufacturing companies that have been duly authorized.

Again, we can see how 'the arduino' exceeds a typical understanding of a technical artifact. Rather than being simply hardware, or hardware and software, or hardware and software and a community, 'arduino' names a unique combination of all three. Arduino is not arduino unless a particular interdependency is deployed between all of its aspects. And again, we can see how the visibility of the strategic work that defines and stabilizes Arduino as a social, digital, and material object makes it a particularly good platform for unpacking the relations between criticality and material practice.

Arduino.cc v arduino.org

What counts as an 'official' arduino became an issue of legal focus in 2013 when arduino SRL applied for a copyright on the use of the term 'arduino' claiming that arduino.cc's use of the term was illegal. **Overview of case here including community response.**

While pursuing their respective cases in court, both Arduino SRL and Arduino.cc have also used multiple means to define 'the arduino'

Banzi's description of the Arduino importantly highlights the value of the agential realist ontology - note his language here - 'follows the Arduino layout' not ''has' or 'contains' the layout, ''properly licensed' not 'has' or 'contains' the arduino license. In each case, Banzi is describing material-discursive practices that work to stabilize attributes by 'cutting' the phenomena of 'arduino' into two aspects - the arduino and the layout, and the arduino and the license. While it is possible to view the Arduino as a network that 'contains' hardware, software, licenses, layout, and documentation, such a description overly stabilizes each element and does not do credit to the intra actions through which they are constituted.

In deciding what arduino board to purchase, you are participating in the process by which the arduino is stabilized. Moreover, the choice of what to obtain does not involve simply 'technical' attributes, but engages you, however, actively or deliberately, in decisions that engage social, political, and legal considerations. Do you purchase an non-authorized arduino clone that, even if it is legal according to trademark law, is seen by the original developers as 'not an arduino'? Do you purchase an actual counterfeit - or more importantly, do you spend the time to make sure the arduino you are purchasing is not a counterfeit?[11] Even in the sourcing of your components you are participating in processes of stabilization (or unstabilization.) We might carry out a similar process of reflection regarding the other parts of this exercise, including the USB cable and PC. Both of these objects are equally the result of complex legal, discursive, and technical engagements, though unlike the Arduino example, are much less available to us for review and critique.[12]

Once you have decided and obtained your arduino (and the other equipment), take a few minutes to look at it. (For simplicity's sake, my comments in the remainder of this experience will focus on the Arduino UNO. Your version may differ in some ways from my description.)
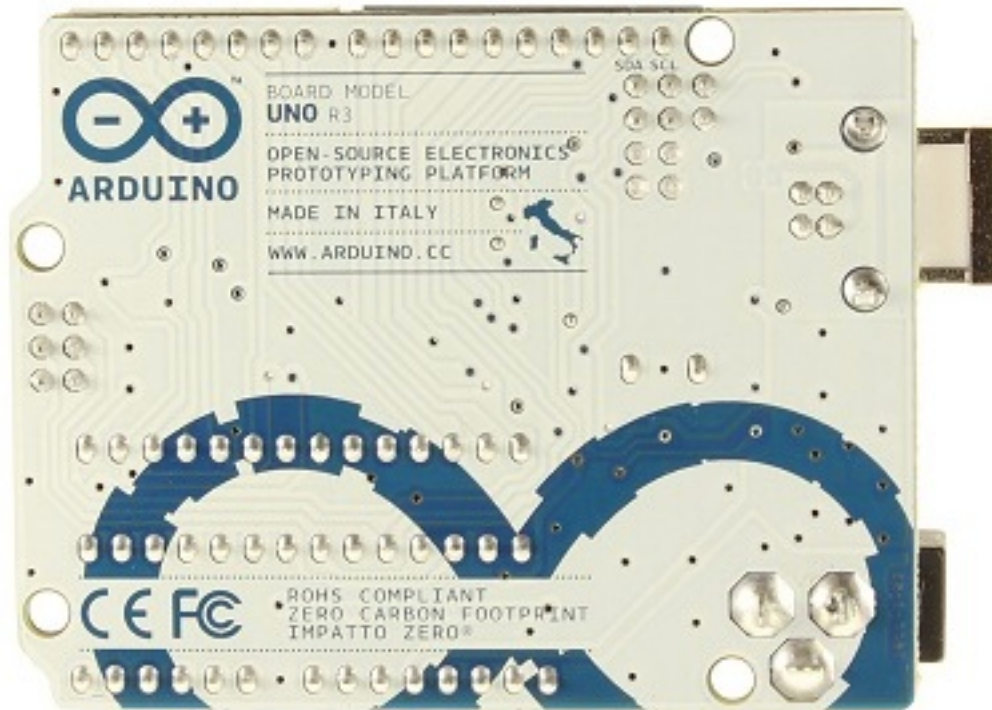
You will see a blue-green (front) and white (back) circuit board, with a number of different components on the front of the board. The most important part is the AVR microcontroller, the black rectangle located at the lower slight right of the board. This is the main component of the arduino, its 'brain' which provides the logic, memory, and input/output functions. A microcontroller is like an entire computer but in a single chip. Like a laptop of desktop computer, a microcontroller contains a processor core, static memory (like a hard drive) and volatile memory (like RAM), as well as ways to accept input (like a keyboard or mouse) and provide output (like a screen.) Other important parts of the arduino board include the barrel connector located on the bottom left (black cylinder) which allows you to connect battery or wired power connector, and the USB port (silver rectangle) which allows you to connect it to a computer for programming and other

