

A Process Ontology (draft) ¹

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Abstract

The paper assumes that to be of interest a process must be understood as physical action that takes place in the world rather than being an idea in the mind. It argues that if an ontology of process is to accommodate actualities, it must be represented in terms of relative probabilities. It is argued that folk physics cannot accommodate this, and so the paper appeals to scientific culture because it is an emergent knowledge of the world derived from action in it. Process is represented as a contradictory probability distribution that does not depend on a spatio-temporal frame. An actuality is a probability density that grounds the values of probabilities to constitute their distributions. Because probability is a conserved value, probability distributions are subject to the constraint of symmetry and must be zero-sum. An actuality is locked-in by other actualities to become a zero-sum symmetry of probability values. It is shown that the locking-in of actualities constructs spatio-temporal locality, lends actualities specificity, and makes them a contradiction. Localization is the basis for understanding empirical observation. Because becoming depends on its construction of being, processes exist as trajectories. The historical trajectories of evolution and revolution as well as the non-historical trajectory of strong emergence are how processes are observed to exist.

Keywords: ontology, process, probability, contradiction, emergence, historical science

1 Introduction

The word ontology is used in multiple ways, but its meaning seems opposite in philosophy and in the sciences (Ceusters [2011]; Guarino, Oberle, and Staab 2009). In information science ontology draws on data sets to create a controlled vocabulary that is explicit, authoritative and unambiguous and that has an organized taxonomy to convey meaning. This semantic meta-model is then used to construct a domain of knowledge that is true to the data set, machine readable and perhaps even universal. The philosophical meaning of the word is less precise, but perhaps basic to it is that instead of starting with data sets, philosophy sees ontology as the investigation of the existential status of conceptual entities; questions are asked about the relation of a concept to other beliefs. For example, to how does the notion of process accommodate our concept of being or reality?

This difference is brought up because the word ontology in this paper, while it respects the aim of information science to construct a controlled vocabulary, rather than its foundation being statements of fact inferred from a given data set, it will instead be the pre-conscious bodily experience of action (Bower 1986). The philosophical concern for existential meaning is respected, but it is not anchored by concepts, but by physical processes.

A process is widely seen as the empirically differentiated state of an identity over time. A fundamental criterion of this difference is the extent to which an outcome is predictable based on knowledge of a prior state. In the historical sciences such as cosmology, geology, bio-evolution and historiography the limitations of prediction are attributed to the determination of a future trajectory by the present state of affairs rather than simply its past. If this recursion or positive feedback is non-linear the outcome rapidly becomes unpredictable even though it remains deterministic in principle. This sharply contrasts with the experimental sciences in which prediction plays a central role because outcomes are viewed as unequivocally determined by causality, more by the closed past than the open present. This criterion of predictability (Cleland 2002) will not be adopted here because it is an artifact of epistemology rather than arise from action.

Here the criterion of difference will not be predictability but relative probability. A failure to predict is because an outcome is improbable in reference to a prior state rather than because of cognitive limitations. This implies that historical and experimental sciences differ only in the relative probability of the outcomes they study. So, with one exception to be discussed, all processes are in principle historical. That is, outcomes in experimental science deviate from what is predicted, but an explanation is nevertheless warranted if it falls within a Gaussian standard deviation. While historical sciences address processes that have far more improbable outcomes, their trajectories are not a random drunk man's walk, but are to some degree a function of the past and to that limited extent are probable.

The paper would be viewed as programmatic if it merely proposed an alternative conception of process that might better support future research. Such manifestos are criticized because they impose cognitive rationality on research programs rather than support discovery in the present (Motterlini 2000, *passim*; Whyte 1950, pp. 92-99). Behind this debate over rationality versus discovery

seems to be the issue of whether the world is assumed to be closed and thus rational, coherent and deterministic, or if it is instead open so that discovery is of the improbable and not governed by deductive logic. Furthermore this paper is not an ideal alternative to current practice if it manages to resolve conceptual dichotomies and logical contradictions that have often hindered scientific progress and if it facilitates improbable action in the present.

