

THE DYNAMICAL BASIS OF INFORMATION AND THE ORIGINS OF SEMIOSIS

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1. Introduction

Every manifestation of information, semiosis and meaning we have been able to study experimentally has a physical form. Neglect of their dynamical (energetic) ground tends towards dualism or idealism, leaving the causal basis of semiosis and the causal powers of representations mysterious. Consideration of the necessary physical requirements for the embodiment of semiotic categories imposes a discipline on semiotics required for its integration into the rest of science, especially for the emerging field of biosemiotics, as well as any future extensions to chemistry physics or other realms that might constitute a general, primal semiotics. Without this discipline, or something equally strong, there is a risk of projection of anthropomorphic semiotic terminology onto unsuitable hosts, leading, if unchecked, to the sort of animism that biology in particular has only recently escaped. The problem is suspect whenever teleological notions are used outside of mental or social contexts.¹ Although our animistic ancestors may have had a closer rapport with Nature than modern scientists, contemporary scientific explanation requires an understanding of causal structure (Salmon 1984). On the other hand, unless the causal rendition of semiosis can capture full blown cognitive semiosis, it is likely to be too restrictive for the evaluation of primal semiosis in general.

I will sketch an information theoretic account of representation that ties information to dynamical processes. Though I rely on accounts of meaning from analytic philosophy, my approach is inspired by Peirce's pragmatism, but I do not intend it to be strictly Peircean. In particular, I do not accept Peirce's idealism, as will become evident, but I do accept both his realism and his commitment to an account of interpretation that involves essentially the role of signs in interactions with the world, the central components of what he called pragmatism. Pragmatics concerns the role of particular circumstances in the fixing of meaning. Analytic philosophy, taking its model from mathematics, has concentrated on syntax and semantics, with pragmatics entering only when there are problems in establishing context (which is not generally a problem in formal logic or mathematics). Peirce was perhaps the first to fully appreciate that pragmatics is essential to meaning, a view that has been developed independently for living systems by Küppers (1990), based on work by Carl von Weisäcker. The idea is not foreign to analytic philosophy², but it has been underdeveloped, perhaps because of the prevailing formal approaches to the philosophy of language.

My main concern will be with giving a dynamical information theoretic account of the elements of semiosis and their connections with an eye on making clear what is required for the cogency of generalised semiotics. Many of my examples will be from biology, because these are most cogent, but most of what my conclusions can be applied to other candidate semiotic systems. Since there are natural as well as conventional and artificial signs, semiotics requires both an understanding of the causal basis of signs as well as their mental, or intentional aspects. Ideally, these should be unified in a common system. In order to lay the basis for this, I will begin with the requirements for intentionality, followed by a discussion of Peirce's classification of signs. This will be followed with a brief account of intrinsic information in natural things, and an information theoretic account of causality.³ Finally, I will bring this all together to give an information theoretic account of a sign, and a sketch of an information theoretic account of representation.⁴ I will not venture to say exactly what a representation is in terms of biological, brain or other processes; that is a job for empirical science, and is probably premature in any case. Future empirical studies may well force revision of the general view of representation I propose. My concern here is to lay down a clear position from which the merits of extensions of semiotics can be debated.

2. Autonomy, a key concept

The importance of autonomy can be summed up in the following slogan: No meaning without intention; no intention without function; no function without autonomy. First, meaning requires intentionality, for which mental experience is paradigmatic. The tenability of a generalised semiotics rests on whether mental experience is the only case of intentionality (see also Emmeche, this volume). In this chapter I will be concerned with the special sort of meaning that Peirce calls "intellectual", and has more recently been called "cognitive", i.e. meanings upon which arguments concerning objective fact might hinge (Peirce 1940, p. 272). This sort of meaning, which I will call *referential* to avoid the mental connotations of "intellectual" and "cognitive", is the sort of content of thoughts that is often called propositional or conceptual, whether or not these terms are used in their psychological sense or the logico-metaphysical sense popular since Frege and Husserl's attacks on psychologism.⁵

That referential meaning requires thought might be challenged by the observation that many things that do not involve thought can still serve as signs. For example, dark, heavy clouds are a sign of impending rain, and snow outside is a sign of cold temperatures. So, it might be argued that something can represent without thought, but since representation implies meaning, therefore meaning is possible without thought. If sound, this argument would open the door widely to general semiotics, since almost anything in a complex interactive network, like a biological system, can be conceived as serving as a sign by adopting the intentional stance (Dennett 1987). I believe that the problem with the argument is the pivotal second premise that representation implies meaning. It is too vague to support the inference to the conclusion. A sign that represents without thought might be a representation only in the sense that it *can* serve as such under the condition that it is so interpreted. In other words, the sense in which something that serves as a sign is a representation is purely potential. Adopting the intentional stance, however useful it may be for producing insights, cannot itself turn a potential into an actuality (cf. Foss 1994). Thus the second premise establishes only potential meaning in the context of the first premise. Actual meaning requires the existence of an actual, not merely potential interpretation. The argument does not establish, then, that signs actually have meaning. Interpretation is required, and this seems to require thought (for what is thought but interpretation and the manipulations of the interpreted?) This is what is at issue in consideration of the cogency of a generalised semiotics (and, in particular, biosemiotics), since it requires the possibility of semiosis without thought.

On Peirce's pragmatic view of the meaning a mere correlation or correspondence between a sign and its reference does not in itself produce a meaning. This requires a triadic production of what Peirce calls the *interpretant*, a relation in which the sign (*representamen*) bears some variety of correspondence to its reference through the immediate object of the sign (*ground*), which is an "idea" corresponding to the object not in all its respects, but only under certain considerations⁶ (Peirce CP 2:228⁷, 1940 p. 275; see Figure 1 below). A sign must be taken as a sign in a context supporting interpretation in order to be interpreted. Mere function is not sufficient (Peirce argues) since, for example, a

... thermometer dynamically [...] connected to a heating and cooling apparatus, so as to check either effect, we do not, in ordinary parlance, speak of there being any *semiosis*, [...], but, on the contrary, say that there is an 'automatic regulation', an idea opposed, in our minds, to that of semiosis. (Peirce 1940, p. 275, italics in original)

Semiosis proper, then, has four elements: the sign (representamen), reference, ground and the essentially triadic interpretant. It is the last which is irreducibly pragmatic and contextual in nature, involving anticipated (expected) behaviour of the object in open-ended (and possibly frustrated) interactions with the world.⁸

Peirce allowed that there might be representamens that are not mental, like a sunflower that in turning towards the sun thereby becomes fully capable of reproducing a sunflower that turns in precisely the same way towards the sun, and with the same reproductive power. Paradigmatically, though, a sign has a mental interpretant, and cognition is the chief if not only mode of representation (Peirce 1940, p. 100). The notion of interpretant does not logically require consciousness, but we have no clear cases that do not, so we must at least fix our understanding of semiosis with these clear cases (1940, p. 282).⁹

That functionality is required for intentionality might seem too obvious for comment, but there is the spectre of a Cartesian intelligence with no cares in the world, that nonetheless has clear and distinct representations of the factual world. Such a being would violate Peirce's pragmatism (he dismisses such a being as outside the scope of his inquiry, Peirce 1940, pp. 98-99), but we might wish a stronger reason to reject such a being. The main problem, it seems to me, is that such a being would never have its will thwarted by the brute facts of the world, and would therefore never have need or reason to separate its experiences into internal imaginings and representations. There would be nothing to specify which of the many possible mappings from the supposed representations to the world were the intended ones.¹⁰ Thus functionality appears to be necessary for representation.

