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Four (In)Determinabilities, Not One

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Rationale

Like all chapters in this volume, mine, too, concerns itself with limits of knowing. What distinguishes this chapter from the others, however, is my accounting for these limits in terms of (in)determinability, not (in)determinacy: (in)determinability implicates a human being's (in)ability to ascertain something; (in)determinacy refers to a supposedly objective condition, which assumes human involvement to be superfluous and dispensable. Also, I am suggesting that (in)determinabilities are not merely of one kind--permeating different fields in different guises, as some of the forgoing chapters are assuming (in)determinacy does--but that one needs to distinguish at least four. I contend that (in)determinabilities arise as a consequence of *different* ways in which humans choose to be involved in *their* worlds: spectators construct worlds that are very different from those of, say, builders whose actions are necessary parts of the world they alter. And designing artifacts entails a way of *knowing* that is quite different from that needed to use or consume artifacts made by others. Being a member of a corporation or community entails still other ways that are not derivable from being good at handling things. Not only do these rather different kinds of human involvement entail different epistemologies--different ways by which one comes to know--but they also bring forth different limits for what they enable.

I am suggesting that these epistemologies are not superior or inferior, or better or worse, relative to each other. Their value depends on what one wants to accomplish in one's world. And as I do not care to privilege one epistemology to the exclusion of all others; I can afford to move through them with ease.

Observational Determinability

Let me define: a system is *observationally determinable* if an observer can predict its behavior within reasonable computational resources and time constraints. My question is this: given an observer who is equipped with perfect measuring and recording devices and endowed with a state-of-the art computer, what are the limits on observational determinability that this observer will experience? I shall explore these limits relative to two structures of observed systems that make predictability possible and impossible respectively.

Hans Bremermann (1962) derived a theoretical limit for computation by considering that any computer--past, present, or future--must have some mass and occupy states marked by recognizable energy differences. Heisenberg's Uncertainty Principle suggests that these energy differences, which have to be observed or measured, cannot be arbitrarily small. This, and Einstein's mass-energy equation, led Bremermann to conclude that "[n]o data processing system whether artificial or living can process more than $2 \cdot 10^{47}$ bits per second per gram of its mass" (1962:92). This number, expressed in physical units of measurement that are rather small compared with those commonly used by engineers, might suggest very large computational capacities ahead of us. This is not so, however. Consider: there are only $\pi \cdot 10^{7}$ seconds to a year; the earth is about 10^{9}-10^{10} years old; and its mass is less than $6 \cdot 10^{27}$ grams. To put these quantities in perspective: if the whole earth were to be converted into the most efficient computing matter, it would have been able to process not more than 10^{93} bits since solidification. Under equally optimal conditions, a computer of the weight of a human brain would be able to compute no more than 10^{59} bits during a researcher's productive lifetime of, say, 50 years. But no brain can be as efficient; and, moreover, a human brain has other things to do besides observing the world.

To ascertain more realistic limits for computing observations, let me start then with commonly available computer technology. A workstation equipped with an Intel Pentium III microprocessor runs with a computing speed of 400 MHz. In a simple application, it executes about 167 additions per cycle[1]--or some 10^{8} operations per second--about 10^{17} during that 50-year period, deemed the career span of a determined researcher.[2] According to Moore's Law, the number of transistors on integrated circuits doubles every 18 months. Microchip development has followed the growth rate of Moore's law, since its statement in 1965. But computer technology eventually must reach a ceiling. Yet, supposing that Moore's Law holds for the next 20 years, the number of algebraic operations that human observers could utilize during their active lifetime should increase from 10^{17} to 10^{21}. Stating future capacities is highly speculative, of course. Nevertheless, I submit that

[1] I am grateful to Jon Stromer-Galley of the Computer Center at The Annenberg School for Communication, who has obtained these capacities for me. Using VB, the computer performed 10^{7} additions per second; with C++, the corresponding number was $10^{7.8239}$.

[2] A more advanced microprocessor, with a speed of 1 GHz instead of 400 MHz, would add very little to this limit, changing the number of algebraic operations from $10^{17.0198}$ to $10^{17.4177}$.

computations requiring more than 10^{20} simple algebraic operations remain beyond reach--at least within tomorrow's realistic bounds of scientific research.[3]

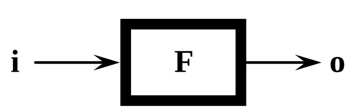
What then is the limit of observational determinability, namely, the limit of a detached observer's ability to predict something not yet observed?

Trivial Machines

Let me examine a system that conforms to the scientific idea of being predictable by observation. Such a system would *behave*--it would change its state over time. It would allow an observer access to a number of observations. And the act of observation would not interfere with the operation of the system. Note that the foregoing does not describe the properties of a system found in nature but spells out what is meant by a detached observer who refrains from influencing how a system is behaving. Observational determinability then means that, after a sufficiently long period of observation, the system has exhibited enough regularity for the observer to be able to predict what it will do. Zoltan Domotor, in this volume, is correct in stating that prediction "rests on the idea that (the) future state(s) of a system depend...on its past or current state(s)." Since Arthur Gill (1962:8), a system that enables prediction in precisely this sense is called *a trivial machine*. It has a set of inputs i, a set of outputs o, and it conforms to a function F that relates the two sets by a many-to-one mapping:

$$o = F(i),$$

--however complex that function may be, Figure 1 below depicts such a machine:



A Trivial Machine
Figure 1

Trivial machines may have any number of inputs and outputs. To predict a trivial machine's behavior means knowing or hypothesizing its function. To obtain this function, the researcher would need to observe n_i input/output pairs <i, o> or as many pairs as there are inputs. Even if the machine reacts to quintillion inputs, this would still remain below 10^{20}. In other words, trivial machines do not present significant challenges to observational determinability. This holds equally true for trivial

[3] To humble expectations, consider that the reputedly fastest supercomputer to date, Q, located at the Los Alamos National Laboratory, operates at a speed of 30,000 billion calculations per second, or mere 300 times faster than Intel Pentium III. Under the assumption of Moore's Law, this supercomputer is but 12 years ahead of what is generally available right now.

machines that are *operationally closed*, in that their outputs become their inputs and define their dynamics. In either case, once their function has been identified, they are perfectly predictable from their inputs. In case of operationally closed trivial machines, the identification of a suitable function is made even easier when they converge to an eigen-behavior[4] as they often do. Hence:

Trivial machines are observationally determinable.