2 Action Foundationalism

Unlike cognitive processing or phenomenal sensation, which assumes that the properties of one thing cause a change in those of another, it will be argued that “agent” and “object” are constructed by a process and so lack the functions implied by the labels. That is, rather than an interaction of a priori hypostatized entities, it is action that lends things existence. If so, ontology is not a conceptual tool that a cognizing agent brings to bear on an independent world, for here the agent and world will merely be aspects of one process. This is sometimes argued for scientific theory in general (B. Smith 2008b). Because both the world and its conception are artifacts of one process, the paper happily escapes the troublesome realism/anti-realism debate.

A primacy of action has a rather profound implication, for it then cannot be accommodated by a spatio-temporal frame. This is because all action is in the present and actualizes possibilities that lack location. So accounts of change typically represent action as the secondary effect of some primary determination, which unfortunately draws explanation into an infinite-regress that begs the question of change. An identity’s differentiated state only shows that change has taken place and fails to explain change itself. This leaves process itself mysterious.

If this paper does manage to construct a physical mechanism of process that is independent of a spatio-temporal frame, it could well be the first available naturalistic representation of process in the literature, or at least in modern Western literature. In eastern traditions there is the principle of wú wéi 无为 (Hershock 1996, pp. 9–14, 156–167) in which action is not caused by a local intention but is enabled by the world’s non-local possibilities.

To view a spatio-temporal frame as secondary or epiphenomenal is certainly not intuitive. It exposes the difference between a “scientific image” of the world and the “manifest image” that employs that frame to make the experience of daily life intelligible (Sellars 1963, pp. 1-40). In cognitive science this manifest image is known as folk psychology (Stich 1992; Bruner 1990) and in natural science as folk physics. Here it will be referred to simply as our “cognitive world”, with the important qualification that it represents only the most probable outcome of genetically-based cognitive processing, not the cognitive possibilities enabled by a distinctively human social being.

2.1 The strengths and limitations of the cognitive world

In the modern West the prevailing ontology relies on the cognitive world and is elaborated as an “entity foundationalism” (Wilson 2012). To suit being mapped to memory, things are represented as closed enti-

ties and systems. These are static states of affairs that are defined by intrinsic properties local to points in a spatio-temporal coordinate system (Weatherson 2002; Butterfield 2010). Because entities preclude the primacy of other determinations, change arising from their relation becomes one of necessity. Explanation then consists in the discovery and description of the apparently necessary relation of empirical changes. It is known as causality.

This entity foundationalism proved remarkably heuristic. A root of Western science was a sixteenth-century belief that the observable properties of things stand in a necessary relation so that the cosmos as a whole thereby becomes coherent and intelligible. Although the belief arose from superstition and a revived Neoplatonic idealism, it supported a rationalist critique of received opinion and offered a basis for a variety of new sciences that have greatly enhanced the efficacy of mankind's action in the world.

However, entity foundationalism is blind to important experiences such as emotion, values, non-local properties and improbabilities, indeed anything that cannot be reduced to local observables. As the result entity foundationalism was from its beginning subject to such challenges as Sturm und Drang. For Nietzsche, the cognitive commitment to being, as in rationality, truth value and systemic coherence, threatens becoming—life itself (Dries 2008). In the twentieth century, it has also proven inadequate in such scientific domains as statistical mechanics, special relativity and quantum mechanics. This has lent support to a widely held view that scientific discovery must go beyond merely the observable properties of entities (Feyerabend 1966).

Today in the West the limitations of entity foundationalism have engendered a skepticism or agnosticism concerning knowledge of the world. This is often a belief that scientific knowledge is nothing more than a social construct. This retreat will not be adopted for two reasons. First, a denial that knowledge has an intelligible relation to the physical world seems an ideological indifference to the fact that most people must live and work under its constraints. Second, it seems an implicit threat to the social consensus a scientific hypothesis needs to become an established theory.

Entity foundationalism's presumption of closure is inimical to an ontology of process in which becoming contradicts being. So this paper will turn to relative probability as an alternative to closure, for the value of probability is extrinsic rather than intrinsic.

2.2 The sensori-motor processing of action

The ability of organisms to choose among the world's real possibilities seems to have arisen very early and is therefore shared by such disparate phyla as arthropods and chordata. They adapt very effectively to the world because through action their sensori-motor system directly engages its real possibilities (Shadmehr, M. A. Smith, and Krakauer 2010; Zimmer 2008). Arising much later was a central cognitive system—a tool to process information conveyed by the sensori-motor system in order to support individuated action less bound by circumstance. To achieve this, cognition segments or samples information conveyed from the sensori-motor system so that it can be framed and mapped to working memory and thereby support cognitive computation (Norton 2003; Norton 2007; Baddeley 2000). But as the result of segmentation and sampling, cognitive processing is unable to access information about processes such as real possibilities. For example, Augustine found it difficult to reduce sensori-motor experience to conscious thought and said of time: "If no one ask of me, I know; if I wish to explain to him who asks, I know not" (*Confessions*, 11.14.17).

