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■ Research Paper

Science and its Discontents: Is There an End to Knowing?

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Is there an end to our scientific quest? This question that continues to divide the scientific community between those who believe that the progress of science is infinite and those who think that we already understand how the universe works and no major discoveries are to be expected in the future. This article explores the philosophical worldview of modern science that has given rise to this question. It argues that an approach to knowledge that focuses on the process of construction of knowledge rather than its products offers a possibility of definitively answering this question and opening paths for a more rational approach in advancing and managing the scientific progress. Copyright © 2012 John Wiley & Sons, Ltd.

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In 1996, John Horgan, then a senior writer for *Scientific American*, wrote a book that made quite a stir in the science community. The title of the book was very provocative: *The End of Science: Facing the Limits of Knowledge in the Twilight of the Scientific Age* (Horgan, 1996). As the title indicates, the author made a claim that modern science had reached its limit. Horgan argued that although some incremental progress was still occurring and might even continue to occur for some time, nothing comparable to the theory of relativity, quantum mechanics or the discovery of the structure of DNA was even in the realm of possibilities. Science simply already made all

the major advances there were to be made; our understanding of how the universe worked was, on the whole, completed.

Responses to Horgan's book revealed sharp divisions in the scientific community. Numerous disagreements with the arguments and the main conclusion of the book ranged from well-mannered academic criticisms to sharp vitriolic attacks. John Maddox, former editor of the *Science* magazine, for example, produced a lengthy book entitled *What Remains to Be Discovered* in which he politely challenged Horgan's contentions and outlined major areas of science where significant advances should take place in the future. By contrast, biologist Stephen Gould described Horgan's book as 'boring' and physicist Stephen Hawking called it 'nonsense'. There were also much harsher reactions that revealed raw

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emotions, irritation and even anger. Horgan was called a quack and a phony whose views of contemporary science were extremely subjective, ill informed and very biased.

However, there were a significant number of scientists who, on the whole, agreed with Horgan's arguments and did not dispute his reading of the facts. Like Horgan, they believed that in its main contours, the work of science had been completed and no major illuminations awaited us in the future. Biologist Kenneth Miller, for example, observed that 'at the core of his [Horgan's] thesis was an observation that met with agreement among most of the scientists I know—namely, that in a general way, we really do understand how nature works' (Horgan, 2008, p. 43).

The book definitely touched the nerve in the scientific community. Unlike some critics of science from among its opponents (e.g., religious extremists), Horgan was, for many decades (and continues to be), an integral part of the scientific scene. He was well informed about scientific developments and had written a great deal on the subject. He received numerous awards for his writings about science; his contributions appeared in some of the most prestigious publications both in the United States and around the world. He personally knew many distinguished scientists. In a word, Horgan was definitely an insider. His pessimistic conclusions did not spring up from some anti-scientific persuasion but from the very midst of the modern scientific scene.

By his own admission, Horgan was a believer in the open-endedness of science and its infinite progress. His first doubts appeared at the end of the 1980s largely in response to proud affirmations of the capacity of modern science to solve the remaining mysteries of the universe. Stephen Hawking, for example, categorically declared in 1988 that there was a good chance that 'the study of the early universe and the requirements of mathematical consistency will lead us to a complete unified theory within the lifetime of some of us who are around today' (Horgan, 2008, p. 43). Although Hawking later retracted this statement (Hawking, 2003), there are still many physicists who continue the search for the elusive final theory of everything. The European Organization for Nuclear Research (CERN) has

spent over 10 billion dollars on the Large Hadron Collider to search for the so-called god particle—the Higgs boson—that is supposed to explain gravity and, thus, solve the last mystery of the physical universe. What is going to happen when the last mystery is solved? Where would physics go then? In his book, *The End of Science*, Horgan describes his interview in 1989 with distinguished physicist Roger Penrose. Their conversation drifted to the theory of everything—a theory that is supposed to unite all known physical forces in nature and provide the ultimate answer to the puzzle of the universe. 'Solving mysteries is a wonderful thing to do', Penrose ruminated. 'And if they were all solved, somehow, that would be rather boring' (Horgan, 1996, p. 3).

Penrose's words were a revelation for Horgan. Indeed, if the final theory is attained, what does it mean for the scientific enterprise? Does that mean the end of the scientific quest? After all, how much is there to know? As we learn more about the fundamental aspects of reality, is it possible that we will one day learn it all? 'In the same way', Horgan argues, 'scientists might be unlikely to discover anything surpassing the big bang, or quantum mechanics, or relativity, or natural selection, or DNA-based genetics' (Horgan, 2004, p. 38).