Observational determinability is an attractive condition--the very reason for the natural sciences to bank on detached observation rather than on other forms of inquiry into their objects of interest. It is also the reason why so many explanatory devices are aligned with trivial machine conceptions. In regression analysis--commonly employed in the social sciences--analysts distinguish between independent and dependent variables, the trivial machine equivalents of inputs and outputs. And although regression equations have a distinctly probabilistic flavor, their use imposes nothing short of trivial machine conceptions on observational data. In logic, deduction is trivial in the sense that the minor premises are its inputs; the major premises, its functions; and the logical inference--the conclusion--its output. Representational conceptions of language (mappings from a given language to a meta-language) are also trivial for mapping referents into symbols. Attempting to locate brain activity when performing a task (Gur et al., in this volume), too, is tantamount to selecting the function of a trivial machine. Viewing communication as the accurate transmission of information from a source to a receiver (Shannon and Weaver 1949), using a code, only trivializes communication.

Unfortunately, reality seldom cooperates with how it is being conceptualized and observed. When facing difficulties in prediction, instead of changing paradigms, it is customary for researchers to hold on to the analytically convenient trivial machine conceptions and either complicating their conception of the inputs, or weakening their criteria for prediction. In the first scenario, a researcher may consider outputs to be predictable from multiple inputs. To so predict a machine, the researcher needs to make not n_i but up to 2^{n_i} observations, thereby reaching the limit of 10^{20} already by n_i=66 inputs. Thus, the consideration of multiple inputs drastically limits the complexity of a system whose behavior is predictable by an observer. Regarding weaker criteria for prediction, Domotor and Batitsky's chapter distinguishes between *strongly deterministic systems* (Gill's trivial machines); chaotic *systems* that, while deterministic, can be unpredictable as their behavior depends on the

[4] The *eigen-behavior* of a dynamic system is an equilibrium, peculiar to that system, in which it follows a regular cycle within a subset of its possible states (Dictionary of Cybernetics, http://pespmc1.vub.ac.be/ASC/EQUILIBRIUM.html).

(unknown) precision of some earlier state--causing the so-called butterfly effect; and *probabilistic systems* whose outputs are random within limits, but knowable by their probabilities of occurrence. I offered regression analysis and Claude Shannon's communication theory as two research methods that assume probabilistic systems. In probabilistic systems, the number of observations required to establish probability distributions is a function of the desirable level of statistical significance, calling for sample sizes far larger than n_i; again, significantly reducing the complexity of a system within the limit of observational determinability. To these three systems come *possibilistic systems*, for which observers are content when they can predict a reasonably small subset of outputs--their hope being that actual observations are contained in the set of predicted possibilities. The rules of chess, for example, are possibilistic. But none of these qualifications fundamentally deviate from trivial machine conceptions. They merely reflect scientific observers' willingness to accept imperfect predictions, while holding on to their customary detached observer role and to the analytically convenient trivial machine conceptions of their world.[5]

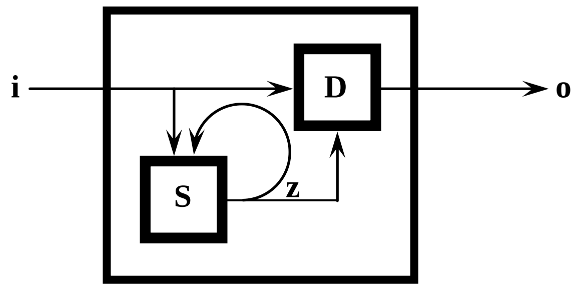
Nontrivial Machines

In contrast to trivial machines, a nontrivial machine:

- Has internal (unobservable) states z whose values codetermine its input/output relations <i, o>.
- The relationship <z, z'> between present and subsequent internal states is codetermined by the inputs i.
- D is the driving function: $o = D(i, z)$
  and S is the state function: $z' = S(i, z)$

Diagrammatically, this nontrivial machine is shown in Figure 2. Notice the loop involving its internal states z, which can keep information circulating inside such a machine for a very long time.

[5] In this volume, Domotor's chapter expresses this attitude quite succinctly: "Because scientific inquiry is most effective under deterministic methodology, determinism should not be given up easily, even if this should require switching to a more complex level of description."



A Nontrivial Machine
Figure 2

To predict the behavior of a nontrivial machine, accurately, amounts to finding not one but two functions, D and S, which jointly determine the output from a record of previously observed inputs. Heinz von Foerster (1984:12) calculated the quantitative relationships among the number n_i of two-valued inputs (0 or 1, for example), the number N_z of effective internal states, the number N_D of possible driving functions, and the number N_S of effective state functions, for machines with only one two-valued output o and n_i = 1, 2, 3, and 4 two-valued inputs i, 2^{n_i} in number:

n_i	N_z	N_D	N_S
1	4	256	65,536
2	16	$2 \cdot 10^{19}$	$6 \cdot 10^{76}$
3	256	10^{609}	$300 \cdot 10^{4000}$
4	65,536	$300 \cdot 10^{4000}$	$1600 \cdot 10^{70000}$

Numbers within nontrivial machines, as in Figure 2,
among which informed choices would be required in order
to determine observationally *which* machine it is.
Table 1

In Table 1, one can see how a rather modest increase in the numbers n_i of two-valued inputs increases hyper-exponentially the number of possible functions (among which an observer would have to select an appropriate pair), which quickly exceeds computability. With n_i = 2 two-valued inputs, the number $N_S = 6 \cdot 10^{76}$ of state functions is already far above 10^{20}--indeed, beyond computability on earth. But for the simplest possible case, $n_i = 1$ two-valued inputs, all other nontrivial machines are transcomputational. One can therefore conclude:

Nontrivial machines are observationally indeterminable

and:

The ability to predict behavior from observations is limited to trivial machines.

These striking findings might come as a surprise to hard-nosed behaviorists, who insist on theorizing observations only. Yet, as von Foerster (1984:13) has pointed out, the fundamental limitation, here re-stated, "joins their famous sisters, who sing of other limitations:

- Gödel's Incompleteness Theorem;
- Heisenberg's Uncertainty Principle;
- Gill's (1962) Indeterminacy Principle."

This limit on *observational determinability* spells out the limit of empirical research as we know it.

Synthetic Determinability

Notwithstanding this fundamental limit for understanding a system by detached observation, we seem to have no difficulties conceptualizing and building nontrivial machines, computers, for example, which have an extensive memory in the form of internal loops, and proceed recursively--just as the minimal nontrivial machine in Figure 2 does, only in a more complex manner. This discrepancy signals a very different kind of human involvement: the design, engineering, building, and manufacture of tangible artifacts.

Let me define: a system is *synthetically determinable* if it can be realized as intended, according to specifications (instructions, programs, or plans) within reasonable resources and time limits. I shall call such systems *technological artifacts* to distinguish them from other human creations that cannot be *built* to specifications, as shall be seen below.

All technological artifacts are designed to serve intended functions in the context of other technological artifacts, often comprising larger technological systems. And obviously, the mere existence of human artifacts is sufficient proof of their synthetic determinability.