It could be argued that joint improbable action by humans gives rise to a socially transmitted ideational

and material culture that greatly enlarges the cognitive world's capacity for improbable action. While this would compensate for cognition's genetic limitations, the focus here will instead be on physical action in general that engages the propensity of things to change. The special case of human action will be a concern only at the paper's end.

The sensori-motor system is an extension of the body. It is commonly believed that bodily action unites body and world in one process in which the body directly engages the world's possibilities (White 1999; Cohen-Cory 2002; Demos 1926). Thus action will not be represented as a causal relation of entities but as a superposition of the processes of the "agent" and the "object" of action in which those functional terms lose meaning. However, it will be argued that engaged are not ideal possibilities but the real propensities of body and world to change, which will be understood in terms of probabilities.

Action is taken to be foundational, and it will be analyzed in terms of probabilities that are non-local because probability is relative. It might seem adventurous to view reality as essentially non-local, but this is not a novel idea. Alternatives to entity foundationalism's localization of reality range from Spinoza to David Bohm.

As for making probabilities primary, there are precedents for that as well. Thermodynamics sees the dissipation of a probability gradient measured in terms of energy as the engine of change. This is appealing because probability is the only property that is universal in the sense that it characterizes the relation of all states of affairs independently of their empirical specifics. However, thermodynamics relies on energetics, on a conservation of energy through its transformations. While this is appropriate for isolated thermodynamic systems and is useful in chemistry, biology, and ecology, it remains one sided and domain specific. A presidential election can certainly be analyzed in terms of energy, but the resulting explanation would surely be impoverished.

To avoid being one sided this paper will boldly adopt a conception of action as a change in relative probabilities rather than infer it after the fact from a change in observables. In so doing relative probability will remain well anchored by actualities so that the conception of the world does not gravitate on one hand toward a reification of abstractions or reduce to the intrinsic properties of particulars on the other.

3 Process as a Contradictory Probability Distribution

An ontology that ventures to enlarge upon the cognitive world necessarily lends unconventional meaning to familiar words, and so there must be definitions that are explicit and precise. Because a process will be viewed as a contradictory probability distribution, of major concern is the meaning of probability. The word is defined in a variety of ways for different purposes (Fitelson, Hájek, and Hall 2013; Krüger 1986). Here, rather than being subjective, probability is taken to be objectively real in the sense that it makes a difference independently of cognition (Krips 1989; Martin 2007). As such it refers either to a distribution of outcomes (frequentist probability) or to an intrinsic property of chance (propensity probability)—a disposition or tendency of certain particulars to produce certain outcomes. While this last meaning might seem close to the how the word will be used here, probability will not be viewed as a property of entities but as an extrinsic property.

A frequentist probability is measured as a percentage of runs, while a singular propensity is most often

measured as a numerical value for a probability that lies between zero (impossible) and one (inevitable). In the physical world these limits for probability are only hypotheticals, for the universal contingency implied by materialism implies that nothing can be absolute. That is, nothing can have a probability of 0, either as absolutely random in terms of frequency (ideal non-contingency) or as absolutely impossible in terms of propensity. Nor can it have a probability of 1, of absolute certainty.

Probability is defined in terms of three parameters. First, probability will not refer to a “property” of things in the problematic philosophical sense of an “abstract” attribute of a hypothetical “substance”. Instead changes in probability will constitute properties; probability is not an artifact of existence but its condition. Second, probability is always relative or extrinsic in that its value depends on other probabilities. To say that things arise from changes in probability distributions is to say that things are not self-contained entities. For a discussion of these first two parameters, see Hellie 2008. Third, a hypothetical probability without a value cannot make a difference and so is not real. While it may be conventional to see probability as the constraint of actual structure on possibilities (Mellor 2005), not only will modal realism not be adopted but the relation of these categories is reversed: possibilities will be viewed as an abstract property of probabilities rather than as ideally a priori to them.

