CYBERNETICS AND THE INTEGRATION OF KNOWLEDGE

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Summary

Cybernetics was formulated by its founders as a metadiscipline with the aim, not only of fostering collaboration between disciplines (interdisciplinarity), but also of sharing knowledge across disciplines (transdisciplinarity). As a metadiscipline, cybernetics comments on forms of knowing (the cognitive processes and communicative practices of observers) and also on forms of knowledge (for example, similarities and differences between different discipline areas). This article presents cybernetic models of "coming to know" and of "knowledge sharing". The distinction between first and second order forms of cybernetics is introduced to mark the reflexive nature of cybernetics as a metadiscipline. There is then a discussion of the first order study of natural systems, noting in particular:

- the emergent discovered properties of such domains;
- the role played by the observer's a priori assumptions and decisions about what to study and how to study.

This is followed by a discussion of cybernetics and the social sciences. Here the

distinction between first and higher order forms of cybernetics is brought into play in order to characterize:

- studies of social systems and social behaviour that adopt classical scientific modes of investigation;
- studies that investigate the interactions of social actors;
- approaches that attempt to characterize social systems as distinct forms of autonomous whole.

Finally there is a discussion of how the metadisciplinary perspective of cybernetics can help inform and enlighten the "other than science" domains of knowledge and activity known as the arts, the humanities, the vocational disciplines and philosophy.

1. Introduction

One of the major sources for the development of the transdisciplinary study of complex systems in modern times is the series of meetings convened by the Macy Foundation in the 1940's and 1950's on "Circular Causal and Feedback Mechanisms in Biological and Social Systems" (other sources for transdisciplinary work includes von Bertalanffy's "general systems theory" and Korzybski's "general semantics"). During the course of those meetings, Norbert Wiener adopted the name "cybernetics" for the emerging discipline and defined it as the study of "control and communication in the animal and the machine". From the outset, it was conceived as both art and science and was seen as encompassing traditional concerns in the study of the "governance" of human systems (see ***History of Cybernetics, General Systems Theory***).

Before it was named the founding conception of cybernetics was that it should serve as a way of "integrating knowledge". In this article the idea of integration (from the Latin "integrare", to make whole or make into one) is developed in several ways.

1. Integration through interdisciplinarity.
   By this is meant the use of the "language" of cybernetics (formal concepts and associated terminology) to build bridges between different knowledge domains (Latin "inter" - between). An example is the concept of control by negative feedback and the associated terminology. The concept as a model may be applied in many different domains. Indeed, a major motivation for the founding of cybernetics was that this was the case. Engineers, anthropologists, neurologists, psychologists and economists (to name some) were constructing "similar" models, albeit with different domains of application and terminology. Thus cybernetics as a lingua franca serves to facilitate communication between discipline areas. A psychologist can learn from a computer scientist and vice versa. For example, "memory" is modelled as data storage; data retrieval is conceived as "remembering" how objects and events are classified and related together within a conceptual system. The fact that models, metaphors and analogies are shared does not legitimize them as being particularly true or useful; that is a secondary consideration.

2. Integration through transdisciplinarity.
   Here as in the hands of the masters (Ross Ashby, Gordon Pask, Stafford Beer) the models and terminology of cybernetics become systematized as a set of inter-related

concepts. Cybernetics "has its own foundations" (Ross Ashby). With this conception it is now possible for someone to be "a cybernetician". Cybernetics becomes a "window on the world". Wherever he looks, the cybernetician sees the ubiquitous phenomena of control and communication, learning and adaptation, self-organization and evolution. His "cybernetic spectacles" allow him to see any particular knowledge domain and the systems within it as special cases of abstract, general cybernetic forms. Brains and societies may be modelled as hierarchical or heterarchical systems (with or without an overall controller). Processes may be serial or parallel, synchronous or asynchronous; all controlled processes are subject to the law of requisite variety ("Only variety can control variety", Ashby). All self-organizing systems from amoebae to human societies adapt and evolve to become "informed" of the constraints in their worlds - or perish.

