Emergence from Within and Without: Juarrero on Polanyi's Account of the External Origin of Emergence

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ABSTRACT

This paper assesses a recent criticism of Michael Polanyi's account of the origin of complex entities by Alicia Juarrero. According to Juarrero, Polanyi took higher-level complex entities like machines and organisms to come into existence through the imposition of external, top-down forces. This paper argues that while Polanyi took the emergence of machines to come about in such a way, Polanyi's reading of 19th and early 20th-Century experimental embryology indicates his position is more sophisticated. Polanyi appears to have thought a synthesis was possible between reductive-mechanical and holistic-vitalistic approaches in embryology and he appears to have relied on this synthesis in his account of the origin of complex organisms. While I argue that this synthesis is unclear, it suggests that Polanyi conceived of the emergence of organisms as the result of internal, complex, and non-deterministic processes.

Introduction

There is significant overlap between the work of Alicia Juarrero (1998, 2000, 2002, 2008) and Michael Polanyi.[1] Their hierarchal ontologies, hermeneutical models of explanation,[2] and certain accounts of tacit knowing (Polanyi) and explanation of vague or schematic intentions (Juarrero) overlap and interact in philosophically significant ways. In this paper, however, I focus on a way in which their ontological theories diverge. More specifically, I address a criticism by Juarrero of Polanyi's account of the *origin* of emergence. Juarrero contends that Polanyi's explanation of how complex entities emerge is *too narrow* as it explains the origins of emergence *only* by appealing to an *external force* that carries lower-level physical-chemical particulars to a higher-level of complexity. Juarrero's account in *Dynamics in Action* and elsewhere is that emergence *also* occurs as a result of complex networks of internal, autocatalytic reactions.[3] Such emergence is *internal* to a system. While Polanyi offers nothing near the nuanced account of emergence through complex systems theory that Juarrero provides, I argue that Polanyi's account is more sophisticated and scientifically sensitive than is typically realized. In drawing on work done in experimental embryology and morphology, Polanyi attempted to articulate an account of the maturation (embryological differentiation) of living beings and use this account to explain emergence of organisms. I will argue that Polanyi sought to synthesize *both* causal-mechanical and vitalistic accounts of maturation, and this synthesis, at least in outline, can avoid Juarrero's criticism. However, I will argue that Polanyi isn't always clear on his view and he often speaks in a vitalistic way, i.e., where external top-down forces play a role in maturation.

Emergence from Without

Polanyi rejects the view that all of the complexity of the universe can be derived from a complete description of physical-chemical particulars considered in isolation from each other. Complex entities are ontologically different than the aggregation of the lower-level parts that compose them and new laws or principles are required to explain the behavior of such higher-leveled entities. Polanyi offers a wide array of arguments for why the behavior of higher-ordered things like machines, organisms, and conscious human beings cannot be adequately explained, reduced, or even identified by the language and laws of physics and chemistry. These arguments have been the subject of intense scrutiny by Polanyi scholars, but my goal here is not to rehash them.[4] For the purpose of discussing Polanyi's account of emergence, however, it is necessary to give a very general idea of this hierarchal ontology.

Polanyi's Hierarchal Ontology

Bottom-Up Considerations

(O1) *Supervenience:* higher-level things and laws (e.g. organisms and machines) depend upon lower-leveled things and laws (e.g. physical and chemical entities). That is, higher-order objects are not free-floating entities, but, as Polanyi writes "each level…relies for its workings on the principles of the levels below it" (LIS 233; cf. *PK* 382; Wesleyan V:5).

(O2) *Underdetermination:* lower-leveled objects and laws do not fully *determine* higher-leveled objects and laws. Rather, a lower level "leaves open" different possibilities at a higher level. As Polanyi puts it, "the principles governing the isolated particulars of a lower level leave indeterminate conditions to be controlled" (LIS 233; cf. *PK* 382; *TD* 45; Wesleyan V:3-4).

(O3) *Restrictive Control:* Lower-level things and laws place restrictions (constraints) on higher-level things and operations. They limit what types of activity is possible at the higher level.

Top-Down Considerations

(O4) *Marginal Control:* Higher-level principles control the marginal conditions (the indeterminate space) left undetermined by the lower-level principles (*TD* 45; Duke IV:16, V:1; Wesleyan V:5)

(O5) *Entities of Various Complexity:* there are low-level entities composed of relatively isolated parts and there are high-level entities whose parts are functionally related (Wesleyan V:5).