That autonomy is required for functionality is more controversial. I can give only a brief argument here (for a more complete version, see Christensen et al submitted). Intelligent systems, and living systems generally, are not passively independent in the way a rock is. Instead, 1) the bonds of living systems are relatively delicate, vulnerable to disruption by many disturbances – knocks, poison, predation, cold, etc, and 2) living systems are constantly in need of replenishing their dissipating energy and order to sustain activity and repair internal damage. From (2) it follows that these systems are internally organised so as to have the capacity to interact with their environment in order to avoid damage and acquire the resources they need to remain viable. (1) explains why those living systems we do see are adaptive, for unless they can constantly adapt to mitigate or compensate for disturbances, including internal dissipation, they will die.¹¹

Naturally autonomous systems have a dynamical cohesion that is actively maintained by processes of various kinds, i.e. they are substantially dynamically self-maintaining. Autonomous systems have many functional properties that preserve system properties through cycles of interaction, both internally and with the environment. These cycles are typically complex and self-reinforcing. They must achieve both process closure and interaction closure. *Process closure* concerns the fact that an overall process must achieve self-reinforcement by supporting system viability, and hence the continuing system capacity to carry out that process. If the system is to achieve overall process closure the elements of the system must interact with each other and with the environment in particular, circumscribed ways. This is *interaction closure*. This closure is essential to self-regulation, and distinguishes autonomous systems from systems like rocks that maintain their integrity merely through strong bonds that tend to isolate them from other systems, and from systems like gases, and liquids that are more open than solids, but do not have any closure of environmental interaction required for self-regulation; they remain independent only at the whim of environmental contingencies. To maintain themselves, autonomous systems must display an internal coherency of processes; namely the processes must interrelate flexibly so as to preserve the whole organised complexity that underwrites control of that very responsiveness and adaptability. Their functional properties must be so integrated that they are able to maintain an active independence. Unlike other kinds of natural systems (e.g., mechanical systems like the solar system, systems governed by local interactions among parts like rocks, and systems maintained by boundary conditions like gases in a chamber) autonomous systems are dominated by these global functional constraints. Although autonomy is a property at the ecological level, in the sense that the closure conditions for its definition

make essential reference to the environment, it “belongs” to the autonomous individual in the sense that what makes the difference to autonomy lies in the individual.¹² To sum up, autonomy is dynamical self-maintenance with closure conditions of processes and interactions.

Paradigmatic examples of autonomous systems are uni- and multi-cellular organisms, in which membranes differentiate internal and external environments and metabolic systems maintain critical physiological parameters for system functioning (membrane integrity, pH level, temperature, stored energy in forms such as ATP) and control entry and exit of food and waste. For more deeply complex multi-cellular organisms a sensorimotor system regulates environmental interaction, seeking out critical resources (food, water, shelter, mate) and avoiding danger (poisons, predators etc.), and, along with other physiological processes, also regulates internal compensatory response when these strategies fail. In even more complexly organised creatures, an autoimmune system destroys harmful invaders, and a cognitive system is superimposed on and regulates sensorimotor activity. Higher levels of regulation involving interactions with conspecifics are found in social animals (and plants).

Autonomy is multi-dimensional and varies in degree. If the dimensions are distinct enough, we can talk of kinds of autonomy, such as material autonomy, psychological autonomy, social autonomy and informational autonomy. These kinds of autonomy are at different levels, so autonomy is also relative to level. Something that might not be autonomous at the most fundamental physical levels might be autonomous biologically, and minds, for example, might be autonomous in terms of information content, but not from their biological embodiment. Levels and kinds of autonomy can compete as much as autonomous individuals compete at the same level. Autonomy may be largely in one dimension or interdependent range of dimensions, despite large dependencies of other kinds. It might be argued, for example, that minds, although highly dependent on bodies materially, are informationally quite autonomous, as would be other autopoietic entities (Maturana and Varela 1980). The use of the body by the mind to maintain itself, it might be argued, is analogous to the use of the environment by the body to maintain itself, creating not only an informational independence but arguably self-sustaining as well. This maintenance can conflict with bodily function except in extreme cases. If representations can be autonomous, their autonomy will be of this informational kind: they must actively use their own information to maintain their own informational structure and reproduction.

Autonomy requires some degree of informational independence in the resources required to maintain integrity, but some things are more autonomous than others. Viruses are not very autonomous, since they require other organisms to function and reproduce. Bacteria are much more autonomous, and humans are more autonomous still because of our extreme adaptability that allows us to survive in almost any environment. It must be noted, however, that our social nature and our need to reproduce sexually places limits on our autonomy that are the stuff of novels and movies. The nature of autonomy ensures that all autonomous systems above a minimal level of organisational complexity possess a capacity for functional control, with the goal being to keep the system-to-be-controlled within its range of viable states. Control is the control of interaction with the world so as to achieve the resources necessary to preserve viable function, and of internal interaction to ensure these resources are effectively deployed. Given that autonomy can exist at different levels of an internested system, differing requirements for autonomy at different levels can lead to conflicting functions (even within the same subsystem). For example, cancerous cells are too autonomous for the body, and organism autonomy may conflict with lineage (reproductive) autonomy, and also with population autonomy. The same sort of conflict can occur between the personal and social levels. Later I will argue that certain types of communicable representations (memes) can compete with the functionality of their carriers.