communications. Finally, the top and bottom of the board have female headers (rows of black sockets) which allow you to connect input devices such as switches, buttons, and sensors, or output devices such as lights or motors.

The board is also covered on the front with white letters, numbers, and logos, intending to, among other things, provide instructions to users. In particular, the top row of female headers is labeled 'Digital' and each hole is associated with a number or other label. Similarly, the bottom role of female headers is labeled 'Power' and 'Analog In' with labels such as 'A0' or 'GND' associated with each hole. Other visual elements include the Arduino logo, a web link, and the words 'made in italy'. On the back, you can see the silver solder points which each of the components on the board are attached to the board traces that connect everything together. These traces are themselves visible on both the front and back of the board as a series of lines running between components. Also, words such as 'open source electronics prototyping platform' and 'ZERO CARBON FOOTPRINT' declare the political and social status of the device.

Spend a moment also reflecting on how it feels to hold and examine your arduino. If you have used the arduino before, have you ever looked at it in such detail before? Think back to critical making experience #1 and your reflections on the material technology object you examined then. How different is the arduino from your previous object? Are you experiencing any specific emotions as you engage with the arduino? What is engendering them?

Step 2: Downloading and Installing the Software

Go to http://arduino.cc/en/Guide/HomePage and follow the 'Getting Started' instructions.[13] Note that there are different procedures depending on whether your PC is running Windows, Linux, or MacOSX. These instructions will walk you through the following steps:

downloading the software,

 installing it and any necessary drivers,

connecting the board,

launching the IDE application,

Opening example code,

Setting the IDE environment to your board,

Uploading code to your board.

I have found three steps to be the most trouble. First, the process for installing the software and drivers can be somewhat difficult. If you are running Windows, you must follow the driver installation process to the letter. This requires letting Windows try and fail to find and install the appropriate drivers before moving on to a manual process. If you need additional assistance, try looking at a different tutorial for installing the drivers, such as the one at http://learn.adafruit.com/lesson-0-getting-started/installing-arduino-windows. Also, I have found that many MacOSX users fail to copy the application to their 'Applications' folder and, instead, try to run it from the disk image or desktop. While this

mostly works, you may sometime encounter strange errors including an inability to upload code to your arduino board.

Second, after launching the Arduino IDE, it is important to correctly set the Arduino IDE to your board and serial port. As noted above, there are many different Arduino and Arduino compatible boards. In order for the IDE to work properly, it must be told what board you are using. THis step is described in the guide listed above, but is a step that is sometimes missed. Similarly, the IDE needs to be told which serial port on your laptop or desktop is connected to your arduino board. It can sometimes be difficult to figure out which of the serial ports listed under the 'Tools/Serial Port' menu item in the IDE corresponds to your Arduino board. The simplest way I have found to discover which it is, is to look under the Tools/Serial Port menu in the IDE **with your Arduino unplugged,** and make a note of what is there. Then, plug your Arduino into the USB and look again at the Tools/Serial Port menu item. Select the new item that you see there and you should be good to go. If you do not see any change, check to see if you properly installed the drivers.

