The Internalist Perspective
and
Non-Cognitive Value

Robert E. Ulanowicz
University of Maryland
Chesapeake Biological Laboratory
Solomons, MD 20688-0038 USA

Tel: +1-410-326-7266
Fax: +1-410-326-7378
Email: ulan@cbl.cees.edu

ABSTRACT

The internalist stance explicitly recognizes system attributes that have been precluded from the externalist discourse. Fundamental to the internalist narrative is the concept of internal measurement as it is effected by local agents. It is but a small step from this postulate to the notion of self- measuration. System properties such as direction, autonomy, selection, competition and creativity all follow clearly and naturally from the consideration of self-mensuration. Value, however, requires a hierarchicalist overview, because value has meaning only in the context of a community of agents that interact with each other. Externalist tools, such as probability and information theory can be invoked to analyze the process of valuation. The quantitative outcomes of the analysis, nonetheless, have remarkably internalist characteristics.

INTRODUCTION

The action "to value", although generally considered even more subjective than the process "to measure", nonetheless shares with the latter a host of externalist connotations. Valuation generally is considered to be a cognitive action -- one that requires simultaneous information on the circumstances that surround the relationship between what is being evaluated and the agency that is doing the evaluation. To most people, the suggestion that either nonliving or non-sentient beings can engage in valuation is, at best, a stretched metaphor, or more likely, an absurdity.

Prior to the articulation of the internalist stance, many of the same objections could have been directed at the idea that non-sentient beings measure the world around them. But analysis of the process of mensuration has revealed that the externalist action of measurement bears analogy to the internalist view of the local interaction of two bodies with each other (Matsuno 1996). The very dynamics of one body as it interacts with a second constitute a form of measurement upon the latter carried out by the former. Of paramount interest here is the notion that this local response of one element to the actions of another, when viewed in the context of a system of like interactions, reveals the quantitative degree to which the first agent values the second.

The reader will notice in this last statement that I have purposely mixed perspectives. Measurement occurs at the local (or focal) level; but value does not become apparent until one takes account of the results of any measurement in the larger context of the community of similar measurements (the hierarchical viewpoint.) Considered separately, the internalist and the hierarchicalist viewpoints are both modern and universal, but it is the accounting for the difference between them that "tunnels through to postmodernism" (Salthe and Matsuno 1995.) Hence, non-cognitive value, as will be defined here, is a distinctly postmodern concept.

SELF-MEASUREMENT

A necessary preliminary to considerations on value is the introduction of the idea of self-measurement, or feedback within a community of interactions. Indeed, to assess the value of one agent to another makes sense only in terms of how any action initiated by an evaluator is reflected back to that agent through the lens of the mutual interaction. For current purposes, it shall suffice to consider only feedback that consists entirely of positive interactions, or what elsewhere has been termed "autocatalysis" in chemistry or "mutualism" in ecology. That is, by "mutualism" is meant "positive feedback that is comprised entirely of positive component interactions." Defined thusly, mutualism is not confined to combinations of only two processes. When more than two elements are involved, it merely becomes "indirect mutualism."

As an example of indirect mutualism, the reader is asked to consider the mutual interaction of three agencies or elements, A, B, and C. The mutualism between A and B implies that an increase in the rate of process A has a strong propensity to increase the rate of B. Likewise, growth in process B tends to augment that of C, which in its turn reflects positively back upon process A. In this sense, the behavior of the loop is said to be "autocatalytic", a term that means "self-enhancing". In an autocatalytic system, an increase in the activity of any participant will tend to increase the activities of all the others as well.

The intention behind the internalist perspective is to move beyond an accounting of events that is exclusively mechanical. In keeping with that intended generality, the reader will notice that the language used does not require that A, B and C be linked together in lock-step fashion. To achieve autocatalysis it is required only that the propensities for positive influence be stronger than cumulative decremental interferences. I.e., if there is some increment in the action of A, the net probability is that that change will engender a subsequent rise in B. The word subsequent is important, because, according to the tenets of the internalist perspective, "measurement cannot identify that which will be identified before the actual measurement" (Matsuno 1996.) As a consequence, the action of the initiator upon itself always occurs at some later time. This brings up the issue of the phasing of the returning signal. It is conceivable that the timing of sequential positive effects could result in overall negative feedback. Such configurations are simply excluded from the definition of autocatalysis.