A propensity could be viewed as a tendency of an actuality to become other than what it had been. This perspective cannot be embraced because here an actuality will not be hypostatized and because the implied temporality will be viewed as a secondary effect. In lieu of a spatio-temporal frame, propensity will be the local manifestation of a change in non-local probability distributions. The aim is to prevent structure from becoming an idealist reification.

Less contentious will be the meaning given to the word “improbable”. It will here refer to what is non-probable rather than what is very unlikely: the word will not imply any degree of improbability. The value of probability is variable and depending on other probabilities is more than zero and less than one, ranging from being very unlikely to highly probable. Taken together the different values of probability constitute a “probability distribution”. A probability “density” is the value of probability at some point in a probability distribution.

Two probability densities will be of concern. One is a maximal probability density and the other a localized probability density or more simply an “actuality”. An actuality is both a local density in a probability distribution and is itself a probability distribution. It will be argued that a maximal density is universal in the sense that it references all actualities, and an actual density is local in that it references its own particularity and does so by generating spatio-temporal locality. Probability values that are not actual are “non-local” and so improbable in reference to it.

An actuality is a probability density that lies at some distance from its maximal probability density. Seeing actuality as a probability density will surely displease empiricists who are inclined to think of things as an observable state of affairs arising from a path of least action or minimal free energy. It will instead be argued that paths arise from action rather than paths or degrees of freedom being the ideal condition of action. Because the paper’s ontological monism refers simply to distributions of probability values, there is no room for an ontological distinction of matter and ideal or abstract non-materiality. Non-actual simply refers to probability values that are not actual and thus are improbable in reference to an actuality.

It will be argued that “existence” is a secondary effect of the relation of actualities in a symmetry group, and because this is variable, actualities end up having degrees of existence rather than being either existent

or non-existent. That things exist to a degree that depends on the degree that other things exist is alien to the cognitive world.

A probability distribution is often represented as a vector field. In terms of a spatio-temporal frame a vector has two components: direction and magnitude. When a vector field is viewed independently of this frame these components become rather opaque. Given that the value of a probability is relative, the direction of a probability vector will be the degree to which its value is relatively more or less probable in relation to another probability value, that of an actuality. It will be shown that these directions must be zero-sum. Its magnitude on the other hand will be the degree to which an actuality grounds (also discussed later) a probability distribution to establish its values. Similar to a gravity field, the magnitude of a probability field can diminish to insignificance, but nevertheless remains spatio-temporally unbounded.

To suggest that all things are processes may be conventional but begs the question of just what a process is. The argument here will be that a process is a contradictory distribution of relative probabilities. While this metaphysics cannot be proven or disproven, it gains warrant if it facilitates improbable action in deed and thought. However, the metaphysics means little until it engages the cognitive world through a description of its mechanisms.

3.1 Process: Action in a Symmetry Group

That relative probability is real, primary and universal implies that it is a “conserved quantity”. There is nothing beyond it that can account for its coming into being or disappearance in lieu of a miracle. In thermodynamics energy is also thought of as a conserved quantity: its can be transformed, but the total quantity necessarily remains unchanged in an isolated system such as the universe. While no one quite knows what energy is, it serves as a useful measure of work. Here the point is carried to a more general level, and changes in probability itself rather than just its particular manifestation will be taken, as in statistical mechanics, as the measure of work. That is, work manifests an improbable change in probability. Given that equal and opposite changes in probability are entangled to be zero-sum, the magnitude of both a decrease in probability (“emergence”) and its increase (“dissipation”) is seen as the basis of work.

If equal and opposite changes in probability are entangled, it suggests a basic conceptual unit defined by this balance. Because probability distributions are unbounded, a mereological analysis that presumes a closed unit is of little use. An example of an unbounded unit is Newton’s laws of motion. Because of the conservation of motion, for every action there must be an equal and opposite reaction. The unit employed here is defined by a zero-sum change in probability values and will be referred to as a probabilistic “symmetry group”. While this term was appropriated from mathematics, the concept and argument here will be macro-physical rather than mathematical. A helpful discussion of symmetry is that of Anderson [1972](#). Because probability is conserved, all probability distributions exist in symmetry groups.

