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Perspective

Indigenous Concepts of 'Living Systems': Aristotelian 'Soul' Meets Constructal Theory

Raymond Pierotti

Author Address: Department of Ecology and Evolutionary Biology, University of Kansas, Lawrence, Kansas 66045-2016, USA.
Email: pierotti@ku.edu

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Abstract: *I examine similarities among the ways of thinking concerning the natural world of Indigenous peoples of North America and Australia and two aspects of Western Science from different historical periods. The first comparison is with constructal theory, a set of ideas and models recently developed to explain how 'design' arises in both biotic and abiotic systems. Both traditions emphasize the importance of flow and motion and how these generate connections, not only within biotic systems, but also between biotic and abiotic phenomena. The second comparison goes back to the beginnings of the Western scientific tradition, and involves the Aristotelian concept of the 'soul,' an entity which is not considered to be supernatural, but more of an emergent property of living systems that also involves flow, especially of heat and air within living systems. Both comparisons reveal that indigenous knowledge is thoroughly scientific, but not in the sense characterized by the Baconian/Cartesian tradition, which is more focused on mechanism and application to human affairs than to understanding how natural systems actually function. Indigenous knowledge focuses more on relationships than on mechanisms, and thus is best compared to Western scholarly traditions that also emphasize relationships and emergent properties.*

Keywords: Indigenous peoples, Living systems, Metaphysics, Epistemology, Aristotle, Constructal theory, Flow

> Reality is a single matter-energy undergoing phase transitions of various kinds… Rocks and winds, germs and words, are all different manifestations of this dynamic material reality, or, in other words, they all represent the different ways in which this single matter-energy expresses itself (De Landa 2000).
>
> Even if it sometimes congeals into feldspar or amethyst, all rock is a flow. Even if it sometimes congeals into an aphid or a dinosaur, all life is a flow (Cohen 2010:62).
>
> Ta panta rhei (all things flow) (Simplicius, as cited in Peters 1967:178).

One issue arising frequently in ethnobiology is the tendency of Western scholars to either misunderstand, or even reject knowledge traditions of Indigenous peoples (Anderson 1996, 2013; Pierotti 2011).

> (P)art of the reason why western scientists do not readily recognize the value of traditional knowledge is that traditional communities often package knowledge along with poetry, metaphor, art, religion, and all the wonders of the imagination (Anderson 2013:48).

Interactions between Indigenous peoples of the Americas and Western Europeans have been described as "a war between those who think they belong to the world and those who think the world belongs to them" (Bringhurst 2008:40). Much of what is called Western "science" might be more appropriately described as European ethnoscience (Medin and Bang 2014).

I compare North American and Australian indigenous ways of knowing concerning what constitutes a "living system" to two distinct approaches that emerged from but go largely unrecognized by Western scholarly traditions. One, Aristotle's concept of the "soul" (as cited in Leroi 2014), is a crucial taproot; the other, constructal theory, a recently proposed new law of thermodynamics (Bejan and Zane 2012), holds promise for important insights into

how nature functions. These concepts, although widely separated in time, converge on a view of living systems in which flows of energy, liquid, and heat, as well as any plastic phenomenon in open systems, generate a range of phenomena involving a sort of controlled entropy that generate structure and function at geological, meteorological, ecological, and physiological levels.

These concepts are relevant to indigenous ways of knowing because one area of indigenous metaphysics regularly dismissed by Western scholarship is that many Indigenous peoples consider bodies of water, air (winds), and even stone to be "alive." In the scientific view of Western Europeans, "living" systems are restricted to biological entities, i.e. plants, animals, fungi, protistans, bacteria, and perhaps viruses. I argue that this does not reveal a weakness on the part of indigenous knowledge traditions, but rather an overly restrictive concept of what "living" means in the Western scientific tradition.