Representations, being functional, must ultimately function to preserve autonomy. It is only in their potential or actual application and use in this function that they can be meaningful. The use of representations contrary to this principle (except in jocular, speculative or otherwise protected environments) is widely perceived as senseless or crazy, and rightly so. Lewis Carroll’s *Alice in Wonderland* is full of nonsense, but its goal is to entertain and instruct. A smile without a face is a ludicrous idea, and it would be crazy to go looking for one. Nonetheless, the haunting smile of the Cheshire cat is meaningful enough to have entered into our folklore. Likewise, hunting for the pot of gold at the end of the rainbow is a paradigm of folly. These ideas are meaningful only because they are not applied in practice. Another requirement is that representations must themselves have a certain

autonomy. They cannot be too closely tied to what they represent, like the sunflower is to the sun, without trivialising interpretation to a dyadic relation. Intentionality requires the possibility of error (Matthen and Levy 1984), which in turn requires a projection beyond the immediate into the realm of possibility. This requires a Peircean interpretant, a systematic set of relations among representations not fully determined by the actual relations of their objects, but connected to those objects through the anticipation of how those objects would behave when interacted with. In other words, meaning requires not only that the subject be autonomous, but that the representation itself have a somewhat independent relation to its interpretation so that it can play an appropriate role in its interpretation. Only in the ideal limit when its functional role in its own interpretation is fully articulated (freed from unnecessary or irrelevant connections that constrain its use) does a representation begin to correspond to a concept in the sense that analytic philosophers like Frege use the term. Ironically, this limit is not attainable without undermining the very open-endedness required for meaning, and full articulation of the meaning of a representation reduces it to an empty tautology.

3. Peirce’s categorisation of signs and the pragmatics of interpretation

For the discussion of the dynamical basis of information of signs it is useful to have a taxonomy of semiotic categories and some concrete examples. Peirce’s taxonomy of signs is nearly suitable for this purpose, but requires some revision in order to insure the priority of dynamics. As argued in the previous section, full semiosis involves the production of a triadic interpretant in an autonomous entity, involving a sign and a dyadic relation of sign to object, such that the sense of the sign is given within a background of interpretation (context) involving functional (and causal) interactions (necessarily two-way) with the world, also connected to the world through the reference (if actual) picked out by the sense. This idea is closely linked in Peirce’s writings with his triadic metaphysics. I won’t try to explain Peirce’s metaphysics of firstness, secondness and thirdness here, except to remark that firstness is monadic, secondness is dyadic, whereas thirdness is triadic. Peirce held that while triadic relations cannot be composed of monadic and dyadic relations, all higher order relations can be composed of triadic relations, so we need at most three basic logical categories, monadic, dyadic and triadic. Since each aspect of semiosis can be correlated with each logical category, the semiotic categories are ninefold, as indicated in Table 1.¹³

Table 1.
Peircean Semiotic Categories by
correlates and logical categories

	Firstness	Secondness	Thirdness
Representamen (That which represents)	<i>Qualisign</i> a quality, timbre, colour	<i>Singular Sign</i> a particular item or event	<i>Legisign</i> conventional representation
Relation of representation to object (Ground of representation)	<i>Icon</i> a likeness to some object (naturally or by convention)	<i>Index</i> a causal connection to the object	<i>Symbol</i> a conventionally stipulated relation (most words)
Anticipated relation of sign to object and interpretation (Pragmatic status of interpretation)	<i>Rheme</i> sign of possibility	<i>Dicent (Dicisign)</i> sign of an actual occurrence	<i>Argument</i> sign of a set of stipulated relations

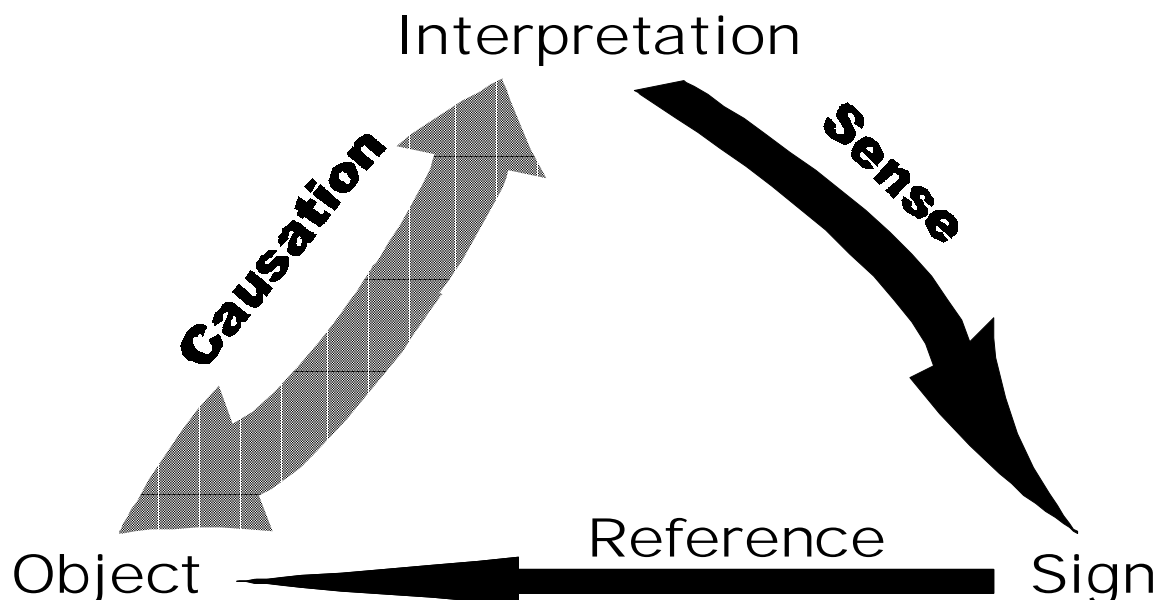
After *Collected Papers* 2.243-253

In Table 1, the various signs are classified according to firstness, secondness and thirdness according to their intrinsic nature (the columns) and their role in representation (the rows). As indicated in the previous section, Peirce believed that full fledged meaning required irreducible triadicity; consequently, only row 3 and column 3 are candidates for representations that are intrinsically meaningful. The other categories require interpretation through extrinsic relations grounding thirdness (they may have derivative function and meaning). For example, qualisigns are but feelings, and have no meaning in themselves beyond themselves, and hence can have no “intellectual”, or referential meaning. They can, however, especially when forming complex patterns, stand for perceived objects when they are properly interpreted. Likewise, an index like the sunflower’s direction or the barometer’s needle in itself requires only a dyadic relation, but when interpreted can stand in for its object. Singular signs and icons also do not carry their own interpretation. Arguments, on the other extreme, are the fullest and most articulate expression of intellectual objective meaning. We should not expect to find them except in fully articulated intentional systems like cognition. If there are non-trivial non-cognitive semiotic categories, they will be among the remaining categories. It might seem that the conventionality of legisigns and symbols would rule them out as candidates for biosemiotic categories, but the apparent arbitrariness of the genetic code should give one pause.