The publication of *The End of Science* has had no significant practical consequences for the scientific community. Scientists continue to do their research as they had had for many years before the publication of the book. The controversy has largely subsided. However, the problem that the book raised has not gone away, and the questions the book asked have remained unanswered (Ben-Ari, 2007), and they are interesting questions. Indeed, many of us are brought up to believe that the progress of science and knowledge will be infinite. However, why should this progress be infinite? Can our belief be proven? In his review of John Maddox's riposte to Horgan for *The New York Times*, Paul Raeburn, while recognizing that Maddox makes a persuasive case for the future development of science, adds

Does that mean Horgan was wrong? It may take a few centuries to find out. Horgan recalls the early explorers, to whom the swelling seas seemed infinite. They were wrong; but

perhaps the belief sustained them (The New York Times, January 10, 1999).

The debates that have followed the publication of *The End of Science* have largely focused on whether Horgan is right or wrong. This approach has not proven to be particularly productive. No consensus has emerged between those whom Mordechai Ben-Ari calls accelerationists and the end-of-science scholars (Ben-Ari, 2007, p. 20). This paper will take a different approach. Rather than deal with the existing division among scientists and decide who is right and who is wrong, it will focus on the possible source of this problem. Why has this problem come up in the first place? What is it in the contemporary scientific worldview that has made the emergence of this problem possible? To answer this question, one needs to examine the worldview of contemporary science.

The philosophical perspective that dominates modern scientific worldview is realism. John Searle provides the following succinct definition of realism:

Realism is the view that there is a way that things are that is logically independent of all human representations. Realism does not say how things are but only that there is a way that they are (Searle, 1995, p. 155; emphasis in the original).

According to Searle, the realist view of the world has the following structural features (Searle, 1995, pp. 150–51)¹:

- (1) World (or alternatively, reality or the universe) exists independently of our representations of it.
- (2) Human beings have a variety of interconnected ways of having access to and representing features of the world to themselves.
- (3) Some of these representations purport to be about and to represent how things are in reality. To the extent that they succeed or fail, they are said to be true or false, respectively. They are true if and only if they correspond to the facts in reality.
- (4) Systems of representation are human creations, and to that extent arbitrary.
- (5) Complete epistemic objectivity is difficult, sometimes impossible.
- (6) Having knowledge consists in having true representations for which we can give certain sorts of justification or evidence. Knowledge is thus by definition objective in the epistemic sense, because the criteria for knowledge are not arbitrary, and they are impersonal.

As one can see from the above, the realist perspective does not promise a complete knowledge of reality; rather, and rather pessimistically, it promises only an infinite asymptotic approximation to such knowledge. Also, according to this perspective, our knowledge in the final analysis depends on the reality external to our mind; this reality is the ultimate arbiter in determining what constitutes knowledge and what does not. Validation of knowledge involves a fit between a theory and the way things are. As a definition standard among realists goes, knowledge is 'justified true belief'. It means that to constitute knowledge a belief must be true, that is, it should correspond, at least approximately, to the way reality is independently of our theory (David, n.d.; Searle, 1995; Otte, 1990; Weston, 1992). In other words, the fit is a necessary condition of knowledge; without it, a belief cannot be considered true and, therefore, cannot constitute knowledge.

Thus, as one can see, the dominant view of modern science is that reality external to our mind validates scientific knowledge. It is only fair to acknowledge that on close reading the view of validation implies a strong possibility that science may indeed come to an end or at least to an end of big discoveries. One can submit several considerations in support of this apparent possibility. First of all, because of our constitution and the constitution of the physical universe, our access to the reality external to our mind and available for validation is limited. According to modern science, we live in a universe where nothing can exceed the speed of light. This universe may or may not be infinite, but because of our physical limitations and the laws of nature, we can physically see only so far in our universe. Our universe has a horizon beyond which our gaze does not penetrate. To put it simply, we cannot see or hear anything that does not reach

¹ For reasons of convenience and economy, I provide a slightly abridged verbatim version.

us. The Big Bang is the ultimate limit to how far we can see into the history of our universe. Also, we cannot see what is going on inside a black hole because gravity prevents light from reaching us. Still, another example of what one might call a natural limitation is the principle of uncertainty that is widely accepted in our theorizing about subatomic events. In accordance with this principle, there is no way we can know the actual state of a particle or a quantum system as it is irrespective of our experimental tools. We cannot, in principle, know the exact state of reality at the subatomic level but only its statistical probability.