Despite the paper’s focus on probability and its theft of some terminology from quantum mechanics, its argument will be that process should be understood as macro-physical action represented in terms of a probabilistic mechanism of grounding and symmetry. This is not to suggest that this mechanism is a necessary condition of process. Rather, a process is simply change in relative probability, and to understand it cognition analyzes it in terms grounding and symmetry. Becoming is therefore spontaneous and *de re natura* rather than caused. Process is “conceived as the mode of existence, the inherent attribute, of matter” (Engels [1940](#), p. 35).

Cognitive processing represents the world in terms that are closed. As the result the world seems logical or coherent and changes appear necessary. In an isolated system the dissipation of observables toward a more probable state must then appear to be the universal engine of change, for the mechanism of grounding and symmetry, being non-local, are not taken into account. For example, the improbable emergence produced by a thermodynamic engine is viewed as a secondary effect of a primary dissipation. These are viewed as separate causally-related processes rather than entangled in a single process of action.

In a symmetry group the entangled equal and opposite changes in probability analyzed in terms of grounding and symmetry will be referred to more simply as a probabilistic “contradiction”. This has nothing at all to do with a “logical contradiction” with which it is frequently confused. Here instead the opposite changes in probability are merely contradictory aspects of one process, of action. Thus a symmetry group is a contradiction, and all contradictions constitute symmetry groups. A contradiction is how a process exists.

3.2 The grounding of probability values by actualities

The value of a probability is extrinsic. While all probability values reference all other probability values, in fact the cosmos is lumpy in the sense that there exists probability densities (actualities) and symmetry groups. To account for this *ab vacuo* would require an appeal to the yet obscure Higgs mechanism. This paper instead cautiously takes the existence of actualities for granted and limits itself to the more tractable problem of how a particular actuality exists by virtue of other actualities.

The mutual referencing of probability values will be characterized as their mutual “grounding” (in philosophical terms, see Audi 2012). Grounding has been seen as a solution to problems associated with causal relations (Norton 2009) and as a move to embrace naturalism (Hovda and Cross 2013), although it will not here be taken to be foundational as in Schaffer 2009. Wilson 2013 objects to the idea that a state of affairs exists by virtue of its being grounded by something more fundamental. However the mechanism of becoming offered here does not presume any describable “state of affairs”, and actual probabilities will not be viewed as being in any way more fundamental than non-actual probabilities beyond their grounding more effectively.

Just why the world has structure is an interesting question. The implication of this paper will be that structure arises because of actualities’ relative specificity and their proximity to maximal probability density. While these features have yet to be discussed, they represent two kinds of specificity, and intuitively specificity does increase grounding efficacy. For example, in the cognitive world causal efficacy increases to the extent an actuality is not fuzzy (Cat 2006). It will be argued that because the proximity and specificity of grounding generate spatio-temporal structure, grounding is *a priori* to it. That is, grounding is a-temporal, and proximity is simply grounding efficacy, with spatial distance being its effect.

Because the cognitive world’s mereology is not adopted, the question of which actualities are in a symmetry group and which are not becomes meaningless. Symmetry groups are not defined by mutual grounding, but by the contradictory and unequivocal changes in their probability values. To keep things simple the only premises needed are that actualities have greater grounding efficacy than other probability values and the degree of this efficacy depends on the specificity of an actuality and its proximity to its maximal probability density.

Three symmetry groups will be discussed. First, an actuality is itself a symmetry group having contradic-

tory actual probability values in reference to its conserved probability value. Second is the contradictory relation of actualities in a symmetry group of actualities that have zero-sum values in reference to the group's conserved probability. Third, in the discussion later of strong emergence, symmetry groups can themselves enter a contradictory relation in reference to the conserved value of the universe. In all three cases decreases in probability balance their increases in order to conserve the probability value of the group.

Analysis will begin with an actuality's probability distribution in which it is a particular density. This distribution is universal in the sense that it has a probability distribution grounded by all actualities in its symmetry group. Other actualities ground as well, but because of group symmetry they do not define a maximal probability density in the actuality's group. An actuality's maximal probability density is the density at which its contradictory relation with other actualities becomes null. At that hypothetical point action cannot occur. To visualize this, the distribution is often described as a "probability well". The well is a distribution of probability values in which its bottom has a probability value of one in reference to all actualities in its group.