The power of cybernetics as a transdiscipline (Latin "trans" - across) is that it abstracts, from the many domains it adumbrates, models of great generality. Such models serve several purposes: they bring order to the complex relations between disciplines; they provide useful tools for ordering the complexity within disciplines; as above, they provide a "lingua franca" for inter-disciplinary communication; they may also serve as powerful pedagogic and cultural tools for the transmission of key insights and understandings to succeeding generations. However, as noted by Immanuel Wallerstein, past President of the International Sociological Association, if a transdisciplinary approach is to make a real contribution in the natural and social sciences, it must be more than a list of similitudes. It must also be epistemologically sophisticated and well-grounded. Cybernetics, with its explicit distinction between first and second order forms, can claim, not only to satisfy this criterion, but also to be making significant contributions to epistemological debates.

Ross Ashby defines cybernetics as the formal study of "all possible machines". In his book "An Introduction to Cybernetics", Ashby uses a simplified version of set theory notation to present concepts such as *change*, *stability* and *regulation* in complex systems. It can still be tough going for non-numerate readers. A simple but powerful formulation of the essence of cybernetics is that its key concepts are "process" and "product" and that its main methodology is to model the *form* of processes and their products, abstracted from any particular embodiment. Thus, for example, a control process, whose product is the maintenance of some state of affairs, may be distinguished and modelled as such, irrespective of its particular embodiment as a biological, artificial or social system (see ***Systemology: Systemic and Non-systemic entities***, ***Transdisciplinary Unified Theory: basic concepts*** and ***Transdisciplinary Unified Theory: formal aspects***).

3. Integration through metadisciplinarity.
   In this application cybernetics is a "discipline about disciplines" (Greek "meta", above). It comments on the forms and procedures that constitute particular disciplines qua knowledge domains. It sees the physicist as a builder of models, constrained by the properties of the domains and systems he distinguishes and interacts with. It sees the biologist the economist, the sociologist, the psychologist likewise. It comments on their activities as modellers, controllers and predictors. Science, pure and applied, is a cybernetic pursuit and art "L'art d'assurere l'efficacité

de l'action" (Couffignal). The metadisciplinary aspect of cybernetic thought was explicit in its founding. It reached full fruition with Von Foerster's articulation in the 1970's of the fully reflexive metadisciplinary activity where cybernetics is used to study its own workings: the cybernetics of cybernetics, also referred to as second order cybernetics (see ***Second Order Cybernetics***).

First and second order cybernetics are the study of "observed systems" and the study of "observing systems", respectively. First order study is of "observed systems", where we may deploy the research paradigms of the natural sciences and seek falsification of hypotheses. However, all this should take place under the rubric of the second order study of "observing systems". First order systems are defined from the perspectives of our second order concerns and understandings. Von Foerster has gone on to discuss epistemological limits and ethical implications of second-order understandings: "we think, therefore we are"; "to know is to be". He invites the observer of systems to "enter the domain of his own descriptions" and accept responsibility for being in the world, thus echoing the longstanding discussions in sociology about the "reflexive" nature of the "social" (see also sections 6 and 7, below). Gordon Pask made second-order concerns explicit by developing a cybernetic "theory of conversations", with particular applications in education and epistemology. Pask's contributions are described in more detail below (sections 3.4 and 5).

The article is structured as follows. First, there is a discussion of cybernetic explanation and the concept of mechanism. This is important because, although cybernetics does not have a commitment to a particular ontology in terms of "what the world is made of", it does make assumptions about "how the world works". Next, there is a discussion of cybernetic epistemology, the processes of coming to know and of knowledge sharing. This discussion expands on what is meant by second order cybernetics and is particularly important in that it establishes the metadisciplinary perspective for the "integration of knowledge". Second order cybernetics provides an epistemology that in recent years has become known as "radical constructivism". There is a brief excursion that elaborates on this usage.