Before going further, let me briefly review the argument that led to the conclusion that trivial machines are observationally determinable whereas nontrivial machines are not. It involved, first, designing two artifacts--one demonstrably below the limit of observational determinability, and the other above it; and then, varying their structure to ascertain the limits of their observational determinability. But note that the knowledge of these systems' functions and the ability to vary them is not available to detached observers of such systems, only to their designers and builders. Designers typically translate their ideas into realizable specifications and, in the above, into pencil-on-paper machines. One most likely could build a machine that was worked out on paper, and then let people make the effort of predicting its future states from past observations. In the course of such explorations, one may well face observational indeterminability. However, without knowing the design of the machine, one would certainly not be able to link the experience of observational indeterminability to the nontrivial structure of the machine: one could not explain it, hence, the importance of having *different* epistemologies at one's disposal.

Clearly, the realization of technological artifacts by design, tantamount to intervening in nature and ultimately creating a human-made world, entails an epistemology that is wholly different from the epistemology of *observing* a world of preexisting objects of nature, or artifacts--as if their genesis were unknown. The shift from knowing by observation to knowing by design is a shift from spectator knowledge (of knowing no more than *what* one can see), to constructive knowledge (of knowing *how* to realize something), a shift from seeking certainty by induction (generalization or categorization) to seeking certainty by solving a technological problem; and a shift from trivializing the world, to creating desirable complexities in that world. These two epistemologies are incommensurate; none is reducible to the other. For detached observers, the problem is one of hypothesizing a design so that it accounts for what happens to be observable. For builders, however, the problem is one of realizing the specifications of a given design. There is an asymmetry for the two epistemologies: once the system has been built and it works as intended, there is no reason to hypothesize and test what its designers already know. When synthetic determinability is satisfied, observational indeterminability is no longer an issue.[6]

But what are the limits of synthetic determinability? I shall mention three frequently cited limits but will rely on a fourth:

[6] This statement assumes communication between the observers of a system and its designers. Once observers have obtained the design of the system, their efforts to figure it out become superfluous. However, there are situations in which such communication is to be prevented. For example, the purpose of designing secure encryption codes is to make them observationally indeterminable. When such codes correspond to trivial machines, they may be broken with adequate computational resources and time. Unbreakable codes, by definition, can only be acquired, not broken.

- ***Physical laws*** are most frequently mentioned. The perpetuum mobile, an old idea that has occupied the imagination of many, contradicts thermodynamic laws and is hence believed to be impossible to build. Traveling back in time is the stuff of science fiction. But since reversibility contradicts the definitions of time in several well-established theories, of evolution, for example, designing a time machine is considered an exercise in futility. The limits of computability, Bremermann's limit for example, states in physical terms why computation cannot exceed $2 \cdot 10^{47}$ bit/sec/gr. Physical limits are seemingly definite, as is observational indeterminability. But the domain of actual technological problems, say, of building fuel-efficient cars, or faster and more powerful computers--are still far removed from these limits, leaving ample space for human ingenuity to take effect. One may experience the feeling of approaching such limits when facing increasing difficulties in designing more powerful computer chips, permanent storage media, extremely small (nanotechnological) mechanisms, very tall skyscrapers, perfectly reliable measuring instruments, cold fusion, travel near the speed of light, or in attempting to build a human habitat on Mars, for instance.
- ***Techno-logical constraints*** in turn are limits on one's ability to manufacture parts, assemble artifacts from components, and to make them work. The hyphen between techno and logical is meant to highlight that there *is* a logic to synthesis. Techno-logical constraints concern known solutions to technical problems and available means of production. These limits are not, however, as definite as physical laws are believed to be. Some such constraints diminish as technology advances, largely because technology applies to itself and bootstraps its complexities to greater heights. Yet, at any one moment, insurmountable techno-logical barriers seem to cause failures should attempts be made to cross them. The reason for not hearing of too many transgressions of techno-logical limits is that synthetic indeterminabilities tend to be caught in the arguments among engineers, well before they manifest themselves as failures. Questions of whether something can indeed be realized, and where the boundary of synthetic determinability hides, dominate the discourse of engineers and permeate the conversations among designers.
- ***Economic constraints*** are obvious. In competition, artifacts that can be manufactured cheaper, distributed with less effort, and perform more efficiently are more likely to succeed than those that do not measure up to these criteria. In his "Architecture of

> Complexity", Herbert Simon illustrated how technological structures imply economic advantages by means of the parable of two watchmakers (1981:188-195). One watchmaker worked components into various subassemblies and ultimately into a functioning watch. The other assembled all components in a single uninterruptible process. When the former answered incoming calls from clients placing orders, all he lost was the subassembly he was working on, whereas the latter had to start all over again. Needless to say, the former could produce more than the latter and stay in business. We know of many technological ideas, the realization of which may easily exceed available community resources--whether they be building a geodesic dome over Chicago, beaming sun energy to a power plant on earth, or eradicating a communicable disease from the human population. Technological artifacts become cheaper over time. In the 1960s, the very idea of putting humans on the moon bordered on economic irresponsibility. Now, space tourism is in the news.

These limits of synthetic determinability appear fluid, at least from a historical perspective. But there is a more definite cut-off point for synthetic determinability: *autopoiesis***.**

As noted, the very existence of technological artifacts is proof of their synthetic determinability. But the earth is populated by many *synthetically indeterminable* systems. Living beings for one, and social institutions for another, simply cannot be manufactured as mechanical devices are. Notwithstanding science fiction, and contrary to the Golem legend, there are no specifications, and no assembly lines--indeed, no ways of putting living beings together from parts, and then blowing life into them. Even major replacements of human organs and limbs are undertaken while the subject is alive.

A crucial structural feature of living beings is their autopoiesis. *Autopoietic systems* produce themselves by manufacturing all the components necessary to operate the very network of production that produces them (Maturana and Varela, 1972). Autopoietic systems also find themselves in continual interaction with their environment without, however, being causally determined by it: their environment may perturb the dynamics of autopoietic systems but cannot determine it, however. This is evident in the very absence of correlations between the organization of living systems and the features of their environments. Hence, autopoietic systems are considered organizationally closed--operationally closed regarding the autopoiesis of their organization. They cannot be instructed from their outside, and they cannot be designed or built according to specifications. Indeed, the genesis of autopoietic systems does not resemble that of machines, whether trivial or nontrivial. Here then, one faces a structural or organizational limit of what can be produced by design:

Autopoietic systems are synthetically indeterminable.

Hermeneutic Determinability

I consider *hermeneutic determinability* as the human ability to understand and to use artifacts in the context of a community or culture. I am speaking here of *cultural artifacts* that exist, not merely on account of having been realized materially, but because of the uses they have acquired for the members of a community. The use of artifacts by individual community members (each an organizationally closed human being) is not explainable in terms of specifications and cannot be so manufactured either. The use of artifacts is, hence, synthetically indeterminable. I shall exemplify hermeneutic determinability via three dissimilar cultural artifacts: texts, public spaces, and personal computers.