AN EXAMPLE

Many examples of indirect mutualism in ecology are subtle and require much elaboration. One, however, is somewhat more straight- forward (Ulanowicz 1995, 1997). Inhabiting freshwater lakes over much of the world, and especially in subtropical, nutrient-poor lakes and wetlands are various species of aquatic vascular plants belonging to the genus *Utricularia*, or the bladderwort family. Although these plants are sometimes anchored to lake bottoms, they do not possess feeder roots that draw nutrients from the sediments. Rather, they absorb their sustenance directly from the surrounding water. One may identify the growth of the filamentous stems and leaves of Utricularia into the water column with process A.

Upon the leaves of the bladderworts invariably grows a film of bacteria, diatoms and blue-green algae that collectively is known as periphyton. Bladderworts are never found in the wild without their accompaniment of periphyton. Process B is now identified with the growth of the periphyton community. Bladderworts provide a substantial benefit to the periphyton in the form of an areal substrate, which the periphyton species (not being well adapted to growing in the pelagic, or free floating mode) need to grow.

Now enters component C in the form of a community of small, almost microscopic (ca. 0.1mm) motile animals, collectively known as "zooplankton", which feed on the periphyton film. These zooplankton can be from any number of genera of cladocerae (water fleas), copepods (other microcrustacea), rotifers and ciliates (multi-celled animals with hairlike cilia used in feeding). In the process of feeding on the periphyton film, these small animals occasionally bump into hairs attached to one end of small bladders, or utrica, that give the bladderwort its family name. When moved, these trigger hairs open a hole in the end of the bladder, the inside of which is maintained by the plant at negative osmotic pressure with respect to the surrounding water. The result is that the animal is sucked into the bladder, and the opening quickly closes behind it. Although the animal is not digested inside the bladder, it does decompose, releasing nutrients that can be absorbed by the surrounding bladder walls.

ATTRIBUTES OF SELF-MEASUREMENT

Although autocatalysis is usually portrayed as a mechanism when used in connection with chemical examples, such identification becomes wholly inappropriate as soon as the elements that constitute the autocatalytic loop show any signs of indeterminacy and adaptability (as is always inferred by the internalist perspective.) Taken as a whole, autocatalytic systems exhibit numerous properties that do not accord with the much- overused metaphor of nature-as-machine (Ulanowicz 1989).

To begin with, autocatalytic configurations, by definition, are growth enhancing. An increment in the activity of any member engenders greater activities in all other elements. The feedback configuration results in an increase in the aggregate activity of all members engaged in autocatalysis over what it would be if the compartments were decoupled.

Of course, even conventional wisdom acknowledges this growth enhancing characteristic of autocatalysis. Far less attention is paid, however, to exactly how self- mensuration arises in autocatalyic configurations and the inevitable selection pressure that it engenders. For example, if a change should occur in the behavior of one member that either makes it more sensitive to catalysis by the preceding element or accelerates its catalytic influence upon the next compartment, then the effects of such alteration will return as a positive signal to the starting compartment. Effectively, the element has changed its behavior in response to the measure of its new configuration that it took via the lens of the positive feedback. If such measurement is positive, the new behavior will be stimulated. The opposite is also true. Should a change in the behavior of an element either make it less sensitive to its catalyst or diminish the effect it has upon the next in line, then a negative signal will be returned via the loop against the change. Selection is thus inherent in self- mensuration.

The exact nature of the initiating change is purposely left unspecified. The eliciting event could represent the pure indeterminacy of matters at the local level (i.e., a true random event.) For example, the internalist perspective allows as how larger- scale and longer- term "laws" need not be satisfied at the local level (Matsuno 1996.) Alternatively, the initial change could arise deterministically from some already- present attribute that had been neglected during system description, as inevitably happens under the "principle of the excluded middle."

Perhaps the attribute of autocatalytic systems most apropos the internalist perspective is the way self- mensuration affects the transfers of material and energy between the members of the feedback loop and the rest of the world. Such transfers generally include the import of substances with higher available energy and the export of degraded compounds and heat. The degradation of energy is a spontaneous process mandated by the second law of thermodynamics. It need not always hold at the local level, where spontaneous order and transient energy surpluses can temporarily appear. But over the long term and on the global scale, dissipation always predominates, so that energy deficits will always be more likely than energy surpluses.

It would be a mistake, however, to assume that the autocatalytic loop is itself passive and merely driven by the gradient in available energy. Suppose, for example, that some arbitrary change happens to increase the rate at which materials and energy are brought into a particular compartment. This event would enhance the ability of that compartment to catalyze the downstream component, and the change eventually would be rewarded. Conversely, any change decreasing the intake of exergy by a participant would ratchet down activity throughout the loop. The same argument applies to every member of the loop, so that the overall effect is one of "centripetality." I.e., the autocatalytic assemblage behaves as a focus which appears to draw unto itself increasing amounts of energy and material. Whence, one discerns in autocatalysis the agency that lends identity to a system. The results of a system's actions point to the system itself. Furthermore, there no longer is any mystery surrounding an agent's "yawning for energy", as Matsuno (1995) has described the physical implementation of the semantic nature of internal measurement.