(O1)-(O5) produces a *hierarchal ontology* that involves higher-order (emergent) objects like machines, organisms, and minds which are subject to *dual control*, i.e., they operate within the confines of physical-chemical laws (O3) yet nevertheless are controlled by their own set of rules (O4). No purely physical explanation can, according to Polanyi, tell us whether an object is a machine, how a machine works, or what purpose a machine is supposed to fulfill (see Agler 2013:24-5). Yet none of this is to say that any machine can break the laws of chemistry and physics.

In *Dynamics in Action* and her "Downward Causation: Polanyi and Prigogine," Juarrero holds that (O1)-(O5) is not a complete account of a hierarchal ontology. While (O1)-(O5) may be used to fend off reductionist foes, a *genetic* account of how higher-order entities and laws emerge is needed. As Juarrero notes, it is one thing to discuss the operations of boundary conditions, but it is another to give an account of the *origin* of these boundary conditions. This raises an important question. How, according to Polanyi, do the higher layers of reality emerge from physical-chemical parts and laws in the first place? If machines, organisms, and consciousness are real emergent entities (and not merely epiphenomenal) operating on a higher-level of reality, what is Polanyi's story for the origin of this emergence?

At first glance, Polanyi's answer appears to be that the organizing/operational principle dictating marginal control is always *external* to the lower-levels. Polanyi seems to say as much when he writes that "boundary conditions expressly left open by physics and chemistry are controlled by principles *foreign* to physics and chemistry" (*TD* 42, my emphasis). And, when speaking about living things, he writes that "a principle not present in the inanimate must come into operation when it gives birth to living things" for a "higher level can come into existence only through a process not manifest in the lower level, a process which qualifies as an emergence."[5] In other words, bottom layers "leave open" room for novel activities; i.e., space for some *external* force to establish marginal control and cause new, ontologically higher-beings to emerge. So, to (O1)-(O5) above, (O6) can be added:

> (O6) *External Origin Thesis:* Higher-order entities and their operations are established by something that is *external* to what is found in the lower-order parts and their laws.

What Polanyi means by a principle being "external" can be partially clarified by his account of the emergence of machines. Polanyi indicates that the organization of machines (i.e., how the boundary conditions of machines are set) is imposed upon it by a designer. Polanyi writes "[t]he machine as a whole works under the control of two distinct principles. The higher one is the principle of the machine's design, and this harnesses the lower one, which consists in the physical chemical processes on which the machine relies" (LIS 225). He writes that "no part of a watch is formed by the natural equilibration of matter. Each is artificially shaped and connected to perform its function" (Wesleyan V:4). In other words, complex entities (machines) emerge as a result of an intelligent external force imposing a design on chemical-physical particulars in a way that gives them purpose, organization, and greater complexity. This new being is fundamentally different in kind as its behavior can only be explained by relying upon a new set of operative (in this case engineering) principles.

When considering *living things*, it may be tempting to say that Polanyi also holds (O6), especially given the fact that he repeatedly stressed that living things are equipped with a number of "living mechanisms" that make organisms very similar to machines. He says that animals have organs that perform functions as parts of a machine do, that morphogenesis—or the process by which the structure of living being develops—is similar to that of the shaping of a machine, and that machines (like organisms) have purposes (LIS 227; Wesleyan V: 15-16). In addition, while he notes that the analogy between machines and living beings is weakened by the fact that origin of the *parts* of a machine are *artificially shaped* while the origin of the *organs* of a living being are the result of a *natural transmission* of information in DNA, Polanyi concludes that in the case of machines and living things, their boundary conditions are "always extraneous to the process which it delimits" and the DNA molecule, much like the design for a particular machine, "is a blueprint of the growing organism" (LIS 227-228, 230). Polanyi thus appears to equate living things with machines and thereby accept (O6) for both, with the caveat that the type of external origin of machines is *artificial* but *natural* for organisms.

But, Polanyi's repeated emphasis on the similarities between living beings and machines must be understood in context. Namely, he equated the two in order to criticize the claim that organisms can be reduced to physical-chemical particulars and their laws. According to Polanyi, the debate between organicists and reductionists revolved around the issue of whether living beings are fully explicable in terms of physics and chemistry. He notes that the aim of writers like 17th century naturalists like Cudworth and John Ray and late 19th/early 20th century biologists like Hans Driesch, Paul Weiss, and Hans Spemann was to undermine the possibility of "explaining life in terms of mere inanimate matter in motion" (Wesleyan V:12; cf. LIS 232). That is, non-reductionists aimed to substantiate the existence of non-machine-like or "organismic" processes. However, Polanyi argues that this concedes too much for it falsely assumes that *machines can be reduced to physics and chemistry*. Polanyi writes that

> [t]hroughout the subsequent controversy between the scientists who supported the organismic view and the predominant school who defended a mechanistic explanation of life, it was taken for granted that the issue between the two camps was whether living

> beings could be represented or not by the laws of inanimate nature—whereas in my opinion both sides equally excluded the representation of life in terms of these laws, whether the process was mechanical or organismic (Wesleyan V: 13).