In order to show this, I follow analytical techniques used to examine the scientific bases of indigenous ideas (Anderson 1996:103-104):

1. Look for practical information.
2. Anything that does not look obviously practical and empirical should be analyzed to see if it is an ordinary, accurate observation described in a culturally unique way. …
3. [Identify what are actually] empirical observations, confirmed by experience but explained by recourse to imaginary constructs. …
4. [Consider if apparent] "errors" can be explained as logical deductions from known principles…
5. [Recognize how] some counterfactual knowledge creeps into belief systems as the result of teaching devices [(e.g. stories) because the use of] myths and fables are great ways to teach morals [and ecological principles] to the young. …

I begin by examining how some Indigenous peoples consider abiotic factors (e.g. water, air, and rock) as 'living' especially when they are engaged in the process of "flow." I then compare such concepts with 'laws' derived from constructal theory – a theoretical and mathematical approach to understanding the nature of "life" and "living systems" – and conclude by comparing Aristotelian concepts to both constructal theory and indigenous beliefs.

Indigenous Perspectives on Abiotic Entities

There is evidence that many Indigenous peoples have broader concepts of what constitutes a "living" entity than the standard Western perspective, which limits such a definition solely to biological entities. For example, the traditional religion of the Dine' people places everything in an orderly and complex web of existence. Every aspect has purpose and meaning. Every effect has a cause and every cause has an effect. They see their world as bound by natural markers; all that exists within these boundaries is intimately related. "*All life and geological formations are animated and connected by means of life giving holy winds*. The same winds that bring life to humans give life to the four sacred mountains and surround each home site" (Bitsuie 1995). The holy wind, like everything else in Din'e Bekeyah, obeys natural law (Bitsuie 1995). Wind existed first, as a person. When the Earth began its existence, Wind took care of it. Wind exists beautifully, they say. Back there in the underworlds, this was a person (Grim 2015; McNeley 1981).

Stones are also abiotic entities to which some tribes attribute the status of "living." One example is the relationship of the Lakota People to stones, which comes from Luther Standing Bear: "[M]an did not occupy a special place in the eyes of Wakan Tanka, the Grandfather of us all…" (Standing Bear 1933, as cited in Grim 2015). He refers to Wakan Tanka as Tunkashila or Grandfather. Etymologically, *tunkashila* refers to rock, thus teaching about relatedness to all things is embedded in the Lakota concept of rocks and stones as persons (Grim 2015). This teaching is further reinforced by oral narratives, mythic cycles, which tell of the roles of stone in the emergence of the people and transformative life (Grim 2015). In a similar fashion, Laguna Pueblo scholar Leslie Marmon Silko writes, "Rocks and clay are part of the Mother … A rock has being or spirit, although we may not understand it" (Silko 1996:27).

For the Cherokee people, the river, or "Long Man," was always believed to be sacred. The practice of going to water for purification and other ceremonies was common. Today the river or any other bodies of moving water, such as a creek, are considered sacred sites; going to water remains a respected

practice by some Cherokees (Cherokee Nation Cultural Resource Center 2015). Following this theme, the 2008 International Indigenous Water Declaration states that, "We assert that water has a right to be recognized as an ecological entity, a being with a spirit and must be treated accordingly." Similarly, for Canadian First Nations, "Water for Aboriginal peoples is the basis of all life," and "Canada's aboriginal populations are profoundly linked to water and waterways for both physical and spiritual health" (Government of Canada 2010). Such declarations demonstrate that recognition of abiotic entities as alive is a general concept, held by a wide range of Indigenous Nations.

Similar beliefs are found among Australian Indigenous peoples. "In Indigenous (Australian) belief systems, water is a(n)… elemental source and symbol of life" (Langton 2009:45). People entering water, "[D]on't swim in the middle—only at the end part, *where it flows*" (Mowaljarlai 2001:80; emphasis added). Spiritual traditions in relation to rock and land derive from a philosophy that establishes "interconnectedness of… animate and inanimate, whereby people, the plants and animals, landforms and celestial bodies are interrelated" (Grieves 2008:364). Aboriginal and Torres Strait Islander people have spiritual connections to "land, sea, landforms, watercourses, [animals] and plant life, [which] exists through the Law developed at the time of creation" (Grieves 2008:369; parenthetical elements added); further, "[t]he Law ensures that each person knows his or her relationships and responsibilities for other people (their kin), for country including water sources, landforms and species …" (Grieves 2008:364). In particular, "the most highly sacred and dangerous are stones …held to be metamorphosed parts of the bodies on ancestral beings" (Tonkinson 1978:106). Song Lines and the Rainbow Serpent, crucial aspects of Australian aboriginal culture, are linked to flow, with the latter being associated with watercourses, rivers, and creeks (Grieves 2008; Rose 2000). Clearly, there are many examples among Indigenous peoples that indicate a more expansive view of what it is considered "living," a perspective that can be accommodated within constructal theory.