This is not to argue that our universe is infinite or finite. It may very well be infinite, but we have access only to its finite part. Because the accepted method of validation requires the establishment of one-to-one correspondence, our knowledge about the inaccessible part of the universe cannot be validated and, therefore, does not constitute, according to the existing standards, proper knowledge. It is simply a speculation at best.

Second, our current theory of evolution also supports the view that our capacity to know, even when enhanced by technological devices, is limited. The evolution made us fit to survive in this world, not to know it; our senses are shaped by the evolution for the purposes of survival. Our knowledge that, according to science, is based on our senses is merely a survival tool. In other words, we need knowledge only to the extent required by our survival, and because there are aspects of reality that are not essential for our survival, we may very well never know anything about them. Finally, science is about discovering the laws of nature, and the number of these laws, however big it may be, still must be finite. If it were not, reality would be chaotic, and it is not. Therefore, there are only so many laws of nature that we can discover.

In light of these considerations, one may very well conclude that reality accessible to us limited creatures is limited and therefore our knowledge of it also has a limit. Moreover, according to realism, we may be able only to approximate this limit without ever reaching it. In accordance with the dominant approach to validation of knowledge, whatever ideas or beliefs we may form about the rest of reality, these ideas and beliefs

cannot, in principle, be validated and, therefore, cannot constitute knowledge.

Although the realist perspective on knowledge dominates the modern scientific worldview, it is not unopposed. There are numerous philosophical perspectives that disagree with realism. Despite their differences and even incompatibilities, they share some common features and are usually grouped together under the general rubric of anti-realism (for an overview of realism and anti-realism, see Psillos, 1999; Ladyman, 2001; Searle, 1995). Broadly speaking, anti-realism is a philosophical critique of the main tenets of realism. It is beyond the scope of this paper to go into all the specifics of issues contested by realism and anti-realism. Although their number is extensive, they largely boil down to one fundamental disagreement over the issue of validation. In contrast to realists, anti-realists maintain that we can never be sure how things actually are because a fit between a theory and data is insufficient for truth claims. Paul Horwich, for example, offers the following generalization:

It [anti-realism] derives from an impression of conflict between the alleged autonomy of the facts (their independence of us) and their accessibility (the possibility of our gaining knowledge of their existence). Consequently, it seems to the anti-realist that something of our naive point of view must be given up; some philosophical move must be made (Horwich, 1996, p. 188).

In support of their argument, anti-realists refer to numerous theories in the past that fitted well with empirical data but have ultimately proven to be false (e.g., the theory of flat Earth, the theory that placed Earth in the center of our planetary system or the ether theory of light). They also point to the phenomenon of underdetermination (i.e., the existence of different and often conflicting theories that are supported by the same empirical evidence) as a proof that a fit is no guarantee of the validity of a theory (on underdetermination, see Hofer and Rosenberg, 1994; Leplin, 1997; Bergström, 1984; Cordero, 2001; Belousek, 2005).

As one can see, in the anti-realist perspective, we cannot make truth claims based on the

validation by a fit between theory and fact. In this perspective, knowledge is not circumscribed by external reality and, therefore, is not limited to the states that the world may be in. Clearly, such view frees knowledge from being dependent on reality for validation; the progress of knowledge can be infinite. However, this freedom comes at a price. In accordance with the anti-realist view, this knowledge is not about anything except our capacity to create. Knowledge has nothing to do with truth; it is relativistic. Although anti-realists reject the realist approach to validation, they offer no adequate approach of their own.

Thus, the realist position maintains that science can attain true knowledge about reality, but the dependence that they establish between knowledge and the reality external to our mind cannot explicitly reject a possibility that scientific exploration may, at some point, come to an end. The anti-realist perspective, on the other hand, provides a strong support to the idea that the progress of our knowledge is infinite, but they also assert that this knowledge has little, if anything, to do with the way reality actually is. Neither of these positions seems to be satisfactory. We are reluctant to accept the notion that our scientific exploration will come to an end, but at the same time, we do not want to give up the notion that our science provides us with true understanding of how things are. Unfortunately, there just does not seem to be any possibility for reconciling these two positions.