Thus, by stressing the similarities between *living things* and *machines*, and then arguing that *machines* don't reduce to physical-chemical particulars and their laws, Polanyi aims to undermine arguments that reduce *living things* to the *physical-chemical particulars* because they are machine-like. "Living beings operating as machines," Polanyi writes, "can not be described in terms of physics and chemistry" (Wesleyan V: 5).

However, the argumentative tactic of equating living things to machines should not imply that Polanyi thought organisms could be reduced to machines. Instead, Polanyi rejects the ontological equation of machines and living things (especially human beings). He claims that despite the fact that organisms have a number of mechanical functions, complex living beings operate on a higher level of reality than machines. For instance, he characterizes the mind's relation to the body as a hierarchy where an individual integrates information from the sensory organs to form the sight of some object, writing that the "mind harnesses neurophysiological mechanisms; though it depends on them, it is not determined by them" (LIS 238).[6]

Emergence from Within

Thus far, my account of Polanyi's hierarchal ontology has taken Polanyi to hold six claims (O1-O6) and Polanyi to specify at least three different kinds of entities: (i) *chemical-physical particulars* and their laws, (ii) *machines* and their laws, and (iii) *organisms* and their laws. In accordance with (O1)-(O3), the latter entities are said to depend upon, not be determined by, yet be constrained by the former. In accordance with (O4)-(O6), the latter items are thought to exist and manifest certain behaviors neither explicable by nor emerging out of the former.

Juarrero seems to agree with much of what Polanyi says here. She claims that certain phenomena (e.g. Bénard cells) "cannot be explained solely in terms of bottom-up energetic conditions" and the "boundary conditions set by an external agent play a critical role in bringing about higher level organization" (Juarrero 2013:5). In the case of machines, Juarrero (2013:2) claims that "an external agent is required to fix or shape the boundary conditions that enable life to appear…It is nevertheless the case that a process *other than* the operations at the lower level is what shapes the boundaries within which the higher level can emerge." In other words, the emergence of *some* complex entities is a result of externally setting certain boundary conditions. In doing this, new properties emerge that cannot be predicated of the constituent parts in isolation.

One example where Juarrero and Polanyi would agree that the emergence of a complex entity occurs through the imposition of external (environmental) constraints on lower-level interactions is the production of laser light (light amplification by stimulated emission of radiation). Consider that when we apply energy to a collection of atoms, atoms absorb this energy insofar as electrons move to higher energy orbits. As the electrons are unstable at these higher energy orbits, they will return to lower energy orbits. In so doing, they release a photon (or particle of light) that has a particular wavelength. The particular wavelength of a photon emitted by an atom depends upon the energy difference between an electron in excited state (high energy) and relaxed state (low energy). The emission of a photon along a particular wavelength increases the likelihood that other atoms will also emit photons and so the initial release of a photon operates as a catalyst for the release of other photons. Without specific environmental controls, what we get is a cascade of disorganized light like in a flashlight. However, by setting environmental controls (e.g., mirrors) and supplying the atoms with an external source of energy (e.g., by using an energy pump), more and more atoms become excited and laser light begins to form because a dominant wave track forces (or "slaves") atoms to release energy along its wavelength rather than along some other wavelength (cf. Haken 1988). This positive feedback process ultimately leads to the generation of a dominant wave track of laser light. In becoming laser light, the organized wavelength of photons take on properties that are not found in the individual atoms, i.e., it is monochromatic, coherent or organized, and directional (rather than the weak, scattered light of a flashlight). Such light can be used, as Juarrero notes, in ways that individual photons cannot, e.g., to cauterize flesh (*DiA*, 143). In short, a set of bottom-up constraints along with external boundary conditions (mirrors, energy pump) make new qualities and behaviors possible by harnessing the physical particulars in a way so that their behaviors can only be ascribed to the system as a whole and not to any of the isolated parts.