Constructal Theory: Generation of Shape and Structure

Constructal theory (and law) was developed in the 1990's to examine the question of "from what principle can geometric form be deduced?" (Bejan 2000:1). Similar structures such as "river basins and deltas, the air passages in our lungs, and lightning bolts" were traditionally regarded as random elements resembling one another because of coincidence (Bejan and Zane 2012:1-2). Constructal law is needed because "the first two laws of Thermodynamics do not account for nature completely" (Bejan and Zane 2012:19):

> Nature is not made of black boxes. Nature's boxes are filled with configurations … [because] the second law commands that things should flow from high to low (energy states), the constructal law commands that they should flow in configurations that flow more … easily over time …if physics is to cover nature completely, it must be endowed with an additional first principle that accounts for the phenomenon of design generation and evolution everywhere and in everything. The constructal law is this new addition (Bejan and Zane 2012:19).

Constructal theory addresses three original topics within Aristotelian metaphysics: the nature of being, first causes of things, and things that do not change (van Inwegen and Sullivan 2014). Under constructal theory, geometric form is generated in natural systems that are internally "alive," which emerges from flows and driving gradients, such as the physical phenomena temperature and pressure (Bejan 2000; Bejan and Zane 2012). "Living systems" resist entropy and are not in an internal state of equilibrium. The "living" world consists of limited numbers of shapes, such as branching "tree" networks, round cross sections, and inverse parabolas (i.e. cross sections of rivers, streams, and glaciers, which are everywhere). A single principle that accounts for them can be characterized as a "law" bridging the gap between physics and biology (Bejan 2000:2).

Constructal law posits that for a finite-size flow system to persist (i.e. live) without attaining internal equilibrium (stasis = non-life), it must evolve in such a way that provides easiest access to internal flow. Constructal theory holds that generation of design (pattern, rhythm) in nature is a phenomenon emerging from physics, and this phenomenon is covered by a principle (the constructal law): "everything that moves

Figure 1. Trail through Lehman Cave in Great Basin National Park showing extensive flowstone formations. Photo by National Park Service (public domain).

and morphs in order to flow and persist is alive" (Bejan and Zane 2012:155).

The abiotic entities regarded as "alive" under indigenous traditions conform to the definition of life under constructal law. This is obvious for air and water, where constant flows and gradients of physical phenomena such as temperature and pressure generate the structure seen in river systems and weather patterns. Even stone flows, especially in a molten state, or if it takes the form of flowstone, which are sheet-like deposits of calcite, a stable polymorph of calcium carbonate, formed where water flows down the walls or along the floors of caves (Figure 1).

Indigenous peoples understand how some forms of stone generate geographic landforms from flowing materials. Near Grants, New Mexico, lies El Malpais National Monument, a mass of rough and jumbled black rock, remaining from volcanic eruptions as recently as 500 ybp (Mangum 1990). To local Zuni, Acoma, and Dine' peoples this area relates to creation stories of their peoples and they characterize this rock as "the coagulated blood of Yé'iitsoh, a giant who terrorized people drinking from springs at the foot of Tzoodzil (Mt. Taylor)" (Native(X) 2012).

This metaphoric description of what is today hard, black stone as the coagulated version of flowing red substance suggests traditional knowledge experience of stone in a liquid, flowing state, illustrating Points 2, 4, and 5 in the analytical technique described by Anderson (1996:103-104), which describe how to deal with examples that seem contradictory to traditional Western scientific approaches.

A strength of constructal theory is that it negates the need to invoke random processes, such as fractal geometry, in the generation of structure and change within physical systems, because "chance and accident are the opposite of rationality … not knowledge, but

an acknowledgment of its absence" (Bejan and Zane 2012:78). Under constructal theory chance is regarded as a "code word for saying there is too much conflicting data, i.e. too many variables to make sense of the whole" (Bejan and Zane 2012:78).