Later parts of the article go on to discuss particular knowledge domains. For reasons of space, coverage is selective. First, there is a discussion of the first order study of the domains of the natural sciences. The applied sciences, such as engineering and computer science and the subdomains of robotics and artificial intelligence, are not dealt with explicitly. Partly because their relations to cybernetics are fairly self-evident and partly because they are dealt with elsewhere (see ***Computational Intelligence***). There is then a more extended discussion of how cybernetics views the social sciences. This is because the topic is controversial and conceptually challenging. Here, the distinction between first and second order study is deployed in order to characterize:

– studies of social systems and social behaviour that adopt classical scientific modes of investigation;
– studies that investigate the interactions of social actors;
– approaches that attempt to characterize social systems as distinct forms of autonomous whole.

This is followed by a brief discussion of the cybernetic perspective on the arts, humanities and vocational disciplines, where emphasis is placed on the role of the human actor as a cybernetic agent, concerned to affect the world directly as a participant or indirectly as a commentator. Finally, there is a discussion of the relation between cybernetics and philosophy. That cybernetics addresses traditional philosophic concerns of epistemology and ethics is a theme throughout the article. Here there is a brief summary that emphasizes the cybernetic view of the complementary nature of "knowing" and "being" and the cybernetic "structural-functional-pragmatic" concepts of meaning and truth.

2. Cybernetic Explanation and the Concept of Mechanism

As noted above, cybernetics is concerned with modelling "how things work". In Frank George's terse phrase, "A theory is a model together with its interpretation". Thus a cybernetic explanation is one where a model of process/product relations is provided, together with an interpretive narrative about the way in which the model accounts for the behaviour of the system in question. In Ross Ashby's formal, abstract cybernetics it is assumed that systems are embodied as classical mechanical forms. To make this account more complete, we will look a little more closely at the concept of "mechanism" in order to generalize and enrich it, first by considering quantum mechanics and second by considering thermodynamics and cosmology.

The concepts of abstract cybernetics may be generalized to quantum mechanics where processes are quantized, not continuous, and the forms of their outcomes are subject to the uncertainties of quantum physics. An important point to appreciate is that, as in Newtonian physics, processes are time-reversible, the "arrow of time" has no privileged direction, what is done may be undone. Current developments at this level include "nanotechnologies" and "quantum computation".

Following Prigogine, we may also distinguish irreversible "mechanical" processes, subject to the second law of thermodynamics and where time's arrow does have direction. Prigogine appears to have a deep intuition about not just the nature of particular dynamical systems within the cosmos but about the cosmos as a whole. With respect to "within cosmos" systems the same intuition and insight is found in a discussion by von Foerster of "self-organizing systems and their environments" and associated paradoxes of observation. Von Foerster defines a self-organizing system as one that is always becoming more organized, more complex in its form. If this is so, it means that the observer is obliged to continually update his model of the system, possibly having to expand the dimensionality of the space of possible states within which the system is defined.

With respect to Prigogine's intuitions about cosmos there is also a paradox of observation concerning our place "as observers" within a cosmos that is "developing", "becoming", "evolving" or "unfolding". The observer is irrevocably a part of what he or she observes. She is inelucably caught in a hermeneutic loop, where, as a "being in time" she constructs concepts of "being" and "time". As Spencer-Brown, Maturana, von Glasersfeld and others stress, our conceptions of cosmos are the constructions we make in order to make sense of our experiences of being living systems. This is where cybernetic explanation confronts the limits of the "ineffable". But, though "explaining" has limits, cybernetics is also a praxis, an art, as earlier: "l'art d'assurer l'efficacite de l'action" (Couffignal). We may still will and do.

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Biographical Sketch

Bernard Scott is Co-ordinator for the University of the Highlands and Islands Project's Learning Environments and Technology (LET) Unit. His research interests include theories of learning and teaching, principles of course design and best practice in distance and on-line education. During the 1970's Bernard worked with Gordon Pask studying styles and strategies of learning and helped develop Conversation Theory as a framework for understanding learning and teaching. He went on to train and practice as an educational psychologist. He returned to academia full-time in 1990 and has held positions in Liverpool John Moores University's Open Learning Unit, the Open University's Institute for Educational Technology and De Montfort University's Centre for Educational Technology and Development. Bernard is a Board Member of the Research Committee on Sociocybernetics (RC51) of the International Sociological Association, a Fellow of the Cybernetics Society (UK) and an Associate Fellow of the British Psychological Association.