While some forms of emergence occur through external controls, Juarrero rejects (O6) as exhaustive of emergence. That is, Juarrero says that Polanyi's emphasis on boundary conditions being set *externally* is not the full story. On her more complex account, the dynamics of organisms and certain chemical reactions can be *endogenous* (the result of complex internal interactions) rather than simply *exogenous* (fixed by some external force or environmental boundary). Juarrero (2013, 5) notes that there is "a qualitative difference between the way boundaries are fixed in chemical autocatalysis" and the way that the boundaries of "physical dissipative structures such as Bénard cells or dust devils [or lasers]" are fixed. The difference can be accounted for through complex dynamical systems that involve "[a]utocatalytic processes [which] rely on the mutually reinforcing dynamics of several positive feedback steps" (2013, 5). In short, the emergence of complex entities can also occur through certain internal, complex, and reinforcing interactions between lower-level parts.

One of Juarrero's many examples of an autocatalytic reaction is the Belousov-Zhabotinsky (BZ) reaction, but some related chemical-clock reactions—the Briggs-Rauscher (BR) reaction, the Bray-Liebhafsky reaction, the iodine clock reaction—equally fit the bill. These reactions are distinctive in that they are *autocatalytic* and involve *feedback loops*. For example, the BR reaction is characterized by two processes: (i) a slow expenditure of iodine by malonic acid at a rate proportional to the concentration of iodine and (ii) a fast autocatalytic process that converts hydrogen peroxide and iodate to iodine and oxygen. The two processes are interrelated. When the BR reaction begins, the fast autocatalytic process—which only occurs when iodide levels are low—begins to produce more and more iodine until this process ceases. The slow process, however, consumes this excess iodine until iodine concentrations return to levels low enough for the fast autocatalytic process to start up again. What is noteworthy concerning this reaction is that it is *mutualistic*: on its own, the slow process only works when iodine is present, the fast autocatalytic process only operates when iodine levels are low.[7]

Reactions of this kind lead Juarrero to conclude the following:

> *The difference between physical dissipative structures and autocatalytic chemical ones is significant enough: in the latter, the closure of a chain of positive feedback processes (A -> B -> C -> D ->… back to A) creates the boundary conditions within which the macro systems level self-organizes.* And what's important is that these processes, these dynamics, are not "other than" the operations of the lower level—they *are* the operations of the lower level, now newly or differently constrained. So there is no external agency that shapes or patterns the boundary conditions as occurs in physical Bénard cells or machines (2013, 6).

And, in *Dynamics in Action*, Juarrero uses these kinds of internal dynamic interactions to develop a hierarchal ontology. When networks of autocatalyic processes or mutually reinforcing dynamics (positive feedback processes) get linked together in a dynamic system, this has the effect of driving "the system far from equilibrium" (*DiA*, 121), and driving "the reaction to a new mode of organization" (*DiA*, 121), driving "the initial regime into a new dynamical organization" (*DiA*, 122) and thereby taking a low-level aggregate of disorganized, uncomplex, and relatively meaningless parts to a higher level of complex and meaningful organization. For Juarrero (1998, 238), the physical make-up of the world, when put into context-sensitive relations generates a hierarchy of complexity where "[c]hemical phenomena can access states that physical phenomena cannot; biological phenomena can access states that chemical phenomena cannot."

In short, Juarrero's criticism of (O6) then is that the origin of complex, higher-order systems is not only through the *external shaping* of the particulars in this way or that way (as we do with machines). And, it is not simply by *externally setting* environmental controls and constraints (as we do with the production of laser light). The origin of certain complex entities can also be explained through the complex, internal dynamics of the lower-level particulars. And, this account of the origin of emergence is a difference in kind.

Polanyi on Field Theory and Regulative Processes

At this point, it is tempting to conclude that Polanyi's account of the origin of emergence was incomplete. He *wrongly* took higher levels to emerge wholly as the result of *externally* imposed operative forces whose presence cannot be found in the particulars that compose those higher levels. We might excuse Polanyi as he was working before complex systems theory, or try to position him as a proto-complexity figure (see Takaki 2013a, 8). However, in this final section, I argue that there are certain aspects of late 19th century/early 20th century developmental embryology that suggest that Polanyi did not fully accept (O6). Polanyi's use of embryological research that aimed to synthesize both bottom-up mechanistic and top-down vitalistic causal forces in embryological development (e.g., Hans Spemann's use of the organizer) suggest that Polanyi held a view similar to Juarrero (although for different reasons). That is, I will suggest a way of reading Polanyi's use of embryological work that has him say that the origin of complex living things is *not the result of external forces* but is rather the result of *complex, non-deterministic internal interactions*.