The bottom row corresponds most closely to the aspects of representation known to analytic philosophy. In Peirce’s system they include the triadic element in which our signs are grounded in our expectations, or, to avoid psychological connotations, *anticipations*. Rhemes, as signs of possibility, correspond roughly to Fregean concepts, dicents to extensions, and arguments to intensions (I say roughly, because there is much debate among analytic philosophers concerning the nature of each of these categories). Standard formal accounts of linguistic meaning from analytic philosophy in terms of syntax and semantics are completely inadequate for semiotics, with its pragmatic grounding of meaning. In order to deal with indexicals, Kaplan (1979) distinguishes two functions, character and content, which he identifies with Fregean sense and reference. Character maps from terms and contexts to contents, and content selects possible states of affairs. On Peirce’s treatment of semiosis, all representations with factual content function like indexicals because they are to be understood through their grounding in the interpretant. Kaplan would take a sentence like “I am here now” and say that its sense is the function from possible utterances of the sentence and the context of those utterances to sets of possible states of affairs. In this case the sentence must be true in any context in which it is uttered, so by its sense it is an analytic sentence even though the content of any given utterance is contingent. If all meaning concerning factual content is to be interpreted pragmatically, however, all utterances with contingent content are indexical, i.e. their content depends on context, especially on anticipations based on their use. A statement like “Force is the product of mass and acceleration,” for example, might turn out to be analytic but contingent because all contexts in which it is used presuppose its truth. It is not necessary, however, even then, because there may be contexts in which it has no use (for example, if there are no masses). Thus even analytic truths can be open to pragmatic revision when faced with reality. The interpretant is required for meaning, and at some point it will involve goal oriented interaction with the world, with the possibility of surprise by brute facts.

The nature of this interaction can be highly complex, involving nonlinear interactions (apparently a necessity for irreducibly triadic relations) and resulting possibilities of chaos and self-organisation. A(n overly) simple model of semiosis is given in Figure 1.

Figure 1. Semiosis



On this model, unlike the Kaplan model, it is the interpretation or thought that gives the sign a sense, and reference is mediated by causal interactions (commonly, but not necessarily, with the object). The immediate interpretant of a representation is often some sort of conceptual framework or background ideology (consider Peirce on disagreements over the nature of the Communal Host, CP 3: 263-266), but ultimately it is the world against which we test our expectations (Peirce noted that in the case of the Host, this would have to wait for death). On Kaplan's model, on the other hand, sign and context determine interpretation which determines reference. It is thus a compound dyadic model, unlike Peirce's triadic model, and it supports none of the possibilities of complex dynamical systems that give rise to self-organisation and autonomy. In particular, it does not allow for motivated corrigibility of attributions of reference, which is essential to meaningfulness. Kaplan's model exemplifies the problems of extending the analytic model of meaning with mere additions. The correct alternative is to map the analytic model into the more fundamentally complex pragmatic model. This is possible only approximately, and I will argue in §8 below that even for our best articulated representations the analytic model is an unattainable ideal.

Syntax determines the formal aspects of relations among signs and of interpretation, sign and object, and provides the formal structure in which meaning is possible. Since it determines actual relations only up to isomorphism, it is completely inadequate for determining actual relations, let alone actual meaning. Semantics gives the possibilities for interpretation of sign, and is given by the Fregean sense. Since it concerns only possibilities, semantics must be augmented to determine actual meaning. Pragmatics in the sense of Montague or Kaplan gives the contextual and practical aspects of taking a sign to refer to an object, and determines sense of a sign – sense is possible only with pragmatics. However pragmatics in this formal sense still underdetermines meaning unless the causal and teleological aspects of representation are integrated in the triadic relation of the interpretant. As noted above, merely adding the two together is not sufficient to make meaning a function for an autonomous being, as required by the argument of section 2 above. Semantics and Peircean pragmatics together cover the intensional (modal, possible) and functional (teleological, purposeful) aspects of semiotics. Together, they constitute meaning in its fullest sense of a goal directed orientation towards the actual world. Objective meaning (barring nominalistic classification of the meaningful) must be open to revision. This *corrigibility condition* should apply equally to generalised semiotics if it is to be genuine semiotics. Together with functional closure conditions, the open corrigibility condition directs us towards what can represent (and away from what can't).

4. Information and causation

Peirce was an idealist, though his arguments for the position are uncharacteristically poor (1940, p. 322). His main reason for rejecting materialism is that he could not see how a mechanism could feel. He rejected neutralism because he believed it required an independent inner and outer world. Neither argument is sound. For one thing, we now know that the material world is not mechanistic, besides which, even if it were, ignorance is a weak argument for the impossibility of feeling matter. In any case, we can safely ignore the problem of the ontological status of feelings here because they play no role in objective meaning. Neutralism is neutral between the mental and physical, not dualistic as Peirce assumes. As remarked in the last section, syntax, or pure form, underlies the possibility of meaning, and is neutral between dynamical form and representational form. I will give an account of causation in terms of information theory that captures the concept of dynamical form, and connect it through pragmatics to representational form.

Pure form in its most general sense can be defined in terms of information theory, as can all purely formal relations, such as syntax. Information in information theory is a measure of the capacity to carry information in the colloquial intentional sense. Where there is ambiguity I will use *information capacity* to refer to the formal notion and *information content* to refer to the more restricted intentional notion. As an account of the capacity to carry information content, information theory constrains meaning and other semiotic notions, but does not determine them. I will suggest how to bring the pragmatic notion of information content under information theory later in this section. The fundamental idea behind information is a binary distinction of something as being of one sort and not another. The form of something is determined by an isomorphic mapping of its form onto a string of 1s and 0s under a set of questions that have an answer “true” or “false”, with 1 corresponding to ‘true’ and 0 corresponding to ‘false’. This mapping, because it is isomorphic, captures every distinction in the original form, and allows the original form to be recovered from the string (see Figure 2). The information in the string, and thus in the original form, is the length of the maximally compressed form of the string from which the original string can be recovered. This is roughly the length of the maximally compressed self-delineating program from which the original string can be recovered by a reference computer (for details, see Collier 1999; Collier and Hooker submitted). This gives a universal measure of form (albeit in general non-computable).¹⁴