Texts are written for being read, usually by others, although their writers always are the first readers and critics of a text. Texts can be reproduced mechanically but are meaningless without someone making sense of them. Quite unlike what the popular *container* metaphor suggests, texts do not literally *contain* meanings that could be conveyed from authors to readers. The use of this container metaphor diverts attention from what readers do with a text to the properties of that text--much like the use of the optical metaphor for observation diverts attention from processes of observation to the properties of observed objects--or from determinability to determinacy for that matter. Also, reading is far from a mechanical process and quite unlike what a computer does when importing data--often described as 'reading files.' Attentive reading involves human imagination, directs readers' attention, and can inform actions. For example, reading one part of a newspaper may direct readers to other parts, which in turn might lead them to revise the former reading and redirect their attention to still other sections of that paper (see Clark's chapter).

The process of reading is aptly described by the well-known *hermeneutic circle*, which is a recursive process of exploring what something could possibly mean against the background of one's previous readings and experiences within a community. It converges to a state of understanding.[7]

[7] On the difference between understanding and comprehension: *Understanding* is the state in which all pertinent questions on a subject under consideration seem to be answered, and one can go on to other subjects. *Comprehension* means possessing full and correct knowledge of something. Thus, comprehension invokes the criterion of *correctness*, as in passing a test, whereas understanding does not.

When hermeneutic explorations occur in conversation, any one participant's understanding takes account of the implications of the other participants' understanding.

Any one reader's *understanding*--namely, the hermeneutic process involved in making sense of a text--is not accessible to observation by someone else, least of all by someone unfamiliar with that reader's background. This makes the reading of text *observationally indeterminable*. The only way to *understand* a text is to read it as a member of the reader's community. Nor is it possible to specify how a text is to be read: authors do not have the power to enforce a particular reading of their writing--despite common expectations and personal disappointments when such expectations are frustrated. Thus, text is *synthetically indeterminable*.

This is not to deny that readers could coordinate their understanding;[8] for example, regarding a text, by conversing on it with other readers, answering questions concerning each other's understanding, negotiating a consensus on what it is to mean, or joining in a relevant action. Hence, no matter the materiality of text and despite the fundamental autonomy of understanding, communication *can* transform a text into a cultural artifact, allowing it to participate in joint community practices. Except for their use as secret messages, texts are created to be hermeneutically determinable; that is, to support certain practices of a community or culture.

Thus, texts are unintelligible without some minimal knowledge of the history of coordination of reading inside the community or culture that produced them. This inescapably ties the understanding of text to its reader's familiarity with, or membership in, a community. Texts are prototypical cultural artifacts. To gain an understanding of the appropriate uses of texts, one cannot afford to play the role of a detached observer, or that of a designer--such as an author who expects that her text would be read as intended. Hermeneutic determinability can be achieved only by participating in the ongoing history of using the very cultural artifacts that one is inquiring about (see Breckman's chapter).

Public spaces are architectural creations for access by people: plazas, parks, streets, sidewalk cafés, shopping malls, restaurants, and official buildings. I shall take a bank building as my second example of a cultural artifact. Any building must be 'read' as its use unfolds, much like a text needs to be understood at each point, in order to lead the reader to its end.

[8] Note: the *coordination of understanding*--aligning the mutually observed (con-sensual) consequences of understanding--is unlike what is commonly expressed as a *sharing* of understanding, information, experiences, or perspectives. The latter expression relies on a metaphor that misleads one to believe one could compare two individuals' understandings while one can ascertain only whether the observed consequences of others' understanding are consistent with the hypothesis that their understanding does not differ from one's own. Literacy is the coordination of reading practices within a culture.

As an institution, a bank could be housed in any building, of course; but in the United States, the exteriors of bank buildings are recognizably different from the façades of other public edifices such as schools, railroad stations, city halls, museums, libraries, post offices, theaters, or universities. Traditionally, it was Hellenistic columns and other ornamentations that served as signs to expect a bank inside, now slowly changing towards glass and chrome structures, expressing wealth and security.

Making sense of and subsequently using a bank building is partly culturally scripted. Outside of office hours, the building is locked and 'breaking and entering' becomes a criminal act. When the bank is open for business, users must enter through designated doors, which they know how to handle, only to find themselves in an interior with multiple clues as to what one can and must not do while inside. The interiors of banks are designed to discourage indeterminability; and mistakes in their use are quickly corrected. The customary subdivision of bank interiors into distinct sections, separating customers from bank employees, is intended to prevent confusion as to who is who, and what each is entitled to do in that space. In this environment, there is room for hermeneutic explorations, of course: customers may ask for assistance and receive instructions for obtaining what they want. The first bank robbery exploited an existing hermeneutic indeterminability, just as any new trick does that a robber may invent. Any repetition, at least at the same bank, is less likely to succeed as the bank devises preventive measures. Nowadays, the very concept of a bank robbery entails the expectation of a sequence of more or less foreseeable events in which bank employees and customers know what to do. This makes the outcome of an attempted bank robbery more hermeneutically determinable.

Merely observing what goes on in a bank would simply bewilder the detached observer visiting from a culture devoid of banks. And how that bank was built would be totally irrelevant for its users. Thus, experiencing hermeneutic (in)determinability is unrelated to observational and synthetic (in)determinabilities, but presupposes full use of banking practices.

Personal computers, although obviously different from printed matter and public spaces, nonetheless are experienced in a similar circular involvement. Computer users continually monitor the effects of their pointing, clicking, and keying, while navigating through a network of options toward desired destinations. Knowing *how* to use a computer is not enhanced by knowing *what* the computer 'really' does, how its internal architecture was conceived, where its files are kept, or why it was manufactured, let alone by whom. 'How-to-use' knowledge manifests itself in the confidence that one’s sensory-motor coordination is afforded by a machine, and the perception of a path to where one wants to be.

In the 1960s, operating a computer was a technical expertise; contemporary computer use is part of a rapidly growing form of literacy, not unlike that of reading text or using public spaces. Today, computers have become important cultural artifacts by supporting innumerable social and cultural practices.

Hermeneutic determinability is the decisive criterion for all cultural artifacts. Just as text is written to hold the attention of its readers, public buildings are designed to allow one's business to be conducted, so are computer interfaces meant to enable users to follow their own paths without disruption in understanding.

Hermeneutic indeterminability is experienced precisely where understanding breaks down. This happens when the natural sensory-motor coordination with cultural artifacts is disrupted; when users find themselves stuck at a place without an apparent escape; or when they unintentionally hurt themselves or others. Even reading may become disrupted upon encountering words with unknown meanings, foreign expressions without an accompanying translation, or complex grammatical constructions. In the latter cases, indeterminability may be only temporary and could be relatively easily overcome by asking experts, consulting users’ manuals, dictionaries in the case of texts, or simply figuring things out on one’s own.