For the purposes of this paper, I want to point out that despite significant differences between the realists and the anti-realists, in one very important respect, their worldviews are very similar: they both posit a gap between the subject and the object. As has already been indicated, the realists believe that this gap can be mediated, whereas the anti-realists think that such mediation is impossible. The gap between the knower and reality indicates that traditional dualism still plays an important role in both perspectives. This dualism can be traced back to the early periods in the evolution of human thought. Plato, for example, believed that mind and body were ontologically distinct. The division between thought and reality, mind and matter, body and soul, subject and object, and the knower and the

known is characteristic for much of the European, and not only European, intellectual tradition (Dickens, 2010; Robinson, 2011).² However, is the positing of this gap justified? Is it supported by empirical evidence?

In his remarkable study, *The Origin of Intelligence in Children* and in his other books, Piaget provides a very detailed empirical account and analysis of the development of symbolic thought (Piaget, 1998). Piaget shows that the process of construction of symbolic representations is bi-directional. On one hand, it constructs mental representations of objects, and on the other, it also develops consciousness or what we often call the subject. Thus, one can see that the same process is involved in the construction of both the subject and the object and intimately relates one to the other. The constructed object and the constructed subject are not mere mental categories; they are represented by the physical organization of neurons and neural networks.

Based on what we know about the way our thinking operates, we can conclude the following:

- (1) There is no ontological gap that separates the subject and the object. The ontological status of this gap is not supported by empirical evidence. Both the subject and the object are products of the same process of construction.
- (2) The ontological distinction between thought and reality is also unsupported by empirical evidence. As organization of neurons and neural networks, thought is merely one of the forms of organization of reality. In other words, it is reality. In fact, it is the most powerful form of organization of reality. Unlike other forms of organization of reality, the process of organizing and re-organizing neurons and neural circuits has no limitations and is capable of infinite number of combinations.

Empirical evidence shows that symbolic thought emerges as a result of combinations of neural networks that conserve sensori-motor operations by regulating them. Although neural networks regulate sensori-motor operations, they, in turn,

² In philosophy of science, dualism often refers to the dichotomy between the 'subject' (the observer) and the 'object' (the observed). Criticism of Western science may label this kind of dualism as a flaw in the nature of science itself.

also need to be conserved—the function that is performed by their own regulatory operations. The combination of these regulatory operations leads to the emergence of mental images—a new level of organization represented by a new functioning organization of neurons and neural circuits. The conservation of these new functioning operations also requires regulatory operations and so on and so forth. Thus, conservation and regulation play a crucial role in the creation of new forms of organization of reality. Conservation is the real drive of this process, and regulation makes conservation possible. Conservation of regulatory operations also requires regulation of these operations. It is always possible and even necessary for the purposes of conservation to construct another level of regulation. Given the number of neurons in an average human brain and their plasticity—the fact that there are no physical limitations to their combinatorial capacity—the number of possible combinations that their networks can compose is infinite.

It is also important to remember that the evolution of human thought has an important social dimension. Conservation of symbolic representations also takes place in the inter-subjective space, not just inside an individual brain. Human thinking evolved as a cooperative social activity. Language is an important tool that serves this inter-subjective mode of conservation and symbolic construction. The spontaneous organization of interacting brains combined with technology that supports and enhances our mental activity (such as computers, the internet, various data repositories, etc.) vastly increases our capacity to construct new forms of organization of reality with increased combinatorial power. Each new level of organization is more powerful than the one it regulates because it offers more combinatorial possibilities; the forms of organization that each new level regulates become merely particular cases in a more general organized whole. Unlike other forms of organization of reality, organization of reality that involves symbolic thought has no limitations; it is, in fact, infinite.

The empirical evidence related to the emergence and development of human thought does not support the positing of the ontological gap between

thought and reality, mind and matter, subject and object, the knower and the object of knowing. This gap is not a product of empirical observation; it is an example of what Kant called synthetic *a priori* judgment or what we more commonly call self-evident or common sense truth. As the term indicates, common sense truth is not a product of rational judgment. The word 'sense' indicates connection to biological factors, whereas the word 'common' suggests coherence—the fact that this knowledge is a product of an agreement among knowers. Neither of these terms signifies any connection to rational and critical assessment. The commonly accepted belief regarding the unbridgeable gap that separates the subject from the object does not exist in reality. It appears only if the process of construction is excluded from our conception of knowledge production. We all have an immediate experience of this process. Without it, we would not be able to know anything. It is real and so are its products—new forms of organization of reality represented by new organizations of neurons and neural circuits.

