A quantum theory of biological autonomy at the macro-level

Tom Froese and Takashi Ikegami
t.froese@gmail.com
Ikegami Laboratory, Department of General Systems Studies
University of Tokyo, Japan

Abstract. There is a peculiar irony at the core of biology that in order to fully understand an organism we have to kill it and dissect it. While the existence of an organism depends on self-determination and holistic integration, our knowledge of it depends on external control and decomposition. There is a deep tension between acquiring knowledge of another autonomous being and the persistence of that being's very autonomy. But if complete knowledge of the living is in the end impossible, because the *explanans* ultimately requires the destruction of the *explanandum*, can there ever be an adequate science of life? We propose that a theory of biological autonomy that is modeled on the mathematical framework of quantum physics might be a workable alternative.

Introduction

Although marginal to mainstream biology, over the years there have been a number of prominent proposals to overcome the aporia that *biology*, the study of life, is in fact premised on *thanatology*, the study of death. The authors of these proposals typically try to compel us to bracket the power structures, which are intrinsic to the control/knowledge construct, by adopting an enabling discourse centered on autonomy/understanding. We can find some aspects of this kind of alternative approach to biology in the writings of, for example, von Uexküll, Jonas, Maturana, Varela, Rosen, Goodwin, and others. All of these authors share the conviction that some form of organizational closure is essential to the phenomenon of life. It is this closure of the organism's defining organization that partly constitutes the possibility of its existence as an autonomous individual.

Several formalisms and mathematical models have been proposed to capture the notion of organizational closure with varying degrees of success. Nevertheless, they do not allow for the essential ambiguity that must necessarily arise out of the tension between our external knowledge and the other's autonomous being. In order to illustrate this shortcoming we can recall one of the earliest attempts to formalize organizational closure, namely Ashby's concept of 'ultrastability' (see Froese and Stewart 2010 for a more extensive discussion).

Beyond Ashby: A self-breaking system

Ashby realized that a defining feature of all organisms is their ability to adapt to changing and novel circumstances, and he linked this adaptivity with changes to their internal organization. In brief, he posited boundaries of viability that, if exceeded, would lead to a new organization due to parametric changes in the organism's old organization. This model of adaptation is based on a mechanism of random change, which Ashby called 'breaking'. He demonstrated that when a system is perturbed to exceed its boundaries of viability, it continues breaking until a new stable organization had been found. The system then ceases to do anything until it is again sufficiently disrupted to trigger the break mechanism.

At first sight Ashby's formulation of ultrastability may also seem to be a useful model of autonomy, given that the ultrastable system is capable of changing its organization. However, as Ashby was keen on emphasizing, it is also possible to view the living system and its environment as one whole system in which there are no 'breaks' and the state of all variables is fully known at every time step. But this presence of complete knowledge about the system violates the prospect that the model can adequately capture a living being's autonomy. In the words of the phenomenological tradition we could say that if the phenomenon can be fully captured by this kind of system, then, although it is closed in one sense, it is still lacking its own 'transcendence' or intrinsic otherness. It does not have the ability to escape from the scope of our awareness to constitute an alternative center of subjectivity. Similar worries can be raised about other theories of autonomy, which also grant that the whole system can be fully known by us in principle.

In order to get an intuitive idea about what type of organization would be more suitable for describing a living being in systemic terms, let us consider the possibility of a *self-breaking* system. Like in Ashby's terminology, we use the term 'break' to specify a change in the system's organization, but in this case the 'break' is applied by the system to itself. On this view, a living system can be conceived as a self-sustaining process of changing organization, which continues changing the way it is organized until it dies. Here we therefore have inverted Ashby's concern with the conditions for a *static stability* by an insistence on the need for a *dynamic instability*, and we have displaced the source of this ongoing instability to become an essential part of the organism.