An artifact with enduring hermeneutical indeterminabilities would be a string of characters from an unfamiliar alphabet that one cannot relate to, much less decipher: Mayan hieroglyphic writing, for example, was initially taken to be art and appreciated as such. But hypothesizing them to be texts entailed the assumption that they must have meant something other than being merely decorative to the members of the culture that produced them. Yet, to determine their original meanings, and how they were used, requires considerable familiarity with Mayan culture.

Archeologists unearth many hermeneutically indeterminable objects: if they do not seem to be a product of nature, they are considered artifacts and having had a use. However, if no one can determine *why* they were made, or *how* they served their culture of origin, one may be able to tell the story of how these objects came into the archeologists’ possession, but their original meanings and uses remain hermeneutically indeterminable--future interpretations notwithstanding.

For handling cultural artifacts, observational determinability is not an issue: computers are nontrivial machines par excellence, and very much in use as such. *Synthetic determinability*, a prerequisite for technological artifacts to become cultural artifacts, is of concern only to the producers of writing and printing matter in the case of texts; to architects and building contractors, in the case of buildings; and to computer engineers and manufacturers, in the case of personal computers. In turn, to become hermeneutically determinable to the members of a community, the designers of cultural artifacts must be members of that community as well and familiar with its culture (Krippendorff, 2005). The key to hermeneutic determinability lies in the practices of a community or culture that through narratives, metaphors, and examples, assign particular meanings and uses to its artifacts, which cannot be understood from outside that culture. Therefore:

Within one's own culture,
*cultural artifacts are hermeneutically determinable***,**

whereas:

Artifacts of alien cultures
are likely to be hermeneutically indeterminable.[9]

As further examples of hermeneutic indeterminability, I acknowledge Warren Breckman's chapter on the indeterminacy of historical facts, Jay Reise's on music appreciation, and Steven Gross's on vagueness, indeterminacy, and uncertainty, in this volume.

Constitutive Determinability

Recall that cultural artifacts are materially and functionally different from those who put them to use. It is by exercising their hermeneutic abilities that the members of a community or culture appropriate them in support of their practices of living. What must be noted now is that cultural artifacts--be they texts, public spaces, or computers--do not have hermeneutic abilities. They cannot understand and do not act the way human beings do. They exhibit physical limits, perhaps, and it is within these limits that they afford innumerably many interpretations and acquire countless uses, but they cannot *understand* what they do, and how or that they are being used. This raises the question: what happens when human beings apply their hermeneutic abilities not just to cultural artifacts but also to each other?

[9] Recalling the difference between understanding and comprehension, one safely can generalize that viable communities provide hermeneutic determinability for virtually all objects of nature and artifacts, even when they originated from an alien culture. Hermeneutic indeterminability always is related to the conviction, if not fear, that there must be more to one’s current understanding. The search for the ‘original’ meaning of an alien text is based on the conviction that there should have been one. Absent access to the original use of a text from an alien culture, there is no criterion to determine whether one’s understanding is correct.

Students of anthropology learn of the extraordinary difficulties if not impossibility of understanding other people in their own terms, and of *comprehending* concepts that are very different from one's own. Trained ethnographers are not exempt from encountering such difficulties. In fact, nobody can escape one's own categories, one's own world, and simply enter the worlds of others. What ethnographers end up providing are accounts of their own observations and interactions with their informants, using as many perspectives as they can. And if this account is both fair and symmetrical, then it must go beyond the ethnographer's understanding of the people studied. It must include these peoples' understanding of the role that the ethnographer is playing in their lives, what his or her questions mean to them. The social *relationships* that arise when people apply their hermeneutic abilities to 'being-with' each other, when they develop an understanding of each other's understanding, are 'artifacts' in their own right. But such relationships do not exist independent of human participation. They reside *between* its participants while being supported by all those involved. Indeed, relationships of this nature are the fundamental building blocks of social systems, large or small.

Let me define a *social system*:

- It encompasses human participants as its members;
- It resides in the interactions between its members, who, at various times, (re-)constitute[10] both the system and their own membership in it. As such, social systems are intermittently active and self-organizing or organizationally closed;
- Its members perform certain acts and utterances that constitute the system's identity;
- Its members act in the understanding that all other members act within their own understanding of the system and hold each other accountable for apparent deviations from their perception of the system's identity;
- Its viability is demonstrated by its repeatable reconstitution, transcending its individual membership.[11]

[10] Note: *Defining* means declaring two linguistic expressions to be equivalent in meaning and, hence, substitutable for each other. A definition does not involve the definer who essentially stays out of the equivalence it declares. By contrast, *constituting* means establishing the identity of a phenomenon (and distinguishing it from other kinds) by the participants in that very phenomenon: by its constituents. The U.S. Constitution, for example, was adopted by the acts of its signatories, who applied to themselves what it stipulated--without reference to or relying on an outside authority. The definition of social systems proposed here, leaves the establishment of the system's identity to its members.

[11] This definition accepts the autopoietic nature of the human participants in social systems and relies on the notion of organizational closure, which is common to autopoietic and social systems. Evidently, I am following not Niklas Luhmann (1995) here, but Umberto Maturana and Francisco Varela (1972), who prefer to limit their concept of

I offer three examples of social systems that might clarify what is meant by constitutive (in)determinability: family, economy, and languaging.

A *family* must have at least two members, who see each other as members of their family. The notion of a family, the evolving practices it embraces, have a long history, due to the fact that various people at different times constitute themselves as a family and demonstrate this form of 'being-with' each other to siblings, friends, and attentive neighbors.

As a social system, a family is constructed not without foundation. It stands on the social institution of marriage, for example, which in turn rests on the idea of making and abiding by contracts. A family is not isolated either. Obligations that arise from being a family member may be enforced by law; for example, regarding the raising of children, or may have political implications, for example, concerning the paying of taxes. As is true for all social systems, a family is also only intermittently active. Family members are not prevented from assuming other roles--whether as students, athletes, art collectors, employees, drivers of automobiles, or tourists. While family members participate in other social systems, their family is temporarily suspended, virtual, not performed, and to be reconstituted when needed. As family members bring their own hermeneutic abilities into the process, a family dynamically defines itself; thus, no two families are alike. Even biological descendency is not a sufficient criterion for defining a family. Lineage is something that family members may invoke and recognize as being constitutive of the identity of their family, but this is not a necessity. The adoption of children, or the deliberate severance of family ties, demonstrates the absence of biological determinism.

A family thus exists by virtue of its members' performing certain constitutive acts, which may include staying in touch, using appropriate modes of address, caring for children, deferring to elders, participating in family rituals, celebrating anniversaries, honoring special family events, keeping family secrets inside the family, freely sharing resources, supporting disabled members, and invoking the 'we' of family solidarity. These family-constituting acts convey a sense of belonging while also successfully distinguishing the family from other social systems.