Unlike newtonian forces, which always act in equal and opposite directions, the selection pressure associated with autocatalysis is inherently asymmetric. Autocatalytic configurations impart a definite sense (direction) to the behaviors of systems in which they appear. They tend to ratchet all participants toward ever greater levels of performance.

Taken as a unit, the autocatalytic cycle is not simply acting at the behest of its environment. It actively creates its own domain of influence. In words appropriate to the internalist perspective, one perceives the "generation of variations internally in an endogenous manner" (Matsuno 1996.) Such creative behavior imparts a separate identity and ontological status to the configuration above and beyond the passive elements that surround it. We see in centripetality the most primitive hint of entification, selfhood and id. In the direction toward which the asymmetry of autocatalysis points we see a suggestion of a telos, an intimation of final cause (Rosen 1991). Popper (1990) put it all most delightfully, "Heraclitus was right: We are not things, but flames. Or a little more prosaically, we are, like all cells, processes of metabolism; nets of chemical pathways." We burn from within.

It must be acknowledged that autocatalytic systems are contingent upon their material constituents and usually also depend at any given instant upon a complement of embodied mechanisms. But such contingency is not, as strict reductionists would have us believe, entirely a one-way street. By its very nature autocatalysis is prone to induce competition, not merely among different properties of components (as discussed above under selection pressure), but its very material and (where applicable) mechanical constituents are themselves prone to replacement by the active agency of the larger system. Internalists speak in this vein about the resolution or removal of conflicts by the internal measuring agency. For example, suppose A, B, and C are three sequential elements comprising an autocatalytic loop, and that some new element D: (1) appears by happenstance, (2) is more sensitive to catalysis by A and (3) provides greater enhancement to the activity of C than does B. Then D either will grow to overshadow B's role in the loop, or will displace it altogether.

In like manner one can argue that C could be replaced by some other component E, and A by F, so that the final configuration D-E-F contains none of the original elements. (Simple induction will extend this argument to an autocatalytic loop of n members.) It is important to notice in this case that the characteristic time (duration) of the larger autocatalytic form is longer than that of its constituents. Persistence of active form beyond present makeup is hardly an unusual phenomenon. One sees it in the survival of corporate bodies beyond the tenure of individual executives or workers; of plays, like those of Shakespeare, that endure beyond the lifetimes of individual actors. But it also is at work in organisms as well. One's own body is composed of cells that (with the exception of neurons) did not exist seven years ago. The residencies of most chemical constituencies, even those comprising the neural synapses by which are recorded long-term memory in the brain, are of even shorter duration. Yet most people still would be recognized by friends they haven't met in the last ten years.

Overall kinetic form is then, as Aristotle believed, a causal factor. Its influence is exerted not only during evolutionary change, but also during the normal replacement of parts. For example, if one element of the loop should happen to disappear, for whatever reason, it is "always the existing structure of the...pathways that determines what new variations or accretions are possible" to replace the missing member (Popper 1990). Although autocatalysis always remains contingent upon a material substrate, it can behave in a manner quite indifferent to (or autonomous of) the particulars of matter and mechanisms. The internalist perspective, accounting as it does for the endogenous generation of change, does not require that we seek a reductionistic origin for de novo variations.

The effects of self- measurement are always perceived locally. To an externalist, however, the autonomy of a system may not be apparent at all scales of observation. If the externalist's field of view does not include all the members of an autocatalytic loop, the system will appear linear in nature, and no self-measurement will be possible. One can, in this case, seem to identify an initial cause and a final result. The subsystem will then appear wholly mechanical in its behavior. For example, the phycologist who concentrates on identifying the genera of periphyton found on Utricularia leaves would be unlikely to discover the unusual feedback dynamics inherent in this community. Once the observer expands the scale of observation enough to encompass all members of the loop, however, then autocatalytic behavior with its attendant centripetality, persistence and autonomy emerges as a consequence of this wider vision.

For the internalist, agency always can arise quite naturally from within. This occurs via the relational form that internal processes bear to one another. That is, autocatalysis, or self-measurement, takes on the guise of a formal cause, sensu Aristotle. Nor should we ignore the directionality inherent in self- measuring systems by virtue of their asymmetric nature. Such rudimentary telos is a very local manifestation of final cause. Under the hierarchical perspective, the agencies that an internalist observed arising at a single focal level can interact at the next level with similar agencies that arose elsewhere. There inevitably will be conflicts at the higher level between these autonomous agencies and the resolutions of those encounters will proceed at that level under the scenario that has just been described.