Constructal law contends that despite the diversity in nature, everything involving movement concerns flow systems. Given freedom, flow systems evolve over time to increase ease of movement; which accounts for patterns referred to as design (Bejan and Zane 2012:127). Life conceived of as flow and movement generates "design," which does not imply the presence of a "designer," but instead emergent patterns or properties that follow similar rules to achieve similar patterns, which are "things that do not change" in the Aristotelian sense (van Inwegen and Sullivan 2014). Because patterns of flow follow the same rules does not mean they generate identical results. Although constructal law focuses on construction and coalescence of entities into larger flow systems, each system shows individual differences. Thus, "On the surface focus on differences makes sense …Even if we look at single species we do not find two identical trees, branches, or even leaves" (Bejan and Zane 2012:128). Thus, pattern generation under constructal law uses the same process to produce variable individuals.

This perspective can be seen in indigenous thinking in the 1911 statement of Okute, a Teton Lakota:

> Animals and plants are taught by Wakan Tanka (the Lakota creative force) what they are to do. Wakan Tanka teaches the birds to make nests, yet the nests of all birds are not alike. Wakan Tanka gives them merely the outline. Some make better nests than others … Some animals also take better care of their young than others... All birds, even those of the same species, are not alike … The reason Wakan Tanka does not make two birds, animals, or human beings exactly alike is because each is placed here to be an independent individual … I have observed leaves, trees, and grass, and I have never found two alike. They may have a general likeness, but on examination I have found that they differ slightly. It is the same with animals...with human beings …(McLuhan 1971:18).

This same insight is described by Bejan and Zane (2012:152): "No two leaves on an oak are identical, but they perform similar functions as part of the same flow system … Unique characters of individuals that compose a system are irrelevant to the character of the flow architecture."

All flow systems can be regarded as connected to and shaped by other flow systems. Thus the constructal perspective involves synergistic networks moving liquids, heat, gases, or combinations thereof (e.g., from soil to atmosphere through trees) revealing that the biosphere, atmosphere, and hydrosphere are not separate entities, but interlocking systems that evolve design through this interaction (Bejan and Zane 2012:145).

We see a very similar concept in the Native American idea that "all things are connected" (Pierotti 2011; Pierotti and Wildcat 2000). This relates in turn to the idea of winds and water being alive, as elements flowing through both abiotic and biotic environments. Such flow systems generate only enough complexity for the size of the area involved, creating working architecture, in river systems, in canyons, also in vascular systems in plants and animals. If we examine how cellular, developmental processes generate body structures, we see that as bone grows, muscle tissue, nerve tissue, and blood vessels track the bone, supplying new cells with nutrients and stimulation (Kirschner and Gerhart 2005). Anatomical structures show the same branching patterns of flow and movement seen in trees and in river drainages. Thus all things are connected, and what connects them is flowing systems that emerge naturally to maximize efficient movement of nutrients, water, gases, and heat (Bejan 2000). Although constructal theory is relatively new to Western Science, it converges upon long held ideas, not only in many Indigenous societies but in Western systems of knowledge.

The Aristotelian Concept of Soul

Concepts involving life as defined through flow systems are evident in the beginnings of the Western scientific tradition (Leroi 2014). Leroi is the first biologist to address the biologically scientific aspects of the Aristotelian canon, demonstrating that according to Aristotle, what distinguishes living forms from nonliving (abiotic) matter was presence of a "soul," whose essence was based on metabolism and move-

ment, and constitutes the structural principle of the visible and material body of a plant or animal (including humans: Bos 2003). For example, "Since the soul is form, and in a sense immaterial … how can an immaterial soul effect, or in Aristotle's language, 'move' a material body? In fact it moves it through the agency of 'organs' or 'instruments' … the most important of (which) is the *inborn pneuma*" (Rist 1985:35). Pneuma, considered as *slow fire* involving the same chemical processes of oxidation, is the fifth element, after the basic four of water, earth, air, and fire. Pneuma is also considered as the *organon* (instrumentation) of movement, the instrument that causes processes to start and stop in the bodily parts of a living creature, i.e. natural material instrumental for the soul to move the visible body (Bos 2004).