This notion of a self-breaking organization ensures that a living being cannot be fully known in principle. In order to precisely know the *state* of a living system's organization we need to measure it a precise point in time, but this means that we cannot accurately measure its *change* in organization since that requires a measurement over an extended period of time. Conversely, if we want to know how its organization changes over time, we cannot simultaneously know its precise state at any one point in time. The upshot of this uncertainty principle is that the being of the organism always escapes our knowledge of the organism to some extent. We submit that this is a necessary condition of autonomy.

And yet this uncertainty principle of autonomy is just the first step: it only gives us a 'shallow' uncertainty based on the fact that a living system's organization is continually in flux. This uncertainty has to do with a fundamental issue of observer-relative measurement, and it does not say much about the intrinsic organization of the system. If we want to conceptualize organisms as necessarily self-breaking systems then we need a deeper sense of uncertainty in order to do justice to their autonomous existence. But this leaves us with a methodological and conceptual problem. How can we replace the certainty of death with the uncertainty of life as the ultimate foundation of biology?

Deep uncertainty: Toward a quantum theory of autonomy

Fortunately, science and mathematics have already provided us with some of the tools we will need, although they have been developed in a different context: quantum physics. Indeed, quantum physics is also faced by the problem that its phenomena are necessarily unknowable to their full extent. And yet this inherent uncertainty has not prevented it from becoming one of the most precise and practically useful scientific disciplines. The basic trick is to formalize the very uncertainty of the phenomenon as a superposition of its various possibilities, and then to conceive of a measurement as temporarily revealing a slice of these possibilities according to a distribution of probabilities.

We suggest that we should construct a quantum theory of autonomy on the basis of a similar kind of formalism. A living being is then no longer fully described by having any one organization, but rather by a superposition of various possible organizations that have different likelihoods of becoming materially manifest at each point in time. This is not as odd as it may sound. It is well known in the field of artificial life that adding an element of chaos to a modeled organism gives its behavior a more lifelike appearance. The quantum theory of autonomy has the same effect, except that here the unpredictability is intrinsic to the phenomenon, rather than merely being due to the addition of an external source of noise.

We do not pretend to have a fully worked out formalism of autonomy derived from the mathematics employed in quantum physics, but at least on a general level of description we highlight the following features:

1) <u>Observer-relativism:</u> most of cognitive science proceeds under the highly questionable assumption that knowledge of other agents is independent from the observer (i.e. it is a representation, not an interaction). But this theory supports a different view: what you perceive depends on what you do! It follows that agency detection, for instance in primatology and infant studies, can no longer be conceived in a decontextualized manner.
2) <u>Non-commutability:</u> most theories of autonomy appear to assume that the processes underlying closure are symmetrical in time, such that the arrow of time can be reversed without effect (Di Paolo 2005). But this theory, again, supports a different view: there is an inherent directionality to the sequence of events! And this makes intuitive sense when describing the behavior of agents. Consider, for instance, that laughing and then being angry has a different meaning than being angry and than laughing.
3) <u>Quantization:</u> Ever since Bergson and Husserl's analysis of our experience of temporality we know that time has a temporal duration; it is not simply a list of infinitesimally small steps. But, as Di Paolo (2005) has argued, organizational closure as such does not entail duration. And yet on this view there may be a certain minimal unit of spatiotemporal existence.

Of course, this is just the very beginning of a quantum theory of autonomy, and much remains to be done to practically work out the details. And we do not deny that there may be other formalisms that are more suitable for the job. However, we strongly suggest that autonomy necessarily entails uncertainty, both for the autonomous agent itself and for its external observer. The main message of our proposal is therefore this: no formal theory of biological autonomy can properly do justice to the phenomenon, if it does not allow for the fact that life involves an essential uncertainty at its very core.

References:

Di Paolo, E.A. (2005), "Autopoiesis, adaptivity, teleology, agency", *Phenomenology and the Cognitive Sciences*, **4**(4), pp. 429-452

Froese, T. & Stewart, J. (2010), "Life after Ashby: Ultrastability and the autopoietic foundations of biological individuality", *Cybernetics & Human Knowing*, **17**(4), pp. 7-50