To recapitulate, our study of indirect mutualism has revealed that self- measuring systems can possess at least eight properties. Indirect mutualism induces (1) growth and (2) selection. It exhibits an (3) assymetry that can give rise to the (4) centripetal amassing of material and available energy. The presence of more than a single autocatalytic pathway in a system presents the potential for and the inevitability of (5) competition. Autocatalytic behavior is (6) autonomous to a degree of its microscopic constitution. It (7) emerges to an externalist whenever his scale of observation becomes large enough, usually in the guise of an Aristotelean (8) formal cause.

QUANTIFICATION OF INTRINSIC VALUE

The attributes of self- measuring agencies having thus been enumerated, we turn our attention back towards value. To see how value arises it is helpful to envision the quantitative and qualitative ways in which indirect mutualism changes the constitution of any community of which it is part. On the quantitative side, systems that incorporate autocatalysis tend to increase their overall levels of activity. If, for example, T_{ij} represents a material or energetic exchange (process) from component i to compartment j within the community, then the aggregate activity of the community is simply the sum of T_{ij} over all i and all j. This sum, written simply as T, is called the total system throughput, a name borrowed from economic theory. The total system throughput obviously requires synchronic information about what is happening everywhere in the system at a given instant. (Having already emphasized that value is not wholly an internalist concept, there is no inconsistency in now adopting externalist measures.)

The qualitative changes occasioned by self- measurement are slightly more difficult to describe and considerably harder to quantify. As an agent interacts with its several sources of sustenance, it continually measures the value of each source to itself in terms of the reward that the particular source returns to it over the network of system interactions. Those sources that feedback more positively will tend to be more valuable than the rest. The result in ecology is what is called prey preference, or trophic specialization. Overall, some connections come to be emphasized over others. Those pathways less effective at engaging in autocatalysis are eventually "pruned" from the network, leaving a less complicated structure of fewer, but more highly active exchanges.

To quantify the effects of this (qualitative) pruning process requires that we resort to the externalist devices of probability and information theories. While information at the local, internalist scale can be diachronic, the estimation of probabilities and their changes (information) relies on synchronic information. For the purposes of illustration, interaction between components shall be limited to the palpable exchange of some material "currency", e.g., the T_{ij}'s.

We now wish to estimate the apriori probability that an exchange will take place between components i and j solely in terms of the amounts of medium currently residing in each compartment. We let B_i be the amount of medium in i and B_j, the quantity in j. As with the flows, the total medium in all compartments will be the sum of the B_i over all compartments and will be denoted simply as B. Hence, the apriori probability that at any time a quantum of medium leaves any particular i will be estimated by the quotient B_i/B. Similarly, the apriori probability that material flowing anywhere enters component j would be estimated by B_j/B. In the absence of any constraints guiding the flows (what we mean by "apriori"), the joint probability that a quantum both leaves i and enters j will be estimated by the product of these two ratios, or $(B_i B_j)/(B^2)$. If there were no constraints ordering the flows (i.e., no bias or expressed values), flows would transpire between arbitrary components i and j according to this "law of mass action", as it is known in chemistry.

Of course, flows are not observed to follow this distribution. The aposteriori probability that flow occurs between I and j is estimated by the quotient T_{ij}/T. The cumulative constraints that give rise to the changes in the two probability assignments just derived represent the information inherent in the structure of the flows. Using information theory, this information can be quantified by what is known as the Kullback-Leibler cross-information (Kapur and Kesavan 1992). If Q_k is the apriori probability of event k, and P_k is its corresponding aposteriori probability, then the non-negative Kullback-Leibler cross-information, I is defined as

$$I = \sum_{k} P_k \log(P_k/Q_k).$$

Substituting the probability estimates just derived above yields

$$I = \sum_{ij} (T_{ij}/T)\log([T_{ij}B^2]/[TB_iB_j]).$$

One can show that autocatalyic pruning of the connections between system components increases the magnitude of I (Ulanowicz 1986, Ulanowicz and Abarca in press.) Hence, I is seen to quantify the effect of progressive self- measurement.