Third, how do you know whether you are successful? Following the instructions in the guide requires you to open example code - File > Examples > 1.Basics > Blink and, following successful configuration, to click the 'upload' button (the right facing arrow icon). This kicks off a complex process involving the following steps;

1) the example code you selected (the 'blink' program) is compiled, e.g. translated from human-readable source code into machine code;

2) the arduino IDE sends a command over the USB cable to the bootloader software

running on the Arduino board asking it if it is ready to receive a program;

3) the bootloader responds that it is ready;

4) the Arduino IDE streams the machine code to the arduino board;

5) the bootloader saves the code to static memory, notices when it is done, and

reboots the arduino;

6) the arduino board executes the code.

Traces of these steps can be seen if you look carefully. The status bar will show 'done

compiling' and the program notification area will respond with the size of the machine code

as 'Binary Sketch size" if the compilation and uploading is successful. Also, you can see the

upload request, response, and the streaming of the machine code by watching the serial

transmit (TX) and serial Receive (RX) lights on the arduino board.[14] Note here that tracing

this process requires you to move between the software IDE and the hardware board, to

look for error messages on a screen as well as physical changes (lights going on and off) in

order to understand what is going on.
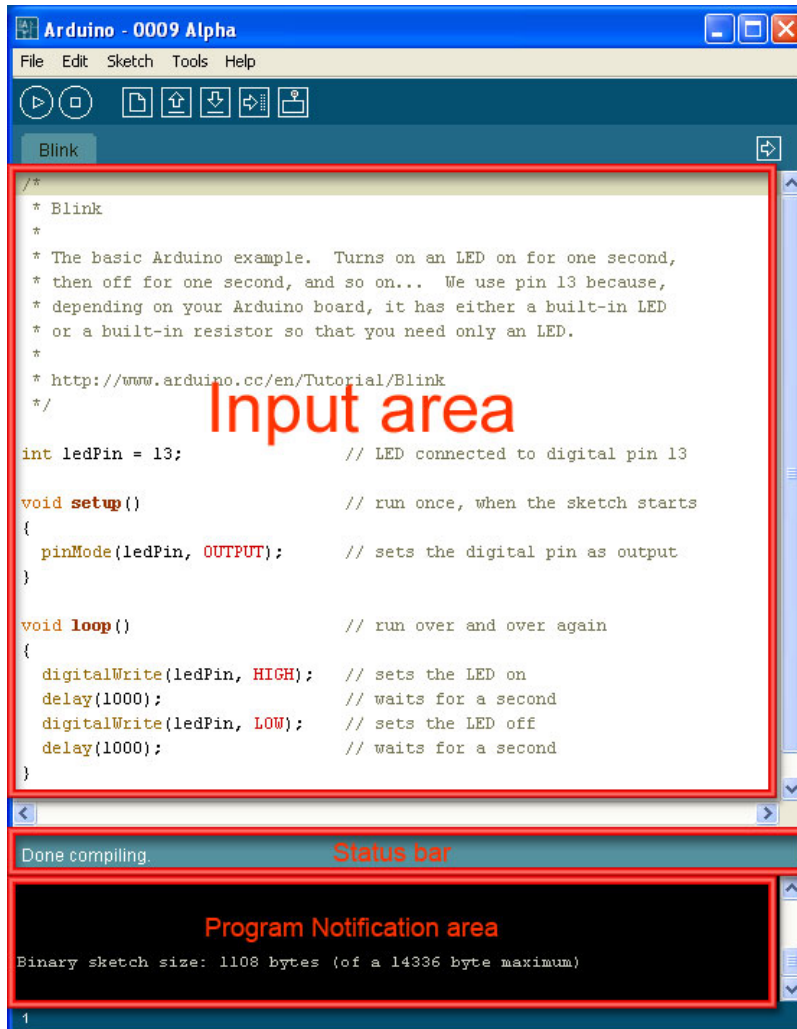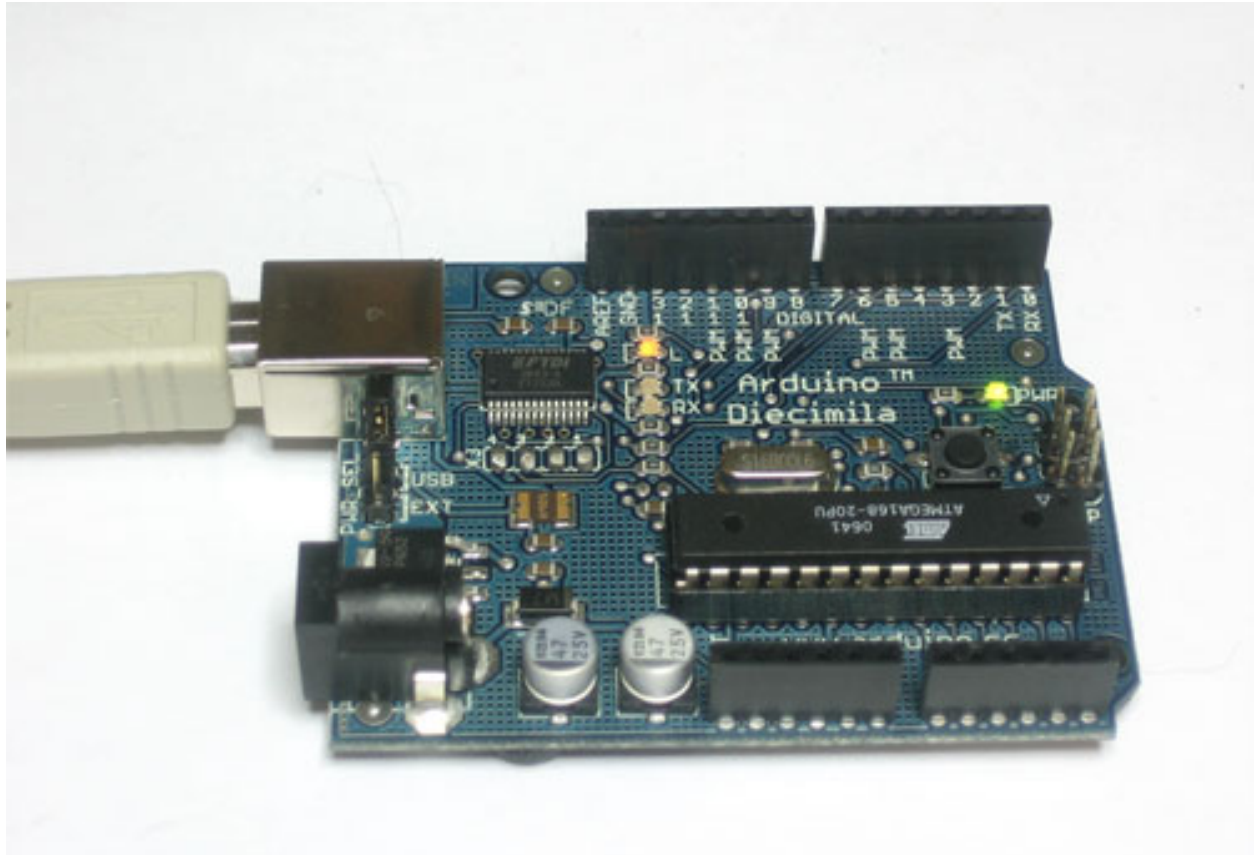
If you have successfully installed and uploaded code to your arduino board - congratulations! The steps involved are somewhat complex and involve operations and activities that are not entirely familiar to non-developers. It can be difficult to trouble-shoot problems when they occur, since the systems works at a number of different levels - software IDE and drivers, hardware board and serial ports - and making the whole chain work together requires you to think across these levels and to figure out where the problem occurs. Success can be as difficult to recognize as failure and the process of observation requires moving between the parsing of debug messages from the software as well as close observation of the hardware.