The controversy that has surfaced in connection with Horgan's book is not accidental. Its source is the worldview held by contemporary science and, specifically, its conception of knowledge production. This conception fails to recognize and embrace the very source of our knowledge—the process of construction that generates reality. Our knowledge production is an integral part of this process. Our capacity to produce knowledge is infinite. This capacity is the most compelling proof against Horgan's assertion that our scientific quest will come to an end. It is also a convincing proof—in fact, the only definite proof we can have—that reality is infinite because our capacity to shape and reshape it is infinite. We are the agents who have the potential to make reality infinite, and our true destiny as a civilization is to realize this potential.

The controversy that this article originally set out to explore leads to a different set of questions that transcend the boundaries of its original subject. How do we realize our infinite potential for constructing reality? What are the best conditions to sustain and enhance this potential? How will its realization affect our life?

These questions are not new. Many thinkers from the Renaissance through the Enlightenment and down to our own time have asked these questions in one form or another. They were captivated by the power of human thought; many of them devoted their lives and careers to seeking ways in which the power of human intellect could be harnessed for the benefit of humanity. Their visions continue to inspire us in our quest for infinite progress, rationally organized political and social order, economic prosperity, and world without violence and wars. Although these goals remain elusive, the inspiration is enduring. We continue to believe that control over the power of our knowing will open unlimited possibilities for humanity.

C. West Churchman is one of the most important and influential thinkers who pursued this quest in recent times. His book, *The Design of Inquiring Systems*, is an extensive, insightful, and engaging exploration of various approaches to understanding the production of knowledge and the most efficient ways of organizing this production (Churchman, 1971). It is certainly beyond the scope of this article to provide a detailed and exhaustive examination of Churchman's ideas—an enterprise that would require a full book-length study. However, it is quite appropriate to engage some of the seminal themes of his works in the following reflections.

The theoretical perspective outlined in this article builds to a significant degree on major themes of Churchman's heritage. It fully embraces his vision of progressively expanding nested levels and forms of organization that he sees as characteristic for inquiring systems. It is an inclusive vision of a democratic and cooperative process. In this regard, Churchman's thinking about design of inquiring systems and the way they operate stands in sharp contrast to the prevalent practice in the contemporary scientific community.

As has been shown, the dominant conception of knowledge production in the scientific community does not recognize the role of the process of construction and does not incorporate this process. This failure has several consequences. First of all, without incorporating the process of construction, one cannot see the vital

connection that always exists between the subject and the object. The world appears as ontologically divided by an unbridgeable gap. The discord between the realists and the anti-realists that plagues our intellectual community is a result of this division. This discord works against an objective and comprehensive understanding of reality, discourages critical introspection on both sides and ultimately hinders our scientific progress. The overall situation is disorienting for all involved. The failure to recognize the process of construction makes realists oblivious to the impact of subjectivity and leads to frequent uncritical projection of specific theoretical conceptions on reality. Insensitivity to the problem of subjectivity often tempts members of the scientific community to substitute their own theoretical perspective for reality. Claims that external reality fully validates theory merely conceal a triumphant subjectivism clad in the mantle of objectivity. The anti-realists do not fare much better and only add to overall theoretical confusion. Their emphasis on subjectivity merely renders all knowledge relativistic. In their case, reality appears as ultimately inaccessible to human reason. As one can see, both approaches are ultimately not conducive to a successful scientific enterprise.

The problem of validation is another important consequence of the failure to embrace the process of construction. Anti-realists simply dismiss this problem. In their view, all knowledge is relativistic—a view that leads to a facile conclusion that no knowledge is valid. By contrast, realists claim that knowledge can be validated by the reality external to our mind. Their approach also does not solve the problem. Human thought is by far the most powerful form of organization of reality. Because it is the most powerful form, are we justified in using other and much less powerful forms of organization to validate knowledge? The obvious answer is no. The less powerful forms cannot validate more powerful ones. They cannot fully encompass all the possibilities of these forms. Conversely, because of the greater power of symbolic operations, there are no obstacles that can, in principle, prevent establishing correspondence between thought and the reality external to our mind. Scientific theories of the

past, such as flat Earth or the geocentric theory of the universe, were perfectly capable of establishing such one-to-one correspondence. Underdetermination also shows that pronouncing any theory to be a unique explanation of empirical data is ultimately a very problematic claim.