According to the Aristotelian concepts of living systems, "All living things have an internal source of 'vital heat' … This internal fire, which is not the same as conventional fire, is sustained by nutrition. Fire is always coming into being and flowing like a river" (Leroi 2014:166). Animals require ways to keep their "fires" under control, which involves flow of air through their systems, or *pneuma* (see above). Aristotelian souls function as a set of interacting units, forming an integrated whole, involving negative feedback circuits (homeostasis). "[C]omponents come and go, therefore a key feature of living systems is how their components are connected together … interconnections between cells and cellular components define the essence of a living process" (Leroi 2014:177). Aristotelian systems function "… as a river, flowing up and down in a circle … partly of air and partly of water. By similar cause the winds blow as well—even the wind has a sort of lifespan" (Leroi 2014:243).

One source of difference between Native American and Western worldviews is that in the Western tradition only humans possess souls (Pierotti 2011). Such thinking represents the legacy of Baconian/Cartesian thought, which underlies the Positivist philosophical attitude towards science (Leroi 2014), under which nonhumans lifeforms are considered to be machines and the primary way to understand life is to dismember (dissect) it and figure out the function of its parts (Pierotti 2011). Aristotle treats mental states (psyche) as physiological phenomena; therefore, the Cartesian explanation of consciousness does not arise. Aristotle's work *The Soul* is not a psychological treatise, but a statement about systems and control that enable life (Bos 2003; Leroi 2014:157).

Schrodinger defined life as a "system that feeds upon negative entropy" (Leroi 2014), such an idea can allow us to link Bejan's constructal theory of "life" as a way of managing or counteracting entropy to create structure through a dynamic system. To Aristotle, living things were "open systems" (cf. Schrodinger's negative entropy and Bejan's open systems): "we must understand [growing life forms] in terms of a constant flow of water. … This is how matter, of which flesh consists, grows: some is eroded in the flow and some arrives in addition" (Leroi 2014:163; parentheses added, emphasis in the original). The preceding statement suggests that under Aristotelian science there was no separation between mind and body. The three fundamental questions of philosophical thought (i.e. the nature of being, the first causes of things, and things that do not change) (van Inwegen and Sullivan 2014) generate the "soul" as an emergent property of the body whose existence ended at death (Bos 2003; Leroi 2014).

In the seventeenth century metaphysics began to change from being a catch-all category for philosophical problems that could not be otherwise classified under epistemology, e.g. logic, ethics (van Inwegen and Sullivan 2014). The word "ontology" was invented to characterize the science of being as such, something the word "metaphysics" could no longer fill. Philosophers began to distinguish "between "general metaphysics" (ontology), the study of being as such, and the various branches of "special metaphysics," i.e. study of objects of special sorts, such as souls and material bodies" (van Inwegen and Sullivan 2014). This separation of the soul from the body, led to what we today identify as Cartesian dualism.

Aristotle tried to convey that seasons, elements, even life itself, are all in some way unified, all are linked together in their coming to be and passing away (Leroi 2014:244). Aristotle understood that: 1) complex morphology and function require a primal source of order or information, i.e. consistent pattern formation, 2) these forms are dynamic, self-replicating systems, which 3) vary among kinds to yield diversity, and 4) exert power by *modifying the flow of materials* during development and in physiology (Leroi 2014:299). This is comparable to indigenous ideas of connection, with wind (flowing air) being "alive," and to constructal theory in which flow systems link together.

Aristotelian science was a primary casualty of the seventeenth century Scientific Revolution because of its synthetic perspective (Leroi 2014:353). Bacon was openly hostile to Aristotle's perspective. The Baconian view was not to understand the world, but to change it; the proper object of study being the artificial rather than the natural. Bacon considered Aristotelian philosophy "barren for the production of works *for the benefit of man*" (Leroi 2014; emphasis in the original). Supporting such mechanistic approaches was Descartes, who argued that nonhumans do not have souls, they are merely machines. Descartes claimed that Aristotle's explanations are not merely wrong, but *unscientific*, based upon Baconian logic that they are unmechanistic. Aristotle was more sophisticated, less mechanistic, than Bacon or Descartes, because he saw that complex objects must be modeled on patterns found elsewhere, as in constructal theory and its comparison of the structure of circulatory and river systems.

