Prolegomenon for a formal theory of referential information: T. Deacon (12/20/14)

A. General case: passive information medium near equilibrium [e.g. geological formation, crime scene evidence, data from a scientific experiment, text, etc.]

1. Shannon (e.g. information) entropy is NOT equivalent to thermodynamic (e.g. Boltzmann-Gibbs) entropy (or to the absolute statistical diversity of physical states). [For convenience these entropies will be provisionally distinguished as Shannon versus Boltzmann entropy, though recognizing that each includes multiple variant forms.]
2. However, for any physical signal medium, a change in Shannon entropy must also correspond to a change in Boltzmann entropy, though not vice versa because the distinctions selected/discerned to constitute the Shannon entropy of a given signal medium are typically a small subset of the possible physical variety of states—e.g. statistical entropy—of that medium. (See notes below.).

3a. The Shannon information of a received message is measured as a reduction of signal uncertainty (= a reduction of Shannon entropy).

3b. For a simple physical medium reduction of Shannon entropy must also correspond to a reduction of the Boltzmann entropy of that medium.

3c. This can be generalized as "any deviation away from a more probable state" (which can violate 3b in the case of media that are actively maintained in an improbable state, such as maintained far-from-equilibrium. See B below.).

4a. A reduction of Boltzmann entropy of any physical medium is exhibited as constraint on its possible states or dynamical "trajectories."

4b. The production of physical constraint requires physical work in order to produce a decrease of Boltzmann entropy, according to the second law of thermodynamics.

5a. For a ***passive medium*** the physical work required to reduce its Boltzmann entropy must originate from some physical source ***extrinsic*** to that medium.

5b. Generalization: Constraint of the Shannon entropy of a passive medium = constraint of its Boltzmann entropy = the imposition of prior work from an external source.

6. An increase in constraint (i.e. deviation away from a more probable state) in the information medium literally "re-presents" the physical relationship between the medium and the extrinsic contextual factors (work) that caused this change in entropy. (= what the information embodied in the constraint can be "about.")
7. Since a given constraint has statistical structure, its ***form*** is a consequence of the specific structure of the work that produced it, the physical susceptibilities of the information bearing medium, and the possible/probable physical interactions between that medium and this extrinsic contextual factor.
8. The form of this medium constraint therefore corresponds to and can indirectly "re-present" the *form* of this work. (i.e. in-*form*-ation)
9. Conclusion 1. The possibility of reference in a passive medium is a direct reflection of the possibility of a change in the Boltzmann and Shannon entropies of that medium due to a physical interaction between the information bearing medium and a condition extrinsic to it.

10. Conclusion 2. The possible range of contents thereby referred to is conveyed by the form of the constraint produced in the medium by virtue of the form of work imposed from an extrinsic physical interaction.
11. Conclusion 3. The informing power of a given medium is a direct correlate of its capacity to exhibit the effects of physical work with respect to some extrinsic factor.
12. Corollary 1. What might be described as the referential entropy of a given medium is a function of the possible independent dimensions of kinds of extrinsically induced physical modifications it can undergo (e.g. physical deformation, electromagnetic modification, etc.) multiplied by the possible “distinguishable” (see notes) states within each of these dimensions.
13. Corollary 2. Having the potential to exhibit the effects of work with respect to some extrinsic physical factor means that even no change in medium entropy or being in a most probable state still can provide reference (e.g. the burglar alarm that has not been tripped, or the failure of an experimental intervention to make a difference). It is thus reference to ***no work performed***.