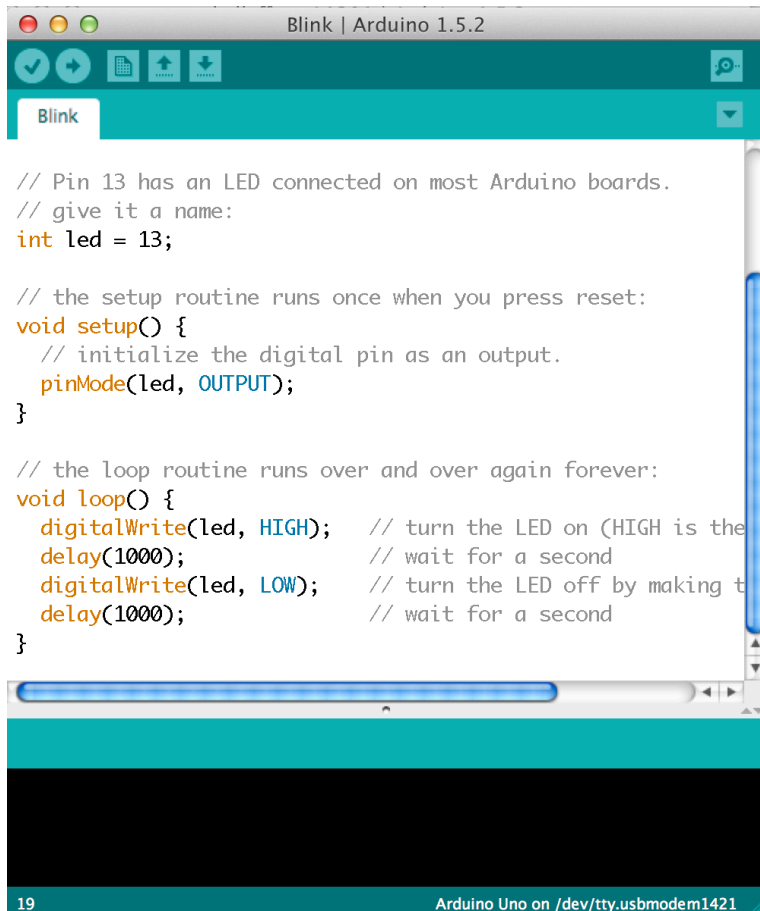**Step 3: Controlling the blinky-blink**

The next step is to customize the example code and extend the arduino hardware. Currently, your Arduino board should be plugged in via USB to your laptop or desktop computer, and you should be running the Arduino IDE. The green PWR light (left middle top) should be lit and the yellow test LED (below Pin 13 close to the top) should be blinking. This test LED shows the status of Pin 13, turning on if power is flowing to this pin, and turning off when no power is flowing.

Take a look at your LED. It should look something like the one below. Note that one leg is shorter than the other. This is because LEDs are polarized, meaning that in order for the to work, the proper leg needs to be connected to GND and the other to PWR. The convention with LEDs like yours is for the shorter leg to be the GND leg. Try inserting your LED into the headers on your arduino. Insert the shorter leg into the top header pin marked 'GND' and the longer leg into the pin marked '13'.

If you did this correctly, your LED should begin to blink in time with the test LED on your board. If it doesn't blink, make sure you have inserted it into GND and pin 13 ,and try reversing the legs. If you cannot get it to blink (and your test LED is blinking) try a different LED.

Now try customizing the source code. Look again at the input area on the Arduino IDE. You should see the following code:

For a more detailed overview of what is happening in this code example, see http://arduino.cc/en/Tutorial/Blink or http://learn.adafruit.com/adafruit-arduino-lesson-1-blink. For now, just focus on the following section of code:

```
// the loop routine runs over and over again forever:
void loop() {
  digitalWrite(led, HIGH);   // turn the LED on (HIGH is the voltage level)
  delay(1000);               // wait for a second
  digitalWrite(led, LOW);    // turn the LED off by making the voltage LOW
  delay(1000);               // wait for a second
```

```
}
```

As noted in the comment (marked by the //) this is the section of the code that repeats over and over again as long as the arduino receives power. In it two commands are being executed; a 'digitalwrite' and a 'delay'. The digitalwrite command is used to set the status of the led (actually pin 13 in this example), with HIGH sending power to the LED and LOW turning this power off. The delay command simply stops execution of the code for the number of milliseconds contained with the brackets. Delay(1000) therefore stops the code for approximately one second.

Try changing these delay statements to speed up or slow down the rate at which the LED is blinking. Once you have made changes to the code, remember that you need to re-upload it to the arduino by pressing the 'upload' button (the right facing arrow icon). What happens if you increase or decrease the numbers equally in both delay statements? What if you increase one and decrease another? What happens if you add additional digitalwrite statements and delays with different values to this section? How would you create a blinking morse code 'SOS' pattern - pause-long blink-short blink-long blink-pause?

Step 4 - Review

What might you have learned from this encounter with the arduino system? First, you hopefully have a better sense of the complexity of technological objects. As the arduino example highlights, technical features alone do not determine a technological artifact.