This is a crucial point: Aristotelian concepts, constructal theory, and Native American and Australian Indigenous knowledge do not recognize separation between mind (soul) and body. Under such systems, metaphysics grades into epistemology [systems of knowledge, or "the study of how we know what we know" (Medin and Bang 2014:139)], indicated in the systems under discussion by shared emphasis on connection, both within biotic forms and between biotic and abiotic elements of ecosystems (Pierotti 2011). In contrast, the Baconian/Cartesian tradition is founded upon the idea that the "soul" is immortal and only possessed by humans, setting up scientific traditions in which epistemology focuses on mechanism and human interests to the exclusion of all other forms of life—decoupling metaphysics from epistemology.

Today, we can recognize Aristotle's accomplishments, and his intentions, more clearly than previous ages because we have caught up with (rediscovered) him, as we are also discovering principles established by indigenous knowledge (Pierotti 2011). A lesson every scientist knows or must learn is, "the practice of science demands a particular intimacy with the object of your investigations. You must know its form, its foibles … You must acquire a feeling for the organism. Biologists must also have special places …for *ideas do not come from nothing, they come from nature itself"* (Leroi 2014:375-376).

Unified nature, in which humans are simply one life form among many, is an ancient concept, probably going back to the beginnings of human thought. As the founder of Western science, Aristotle rejected the teachings of Plato, and created his concept of the "soul," not as a supernatural entity, but as an essential feature of biotic organisms (Leroi 2014). Aristotelian concepts, constructal theory and many Indigenous peoples see life in the flow of matter and energy. As a Yucatec Mayan has stated, "Without right mentality, it is easy to misjudge my people. We are not worshipping idols—we are honoring natural forces, energy" (Least Heat Moon 2013:82).

Conclusions

Numerous points of convergence exist between the knowledge of American and Australian Indigenous peoples and aspects of Western science (Anderson 1996; Medin and Bang 2014; Pierotti 2011). Convergence of constructal theory and indigenous concepts of "living systems" are of interest because each independently arrived at the idea that life involves entities engaged in the phenomenon of flow. Constructal theory involves mathematically sophisticated ideas that describe the dynamics of how liquids, gases, and even heat distribute themselves in nonrandom fashion.

There are fewer similarities between indigenous thought and Aristotelian concepts described, primarily because Aristotle did not include abiotic elements as living systems. The similarities are greater between constructal theory and the Aristotelian concept of life, because according to constructal law (and indigenous thinking) rivers, streams, winds, and lava flows share features with biotic entities that identify all of these as "living systems." In addition, constructal theory and the examples of indigenous thinking discussed here emphasize individuality, while acknowledging that the processes involved in generating "living systems" are similar in nature and form.

Aristotelian concepts emphasize energy flows as the essential aspect of living systems, and that "soul" (life essence) and physiological function are basically synonymous, especially with regard to the flow of heat (internal fire or *pneuma*), and how this relates to movement of air and other materials within biotic systems (Leroi 2014).

The crucial points are that many cases of indigenous knowledge, often seen as "unscientific," even by Indigenous people themselves, share crucial themes

(i.e., connection between biotic and abiotic systems and concepts of how living systems function) with both the beginnings of the Western scientific tradition and with sophisticated contemporary ideas that link physics and biology in nonintuitive fashion. The examples of indigenous knowledge systems presented here are more similar to the modern, mathematically sophisticated approach than they are to the early ideas. This reinforces the argument that indigenous stories share a number of features with mathematical models, i.e. both are generalized and oversimplified, but provide heuristic tools for creating general rules that can be used to examine real life phenomena (Pierotti 2011).

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Biosketch

Raymond Pierotti (Ph.D. Dalhousie University) is Associate Professor of Ecology and Evolutionary Biology at the University of Kansas.