Despite his general claim that the origin of emergence is external to the lower-level parts, Polanyi says—with respect to living things—that the origin of higher-level entities is through a process of *maturation* and maturation is driven by factors internal to the system. Polanyi writes that "[n]o new creative agent, therefore, need be said to enter an emergent system at consecutive new stages of being. Novel forms of existence take control of the system by a process of *maturation*" (*PK* 395). If living beings are driven to emergence through a process of maturation, Polanyi points out that it is necessary then to explain whether the process of maturation (or the increasing development of higher-order levels) is "predetermined from the start," the result of an "external creative agency," or driven by some third way (*PK* 395).

In discussing DNA, Polanyi writes that the "[g]rowth of a blueprint into the complex machinery that it describes seems to require a system of causes not specifiable in terms of physics and chemistry, such causes being additional *both to the boundary conditions of DNA and to the morphological structure brought about by DNA*" (LIS 231-232, my emphasis). Polanyi pulls from the neo-vitalistic work of Driesch, as well as field theorists like Paul Weiss, Hans Spemann, and Waddington to explain the missing "system of causes" that direct the growth of morphological features (*PK* 354-359; *TD* 42-3, 46; SC 219). Given (O6), we would expect to find that this missing system of causes, one that would account for the maturation of things to the point of emergence, is *external* to the structures that are the result of DNA. But, drawing from figures like Driesch, Polanyi claims that the tradition of developmental mechanics in embryology (e.g., Wilhelm Preyer, Wilhelm His, Wilhelm Roux, Jacques Loeb, T. H. Morgan, et al.) need not be abandoned but rather supplemented with organismic principles and a more holistic outlook.

To see this more clearly, it is worthwhile to point out that Polanyi was impressed by a series of experiments that Driesch performed to undermine Roux's version of the *mosaic theory of development* (cf. *TD* 42-43, 46). According to Roux, hereditary particles in cells are distributed in a qualitatively imbalanced way when the cell undergoes division.[8] This uneven distribution of hereditary particles meant that the potentialities of individual cells became increasingly restricted and associated with the development of one tissue type or another. By the time the organism had fully developed, each cell type contained only the hereditary particles that determined that cell type. That is, skin cells had the "hereditary particles" that determined skin cells. Roux's mosaic theory was testable: if hereditary information is equally distributed throughout the blastomeres, then destroying the blastomeres or cells that contained hereditary particles that specified the development of a particular cell type should lead to abnormal development. In that case, that organism should fail to have the corresponding cell type that it determines. In 1883, Roux tested this theory by destroying (but not removing) one blastomere in a two-cell frog embryo with a hot needle. The results were a collection of half-embryos, leading Roux to conclude that an embryo's differentiation proceeded according to a bottom-up, mechanical process where the different cell types were entirely determined by hereditary particles.

In 1891, Hans Driesch tested Roux's mosaic theory of development by using the eggs of a sea urchin. Once the single-celled zygote became a two-celled embryo, Driesch separated the blastomeres of the sea urchin embryo using seawater and found that when the blastomeres were allowed to develop in isolation, each formed a normal albeit slightly smaller sea urchin larva. Thus, in contrast to Roux's mechanical mosaic view of differentiation where embryological development was a result of the uneven distribution of hereditary material, Driesch took the embryo to be a "harmonious equipotential system," one where the parts of the system were equally able to produce a whole organism. That is, the system as a whole was capable of reacting to imbalances between its parts through a process of *self-regulation*. Such self-regulation was certainly recognized in the capacity of lower-level species like hydra, which have the capacity to *regenerate* damaged parts, but Driesch's experiment was novel in that it implied that something like regeneration was occurring in higher-level species, albeit in their early stages of development (see *PK* 355). Driesch thought that this holistic, self-regulative power was *not materialistic* in nature, claiming that it was instead "guided by an 'entelechy', an organizing, directive force that consumed no energy, was immaterial" and was "the factor that distinguished living from non-living matter" (Allen 2005, 271; cf. Driesch 1913).