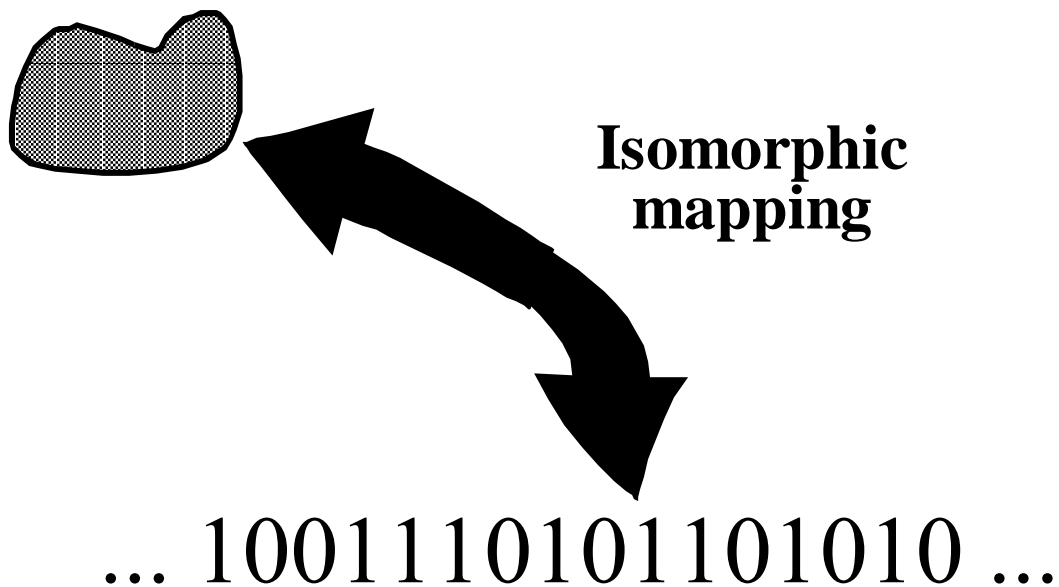


Figure 2. Information

The information content of a representation is limited by its information capacity, which depends solely on its form. A representation might, however, have more information capacity than its content. This is typically true of analogue representations such as pictures, and I will later argue that it is true of all representations to some degree, but it is useful right now to use Dretske's (1981) term *digital* to refer to representations whose capacity and content coincide (which might correspond to Descartes's clear and distinct ideas). Following the pragmatic approach to meaning, the content of a representation is determined by anticipated distinctions in the object of a representation. In digital representations, then, the anticipated distinctions and the distinctions capable with the representation's form coincide. Otherwise the representation has unintentional representational potential. The content (or sense) of a sign can be taken to be the common information of all anticipations contributing to the meaning of the sign in which the object is involved. For example, the content of 'red' is the information contained in every anticipated involvement of redness in something. This will include the usual properties of being a colour, including coming in some shade that does not have a precise phenomenal character, excluding alternative colours, being a visual property, and so on.

A candidate representation has a reference if and only if it in fact (not in intention) picks out exactly one possible object, whether concrete or abstract.¹⁵ A representation refers successfully if and only if it picks out exactly one actual object, concrete or abstract. A candidate representation can fail (and thus be corrigible) in three ways: 1) the presumed representation can fail to have a reference, in which case it is not really a representation (more on this later), or the candidate representation can be a representation, and 2) it can have no actual object, in which case it is false, or 3) it can refer to its object, but fail to accurately represent the form of its object, in which case it misrepresents, and is misleading. Representation can mislead either by commission or by omission. In errors of commission the anticipated distinction is not a distinction in the form of the object. In errors of omission the object contains a distinction not in its representation. Both cases can lead to unanticipated results, but of a different sort. Errors of commission are corrigible by a failure of the object to be manipulable in the anticipated way, whereas errors of omission are corrigible by unanticipated (and perhaps incomprehensible) behaviour of the object.¹⁶

Failure mode 1 is of most interest to deciding whether or not there can be non-cognitive biological representations, but the others are useful for clarifying the pragmatic notion of a representation. On the traditional analytic view of meaning, failure mode 3 is not possible since meaning determines reference dyadically, either directly from sense, or via the dual dyadic relations in the analytic pragmatics of Montague and Kaplan. On this view intentions dominate entirely and meaning is unavoidably internal in the limit (Putnam 1978, 1981), since the satisfaction or failure of anticipations is irrelevant to meaning, only to truth. On the pragmatic approach, however, the interpretant allows another mode of failure, not fully under our control; it can be pulled out from under us unexpectedly (Collier 1990a). This amounts to it being discovered that some presuppositions of our anticipations, and hence of meaning, are either false or questionable, as, for example, happens when we are exposed to a new culture, or perhaps in a scientific revolution. In such cases, we are generally inclined by our usual interpretant to make inappropriate distinctions, by either omission or commission, and even the usual seems strangely new. Whereas the dual dyadic approach must regard this as a consequence of false beliefs, the pragmatic view can regard it as a failure of interpretation.

I have argued elsewhere (Collier 1999) that causation is the transfer of instances of information, or form:

P is a causal process in system S from time t_0 to t_1 iff some particular part of the information of S involved in stages of P is identical at t_0 and t_1 .

I will not argue for this separately here. The causal powers of representations, then, depend on their form and not their content. Our anticipations based in a representation, however, must coincide with its pragmatic meaning, the content of the representation. The causal powers of a representation and anticipations based on its content will coincide only for digital representations, for which the information in the content and the information in the form coincide. For physically grounded representations, the physical basis of a representation token (instance) must have at least an information capacity equivalent to the information content of the representation, and for a digital representation, only that information. For digital representations the causal powers of representations and their embodiments will coincide. For other representations, the information in the content, which is equivalent to the common information in the anticipations that determine its meaning, will be less

than the information capacity of the representation. Furthermore, our anticipations that give meaning to our representations will guide our actions and imagined actions (see Bickhard and Terveen 1995; Bickhard this volume, on vicariants) according to the causal powers of what we represent, and accurate representations will guide us correctly.

This account is not very helpful without an account of physical information. In keeping with the dynamical causal treatment of this chapter, I define information through Schrödinger's negentropy Principle of Information (NPI). According to NPI, the information in a physical system is the capacity for the system to do work, that is to guide energy to overcome some resistance. This is related to the order and organisation in a system, whose measurement is related to the somewhat obscure physical notion of entropy, such that the physical information is the difference between the maximal entropy of the system and its actual entropy (see Brooks chapter, this volume), in its most general form:

$$\text{NPI: } I_P = S_{\text{Maximum}} - S_{\text{Actual}}$$

The notion of work is related to mental notions through the idea of *control*, which is just the guiding aspect of work. Work requires a source of energy together with guidance. For a given system, the available energy is determined by the system *intropy* and temperature, where the intropy is a measure of the uncontrolled order in the system. The fixed, structured or controlled order I call the *enformation* (for more details on this approach see Collier 1990c, Collier 1999, Collier and Hooker submitted). It guides the energy in the system to do work, and represents the structural capacity to guide work, i.e. the dynamical form of the system. *Physical causation*, on this account, is the transfer of enformation. This transfer is dissipative if intropy is used up in the process, and conservative otherwise.

Since informational relations are (in cases of finite information) representable as computations, or logical derivations, NPI and the information theoretic approach to causation have the following consequences:

- C1. The I_p of something is its causal power.
- C2. Causal power is the capacity to make discriminations.
- C3. Causation (causal relation) is the transfer of the capacity to guide work.
- C4. Causation transfers the capacity to control.
- C5. The effect follows necessarily from the cause.
- C6. Causal powers and causal relations determine possible computations.
- C7. Causal powers and causal relations have a syntax.