All other locations in the well are to a degree improbable in reference to this maximal density. That is, the greater the distance from the bottom of the well, the greater become the degrees of freedom in the sense of the number of probabilities that have equal value. The more proximate an actuality is to its maximal density, the more efficacious is its grounding. Put in terms of the cognitive world, the less probable is a state of affairs the greater is its possibilities and, as will be seen, its causal potency. However, this paper does not rely on degrees of freedom because probabilities are not a possibilities, but always a probability having a specific a quantitative value; a probability value is not an abstract measure and is always qualitatively specific.

One might naturally infer that actualities would exist at the bottom of probability wells because it is their most probable state. However, for a process to exist as such it cannot be located there, where it would suffer heat death. We know on the contrary that actualities are not maximally probable and processes do exist, and so actualities in fact are located at some distance from their maximal probability densities. The reason is that an actuality's self-grounding is more efficacious than the universal grounding of other actualities. This means that an actuality's conserved probability value does not reduce to what other actualities determine as being most probable; its relation to them is always contradictory.

So far there are two references that define the probability of an actuality, its particular self-grounding and a universal grounding by other actualities in its group. However, this is insufficient to constitute a process, for it merely defines a probability gradient lacking being or specificity. For this, locking-in has to be introduced.

3.3 Locking-in: the mechanism of process

The argument will be that actualities exist as a contradictory process because it is subject to a mechanism that is at once local and universal. This mechanism will be referred to as "locking-in". In general systems theory locking-in means a synchronization of the observable behaviors in an isolated system, but here it will be the synchronization of equal and opposite changes in probability in a symmetry group, and is simultaneously particular and general, local and universal, being and becoming.

In reference to its maximal density, which is to say in reference to all other actualities, probabilities that have the same value as an actuality's conserved value will be said to be "accessible" to it. Less probable val-

ues are inaccessible because they are improbable, and probabilities that are more probable are inaccessible because of the actuality's self grounding.

However, this is not enough, for if an actuality's conserved probability were simply its accessible probabilities, it would be a chaotic abstraction that lacks local existence. Instead an actuality's conserved probability represents a selection among its accessible probabilities, its "actual" probability values. What accounts for this selection is a differential grounding by other actualities because of both their specificity and their proximity (grounding efficacy). That is, those actualities introduce a selection among accessible probability values so that some accessible become less and others more probable than the actuality's conserved value. This makes the actuality a contradictory symmetry group.

The "specificity" of an actuality therefore refers to the degree to which accessible probability values have become actual and deviate from the actuality's conserved probability value. It means that the locking-in of actualities is mutually constitutive by lending each other a degree of specificity. As Nāgārjuna suggested long ago, in analytical terms "Without one there cannot be many and without many it is not possible to refer to one" (Nāgārjuna 1987, Stanza 7, p. 80). Important to emphasize is that the word specificity here refers only to a restraint on accessible probability values and not directly to empirical properties.

Locking in not only lends actualities local specificity but at the same time moves them closer to their maximal probability density. This is because, while an actuality's differentiated actual probability values must be zero-sum in reference to its conserved value, it lacks access to values that are improbable in reference to its conserved value. By moving closer to its maximal density it is possible to have contradictory accessible probability values. This movement toward maximal probability density is familiarly known as "dissipation".

To accommodate the cognitive world, process has been analyzed as a interdependence of dissipation and emergence in terms of different reference frames, one being particular and the other universal. In the cognitive world these are subjective perspectives, but ontologically they are real and interdependent. Because the cognitive world draw inferences from observables the actuality appears to be a static entity defined by its self-grounding, an "existing actuality" that is an extension of its "past" rather than a process.

The movement of actualities toward their maximal probability is at an ever slowing pace because the closer they are the fewer are the probability values accessible to them. This is manifest as diminished options, growing inflexibility and ossification. Because dissipation occurs at a diminishing rate, emergence must do likewise. There is fewer surprises and diminished innovation. In general systems theory this is known as system maturation or aging. However, to accommodate the mechanism that accounts for it, it will here instead be referred to as a "deepening" of a contradiction. All processes in principle experience a deepening contradiction.

An ontology of process defines how a process exists through the mechanism of locking-in. This mechanism not only defines the actuality's degree of specificity (being), but makes it become something other than what it had previously been. This would seem to imply that a process is simultaneously a state of affairs and its negation. To reconcile being and becoming, actualization creates new dimensions to accommodate differential states of being for a given actuality in phase space. These new dimensions are spatio-temporal locality. While the past does not exist, it is a real and necessary aspect of becoming known as "block time". For becoming to be real requires its referencing a frame of being.