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autopoiesis to biological systems. While social systems are intermittently reconstitutable by its members, the components of autopoietic systems tend to be continually engaged. Equally important is the difference between the social systems concept adopted here and the one typically advocated by general systems theorists (GSTs), following Ludwig von Bertalanffy (1968). In my definition, a social system's identity arises in the interactions among its human constituents. In GST, the a system's identity is contrasted with its environment and this distinction is made by a theorist, who is not part of the system, claims privileged access to the nature of the system and of the environment it is facing. This effectively overrides the system concepts enacted by its constituents.

The constitutive determinability of a family is constantly tested by deviant family members, by family tragedies, or simply by the process of growing up, and out. Constitutive indeterminability comes to be experienced by members not succeeding in reconstituting their family at appropriate occasions, and with previous members; for example, when members refuse to speak with one another, family rituals are no longer performed or attended to, and nothing seems to work as it once did; for example, after a hostile divorce or the death of a key family member. What appears to be the disintegration of a family is the inability of its (former) members to reconstitute its practices. This inability is rarely attributable to any one participant but to the failure of reciprocally performing the constitutive acts and utterances that would keep a family viable.

Another social system is the *economy*, with money as its key (cultural) artifact. Money has no intrinsic value except that which participants in an economy attribute to it. Notwithstanding that a 100 dollar bill may mean little to a millionaire, yet the world to a pauper, money facilitates commerce: the exchange of goods and services; the accumulation of capital; the acquisition of and submission to social or political controls; not least, the mass communication of a collective lifestyle that supports the economy.

All of these activities require the participation of more or less informed, rational, and motivated actors--not as individuals, but as constituents of the economy--each, acting in the expectation that the other constituents value money as well. Absent such reciprocated expectations, no economy could materialize.

Each monetary transaction implicitly tests, reconfirms or modifies the meaning that money holds for its users. It is the intertwined expectations that the members of an economy must have of each other, which render money an economy-constituting artifact. Legal institutions do their part in preserving the constitutional determinability of an economy by discouraging improper uses of money, such as theft, money laundering, bribery, or forgery. And financial institutions--the U.S. Federal Reserve Bank, for example--endeavor to sustain the value of a currency. When the institutions that are determined to prevent deviations from the desirable use of money become weak (or are perceived to be ineffective), and the constituents' intertwined expectations can no longer be relied upon, money would loose its worth, and the economy could collapse. This labile condition is tantamount to a *constitutive indeterminability*, here in the form of an economic crisis during which economic actors would no longer know how much they have, whom to trust, and what to do with each other.

We know of the social and political havoc that can follow when a currency looses its value. Whereas inflation may not be entirely indeterminable when its rate is known, it can cause trust in the use of money to erode, creating underground economies, scapegoats, and upheavals, apt to topple governments. Revitalizing a failing economy is one of the most daunting political tasks, largely because an economy is constituted in the very activities through which its decline is experienced. This makes it difficult to intervene from the 'outside' of an economy as a social system.

Now on to the example of *languaging*: languaging, the process of using language, is not manifest in ways cultural artifacts are. It is a cooperative practice that cannot be touched or photographed. Languaging is constituted in how multitudes of speakers coordinate their living, engage each other in conversations, and construct the realities they come to consider their habitat. Languaging is *observationally indeterminable*: speakers are nontrivial and what they do is rarely less than that. There is no way of predicting where a conversation may go, or which realities may come to be constructed in the process--except by direct participation. Languaging is also *synthetically indeterminable*. True, stretches of speech may be scripted, as in theatrical performances; in routines, such as in common greetings or when ordering a meal in a restaurant; or in ritual practices--but only for short time spans. The rules of grammar cannot predict what people will end up saying, either. Languaging provides room for creativity. It never quite repeats itself. Writing produces texts. But as cultural artifacts, texts are monologous. By representing only their writers' voice, texts are truncated records of what speakers do most naturally: speaking with each other, engaging one another in inherently unpredictable dialogues; coordinating their activities towards specific ends; or developing and testing the existence of consensus. Languaging is *inter*active, and in a speech community, no single member is in charge.

Languaging is also *hermeneutically indeterminable*: when speakers, each endowed with hermeneutic abilities, inquire into what the other speakers meant to say, that very inquiry places the original meanings in the shadow of an emerging coordination. While thus embracing each other's understanding, that coordination cannot be anticipated by either participant. The sounds, facial expressions, and writing that people generate while languaging may be considered technological artifacts, especially when recorded, reproduced, and materially disseminated. Languaging, however, is not reducible to such products. It fundamentally involves the interweaving of cultural products into a fabric that always implicates the bodily participation of its speakers.

By contrast to the verb 'languaging,' the noun 'language' designates a decontextualized abstraction from what happens inside a speech community, its vocabulary and syntax. As such an abstraction, the concept of language resides elsewhere--in the language of linguists for example, who typically put themselves in the role of detached observers, attempting to describe systemic invariances across speakers and situations. For Noam Chomsky (1957:85), the task of linguistics is to construct "a device ... (called a grammar) for generating all and only the sentences of a language." In seeking to design such an explanatory mechanism, linguists limit themselves to the study of the *synthetically determinable* features of languaging. Although this aim recognizes the nontrivial nature of the machinery that produces language,[12] it leaves no place for context-sensitive interpretations, for poetic innovations, and for conversation or dialogue. Since Ferdinand de Saussure (1960), linguistics has managed to protect itself from the challenges of indeterminabilities by theorizing writing or transcribed speech, not languaging, and by narrowing its scope to the structure of sentences--not utterances. By ignoring how language is constituted by its speakers, theorizing sentences becomes a literally meaningless exercise. And studying language as an instrument of persuasion by and of individual speakers, as rhetoricians do; or viewing it as logic, as some philosophers of science insist upon, reduces the essentially interactive or dialogical nature of languaging to a rational monologue.

Social systems, being essentially self-organizing, grant their members the ability to constitute them voluntarily. Thus, it is the users of language who decide who is or is not competent in using it, which usages are or are not correct, and where new metaphors are or are not appropriate**.** It follows that the constitutive determinability of languaging rests on its speakers who, in languaging with each other, ensure the continued viability of the process of languaging. Language is performed much as a family is enacted and not unlike how an economy manifests itself in the very transactions that bring it into being for what it is or is becoming.

How social systems are constituted and how they preserve their identity are major topics of inquiries in the social sciences. In this volume, references are made to economic and political development with regard to urban and regional planning (chapter by Tomazinis), which are phenomena that cannot exist without the active participation of human actors.

Studies of the constitutive nature of social systems often reveal the epistemological difficulties (indeterminabilities) that social scientists encounter when approaching their subjects with

[12] Note that Chomsky's work on generative grammars sought to move linguistics away from behaviorism, which limits itself to observation-based theories. It ushered in linguistics' current alliance with cognitivism in psychology and artificial intelligence.

trivial machine conceptions in mind--to protect the psychologically comfortable and analytically undemanding role of detached and superior observers--limiting themselves to hermeneutic explorations, for example; or trying to design an organization from the position of an authority. Only active participation in the constitutive practices of social systems--without fear of becoming part of and thereby changing the nature of the very social system one is facing--makes it possible to *test* a social system's constitutive determinability. Consequently, and quite analogous to the evidence for synthetic and hermeneutic determinabilities, viability is sufficient proof that:

Social systems are constitutively determinable

in the sense that their identity--namely their boundary and ability to reconstitute themselves--is preserved by the actions of their members.