These consequences tighten the relation between representations and their physical basis, especially in the case of digital representations, since their syntax and content must coincide, and further coincide with their causal powers and logical relations to other representations.¹⁷ In particular, causal relations among systems of representations will reflect the anticipated relations among their references, exactly in the case of digital representations. This permits reasoning about things representationally. In non-digital representations, anticipations guide reasoning, being the basis of content, but unintended results may stem from the extra information capacity of the representations.

5. The importance of dissipativity for the possibility of reference

A putative sign is a sign only nominally if it is a sign only because it is taken to be a sign; call this a *signal*. The function of such a signal can be analysed purely in terms of dyadic relations, either reciprocal causal relations or the traditional dual dyadic sense and reference relations, but not both. Dyadic causal relations establish an index through causal correlations, of which a qualisign may be one of the relata. An index itself can be considered as a signal because the causal relations in a particular instance are sufficient to fix its object. This requires no signal type beyond the individual token. Dual dyadic sense/reference relations establish an icon bearing a resemblance (natural or artificial and conventional) to its object. Again, token icons of a singular kind are possible, since their resemblance allows them to stand for their object in each particular case without reference to any other possibilities, especially the possibilities of unsatisfied anticipations that underlie the corrigibility required for intention. Indices and icons can be functional, and can even be reasoned with, but neither requires intention. Examples, to be discussed in more detail in §6, are the causal correlation of the sunflower and the sun, and the conventional relations of a character in a computer program that stands

for a letter or number. An example involving reason, but not the appropriate intentions, is Searle's (1980) Chinese room thought experiment, in which a collection of clerks receives messages in Chinese characters passed through a slot, and manipulate the characters according to specified rules to form responses that are passed back out the slot. Although the responses are answers in Chinese to questions submitted in Chinese, the non-Chinese speaking clerks do not have the intentions required to give Chinese responses to the questions. They act rationally, but not intentionally with respect to the questions. The digital nature of the deficient representations in the computer is ensured by the way they are causally embodied in the highly constrained operations of the computer, while in the Chinese room the digital nature is preserved by the rules for manipulation, which apply solely to the symbolic aspects of the characters. In both cases relations of sense and reference are preserved by the resemblance, in turn preserving linguistic functionality. But in each case the computer and the clerks lack the sort of autonomy, to be specified below, to interpret the characters.

A non-trivial sign requires a triadic interpretant (see §3 above and Figure 1). The meaning of the sign is fixed by anticipations, which require at least possibilities of causal interactions with the world. The content of the meaning, then is determined by the information in the causal satisfaction of the relevant anticipations. Since anticipations can fail because of errors of commission or omission, but can still pick out some object successfully because the anticipations are close enough to distinguish the object successfully, the reference of a non-trivial sign, unlike for an index or icon, can fail to be accurately picked out by the sense of the sign. That is, there may be sufficient information in the content to allow the object to be individuated successfully from other candidates. Figure 1 is thus somewhat misleading, since it suggests that reference is fully determined by sense. The causal interactions between interpretation and the world, however, allow the sense to be erroneous without undermining reference, so although the sense determines reference, it does so only in the context of interpretation, the pragmatic element of meaning. The determination of reference is not entirely independent of the possibility of our anticipations not being satisfied. Thus although the sense must have the information required to individuate the reference, it need not have all the information in the reference, and may have information not in the reference.

This consequence of pragmatism should not be surprising, though it is often overlooked. Anticipations are somewhat open-ended, needing completion by testing them against the world through interactions. This implies that our interpretation (meaning) does not fully determine its object, and is open to revisions. This consequence was observed by Quine (1960), and called by him *underdetermination of meaning*, which led to his theses of indeterminacy of translation and ontological relativity.¹⁸ Quine was embedded in analytic philosophy, and to preserve dual dyadic sense/reference approach to meaning, he suggested that the best we could do was an ersatz behaviouristic account of meaning that had no need of intentionality. This move is not necessary, however, if we invoke the role of anticipations and corrigibility in the production of meaning. Underdetermination, however, is not fully mitigated by moving to the pragmatic account of meaning; at best it can show the way to reducing underdetermination in the face of failed anticipations (Collier 1987). The open-endedness and nonauthority of anticipations implies that the meaning of a representation is inevitably incomplete and revisable, something not possible for digital representations. Non-trivial signs, then, cannot be digital; at best full specificity of the meaning of a non-trivial sign is an ideal to be approached but not conclusively satisfied.¹⁹ Digital signs are closed and consequently non-productive, unlike the open character of non-trivial signs.

The underdetermination of representational capacity by content in the pragmatic theory of meaning (sometimes called vagueness) is similar to the multiplicity of a macroscopic physical state by its microstate. There will be a corresponding randomness of the representational capacity that permits dissipation. In fact, given the argument above, this dissipativity is essential to genuine representations. Most often dissipation will merely lead to unintended consequences that will cause confusion, humour, or be ignored, but sometimes the uncontrolled elements, given the vast amount of thought and communication every day, will be integrated into our anticipations so as to contribute to meaning. This process is productive, creative, spontaneous, and is a form of self-organisation. The analogy to physical systems is tighter than might appear at first, since the basis of the multiplicity is underdetermination of the causal properties of articulated content determined by anticipations, of the representational capacity of the signs that carry the content. The content is a macrostate integrated by

anticipations, whereas the referential capacity is a microstate that can vary according to person or circumstance.

6. Some simple signs: nominal and genuine signs

Peirce's thermometer controlling an air conditioning system is arguably functional, but it lacks any of the autonomy required for self-maintenance (although a poor thermostat might not be tolerated for long). Its function is derivative from the purposes of the designers, producers and purchasers. The case of the sunflower is more complicated. In this case plant is autonomous, and facing the sun contributes to its autonomy, thereby being functional. Does that sunflower represent the direction of the sun? If it does, there must be an interpretant for the sign, a set of anticipations in which the content sun plays a role corresponding to the sun in the real world. I think we can safely say that in this case there is not. The real sun (or some bright light) is required to evoke the response, and there is no evidence that the plant does anything to anticipate the appearance of the sun, or seek it out in its absence. The behaviour can be explained entirely in causal terms, without reference to meaning or interpretation. However, when we make the move to evolutionary lineages of sunflowers, things may not be so simple.