Churchman was keenly aware of the problem of validation or what he saw as the problem of the guarantor of the validity of knowledge (Churchman, 1971, pp. 274–75). In his efforts to resolve this problem, Churchman combined the legacy of American pragmatism and the intuition about syncretism of human intelligence that perceived an intimate connection between knowledge, on one hand, and ethical and aesthetic values, on the other. He sought to counter the relativistic implications of pragmatism by associating knowledge production with the pursuit of ideals, both ethical and aesthetic. (Ulrich, 2004). Although this approach opened new and very productive directions in Churchman's quest, it ultimately has not resolve the problem of subjectivity and relativism. As he soberly acknowledged at the end of *The Design of Inquiring Systems*, the problem of the relationship between relativism and non-relativism still remained, in his view, the most important philosophical problem of the 20th century. (Churchman, 276).

Churchman's most enduring legacy is his profound belief in human capacity to know—a capacity that is infinite and yet one that we can grasp and understand in its totality. He pursued this quest for objective and universal knowledge throughout his intellectual career. The perspective that centers on the process of construction follows up in this quest and seeks to shed new light on the problems of subjectivity, relativism, and objective and universal knowledge that Churchman confronted in his work.

The following observations may be a good starting point in addressing these problems. If, indeed, there is some dimension that allows observing reality in its entirety, we should have access to this dimension precisely because it must be truly universal and must include our activity. Also, if this dimension is truly universal, the knowledge we gain from this dimension should cover all the future forms of organization of

reality and not just forms that exist now or have existed in the past. Finally, objectivity and universality requires that knowledge should critically incorporate the process of knowing, that is, the knower, or observer, should be part of knowing/observing.

The most essential characteristic of reality is its dynamic character. Reality never stands still; it constantly evolves, constantly creates new forms. We, humans, are one of the forms of organization of reality, and we are endowed with the same capacity for creating new forms as the rest of reality. Therefore, we do have full access to the most essential dimension of reality.

The past and the present of our universe is the story of the construction of new forms. We have every reason to believe that such continued construction will also be the future of our universe (unless, of course, we destroy ourselves). The fact that we can produce knowledge infinitely and that our knowledge is one of the forms of the organization of reality supports this view. Therefore, through understanding the process of construction, we, in a way, gain some knowledge about all forms that this process can create—past, present and future. We may not know in all details what specific forms this process and we will produce in the future, but, as this article argues, we can know how they will be produced.

Objective and universal knowledge should incorporate the activity of knowing, that is, the process of construction itself. In other words, it should include the observer/knower into the field of observation. However, how can we observe the process of construction and ourselves without entering into infinite regress? Observing the process of construction requires constructing a position from which this process can be observed. What such observational position requires seems impossible: to observe the process of construction, one must construct a position outside this process. However, how can one be outside the process of construction because taking such position also involves construction? How is it possible to be inside and outside the process at the same time? Is not this a contradiction? In other words, can one reflect on the process of construction itself?

As has been pointed out earlier, the process of construction involves regulation. Regulation is essentially a reflective function. The fact that the process of construction is infinite may suggest, as it does to Niklas Luhmann, that there is really no way to reflect on the process of construction because for every reflective position, there will always be a possibility of constructing another one (Luhmann, 1984, p. 479). Every point of reflection can and will be succeeded by another one, no less embedded in the process of observing/constructing than its predecessor. Should one conclude, then, that the problem of the embedded observer/knower cannot be resolved and all that is left is to rely on palliatives, such as Luhmann's conditioning (Luhmann, 1984, p. 485)?

It is logically correct to regard, as Churchman has, the process of construction itself as a system. Just like any other system, it requires stabilization and, therefore, regulation that offers a possibility of reflection. If the process of construction requires regulation, there must exist a position from which one should be able to reflect on the entire process without at the same time being outside of this process.

As has been indicated earlier, conservation and regulation are at the heart of the process of construction. Conservation of functional operations requires regulation. At its inception, the regulatory operation is unstable. To stabilize itself, it needs its own regulatory operation that marks the inception of a new level of organization that also needs to be stabilized. Thus, the process of construction combines both equilibrium and disequilibrium. Both equilibrium and disequilibrium are dynamically related in the process of construction. An increase in equilibrium, or entropy, on one level of organization leads, at the same time, to an equal increase in disequilibrium, or order, because it generates a new and more powerful level of organization that regulates this level. This conception of the process of construction is in total agreement with the second law of thermodynamics that says that entropy can only be equal or more than zero (see Shkliarevsky, 2011). In the process of construction, the total amount of entropy is always zero as it

constantly maintains a balance between equilibrium and disequilibrium.

The repetition of the cycle of construction eventually leads to the improvement of the function of regulation, and the process of construction becomes increasingly more stable, despite constant changes. One can probably best describe this dynamic stability as homeorhesis—the term that was introduced by the biologist Conrad Waddington—rather than homeostasis. Homeorhesis is not a static condition and, as such, requires a stable balance between equilibrium and disequilibrium. This dynamic balance has a function of regulation and, as a regulatory operation, offers a possibility of reflecting on the functioning of the system as a whole (Shkliarevsky, 2007).

