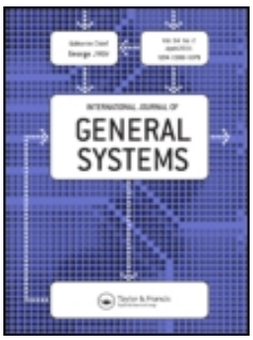

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Valentin Turchin, a mathematician, philosopher, and cybernetician, was for years one of the Soviet Union's leading computer and information scientists. His first work, *The Inertia of Fear and the Scientific Worldview* (IOF), is a treatise on Soviet society, and was first published in 1968 in the underground Soviet samizdat press. In his second work, *The Phenomenon of Science* (POS), Turchin attempts to express a unified meta-theory of cosmic evolution in cybernetic terms. POS was never published in the Soviet Union, but was first published in English in 1977. A revised version of IOF, including an expanded cybernetic social theory, was published in English in 1981.

Turchin holds degrees in physical and mathematical sciences, and has published over 65 articles on computer science and social cybernetics. In the 1960's Turchin entered a period of activism, during which he defended Andrei Sakharov and headed the Moscow chapter of Amnesty International. He was persecuted for these activities, blacklisted, and removed from his position at the Institute for the Design of Automated Construction Systems. In 1977 he emigrated to the United States, where he currently resides in New York and teaches at the City University of New York.

POS is a cybernetic meta-theory of cosmic evolution in the spirit of Chardin and Bergson. The book is perhaps the first grand evolutionary world view from the latter twentieth century, and thus benefitting from modern evolutionary theory. Its ultimate aim is the potentially circular task of studying science as an object in the context of a scientific view of humanity. A natural consequence of this activity is an emphasis on the unity of science; the drawing of attention to principles applicable to both the evolution of science and the evolution of species, from the origins of cells to industrial production; and the stressing of the wholeness of history and evolution.

IOF is a book on cybernetic social theory. In it Turchin elaborates on the general evolutionary schema advanced in POS, relating it specifically to society. He builds from these conclusions to present his view of "scientific socialism" and an ideal society based on cybernetic principles.

Because it is addressed to the general reader, Turchin's cybernetic theory is not developed in an especially rigorous or formal environment. In addition, the English editions are, of course, translations. Keeping this in mind, throughout POS and IOF Turchin suffers from an unfortunate use of the subjective mood. For example, he says "To increase the complexity of the organization of biological forms, nature operates by trial and error" (POS, p. 1), or "Nature's next task is to control movement" (POS, p. 57).

The practice of anthropomorphizing or deifying "Nature" continues to plague general writing on science, especially in biology. At best this usage introduces an unnecessary ambiguity to cybernetics' very difficult task of scientifically explaining teleonomic behavior; at worst it reveals a fundamental failure to understand the potential results of random processes such as biological evolution. I believe and hope that in Turchin's case this practice results primarily from the conditions noted above, rather than from an attempt to advance a vitalist perspective, or

from a breach of scientific ideology. The result is, however, unfortunate and confusing.

This problem in Turchin's work parallels another. Although POS is unquestionably a work of cybernetics and systems theory, Turchin does not reference information theory. Entropy is not mentioned at all, and information is introduced briefly and only in passing. This neglected aspect of systems theory has great potential to augment and illuminate Turchin's ideas.

These problems aside, POS and IOF stand as great works of systems science. In them Turchin grasps the breadth of the task of the unification of science as the study of systems and advances a wealth of general and specific theories.

Turchin's central concept is translated as the "meta-system transition", a process by which a system undergoes a qualitative transformation resulting in a meta-system controlled at a "higher" level. These transitions are the "quanta" of evolution, the process by which qualitative changes are introduced in species. This concept is simple and central to all systems science, yet rarely is its unifying capacity so clearly stated or so thoroughly pursued throughout the spectrum of evolutionary history.

Turchin defines the meta-system transition in this way:

> In each stage the ... system has a subsystem which may be called the highest controlling device; this is the subsystem which originated most recently and has the highest level of organization. The transition to the next stage occurs by multiplication of such systems and integration of them—by joining them into a single whole with the formation (by the trial and error method) of a control system headed by a new subsystem, which now becomes the highest controlling device (POS, p. 56).

Selection in this context is the "trial and error" method generalized beyond genetic evolution to include operation on any indeterminate behavior of living systems. Through this mechanism the complexity of systems increases over time.

This might be formalized as follows. Consider a system $A_0=\{a_i\}$, where $|A_0|\geqq 4$ and $1\leqq i\leqq|A_0|$, so that at time zero the a_i are the subsystems of A_0. The meta-system transition involves the introduction of a new dimension of hierarchy in the form of elements x_j, so that $A_+=\{x_j\}$, where $t>0$, $|A_+|\geqq 2$, $1\leqq j\leqq|A_+|$, and A_+ is a partition of A_0. Note that $|A_0|>|A_+|$.