MacLaurin (1998) gives a somewhat more complex example involving communication among acacia trees under threat. Predation by the kudu antelope causes the trees to increase tannin production in their leaves, reaching a concentration that can kill an antelope. So far, nothing much different from the phototropic sunflower. Interestingly, however, the acacias release ethylene into the air, which causes downwind acacias step up tannin production in five to ten minutes. The original researchers, Allen and Hauser, argue that the ethylene can be said to carry the information that kudus are eating the trees. MacLaurin argues that "[t]his gives us an account of information as a natural property, as something in the world that a developing organism could receive from its genome or from the environment". Nonetheless, this at best gives us an account of the causal side of information – the ethylene carries information about its cause, which in turn, given the identity of informational and causal processes, requires no more than causation. There is no evidence, however that the acacias can interpret ethylene in anything like the open ended way our anticipations provide meaning. The production of tannin in the presence of ethylene is a causal consequence of the functional organisation of the trees, whether kudus are present or not. In particular, the trees have no way to test for the presence of kudus. The ethylene acts very much like the thermostat switch, except that in this case the autonomy of the acacias ensures that it is non-derivatively functional.

On the other hand, simply shouting "Fire!" elicits all kinds of expectations and complex reasoning (and actions) concerning fire. It is only against the background interpretant that the sign can have this power. The word itself cannot convey the information involved; it must already be present in the minds of those who respond to the word. The information in the word itself merely picks out this content from other possible contents; far from functioning as a simple switch it brings into play a whole complex of ideas and behaviours, more or less appropriate to the presence of fire. Although the warning will most likely elicit a good deal of sensible and appropriate response from onlookers, depending on their capabilities and dispositions, the unarticulated informational capacity of the term (not exactly its connotations, but something deeper), can also bring about a number of unexpected responses, desirable or not.

Prairie dogs have a repertoire of calls that indicate threatening things like hawks, coyotes and the like. An investigator was surprised and pleased when a colony of dogs responded to him much later with a call that they had used to identify him before. Apparently they can learn to distinguish threats with different calls, and this allows them to anticipate the threat. This appears, whether or not cognition in the usual sense is involved, to be more like the "Fire!" case than the ethylene case. Other forms of behaviour among social animals show similarly flexible behaviour. *Prima facie*, these are cases of representation, but further experiment is required.

There is something special about the sunflower and acacia cases (and perhaps the prairie dog case) that should be noted. In these cases the signals serve survival and reproduction through adaptation, and the formation of the signalling capacity takes place in an ecological background such that anticipation of the background is advantageous to survival. Although the sunflowers and acacias individually are acting in a purely mechanical way, it might be possible to understand their actions

from a genealogical perspective as anticipative. I do not mean to say that the meaning derives from Nature (cf Küppers 1990), but that the interpretant arises in the evolutionary context as a set of anticipations forming a complex corresponding to environmental conditions. At this point I am not quite sure what might decide the issue, and leave it open as a possibility, i.e., that lineages might have anticipatory functions that are purely mechanical in their member organisms. If this is at all right, the same idea might carry over to ontogenic lineages.

7. Representational autonomy

From the examples above, the main distinguishing feature of genuine semiosis appears to be the existence of a complex of anticipations related to other such complexes within which an interpretant can be formed. Representations permit complex anticipations and relations to other representations so as to allow intentional activity. Causal relations may look representational when they causally carry a signal about something, but this is not enough for them to be representational. Although there is no reason to assume that representations need to be anything like digital (e.g. they could be inseparable states of neural nets), they do need to be able to interact and affect each other according to the anticipations of their subject. This requires that the representational system have a degree of independence from the rest of the organism, so that representations can be used effectively to vicariously represent anticipated situations (see Bickhard, this volume). Furthermore, to maintain the integrity of this system from incidental information or the uncontrolled information capacity of the physical basis of the representations in the system, it must be able to maintain its informational character, and thus be informationally autonomous. This does not mean that it is closed to all information, but that it is capable of ignoring or interpreting information that impinges on it as required for its proper functioning (I believe this is what may have been intended by autopoiesis, but the term has been used so widely it is hard to tell).

Matthen and Levy (1984) have suggested that the immune system is intentional, and makes the simple distinction between self and non-self through training by the thymus in early life. I won't go into their arguments here, which took some time to convince me, but I will note the peculiar fact that the capacity to distinguish self from non-self is fully integrated into the immune system, though it is a variable of the system. The control of the immune system to keep it from attacking self requires modification of the immune response throughout, and not merely at particular "triggers" signed 'self'. This informational aspect of the immune system is encoded so that the system can anticipate and react to non-self, but (usually) not to self. In itself, this description is not enough to determine whether or not the immune system represents self, since much depends on the nature of the encoding, and the ways the immune system interacts with itself to maintain this encoding.

The question of whether DNA represents the environment or the phenotype or both is not one that I will not attempt to answer here, but I will mention some considerations. The so-called genetic code is a simpler dyadic relation. If there is any sense in which genes represent, it will have to be in the context of the protoplasmic environment, perhaps augmented by ecological and evolutionary considerations. Despite Dawkin's talk of the selfish gene, genes do nothing in themselves to maintain their identity except perhaps to duplicate, which is not self-maintenance so much as lineage maintenance. At best, it would be complexes of genes in typical protoplasmic environments that are self-maintaining. Again, I leave the details to the experts.

One point of interest in the theory of representation that I am suggesting is the that representations have not only an informational independence, but whole semiotic systems, inasmuch as their semiotic character is innate and not derivative, are to some degree informationally autonomous. This autonomy certainly does not support mental dualism, but it does suggest why it has been so plausible. In order to answer the dualist it isn't enough just to point to the physical correlations between neural and mental events, but to show how representations are both mentally and physically causal, in such a way that their causality corresponds. The information theoretic approach to causation takes us some way in this direction.

8. Conceptual autonomy

One further topic that needs far more treatment than I can give it here is the role of memes, representational or not. Memes are repeatable and copyable practices, behaviours, styles, rituals and the like that carry meaning. They are a special sort of sign whose existence is inseparable from their meaning, unlike other signs, whose meaning derives from their interpretation. Memes, on the other hand, carry their interpretation with them. They cannot exist in isolation, and are completely dependent on their biological substrate, communicated from one to another by physical copying rather than direct transmission. The word “hello” is transmitted directly, but its meaning cannot be, if anything I have been saying about the reliance of meaning on expectation is correct. It seems that memes like fashions, ideologies, scientific paradigms, power structures, and so on are communicated indirectly at least in part by rearranging the thoughts of their hosts. In this sense they have both independence and informational self-maintenance, and seem to be informationally autonomous. This idea strikes directly at ideas of our own autonomy and independence, but I noted in the section on autonomy that autonomous entities at different levels can be in conflict with each other. We are no more at the mercy of memes than we are fully in control of them. The same could be said for society as a whole.