The universal knowledge cannot be reduced to any particular product of the process of construction. There are no god particles. The search for a universal knowledge in this direction is utterly futile. Rather, the universal knowledge can only be about the common denominator that underlies all that have emerged, is emerging and will emerge in the future. It involves knowledge of the process of construction itself. This knowledge is not a lifeless abstraction that lies outside our daily experience. On the contrary, it is integrally connected to our life. We just have to know how to look to recognize this fact. Every phenomenon that we encounter is a product of the process of organization in its constant interplay between equilibrium and disequilibrium. Every level of organization of reality is a product of equilibration, and every equilibration creates disequilibrium. Observing reality from the vantage point of this delicate but very stable balance will include in our field of vision not only the particular phenomenon that we are trying to understand but also the knowledge of the universal process that made this and all past, present and future phenomena possible. This conclusion suggests that the current differentiation between epistemology and ontology is purely analytical. As this article suggests, ontology (i.e., what relates to being) and epistemology (i.e., what relates to knowing) are intimately connected because, despite isomorphic differences, the process of construction that underlies reality is structurally the same process that we use in constructing knowledge.

The perspective that incorporates the process of construction offers a different approach towards validating knowledge that is non-exclusive and, at the same time, non-relativistic. As has been indicated earlier, the combinatorial power is what distinguishes one level of organization of reality from another. Therefore, we can use combinatorial power—or in other words, inclusiveness—as the criterion for validating knowledge. The more inclusive a theory is, the greater is its combinatorial capacity and, therefore, the greater is its explanatory power. For example, non-Euclidean geometry includes Euclidean geometry as its particular case with the curvature equal to zero. Therefore, non-Euclidean geometry has greater explanatory power. It can operate with both flat and curved space.

This approach to validation demonstrates a vital aspect of knowledge production that resonates with Churchman's view of cascading inquiring systems. Knowledge production is ultimately inclusive. Old theories are not discarded as a result of the adoption of new theories; preceding levels of organization are not obliterated as new ones emerge. On the contrary, old theoretical perspectives and their levels of organization are conserved in new and more comprehensive constructions. They merely become a particular case of a broader and more inclusive perspective. It is also a profoundly democratic approach. All knowledge is part of our quest, and no knowledge should be excluded. Legitimate disagreements should not trigger power struggle where one perspective seeks to de-legitimate and obliterate another. Rather, they should motivate a search for another, more inclusive and even orthogonal perspective that would dissolve the dissonance into a new harmony.

Such approach stands in stark contrast to the dominant current practice of knowledge production that tends to be exclusive. Dominant theoretical perspectives seek to silence alternatives. Control over funding, exposure, publishing and academic appointments provides ample opportunities to enforce orthodoxy. More often than not, knowledge production turns into an exercise of power.

The driving force in this exercise of power is fear. The exclusion of the process of construction

from our conception of knowledge production often leads to uncritical projection of specific subjective interpretations on reality. Such uncritical projections foster an institutionally supported and proliferated illusion in which a particular theoretical perspective stands for the actual reality. Alternatives that compete with accepted standard models get little consideration or exposure. Research programs that choose to focus on other than mainstream approaches are not particularly high on the list of projects that receive funding.

Fetishization and absolutization of specific constructs is among some of the most adverse effects of the conception of knowledge production that excludes the process of construction. A limited one-sided consciousness impaired by this exclusion takes its own projections for a true reality. As the process of construction evolves and new forms and levels of organization of knowledge emerge, such consciousness experiences this legitimate process as a loss of reality.

There are few traumatic experiences that can compare to losing one's ability to understand and interpret reality. For a consciousness that undergoes this experience, reality becomes a void, an abyss devoid of any meaning; or worse, filled with negative meaning. In words of Shakespeare, 'time comes out of joints'. Such consciousness develops a sense of disorientation, confusion and fear. To make things worse, its capacity to cope with this condition is severely limited to only one cognitive operation—assimilation. Such consciousness is incapable of critically examining itself; it simply cannot see internal sources of its predicament. Rather, it takes an easier approach: it rejects the challengers and uses power to silence them. Thomas Kuhn has discerned the disruptive effects of such conflicts in his *Structure of Scientific Revolution* (Kuhn, 1970).