The debate between Roux and Driesch has ontological implications. Roux's results support a kind of *reductive materialism* insofar as an organism's development can be understood as *bottom-up* causal-mechanical forces operating on isolated parts. That is, Roux's experiment takes the isolated parts (hereditary particles) to be *fundamental* and completely determinative of higher layers of reality (specialized cells). These parts were fully predictive of the embryo's differentiation. While studying higher layers of reality is informative and instructive for scientists, all higher level entities and their interactions could be predicted by the analytical approach, namely by investigating the parts of a system in isolation and then calculating the behavior of higher-order interactions. In this kind of analytical mechanistic tradition, interactions between parts produce increasingly complex *quantitative* problems, not new *qualitatively* different properties. In contrast to this kind of reductive materialism is Driesch's *vitalism* (or neo-vitalism). Driesch, in pointing to the capacity of the embryo to self-regulate, adopted a *holism* where the complex organism reacts in a *top-down* way to direct the activity of its parts. In the context of experimental biology in the late 1800s/early 1900s, neo-vitalistic theories like Driesch's argue that regeneration, organized behavior, and self-regulation were behaviors that required a top-down, regulative force. Such behavior, so it was claimed, could not be adequately explained no matter how far the reductive approach extended its computational capacities. In short, Roux and the school of developmental mechanics in biology took maturation to be *internally* "predetermined from the start" while Driesch understood it to be the result of an "external creative agency" (*PK* 395).

Polanyi contends that there is a third way, one that synthesizes the two approaches. He writes that the "regulative principle of Driesch and the mosaic principle of Roux-Weisman actually operate in combination" (*PK* 355). In contending that there is a third way, the effectiveness of Juarrero's criticism of (O6)—i.e., whether the *origin* of higher layers of reality is always "external" to the lower-level parts—hinges on the specifics of Polanyi's synthesis of *mechanistic* and *organismic* accounts of maturation. I will not go into the details of Polanyi's knowledge of experimental embryology nor will I give an exhaustive account of the ontological implications that Polanyi drew from this work. Instead, my goal here will be simply to point out that Polanyi's view is more complicated than Juarrero's objection seems to assume.

Polanyi's synthesis of the two views relies on Hans Spemann's notion of "localized embryonic *organizers*" (*PK* 355), the "embryonic field" of Spemann and Paul Weiss, and the concept of "competence" and "epigenetic landscapes" of C. H. Waddington (see *PK* 355-356; cf. LIS 232). The notion of "localized embryonic *organizers*" (or Spemann-Mangold organizer) refers to a cluster of cells situated in a certain region of the developing embryo that are responsible for inducing further differentiation and development. The influence of these localized embryonic organizers effects development by way of an "embryonic field", an organizing force thought to *extend beyond* the embryo itself much like magnetic force extends beyond the spatial limits of a magnet.[9] Such organizers do not strongly determine tissues to certain developmental fates. Instead, a landscape of different outcomes is possible and Polanyi writes that tissues had to be "competent" or intrinsically prepared for development. Thus, organizers don't strictly determine but have an *evocative power*. At an early stage of development, organizers are highly centralized in the embryo and capable of evoking a wide variety of different possible outcomes from the parts. However, as the organism becomes increasingly developed, and its parts become increasingly differentiated, organizers become increasingly localized and dedicated to more specific developmental tasks. As development occurs, the organism becomes more and more mosaic-like and the equipotentiality of the organism as a whole became increasingly diminished (see *PK* 356).

In interpreting Spemann's organizer, Garland Allen identifies a change in Spemann's thought that bears on Polanyi's view. Whereas early on Spemann thought that induction was a "simple mechanism, such as pulling a trigger, from which a whole sequence of events proceeded," he began to see it more as a holistic, interactive process.[10] This type of holism was *not* the vitalism of Driesch. Rather it was a *holistic materialism* (dialectical materialism) such that "all processes can be best understood in terms of the interaction of opposing forces, or agents within a system, and between any system and its external environment."[11] Allen (1975:120) writes that Spemann saw the "initial induction produced a reaction in some target tissues, which in turn influenced the future activity of the inducer. It was not a one-way military hierarchy, but a multidirectional system of many interrelating effects."[12] Thus, if emergence in living things is through a process of maturation, and maturation is through an internal, multidirectional, interactive process between inducers and induced tissues, then the origin of higher-order living things is *internal* rather than external.

Supposing then that Polanyi accepted the supposed synthesis of Roux's mechanistic approach with the holistic approach of Driesch in the work of Hans Spemann, Weiss, and others, we might contend that Polanyi's position concerning the origin of emergence of living things was this:

> *Polanyi's Embryologically-Inspired Account of the Origin of Emergence*: the emergence of complex, higher-order living entities is (i) a continuous, mosaic development (not a hierarchy of discrete layers nor a quantitative increase à la preformationism), (ii) this

> development was partly the result of mechanistic and organismic (regulative) processes, (iii) differentiation moves from a state where the system as a whole is highly flexible (parts are highly equipotential) toward one that involves increased (but not total) rigidity (parts are differentiated and dedicated to certain tasks), and (iv) the controlling force undergirding such organismic (regulative) processes is not vitalistic but field-like and explainable in terms of the system's internal and multidirectional dynamics (see *TD* 43; LIS 232).[13]

Given this picture, (O6) might be revised as follows:

> (O6*) *Internal-External Origin Thesis:* Higher-order entities emerge when either (a) the parts are put into certain functional relationships by some *external* entity, e.g., machines or (b) the parts integrate into certain functional relationships through mechanical principles and *internal*, multidirectional dynamics.