Whether or not memes as such exist, the idea points to fundamental property of communicable ideas in general. Ideas that are communicated must have some autonomy, or we could not teach them to people who do not already know them. This autonomy resides in their capacity to form complexes of expectations with a common informational core, integrated informationally with prior representations. Current methods of programming computers conventionally set one symbol to represent another, and all the signs are fully digital. We will not get intelligent machines until we can make autonomous machines into which we can introduce and integrate the representations we wish. This is much the same as training students. New ideas are sometimes communicated as mere combinations of old ideas, but really novel ideas must be allowed to form themselves, in part taking advantage of the unarticulated representational capacities of pre-existing representations. Unfortunately, I have no room to pursue this further here (see Collier 1998).

The essential point is that digital representations are too independent to have real meaning. They lack the open-endedness of anticipations, and cannot produce new ideas that can be integrated with previous experience, broadly construed. At best they can be integrated formally with other digital representations, giving something that might be formally exquisite, but has little to do with the role of meaning in the real world. Although an approach to digitality is useful for articulating our ideas, to achieve it would turn us into formal devices with no reason to use our ideas, and would close off any further productivity inherent in the properties of representations that are not fully articulate. Fortunately, there is little likelihood of this occurring, but the surest way to kill the development of a discipline is to insist on specific fully articulated meanings (I believe this applies even in mathematics).

9. Conclusions

The pragmatic approach to meaning cannot be merely added to contemporary analytical accounts, but requires a complete reformulation. Since meaning depends on interactions, which are causal, and presumably mental entities and processes are also causal, a mind/matter neutral analysis is required to give a complete account of pragmatic meaning. I have suggested information theory with a causal part, involving information carrying capacity, and a formal part that can represent content in terms of common information in anticipations. Anticipations of correspondence across individuals mean the same information is carried by both, and allows the same reasoning. This permits communication.

I have left the question of the truth and range of applicability of generalised semiotics open, though I would agree that it can be used freely as an analogy as long as its limitations are kept in mind. The main problem in each case is to find the interpretant, show why it is in an autonomous entity, and show why it is irreducibly triadic. This is a lot to ask, but the problem is not an easy one, open to facile similarities with cognitive cases.

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¹Von Brücke is reputed to have said "Teleology is a mistress with whom no biologist can live without, but with whom he is loathe to be seen with in public."

²Cf. Russell on the significance of knowledge by acquaintance, and recent work on pragmatics, e.g. Montague (1974), Kaplan (1979), Perry (1977, 1979), Barwise and Perry (1983), Stalnaker (1976, 1978), Lewis (1979), and also the Structuralist approach to scientific theories (Stegmüller 1979).

³The account of intrinsic information is sketched in Collier (1990c), with more detail in Collier and Hooker (submitted) and Collier (1999). The last is an account of causation as the transfer of information.

⁴This account uses Dretske (1981), Perry and Barwise (1983), and Israel and Perry (1990) as a starting point. See Collier (1990c) for the basic ideas and some criticisms that go beyond the ones in this chapter.

⁵I leave open the question of whether or not pure feelings, desires or sensations, e.g. pain, hunger or a sensation of a shade of redness respectively, are intentional. While feelings and other experiences can represent, in themselves they have neither referential meaning nor sense, and have no meaning or significance beyond themselves.

⁶Peirce refers to ideas as "to be understood in a sort of Platonic sense, very familiar in everyday talk", suggesting Platonism. This can be replaced (relatively) uncontroversially with Locke's notion of abstract ideas based in "partial consideration", or, in more modern and less psychologistic terms, as situations (Barwise and Perry 1983).

⁷Here and hereafter CP stands for Peirce's *Collected Papers*; the specific reference is to volume and paragraph, except when only page numbers are in the original.

⁸I use "anticipated" rather than Peirce's "expected" to reduce psychological connotations in pragmatic theories of meaning. Analytic philosophy of language has no such concerns, and following Frege has generally made do with sign (syntax), reference and ground (in this case, sense). The meanings of syntax, reference and sense must be substantially reconstrued to include the interpretant in the system. The notion of interpretant cannot be simply added incrementally without courting irredeemable confusion: the standard approach can be construed purely formally; the enhanced pragmatic approach cannot. This will be developed further in the rest of the chapter.

⁹Peirce allows that how we limit the extension of the term "sign" (Peirce 1940, pp. 275-76) determines what is a representamen. This seems to be a large concession, since the role of the interpretant in semiosis is more than a matter of convenience. Presumably Peirce meant that one could

use “sign” to include interpretantless cases, but that this would be inconvenient. Note that any status the sunflower might have as a potential representamen of the sun arises through the nature of its functionality in reproduction, which minimally allows us to adopt the intentional stance. Whether or not this is sufficient is not obvious, or Peirce would likely have said so

¹⁰There is a theological tradition that such a being with sufficient power could simply will which interpretation was correct. This appears to me to be incoherent, since willing would be subject to the same problem of multiple interpretations.

¹¹Many standard accounts of function appeal to etiology to determine function, suggesting that without considering etiology one cannot fully consider function. The present account reverses this to explain etiology in terms of functional preservation of autonomy.

¹²I am grateful to Robert Ulanowicz for reminding me of this important point.

¹³Peirce further categorised signs according to their role in expressing possibility, existent or law. It would seem that this should give a total of 27 classes of sign, but Peirce reduced this to ten under his belief that possibility is simpler than existence, which in turn is more simple than law, together with his belief that the interpretant must be at least as simple as the ground and object of the sign (CP 2.254-264). These beliefs seem to derive from his extreme idealism, though exactly how they are motivated is obscure to me. In any case, this categorisation is irrelevant for the purposes of a scientific treatment of semiotic categories in terms of dynamical notions, since the dynamical approach must be based in particular existents.

¹⁴The usual probabilistic measure of information can be recovered from this more fundamental notion of information (Ingarden et al 1997). I call it more fundamental since it applies to any form, whether or not probabilities are well-defined on the form.

¹⁵By “picks out”, I do not mean Frege’s notion of falling under a concept, which selects to what the concept applies, but to the Fregean concept itself when that is what is picked out by a representation. Thus “1” picks out the number, and not one-numbered collections.

¹⁶For an example of possible incomprehensible behaviour, see Collier (1990a) on Putnam’s argument that we could not be referentially isolated brains in vats. Other examples arise (at least pragmatically) when paradigms are challenged (Collier, 1984). See also Emmeche et al (1997) on this as a necessary condition of emergence.

¹⁷Assuming that reasoning is causally based. The digital view of intentionality severely limits the productive capacities of digital representations and their use in creative reasoning (Hooker, personal communication).

¹⁸I prefer this more precise term to Peirce’s *vagueness*, which is itself disturbingly vague, apparently applying to both semiotic and non-semiotic entities. This is perhaps another aspect of Peirce’s idealism.

¹⁹This conforms with the open-ended nature of truth in realist metaphysics, though it does not in itself necessitate a realist approach to truth.