It is a startlingly simple matter to combine the measures for the quantitative and qualitative effects of autocatalysis into a single index that gauges the action of the eliciting unitary agent. One simply multiplies I by T (which latter factor immediately cancels with the denominator of the first term in I) to yield a variable called the system ascendency, A,

$$A = \sum_{i,j} T_{ij}\log([T_{ij}B^2]/[TB_iB_j]).$$

Expressed in words, system ascendency is a measure of a system's size combined with its degree of organization. Any increase in this system attribute quantifies some aspect of system growth and development (Ulanowicz 1986.)

We now pose the quantitative question, "Of what value is the stock of medium in any particular compartment to the functioning of the system as a whole?" Because any increase in ascendency signifies a form of growth and/or development, one is led to rephrase this question by asking how A changes in response to a minuscule increment in the particular stock? That is, what is the sensitivity of A to a small rise in the stock of, say compartment k? The answer is calculated by taking the partial derivative of A with respect to Bk, or

$$\frac{\partial A}{\partial B_k}=(\frac{2T}{B}-\frac{T_{.k}+T_{k.}}{B_k})$$

where $T_{.k}$ represents the sum of all the inputs into k and $T_{k.}$ the sum of all the outputs from k (Ulanowicz and Abarca, in press.)

When interpreted in words, this result is rather surprising. The first quotient in parentheses (T/B) estimates the rate of turnover of the system as a whole. The second term ($[T_{.k}+T_{k.}]/B_k$) estimates twice the turnover rate of compartment k in particular. Hence, the slower the turnover rate of compartment k, the more it contributes (proportionately) to an increase in ascendency. Because turnover rates are related inversely to retention times, the last statement can be rephrased as, "The longer medium is retained by compartment k, the greater the value that B_k has for system growth and development. The final outcome of this externalist analysis is remarkably internalist in character. It says that medium that is internalized for the longest time is the most valuable to overall system functioning.

It can be demonstrated that the element in any foodstuff that is presented to an organism in least proportion is always the one retained longest by the organism (Ulanowicz and Baird, in review). When applied to a system in which several elements are circulating, the result of the sensitivity analysis recapitulates Liebig's "Law of the Minimum". In 1840 Justus von Liebig stated that the element presented to a living system in least proportionate amount is the one that controls the rate of system development. The same deductive result also accords with Herbert Simon's observation (T.F.H. Allen, personal communication) that organisms retain stores of necessary resources in inverse relation to their availabilities in the environment. For example, the human body has reserves of oxygen that can last for 3 minutes, water enough for 3 days, and food for about 3 weeks. Retention time appears to be a suitable surrogate for the value placed upon any item in storage, and the connection of that value to the internalist process of self-measurement is evident.

Neither Liebig nor Simon, however, tells us how to identify which particular source among multiple inputs of the same resource is valued most highly by the acquisitor. Made confident by our success in identifying the relative values of stocks, we attempt to use the same methodology to identify and quantify the value of controlling transfers. Thus, Casey (1992) has calculated the partial derivative of the system ascendency with respect to any particular flow, T_{pq}, as

$$\frac{\partial A}{\partial T_{pq}}=\log([T_{pq}B^2]/[TB_pB_q]).$$

When we apply this criterion to multiple inputs to an element, we note that the highest value of this sensitivity always belongs to that flow which is depleting the stock of its donor at the fastest relative rate (Ulanowicz and Baird, in review.) For example, we suppose an element is being removed by a predator from two hosts with stocks of 1000 and 200 units, respectively. The rate of predation upon the first host is 50 units per diem; that from the second, 20 units per diem. The predator's depletion of the first stock is thus 5% per diem, whilst that from the second is 10% per diem. The second flow, although it is smaller in absolute magnitude, will be valued by the predator on a per- unit- basis twice as much as the input from the first host.

In making this comparison, we essentially have accomplished the task we set for ourselves at the outset. From among the multiplicity of interactions that a given agent maintains with other similar agents we are now able to quantify and rank the values that the original agent places on each of the others. We have made a beginning on attaching internal assignments of value to collections of interactions among non- cognitive agents.

SUMMARY AND CONCLUSIONS

A number of concepts inherent in the internalist perspective fit poorly into the externalist worldview. Prominent among these is the generation of true change through the process of self-mensuration. Furthermore, direction, autonomy, selection and the generation (and resolution of) competition all have a legitimate place in the internalist view of nature. The identity and integrity of a kinetic configuration is assured through the same process of self- measurement.

To perceive and estimate value, however, requires that one move between scales of observation and necessitates, therefore, some degree of externalist vision. Values exhibited by individual components can be gauged properly only in the context of a full community of interactions. The actual assessment of value depends, nonetheless, upon concepts that are more fully developed in the internalist view and the criteria that result have a very internalist bias.

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