Instead, they are better addressed as complex phenomena and as resulting from and maintained by material-discusrive practices through which the political, the technical, and the social are depicts and deployed. Further, you have participated in this process through the decision-making you engaged in when sourcing your arduino, an experience which highlights our complicity even as consumers in the complex arrangements through which objects are stabilized and maintained.

Although it seems obvious to state, your own engagement with the arduino was markedly different if you actually obtained the parts listed above and attempted to carry out the above steps, rather than reading them and imagining yourself doing so. The experiences of finding an arduino and the other parts, downloading and installing code, and working through the example code make use of different physical and cognitive resources than the apprehension and act of imagining yourself engaged in such operations. Even if your experience matched act for act and cognitive operation to cognitive operation the depiction of the process in the text above, your phenomenological experience would be different. Of course, your experience probably did not match all that well, given the reductive way the text and images above depicted what you were expected to accomplish. You might have borrowed an arduino from a friend and had a heated discussion regarding its status as 'official' or not, or ordered one from an online vendor through a complex process involving drop down menus, credit cards, and postal codes. The phrase 'obtain an arduino' could not hope to capture all the possible complexities attending such a process. You might have had difficulty connecting the arduino to the USB cable and to your PC because of the resistance of the cable and the way it can flip the arduino around. The phrase

'plug it in' could not hope to capture the complicated physical moves you needed to carry out to accomplish this.

One way to parse these differences is by noting the differences between tacit and explicit knowledge and, following Polyani and others (Polyani, 1958, 1966; Lam, 1996, Nonaka and Takeuchi, 1995; Collins, 2001) highlight the difficulties in formally and explicitly articulating even simple activities such as using a hammer to hit a nail. More over, we might emphasize the need for a 'knowing subject' and practical and shared experiences in order to engage in activities requiring tacit knowledge. We can also affirm the importance of an individual's commitment and relation to the context of action (Nonaka, 1994:21) as other key elements in making sure we can move easily between these two levels. We do not need to defend the importance of tacit knowledge or the value of explicit articulations - that has already been done for us. But critical value can be found by examining how these levels are established and maintained, what kinds of information are made explicit within relevant communities, and how such practices work to normalize certain activities and denormalize others. But leveraging definitions of tacit/explicit do little to explain the relevance and importance of the differences between your experiences and the textual and pictorial descriptions above, particularly since we are not interested in coherence between explicit descriptions and tacit experience. Instead, we need to focus on the differences and incommensurable aspects, given our goal is to better understand how the physical, embodied engagement supplements and extends critical reflections that are typically considered through explication and formal means.

For example, this critical making experience mirrors in many ways the form and content of other Arduino tutorials. It walked you through a technical process, makes use of example code, and even uses the ubiquitous 'hello world' of physical computing, the blinking of an LED. However, it also intersperses this technical focus with prompts for other kinds of reflection, asking you to think about the social and political work associated with the Arduino licenses and to examine your own feelings and emotions regarding your engagement with the device. The goal of the experience itself was not to engender a pure technical literacy but to begin to instantiate an understanding of technological objects and associated modes of labor as connected to social forms and critiques.[15] This goal and the blended form used to communicate it might be seen as violating the conventions of technical work and training more generally.

I have noted above that Arduino developers and users do recognize the politics and social nature of the Arduino object and that they engage in this work as part of the process by and through which the Arduino is constituted as Arduino. However, it is clear that the 'social and political' work of Arduino is kept separate from the 'technical' work. The tutorials linked above and, in fact, all tutorials that I have seen that teaches how to use and develop with the Arduino, provide resources for carrying out technical operations - writing code, installing drivers and libraries, and assembling hardware. Breaking out of this domain to engage in subjective reflection (e.g. 'How do you feel when...') or political critique seems foreign precisely because of "the whole tacit system of intellectual procedures" (Agre, 1997) associated with the technical disciplines. This is a good example of how social formations and objects are co-constructed through specific agential cuts that link material phenomena and material-discursive practices. Equally, despite my best attempts, the

arduino critical making experience described above does not entirely steer clear of reductive separations of 'social' and 'technical' due in part to a desire to make the process comprehensible - requiring a certain obedience to genres and processes associated with technical work. This issue - what I will now term 'the problem of steering clear' - is one that we will continue to address throughout this book. For now, I will use this issue to defend critical making's focus on material production - emphasizing the obdurancy of material-discursive practices and agential cuts regarding material objects and social formations, e.g. the ways in which past 'cuts' continue to effect how engage with objects, and related to this, a concordant need to address materiality as part of critical analysis. Here, other critical materially-engaged academic work can provide additional details. In the section to follow I survey three illustrative engagements; Agre's experiences in formulating a 'critical technical practice', DiSalvo's development of 'adversarial design', and Drucker's experiments in speculative computing.