Turchin uses the device of the meta-system transition to explain how, through a surprisingly small number of steps, biological systems evolved from unicellular organisms to industrial societies. The following is a paraphrase, in reverse temporal order, of the sequence of meta-systems he suggests as an evolutionary schema:

> Culture is the control of thinking;
> which is the control of learning;
> which is the control of instincts;
> which is the control of reflexes;
> which is the control of the movement of parts of organisms;
> which is the control of the positions of parts of organisms.

A number of general points Turchin makes concerning meta-system transitions should be mentioned here. The first is that through a meta-system transition "something that was once fixed and uniquely determined by external conditions becomes variable and subject to the action of the trial and error method" (POS, p. 75). For example, the stimulus-response relations of organisms without the

ability to learn are genetically fixed over the lifespan of the organism, whereas those of organisms with the ability to learn are to a certain extent free to change. Presumably the organism tries, somewhat at random, different responses to given stimuli and selects some and rejects others according to an internal criteria of a "good" result.

This first point provides an example of where Turchin's work could be carried on in the context of information theory, which directly addresses the issues of freedom and determinism. In particular, formulas for the entropies of the systems, subsystems, and the whole environment in question should be developed.

A second point concerns a phenomenon which is translated as the "branching growth of the penultimate level" (POS, p. 59). Let $i_{max}(+)$ be sum$(|x_j|)$ at time t, and $i_{max}(0)$ be $|A_0|$. Turchin asserts that while the meta-system transition may occur when $i_{max}(0)$ is rather modest, after the transition $i_{max}(+)$ greatly increases with t. The "penultimate level" is thus the set of sub-subsystems of the system in question. Little explanation is offered, but presumably after the transition no replication of an element a_i is deselective, and so the full force of exponential growth is unleased. Examples are intruiging: the massively distended human cranium is a result of the branching growth of neural mass, the mechanism of learning, following the transition to thought.

A third point is that, following a transition, the elements a_i at the penultimate level become specialized. Examples include the tissues of the organism following the transition to reflexes and the mental capacities of the human following the transition to thought. Again, this point could be pursued using information theory, and by examining the entropies of the subsystems.

A final point is that Turchin only concerns himself with the "functional" aspects of organism, as opposed to their "structural" ones. For example, the transition from unicellular to multicellular organisms is certainly a meta-system transition in some sense. Yet from a functional perspective it is irrelevant whether the bits of matter which accomplish digestion, for instance, are made of molecules, organelles, cells, or tissues. These are issues of structure, not function.

Turchin's evolutionary hierarchy begins at the level of living cells. It assumes existing life forms which can replicate and evolve. I believe an argument can be made that the origins of life itself were a meta-system transition at the molecular level. In particular I refer to the work of Ilya Prigogine[1] and others[2] on catastrophe theory and chemical systems far from equilibrium. I suggest that a "bifurcation" or "cusp catastrophe" may be a case of a meta-system transition, where a higher level of organization of a system is discontinuously arrived at through the indeterminate processes acting on the lower level.

Turchin's grand evolutionary perspective is at the heart of POS and IOF. Around the outside of this structure is a wealth of more specific theories on all the stages of evolution, but in particular concerning psychology, language, and society. On psychology, Turchin appears to stand in the tradition of the American cognitive scientists. "Representations" (Russian predstavlenie: presentation, idea, notion, representation) are fundamental to him, and form the link between the psychologies of humans and animals.

Anything with the capacity of the reflex can represent. Consider the famous example of the thermostat that can have two beliefs: hot enough or not hot enough, or the snail that "loves" water of 16 degrees centigrade. Reflexes are "atomic concepts", fundamental representations involving single neurons only. Building from this, instincts are hierarchies of representations involving more than

one neuron or other complex reflex. For example, the snail that loves 16 degree water and light, or moves more than one muscle fiber at a time, is acting instinctually, not reflexively. Learning is then the ability to relate these complex representations together to control and form new "instincts" not provided by the genetic code.

And finally, thought is the internal control and generation of representations, rather than simply the reception of them from the environment. Turchin understands imagination, play, music, and beauty as the uniquely human generation and manipulation of representations. Language is the ability to relate arbitrary representations, for example one's representation of a thing and the representation for the name of it.

Turchin claims that a hierarchy of beliefs and desires exists in the minds of organisms. Such a hierarchy might run: 'I want to move my hand because I want to flick the switch because I want to turn on the light because I want to read the report because I want to be prepared for the meeting because I want to do well at work because ...' Positive and negative emotions can be defined in this context as the result of either meeting or failing to meet a goal at a certain level. Thus emotions would exist in any creature with instincts, that is, with nervous systems of sufficient size to represent goal hierarchies. According to this view, emotions are very deep and ancient aspects of nervous systems.

Turchin takes an unusual stance on theories of society. On the one hand, he is a Soviet dissident, and IOF is a scathing indictment of the evils of totalitarianism. On the other hand, he is a Soviet academic, and the concepts that he invokes have their roots in Hegel and resonate with Marxism. In particular, Turchin views the Hegelian dialectic as the "archetype" of the system. And the meta-system is described as transition arising when a quantitative change is sufficient to result in a qualitative change in a system.