Myriad social systems are known to have become *constitutively indeterminable*. Some, like empires or monopolies, became too big to be self-governable; some others, plagued by members' incompatible conceptions concerning what it is that they participate in--have ended in break-ups, divorces, or civil wars. Still other social systems have disappeared for lack of resources, as when social movements loose their members; for reasons of inefficiency, as when businesses loose their competitive edge; for lack of requisite solidarity, as when essential cooperation turns into distrust; and for inappropriate interactions, as when members fight to gain individual power at the expense of what is constitutively required. What these examples have in common is that the constitutionally required acts that gave the system its dynamic coherence and viability are no longer performed.

In conclusion

So far, I have avoided referring to philosophical doctrines. This served my effort to state limits of different kinds of knowing with a minimum of academic prejudice. Now, however, I would like to place the distinctions that emerged from my explorations in the context of some other literatures.

The belief that knowledge, in order to be valid, must be predictive and stated from the position of neutral and objective observers is central to positivism, of course. It essentially seeks to bypass human observers for their supposed unreliability. This futile effort is correlated with belief that the world is one coherent causally determined system that affords but one and only one accurate description: a uni-verse, a single-version of that world. It denies the *positionality* of knowledge and excludes the observer from the determination of that uni-verse. This epistemology has fueled the natural sciences and underlies the very idea of indeterminacy--as if the inability to figure out what something *is* were a property of the unobserved uni-verse. Perhaps those who adopt this stance should avoid the word 'predictability' altogether, as it implies a human ability. While stating my position so strongly, I wish to reaffirm: there is nothing wrong with being a spectator at least occasionally. Who would not enjoy watching, wondering, or being entertained? Surveying the sky has fascinated people for eons. But privileging *this* epistemology at the exclusion of all others does not do justice to what it means to be human. I am therefore suggesting that we:

(1) Recognize as an illusion the belief in being able to observe without acknowledging being the observer, without acknowledging our bodily, emotional, conceptual, and social participation in what we see;

(2) Discontinue the practice of objectifying one's experiences, in this instance, of projecting determinability or indeterminability onto the systems of one's interest and casting them as properties of such systems, that is, in terms of determinacy or indeterminacy;

(3) Cease trivializing the world by, on the one hand insisting on predictability as the sole criterion for scientific knowledge, and, on the other hand adopting trivial machines as the models of choice for scientific explanations, thereby unwittingly delegitimizing other ways of knowing.

	Observational determinability	**Synthetic** determinability	**Hermeneutic** determinability	**Constitutive** determinability
Objects and **happenings** are found in nature	***Predictability*** *from past observations*	may enter a design as resources	may acquire meanings and uses	may participate in social systems
Technological artifacts are designed to serve functions	irrelevant to design	***Realizability*** *from available resources*	may acquire meanings and uses	may participate in social systems
Cultural artifacts are used within a community	irrelevant to use	irrelevant to use	***Usability*** *(and understandability) within a community*	may participate in social systems
Social systems are constituted by their members' actions	irrelevant to being	irrelevant to being	Irrelevant to being	***Viability*** *of a social system's identity as constituted*

Four Determinabilities and their Criteria,
Based on Human Involvement
Table 2

Table 2 gives an overview of how human involvement with artifacts, including objects and happenings of nature, relate to the four determinabilities, which I have distinguished in this chapter. Its diagonal lists human abilities, which serve as criteria for determinability and define the artifacts in question. The six cells of its upper right triangle spell out the roles that these artifacts may play in what each determinability specifically addresses. And the six cells of its lower left triangle speak to the relevance of a determinability to the artifacts of each kind. I would like to discuss these relationships further.

The design of technological artifacts--whether in composing music (Reise, in this Volume), planning urban development (Tomazinis), or constructing mathematical models (Domotor and Batitsky)--is not derivable from observations of nature. Rather, designing entails the distinctly human ability to envision desirable futures, create paths toward their realization, and inspire others to join the effort of changing the world in ways that could not come about naturally. Consequently, the genesis of technological artifacts is inherently non-deterministic, and thus unpredictable by observation. Designers are involved, not detached; and what they specify changes the world as experienced without following natural laws. Calling disciplines that intervene in the world 'applied' insinuates their inferiority to pure theoretical knowledge (Simon 1981) and to their practitioners' inability to assume a God's eye view (Putnam, 1981)--so uncritically enjoyed by scientific observers. Today, most technological artifacts are nontrivial and, hence, escape observational determinability.

There are a few approaches towards an epistemology of design (for one attempt, see Krippendorff, 2005). *Radical constructivism* (Glasersfeld, 1995) comes close, but goes beyond the specific definition of technological artifacts that I have adopted in this chapter. The 18th century Italian philosopher and political scientist, Giambattista Vico (1962), was probably the first to distinguish the *epistemology of construction* from *Cartesian representationalism*. Vico also wrote on social institutions as human accomplishments, recognizing constitutive features of what I described here as social systems. Simon (1981) was the most recent philosopher of *the sciences of the artificial*. He focused largely on engineering, computer design, and management and, unfortunately, dealt with these as technological problems. Although Simon was not concerned with the synthetic indeterminabilities in these sciences, he recognized the difference between the *kind* of knowledge that underlies processes of designing, and the kind of knowledge that the natural sciences create about the world as is: *deontic* knowledge and *propositional* knowledge, respectively. Designers know the structure of their design and how it *should* work. And once a technological artifact is realized and works as intended, trying to predict its behavior by observation becomes a redundant academic exercise. At best, it could serve as a test for the correct implementation of what designers had specified, without, however, gaining additional understanding.

Knowing how to use artifacts, what can be done with them, differs from knowing their composition and genesis. *Pragmatism* has made useful knowledge the centerpiece of its attention. And *symbolic interactionism* has carried this philosophy into sociology. I situate myself closer to *cultural anthropology* here. It has taught me to respect the great diversity of uses, understandings, and meanings that cultural artifacts can acquire in different communities. Usability and understandability co-evolve in the actual use of such artifacts, but they also provide support for the continuing evolution of technology within a community or culture. As *hermeneutics* has taught, understanding is a project that is never finished. Its limits are experienced at the boundaries of one's communities. As Table 2 suggests, if usability is at issue, observational determinability is of little relevance, and synthetic determinability can be taken for granted. Usability, it should be noted, has nothing to do with the unattended nature of artifacts, but everything with what it enables humans to do with them.