Attractive as this may be for an interpretation of Polanyi, it is somewhat difficult to discern whether Polanyi actually held this view or if he drifts toward a more vitalistic position.

On the one hand, there seems to be confirmation of (O6*) in what Polanyi says when writing about a parallelism that exists between the *structure of comprehension* and *morphogenesis*. He remarks that the two kinds of *biological achievement* are parallel to the two processes of *morphogenesis*. First, there are achievements that are "performed by the rational concurrence of several parts with fixed functions" and these parallel those "machine-like" processes that are "present in the stratagem of independent interlocking morphogentic sequences, based on a mosaic of fixed potentialities" (*PK* 357). This is the mechanistic view of Roux or the idea that there are regional organizers. Second, there are achievements that are "performed by the equipotential interplay of all parts of a system" and these parallel those "integrative" processes "induced by the field of an organizer, as well as in the autonomous morphogenetic responses of isolated tissues" (*PK* 357).[14] In this case, we don't have the acceptance of Driesch's vitalistic claim, but the synthesis relying on Spemann's work mentioned above.[15]

On the other hand, sometimes it appears that Polanyi might understand the above synthesis in a vitalistic way. For example, in Polanyi's discussion of the conception of the generalized field (see ch.13, §5 of *PK*), Polanyi recalls the parallelism mentioned above (*PK* 357) and extends it in several ways. Perhaps the most striking is that he attributes *unspecifiable yet identifiable entelechies* to embryos. Polanyi posits a parallelism between an agent's capacity to attain some successful intellectual achievement (e.g., the resolution to problem) and a corresponding intellectual capacity in embryos. The morphological development of living beings is guided by a biotic notion of success and the achievement of this success involves the organism calibrating itself with some notion of *morphological rightness* in view (see *PK* 398). Polanyi seems cognizant that this commits him to a kind of *vitalism* that many would regard as "spooky," for he remarks that most biologists would reject "the assumption that living beings have peculiar faculties for achieving biotic success, on the grounds that this would impute to them magical powers which could explain anything" and that biologists are likely to treat this power as "mere speculation" (*PK* 399).

Conclusion

In this essay, I have tried to give an account of how Polanyi's account of the *origin* of the emergence of higher-order entities is more complicated than Juarrero gives him credit for. I did this by pointing to Polanyi's understanding of the metaphysical significance of experiments performed in embryology and morphology in the late 1800s/early 1900s. I argued that the way to understand Polanyi's model of emergence of living beings requires dealing with his understanding of late 19th/early 20th century developmental embryology. While I did not provide a complete account of Polanyi's view here, in my sketch of his position, I took Polanyi to draw his account of emergence from those embryologists (Spemann, Weiss, Waddington) who tried to synthesize Roux's bottom-up reductive account with Driesch's top-down vitalistic account. I noted that this view is sketchy and Polanyi may not have been committed to such a synthesis. He may have preferred a more vitalistic understanding of emergence. If the latter is the case, then Juarrero's criticism of him sticks. To try and explain the co-constituting and co-evolving nature of things by appealing to a kind of vitalistic force regionally located in specific morphogentic fields would be to (i) appeal to something *other than* the parts that compose it (some external force) and this would (ii) betray an inclination of Polanyi to retain the modernistic assumption that the only kind of causes are top-down or bottom-up efficient causes.

ENDNOTES

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[1]Abbreviations for this paper follow the following conventions: *SFS*: (Polanyi 1964 [1946]); *PK*: (Polanyi 1962 [1958]); *TD*: (Polanyi 1966); Wesleyan: (Polanyi 1965b); *KB*: (Polanyi 1969); Duke: (Polanyi 1964); LIS: (Polanyi 1968; also in *KB*: 225-239 [copy cited here]); *SC*: (Polanyi 1965a; also in *KB*: 211-224 [copy cited here]). *DiA*: (Juarrero 1999).