In addition, since not all information media are physical structures or otherwise passive systems at or near thermodynamic equilibrium we need to modify certain of these claims to extend this analysis to media that are themselves dynamical systems maintained far-from-equilibrium. This yields the following additional claims:

B. Special case: non-passive information medium maintained far from equilibrium [e.g. metal detector or organism sense organ]

1. A persistently far-from-equilibrium process is one that is maintained in a lowered probability state. So certain of the above principles will be reversed in these conditions. Specifically, those that depend on extrinsic work moving a medium to a lower probability, lower entropy state.
2. Maintenance of a low Boltzmann entropy dynamical process necessarily requires persistent physical work or persistent constraints preventing an increase of Boltzmann and Shannon entropies.
3. Any corresponding increase in Shannon entropy therefore corresponds to a disruption of the work that is maintaining the medium in its lower entropy state. This can occur by impeding the intrinsic work or disrupting some dissipation-inhibiting constraint being maintained in that system.

4a. An increase in the Shannon entropy of a persistently far-from-equilibrium information medium can thereby "indicate" extrinsic interference with that work or constraint maintenance.

4b. A persistently far-from-equilibrium dynamical medium can be perturbed in a way that increases its entropy by contact with a passive extrinsic factor. Any passive or dynamic influence that produces a loss of constraint in such a system can provide reference to that extrinsic factor.

5a. Since work requires specific constraints and specific energetic and material resources, these become dimensions with respect to which the change in entropy can refer to some external factor.

5b. The dynamical and physical properties of a far-from-equilibrium information bearing medium determine its "referential entropy."

6. Corollary 3. This can be generalized to also describe the referential capacity of any medium normally subject to regular teleodynamic or teleological influences that tend to cause it to be in an improbable or highly constrained state. This therefore is applicable to living systems with respect to their adaptations to avoid degradation and also to far more complex social and cultural contexts where there is active "work" to maintain certain "preferred" orders.

Notes:

Shannonian theory is the necessary but not sufficient foundation for defining information: Shannon's and related forms of "information theory" do NOT provide an account of what it means to inform. Shannon's theory only concerns the medium (or signal) properties that are a prerequisite for a given medium to be able to inform: i.e. to refer to an extrinsic/absent feature relevant to some interpretive system. For this reason Shannonian analysis is both applicable to all forms of information and yet cannot explain any higher order feature of informational phenomena. These are only distinguished once the theory of reference is included to augment the Shannonian analysis.

Non-equivalence of the two meanings of 'entropy': Shannon entropy is typically a very small subset of the physical entropy (aka Boltzmann-Gibbs) and statistical entropy of any given physical medium. Shannon entropy is that small fraction of the physically distinctive states of the medium corresponding to those discernible by a given interpretive process. Thus Shannon entropy assumes an interpretive process that must have its own entropy (related to Ashby's "requisite variety") which corresponds to the system's capacity for state changes capable of contributing to a completed end-directed (teleodynamic) work cycle (see below).

Limitations: The expansion of information theory (above) to include the necessary and sufficient conditions for reference does not yet address either the dynamical organization required to constitute an interpretative process nor does it provide a means to distinguish between the variant forms of reference (e.g. iconic, indexical, symbolic) that are possible. This requires expanding this analysis to formalize what is meant by an interpretive process and the nature of a semiotically competent system.

Interpretation and Significance: The realization that work plays a critical role in the potential-to-refer is a critical clue to the problem of assessing significance –

something that has often left the bounds of science by arguing that it is a “subjective” issue (e.g. MacKay’s critique of Shannon). This is because work is also the relevant measure when it comes to assessing the “usefulness” of information. In general, I argue that it is the amount of work “saved” toward the completion of a teleodynamic work cycle* (as a result of access to information) that determines the significance or usefulness of that information. Since “work saved” is a comparative measure with respect to achieving a defined end, this assessment is necessarily a competitive selection process with respect to alternative variant processes “aimed” at achieving the same end — hence Darwinian in a general sense.

* A teleodynamic work cycle is not merely a thermodynamic work cycle (though it must also include both endergonic [catalytic] and exergonic phases [self-assembling] phases), but is additionally an organizational work cycle that contributes to its own preservation and reproduction. A simplest example of this is provided by autogenesis, which if structurally degraded or disrupted will initiate a work cycle to reconstitute the boundary constraints required to support future work cycles to perpetuate this same capacity.