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[1] This statement predicts the ideas of Karen Barad, and particularly her idea of the agential 'cut' that I will address later in this chapter.

[2] I want to note here that not all scholars embrace this notion of the 'material-semiotic'. SOme of these critiques will be addressed below.

[3] I should note here that the idea of 'translation without transformation' of which this is only one articulation is addressed in the next chapter, specifically regarding the idea of 'information' as a vehicle for moving seamlessly across materialities.

[4] (Baxandall, 1987, 3) Patterns of intention: on the historical explanation of pictures. Yale University Press.)

[5] They align 'meaning' with what the call the 'semiological approach' typified by Bryson, and "New Art History."

[6] In the section to follow I use Karen Barad's 'agential intra-action' as an useful alternative to representationalist accounts. But there are alternatives to this alternative. A potentially interesting one might start from Charles Taylor's phenomenological explorations that leverage Merleau-Ponty and Heideggar to explore 'coping' and 'living with things' as a way to overcome simplistic relations to materiality as 'causal.' Taylor calls a 'mediational epistemology' (Taylor, Merleau-Ponty:1) This is based on a deeply held understanding of the world as made up of two parts, an outer reality and inner states intended to represent or bring to world to us. Taylor notes the beginnings of this understanding within Descartes and notes the continued acceptance of this duality despite a rejection of Descartes more generally. Importantly, Taylor posits an alternative to the structuring frame of mediational epistemology through a notion of 'coping' that he draws from Merleau-Ponty and Heiddeger. This 'coping' starts from a 'living with things' that emphasizes our non-conceptual engagement with the world but also highlights that these relations are also not simply understandable through simple causal terms. Taylor: need to overcome mediational epistemology that posits I/O; need to find ways to engage in work that acknowledges the non-conceptual aspect of our 'living with things' while not defining these aspects as purely casual and inanimate. Don Idhe's expansions of 'postphenomenology' might be similarly useful.

[7] She does not mention any specific tripartite representationalist theories, but we might consider Piercian semiotics as one such version.

[8] At the end of this paragraph, Barad cites Judith Butler's 1989 article "Foucault and the Paradox of Bodily Inscriptions". (1989) The title of this article nicely captures Butler's main points, first, Foucault's reliance on what Barad would call a representationalist account of bodies and inscriptions and second, his pradoxical attempts to overcome this reliance through much of his work. Engaging Butler's argument is beyond the bounds of this book. However, it does serve

as an excellent example of how difficult it can be to overcome representationalism even when one intends to do so.

[9] say something here about having to work against the problems with terms used by Latour - networks, assemblies, constellations - each of which encourages the idea of discrete elements that must be brought into relief and relation in order to create a whole. Comparison to   Haraway's terms is fruitful here - hybrids, monsters, cyborgs - which, while they still entail the work of bringing together, do not seem to require the same atomic structures.

[10] I will return to the value of the maker movement for critical making later in this chapter. For now, suffice it to say that the openness and willing to share expertise

[11] This turns out to be relatively difficult to do, given the ways most arduino counterfeits mimic the design characteristics of official arduinos. See here for guidance by the official developers regarding counterfeits - http://arduino.cc/en/Products/Counterfeit.

[12] Though note the emergence of this complexity when controversy arises. For example, USB as a social, technical, and institutional standard is revealed by cases involving the emergence of new standards and the ways tech companies jockey for power regarding these developments, e.g. Intel and USB 3.0 specifications.

[13] If you need additional assistance, there are a variety of excellent online tutorials that can walk you through the process of installing the Arduino software. My personal favorites are the tutorials up at http://learn.adafruit.com.

[14] need to replace images in this section with my own. current ones pulled from arduino.cc and adafruit guides.

[15] Later in this book I will explore this as 'socio-technical literacy' but for now let me merely bracket this out as a particular goal of this experience.