Being--performing the very social system whose identity is the product of what its constituents do, and shapes the identity of its members in return--involves a recursively interlaced co-knowing, that cannot be acquired from outside that system. This is not to say that social systems could not be recognized by non-members and used for all kinds of purposes by them. Members of a family can talk about the economy, for example, much as social scientists can do research on families, yet in so doing, they remain outsiders of the system of their interests. What keeps any social system viable is the performance of constitutionally required reciprocal practices, preserving its identity over time. However, the effects of these practices can be experienced only by being part of the system. Similarly, a language can be used in its capacity to describe, instruct, or influence, as a cultural artifact. This, however, is beside the point of what languaging does[13] as a social system: coordinating speakers' practices of living, bringing particular realities to speakers' attention, but especially directing the evolution of languaging within the community of speakers. I consider all reconstitutable patterns of 'being-with' each other as social systems: determinable when they prove themselves viable and indeterminable when they do not. Social systems are human artifacts. They are distinguished, however, from artifacts that are merely observed, manufactured, or used, by their inclusion of constituent members whose perceptions, actions, and utterances determine the system's organization and identity and their own role within it**.**

[13] See Ludwig Wittgenstein (1958) and other philosophers of language.

In the beginning of this chapter, I suggested that I did not want to privilege one kind of knowing at the expense of others. I hope that this chapter has demonstrated the epistemological benefits of navigating across different kinds of human involvement. My explanation of the limit of observational indeterminability, for instance, relied on knowing the internal makeup of two systems, a knowledge that would be available only to their designers, builders, or those willing to take especially nontrivial artifacts apart, reassemble them, and put them back to work. Allowing oneself to so enter one's domain of interest provides more information than merely observing that domain from its outside. And without the liberty to examine one kind of knowing by means of another, indeterminabilities could not be explained or accounted for. The chapters on chaos and complexity, and on structure, by Domotor and Batitsky, have less to do with nature than with theories about nature. Before the invention of chaos theory, few people cared about the phenomena that the theory purports to describe. This fact provides still another example of how language is implicated in the social construction of reality, even in the ratiocinations of scientists.

For good reasons, I am resisting to force the four (in)determinabilities discussed here into a logical hierarchy: conceiving objects and happenings of nature to be its base, attended to by an observer; and then, considering the coupling of these objects and happenings with their (possibly flawed) observer as a (higher-order) meta-system, in turn examined by a meta-observer; and so forth. Underlying such a hierarchy of including observers on different levels is the Theory of Logical Types.[14] Separately investigating systems on different levels of description--without allowing communication or interventions across different levels of observers--stays entirely within the limits of observational determinability. In adopting this hierarchical view, one remains trapped in just one epistemology--much as intended by the Theory of Logical Types--unable to appreciate the reason for observational indeterminability.

My explorations suggest another relationship between these ways of knowing: *requisite backgrounds*. Languaging is often taken for granted, particularly when talking *about* phenomena. Aboutness implies a separation of the phenomenon of interest and what languaging brings to one's

[14] Note that Bertrand Russell's (1908) Theory of Logical Types was formulated to prevent paradoxes of self-reference from entering the logic of representation, causing that logic to become indeterminable. It manages to preserve determinability by stipulating this injunction: sets shall not contain themselves as a member--translated into the issues considered here: observers shall not be part of the system they observe. According to the theory, observers belong to a logically superior meta-domain. I am pleased to violate this injunction, and thereby open the door to other epistemologies: where self-reference is allowed, where observers are able to communicate with one another across different kinds of involvement, where human beings can be recognized for entering the world they seek to alter, and where the members of social systems constitutively participate in describing themselves and the very system of which they are a part.

attention. In contrast, the awareness of languaging one's identity into being provides the requisite background to understanding the use of cultural artifacts. Having a sense of how particular artifacts come to be used within a community is a prerequisite for improving them by design but for their use by others. Creativity in designing conceptual systems, theories, and mathematical models is often taken for granted--as background--if not denied in the belief that the outside world is decisive in what 'really' matters. Claiming to have 'found' a 'natural law,' for example, discounts the crucial role of human creativity in the construction of such a law. Not only is creativity a latitude taken for granted, but also one gone unrecognized, and therefore going to waste in claims of merely observing what is presumed *to be* in front of one's eyes.

The (in)determinabilities discussed here are not the end of the story. Much exciting work is ahead of us, unraveling their empirical, social, and philosophical implications.

REFERENCES

Bertalanffy, Ludwig von (1968) *General Systems Theory: Foundations, Development, Applications*, New York: George Braziller.

Bremermann, Hans J. (1962) "Optimization through Evolution and Recombination" in M. C. Yovitz, G. Jacoby, and G. Goldstein, Editors, *Self-Organizing Systems*, pp. 93-106, Washington, DC: Spartan Books.

Chomsky, Noam (1957) *Syntactic Structures*, The Hague, Netherlands: Mouton.

Foerster, Heinz Von (1984) "Principles of Self-Organization in a Socio-Managerial Context", in H. Ulrich and G. J. B. Probst, *Self-Organization and Management of Social Systems*, pp. 2-24, New York: Springer Verlag.

Gill, Arthur (1962) *Introduction to the Theory of Finite State Machines*, New York: McGraw Hill.

Glasersfeld, Ernst von (1995) *Radical Constructivism; A Way of Knowing and Learning*, London, Washington DC: Falmer Press.

Krippendorff, Klaus (2005) *The Semantic Turn; A new Foundation for Design*, London and New York: Taylor & Francis, in press.

Luhmann, Niklas (1995) *Social Systems*, translated by J. Bednarz, Jr. and W. D. Baecker, Stanford, CA: Stanford University Press.

Maturana, Humberto R. and Francisco J. Varela (1972) *Autopoiesis and Cognition; the Realization of the Living*, Dordrecht, Holland: D. Reidel Publishing Company.

Putnam, Hilary (1981) *Reason, Truth and History*, New York: Cambridge University Press.

Russell, Bertrand (1908) "Mathematical Logic as Based on the Theory of Types," *American Journal of Mathematics*, 30, pp. 222-262. Reprinted in B. Russell (1956) *Logic and Knowledge*, pp. 59-102, London: Allen and Unwin.

Saussure, Ferdinand de (1960) *Course in General Linguistics*, C. Bally and A. Sechehaye, Editors, London: Peter Owen.

Shannon, Claude E. and Warren Weaver (1949) *The Mathematical Theory of Communication*. Urbana, IL: University of Illinois Press.

Simon, Herbert A. (1981) *The Sciences of the Artificial* (2nd.Ed.), Cambridge, MA: MIT Press.

Vico, Giambattista (1961) *The New Science*, translation by T. G. Bergen and M. H. Fisch of his *Principi di Scienza Nuova* (1744), Garden City, NY: Anchor Books.

Wittgenstein, Ludwig (1958) *Philosophical Investigations,* 3rd Ed., translated by G. E. M. Anscombe, London: Basil Blackwell & Mott, Ltd.