Turchin specifically advocates a "Whorfian" view of the relation between language and thought. Thus for him the final level of evolution is that culture or society is the mechanism which controls thought by standing as a meta-level to it. Social integration is both good and natural, and the growth of society marks the appearance of the social "super-being"; language, and especially science, is its mind and industrial production is its body.

This stance can be criticized as being inconsistent with the general schema of evolution by meta-system transition. A key component of a meta-system transition is that the new level appears subsequent to its sub-systems; it is in effect a new "vanguard" level of evolution. It is probably untrue that human culture arose after its mental capacity; undoubtedly mind and culture arose together. The individual and the collective coexist in almost all species. Perhaps even non-human primates have rudimentary culture in the form of learned inhereted behavior.

For Turchin the profession of socialism ultimately becomes a religious project, an exercise in scientific pantheism. Socialism is defined as

> a religion which proclaims the integration of mankind as its supreme goal. However concretized the concept of the Good, for all socialists the highest goal that the individual can and should have, is the good for the society as a whole (IOF, p. 127).

This usage of religion is directly related to the above psychological theory. The goal hierarchy in human minds is greater than in other animals, extending to our ultimate questions of self-worth and moral alignment with the world. "I want to

do well at work ... why?" These are our ultimate goals, our "meaning" of life, and Turchin defines the emotions related to them as religious.

As we said above, through the meta-system transition our instincts are free to be controlled by our higher mental levels, and so our religious goals may even run counter to basic instincts for survival. And while these ultimate goals are mostly received from our culture—that is our society's religion or ideology—we are also free to reject them. In addition, our ultimate goal must be addressed at a supra-personal level. Even for animals, whose ultimate goal might be reproduction, that is a supra-personal goal. So, for humans, our religious goals are directed towards a perceived supra-personal deity, or back to the supra-personal society.

Turchin's socialism is a radical depature from existing religions. Most religions are defined as a set of beliefs, usually regarding a spiritual reality. Turchin, on the other hand, defines religion as a set of desires. Yet a complete psychology consists of systems of beliefs and desires. If religion provides our ultimate desires, then certainly in this era it is science that provides our ultimate beliefs. Science cannot provide a set of religious goals; it can only constrain that set to be consistent with it. Science and religion are not opposed to each other, as so many have argued; rather together they form a system that completely encompasses our view of the world.

Finally, Turchin presents a model of an ideal socialist society. This idea is based on the belief that people generally have two kinds of relationships with each other. There are those, like strangers, acquaintances, and celebrities, of whom we only know; these are called "m-bonds". There are also those, like family, friends, lovers, and colleagues, with whom we have close emotional or intellectual contact; these are called "v-bonds". V-bonds take much time to develop and maintain, but they are also the most creative, productive, and meaningful. There is also some upper limit on how many v-bonds an individual can maintain, certainly greater than one or two but less than 100. Turchin asserts that an ideal society would be structured around v-bonds.

Many institutions of Western societies are built from v-bonds, for instance families, or business and professional organizations that recruit by nepotism. Most work groups eventually grow together to form v-bonds. Yet representative governments are structured around m-bonds. Our leaders maintain m-bonds with vast numbers of people through the media; and our deliberate bodies are mostly maintained by m-bonds between strangers brought together for brief terms.

Turchin proposes a model for a society completely composed of v-bonds. First we define a v-group as a collection of people, all of whom maintain v-bond relationships with each other. The size of any v-group must remain small, perhaps less than ten. The zero-level v-groups are probably relatives and close friends. They would select by consensus one of their members to the first-level v-groups, who would be given time to forge v-bond relationships. This representative would thus be a member of two v-groups. The members of any group would have the right to recall any representative member from any higher level.

Through recursion the groups would grow to include the world's population in a v-group hierarchy. If we let v be the size of the v-groups, and N the size of the population, then the depth of this tree is $d=\log(N)/\log(v)$. If an individual participated in the hierarchy at a maximum level 1, then he or she would have to maintain $r=1(v-1)$ v-bond relationships altogether. For a world population of five billion and a v-group size of ten d is only 9.7, and for the president of the world r would be 87.3.

Turchin's work is a critical contribution to systems theory and cybernetic philosophy. It can only be hoped that he will continue his work in the relative freedom this country can offer him.

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SPECIAL ISSUES ON FUZZY SETS AND EXPERT SYSTEMS

The year 1985 represented the 20th anniversary of the publication of Lotfi Zadeh's seminal paper that established foundations of the theory of fuzzy sets (*Information and Control*, Vol. 8, 1965, pp. 338–353). The theory was in a healthy state at this anniversary, with a record of several thousand publications, an existence of the International Fuzzy Systems Association (IFSA), and a well attended International Congress organized by IFSA in 1985. It is increasingly obvious that this new type of mathematics is well suited for the study of complex systems.

The journal *Information Sciences* commensorated the 20th anniversary of fuzzy set theory by publishing two special issues, one on Fuzzy Sets (Vol. 36, Nos. 1 and 2, edited by Ronald Yager) and one on Expert Systems (Vol. 3, Nos. 1–3, edited by Abraham Kandel) with heavy emphasis on approximate reasoning based on fuzzy logic. These special issues are rich in information and we recommend them to readers of this journal.

EDITOR