[2]In Part III (chapters 14-15) of *Dynamics in Action*, Juarrero gives her proposal for how to explain activity in open, complex systems and she offers a brief outline of its social, political, psychological, and ethical implications of this new model of explanation. In contrast to covering-law models of explanation, which are deductivistic, acontextual, ontologically deterministic, which attempt to rid the universe of all aspects of randomness, and which seemingly ignore idiosyncratic events in favor of lawful regularities, Juarrero's *hermeneutic model* differs in many key ways. Explanation of action is context-sensitive, is sensitive to aspects of reality that are *indeterministic* and *unpredictable*; it is one that attempts to move back and forth between an understanding of the whole in terms of its parts and the parts in terms of a larger whole; it is a *fallibilistic* model, one that is sensitive to the fact that new information about the agent or the agent's previous behavior calls for modifying one's explanation; it is a model that focuses on explanatory *narratives* that often proceed by trying to explain why an individual acted in one way over another. With this new logic of explanation and account of action in systems theory, Juarrero contends that we get a new understanding of *free* action, one with important implications for how we conceptualize decision-making in the real world, how we account for resolve and weakness of the will, how we think about teaching children, developing and resetting habits, what type of social systems we should develop, and how to think about the gains and losses involved in being a part of a social system.

[3]For reviews of this book, see Adams 2001, Riley and Turvey 2001, Towl 2001, and Pols 2000. For a helpful précis of *Dynamics in Action*, see Juarrero 2000.

[4]For a useful overview of three arguments Polanyi uses to block ontological reduction, see the argument from the correspondence thesis (Margitay 2013a:42-43), the argument from dual control (Margitay 2013a:43), and the argument from identification (Margitay 2013a:44). For debate over these arguments and Margitay's criticisms of them, see Gulick 2012, Kertész 2012, Agler 2013, Apczynski 2012, Héder 2013, Takaki 2013b, Lowney 2013; cf. Margitay 2010, Margitay 2013a, and 2013b. For the development of these ideas in Polanyi's work, see Mullins 2013.

[5]*TD* 44; cf. *TD* 45, 49; Wesleyan V:4; cf. Juarrero 2013:2.

[6]In addition, Polanyi distinguishes between the *mind* as a "from-to" experience and the subsidiaries of this experience as a bodily mechanism (LIS 238). If we take Polanyi's so-called correspondence thesis in the weak sense—where the structure of tacit knowledge is parallel to the structure of ontology—then Polanyi is saying that the mind and mental properties are on a higher level and emerge out of neurophysiological processes.

[7]Despite the dynamics of certain reactions being characterized as *endogenous*, these reactions nevertheless depend upon the environment in which they are enmeshed. The BZ, BR, and related chemical clock reactions operate until certain reagents get burned off and so the internal dynamics of these systems and the boundary conditions set by this kind of positive, mutualistic, runaway feedback is at least partly fueled by interactions *external* to its internal dynamics. All of this is to insist that when discussing whether the origin of complex entities is internal or external, the debate is not a genuine dichotomy. We are not dealing with a perpetual motion device or a Keely motor. The origin of complex entities depends importantly on (to use Juarrero's language) certain interfacing with the environment.

[8]For various accounts of Roux's famous "pricking" experiment, see Spemann 1938:18-21 and Allen 1975, 2005.

[9]See Spemann 1938, 298-299.

[10] See Allen 1975, 120.

[11]See Allen 2005, 268.

[12]For more on this, see Hamburger 1969, 1123.

[13]Polanyi saw embryological development to be a combination of mechanistic and regulative (organismic) principles. He writes that the "regulative principle of Driesch and the mosaic principle of Roux actually operate in combination" (*PK* 355). That development was directed by two principles "(1) Its division into areas of fixed determination lends it a machine-like structure; (2) the regulative powers which mutually adjust the several areas of fixed potentiality, and preserve equipotentiality within each area, represent, on the other hand, an organismic principle" (*TD* 43).

[14]In characterizing the so called equipotential interplay of all parts of a system, Polanyi is referring, on the one hand, to creative, skillful behavior and characterizes this not as an external control of the body (e.g., some kind of mental movement of the limbs to paint a picture) but as "an independent force operating *through* the body in combination with the existing machinery of the body" (*PK* 335). On the other hand, he is referring to the capacity of wholes to self-regulate and creatively adapt given alterations to its parts.

[15]Polanyi sees Spemann as accepting this type of parallelism for in a footnote in *Personal Knowledge*, Polanyi quotes at length (with some emendation) a passage in Spemann's *Embryonic Development and Induction* where Spemann writes that the field's behavior is "not a common chemical reaction" and is comparable to "nothing we know in such a degree as to those vital processes of which we have the most intimate knowledge, viz. the mental ones" (see *PK* 338 n. 4). In addition to the instance cited above supporting this synthesis, see also Polanyi 1951:109.

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