There is no rational justification for resistance to new forms and levels of organization. These changes do not destroy the old forms. They conserve them in broader and more comprehensive visions. When old forms are subject to pressure of change, we are not losing reality. On the contrary, it is precisely

during these transitional moments that we experience the most direct and most intimate contact with the ultimate reality—the process of construction. The focus on the process of construction helps to understand that it is this process, its constant and unimpeded evolution, and not the specific forms it creates, that we should view as the only true and desirable product of our efforts.

The perspective that embraces the process of construction also recognizes, as Churchman has, the essential and necessary syncretism of all human mental activities—a profound connection between our capacity to create knowledge and our aesthetic and ethical values. Gratification of our functions is the source of pleasure and contentment. When we perform our essential functions—visual, audio, gustatory, tactile, and others—we exercise these functions and experience pleasure. A familiar face activates mental operations in the mind of a child. Exercising these mental operations gratifies and conserves these operations, and the child experiences a sense of pleasure and contentment, as he or she does when seeing a familiar face of the mother.

Construction of knowledge is the most essential human function. All humans are capable of performing this profoundly creative act. The fact that we all become conscious beings by the end of the first year of our lives is a compelling proof of this capacity. It is hard to overestimate the magnitude of this creative transformation. Nothing that we humans have or will accomplish—no theory of relativity or quantum mechanics—will ever exceed in its significance this act of creation. When we construct knowledge and perform acts of creation, we exercise our most essential human functions and, as a result, we, experience pleasure and contentment. It is this pleasure and gratification conferred by the act of creation that is the source of enjoyment that we associate with aesthetic value.

Construction of knowledge involves two basic operations—assimilation and adaptation. Assimilation is an operation that incorporates objects of reality into internal functional schemata of the organism. This operation reduces

the multiple and diverse world to the internal functions of the organism. It is, to be sure, a violent operation that essentially denies any autonomy to the reality external to the organism. Devouring of one organism by another is a good example of this operation.

By contrast, adaptation adjusts internal functions of an organism to reality. Recognition of autonomy of the reality external to the organism is essential in this operation. Such recognition is the basis for the development of moral sentiment that grants autonomy and agency to other human beings in our moral universe. Thus, our capacity for constructing knowledge, that is, exercising both assimilation and adaptation, is closely related to our ability to function as moral beings in our universe. Piaget has noted this connection in his book *The Moral Judgment of the Child* (Piaget, 1965). His remark that 'Logic is the morality of thought just as morality is the logic of human action' is a poignant affirmation of the essential connection between knowledge and morality (Nicolopoulou and Weintraub, 1998, p. 222). We cannot get an objective view of reality if we insist on viewing reality on our terms, rather than on its own. Objective knowledge requires granting the same autonomy to reality and its objects that we grant to ourselves and others in our moral universe.

Our civilization firmly holds on to an inspiring belief that knowledge is the key to ensuring unimpeded progress, rational political order, economic prosperity, judicious use of natural resources and a world free of wars and violence (see, e.g., Banathy, 2000; McIntyre-Mills, 2010; McIntyre-Mills and De Vries, 2011). Both Churchman and Piaget, among many other thinkers, fully grasped the importance of understanding knowledge production for achieving these goals. By combining systems thinking with the constructivist approach, the perspective outlined in this paper largely builds on their legacy. Much has been carried out to understand the specific aspects of the process of construction, including works by this author (Shkliarevsky, 2007, 2008, 2010, 2011), but much still has to be learned. It is the hope of this author to contribute to further exploration of this important subject.

This paper has shown that the problem raised by Horgan in his book is not a fortuitous one. It is not due to ignorance, obscurantism or some insidious agenda. It is deeply rooted in the views on knowledge production, the relationship between subject and object, and our relation to reality—in a word, the philosophical worldview held by modern science. The resolution of this problem requires a critical rethinking of this worldview. This paper suggested some ways in which this worldview can be revised.

Fundamental revisions are not easy and are often resisted. There is a reason for such resistance. Conservation plays a crucial role in the process of construction. However, conservation inevitably requires regulation, and regulation leads to the emergence of new levels of organization. This process works in the universe, and it works in the world of man. We are its practitioners, and our creativity over the entire period of human history is a vivid testimony to this fact. This process has profoundly shaped our civilization and us. Our intimate relation to this process compels us to understand it. Such understanding will help us to practice it more efficiently and with fewer losses. However, most importantly, it will help us embrace our true destiny in shaping and reshaping reality in our infinite quest for knowledge.

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