4 The Historical Trajectories

So far a process has been viewed in isolation, in which case the necessary deepening of its contradiction inevitably leads toward stagnation and inflexibility. However, the world is in fact replete with improbable developments such as revolutionary trajectories and phase shifts that transcend past contradictions to gain access to improbable possibilities. To account for this, attention now turns from the contradiction of an actuality to a contradictory relation of processes in which the dissipation of one balances the improbable emergence of another to be zero-sum.

A process in hypothetical isolation has a trajectory because a locking-in of its actuality's specificity is purchased by the actuality's dissipation toward maximal probability density. Becoming yields novelties, but they are probable. Because becoming and being are effects of the same mechanism, it suggests that actualities always have trajectories. However, to take an actuality's trajectory in hypothetical isolation is of little interest because processes are never isolated, in which case all change would be probable.

Of greater interest are the trajectories of processes in combination, for this means that some acquire an improbable outcome that balances the increased dissipation of another. Three such trajectories are of concern. Two of them, an "evolutionary" and a "revolutionary" trajectory, are historical because the improbability of their outcomes is in reference to existing actualities. Discussed later is a "strong emergence", which has a trajectory that is in a sense independent of existing actualities. In the cognitive world it appears to be independent of its past, while for historical trajectories the improbable future is a function of the past and so can be approximately explained as such.

The difference between an evolutionary and a revolutionary trajectory is that in the former case the existing actualities are only those within its symmetry group. A revolutionary trajectory on the other is also grounded by actualities in another symmetry group. The aim will be to show why an evolutionary trajectory makes revolution both possible and necessary, and why a revolutionary trajectory transcends old contradictions to lay the foundation for a new evolutionary trajectory at a "higher" (less probable) level. Because evolution is slow and revolution is fast and probabilistically incoherent, the former trajectory is often characterized as a stage and the latter as a phase. So a phase shift would be a transition from one evolutionary stage to another less probable evolutionary stage.

4.1 Evolution and revolution

Much of what needs to be said about an evolutionary trajectory has already been covered. The conservation of probability in a symmetry group means that processes can enter a contradictory relation in which the increased dissipation of one, which is known as a "dissipative process" enables the improbable emergence of another, an "emergent process". This contradictory superposition of processes refers to a zero-sum of the conserved probability values of their actualities. It does not imply that the relative specificity of the actualities cease to be locked-in. An example is the thermodynamic engine of a tropical cyclone. The specificity of the Carnot cycle is locked-in with the improbable specificity of the physical properties of the storm itself. Their existence is interdependent in that they enable each other as the two aspects of a contradiction.

A revolutionary trajectory occurs when actualities begin to be locked by actualities in a symmetry group other than their own. That is, a revolutionary phase is an increasing superposition of symmetry groups that

hitherto had been, other than mutual grounding, independent of one another. Revolution's dependence on what is in another group is suggested by such examples as a thermodynamic phase shift that takes place because of a change in outside pressure or temperature. In biological metamorphosis independently programmed cell death (apoptosis) or environmental change opens the way to an actualization of an alternative structural possibility.

Terms are needed to identify the functional distinction of processes that start out as independent, but in the course of the revolutionary phase move toward superposition. The actuality of what will be referred to as an "exogenous process" in one group begins to lock with the actuality of a "revolutionary process" in another to start it on a revolutionary path. At the end of this path the superposition of the two processes is complete, and the result is a single symmetry group that now incorporates one or more exogenous actualities in a new closed symmetry group that therefore opens a new evolutionary stage. If the dissipation of this exogenous process increases, it enables a revolutionary process to actualize improbable probability values.

Unfortunately, this only explains why revolution is possible, not why it is necessary. The mere possibility of action is not action. It becomes necessary if certain conditions appertain. One is that the exogenous process must be able to dissipate more quickly because its exogenous actuality is not very close to its maximal probability density. This rule is *ceteris paribus* because there may be contingencies that move its density in a more probable direction to enlarge the scope of dissipation. Second, what accessible probabilities are actualized by a revolutionary actuality depends on its specificity defined by proximate actualities in its own group.

These contingencies are not of concern here because they engage particular situations. If they are "backgrounded" then revolution becomes a necessary result of the deepening of the revolutionary process's own contradiction. As its contradiction deepens and it approaches its maximal probability density, if the two conditions are satisfied, then to ensure conservation of probability its dissipation necessitates an actualization of possibilities that were hitherto improbable but have become accessible because of exogenous grounding.

While a revolutionary phase is self-negating in that it terminates in a new evolutionary stage, the new evolutionary actualities are less probable than the old. This is because the probability values that were becoming actualized in the course of revolution were improbable in reference to the maximal probability density of the prior evolutionary stage. The new evolutionary stage is not only free of the old contradiction, but starts out at a higher level of improbability because the maximal probability density of the revolutionary process has become defined by improbable actualities. Their relative improbability means they have acquired a greater potency for improbable action.

At the same time, the actualization of these new probability values is subject to a new contradiction for reasons discussed above. This lays the foundation for a possible revolution in the future. The implication is that a possible alternation of evolution and revolution is a bootstrap affair through which actualities become ever less probable in relation to what they had been, while their dissipation toward greater probability because of mutual locking becomes ever greater.

4.2 The localization of processes

The ontology of process has so far focused on the very abstract mechanism of becoming. So it should come as a relief when attention now turns from the mechanism that accounts for the existence of process to its observable effects. This falls under the topic of localization, which is concerned with how processes acquire spatio-temporal existence and empirical properties. The argument here will be that while empirical properties are a subjective construction, they are not for that reason epiphenomenal. Indeed, it will be argued that in a sense they are truer to the world than statements of fact concerning them.

As an actuality actualizes accessible probability values, it generates a contradiction between a static state of an existing actuality and its transcendence of being. Because different states of a process cannot be located at the same point in phase space, a spatio-temporal dimension is created to make them separate. This separation of actualities will now be referred to as their “localization”. Localization refers to spatio-temporal separation of actualities in a symmetry group, but it also implies that an actuality in one group can function as an actuality in another where its effect will be quite different. To illustrate this, an example is useful. It will be a chain of localizations that terminates in a symmetry group that happens to include an observer process for which probability densities end up being static empirical properties pickled in memory.

An electrocardiogram converts electro-chemical signals from the heart into the mechanical movements of a pen. This can be viewed as a superposition of two processes in a symmetry group in which dissipation in the signal circuit balances the pen’s movement to a position that would be improbable were the power turned off. An observation of a constant conjuncture of the state of the signal and that of the pen leads to confidence in their future correlation. This correlation is not illusory, but neither is it an explanation. It is addictive, for the brain provides a dopamine reward for successful prediction and avoidance of standard deviations (Schultz et al. 2008). Although in the historical sciences interest is in deviation, its explanation escapes the cognitive world. For example, a factor analysis simply imposes the methods of experimental science on historical science.

Once the trace left by the pen is deposited on paper it no longer participates in the symmetry group that had included the patient’s heart, machine and pen and is now localized as an actuality in a new group that includes environmental conditions that may in time fade the ink. Localization occurs again when the doctor views the trace, for light reflected from it becomes localized as an actuality in the symmetry group of the doctor’s visual system and there enables the emergence of improbable phenomena.

The photons striking the retina are not the trace, and the phenomena are not photons. The cognitive world’s search for their empirical relation typically appeals to their being analogous. An analog is a reduction of specificity to commonality. While this commonality must become rather tenuous in a chain of localizations, the point is that it deprives explanation of most of what is specific to things. Instead it has been suggested here that the trace merely locks-in the specificity of the visual system’s own electro-chemical probability distribution. No empirical reduction is entailed.

The phenomena are in turn localized as existing actualities in the symmetry group of the doctors cognition. Cognition is enabled to actualize its own improbable possibilities because its specificity is locked in by the degree of the specificity of the phenomena. These cognitive possibilities are also locked in by the doctor’s training and experience, and the emergent cognitive representation is their net effect.

Each step in this sequence, from the actuality of the heart to that of cognition, represents a different sym-

metry group that locks in an actuality that had evolved in the prior step and may or may not become separated from it. Despite continuity because of self-grounding, the actuality has become something fundamentally new in the new group because it has a new probability distribution. The specificity of the trace grounds probabilities accessible to cognition to enable its formation of a cognitive actuality peculiar to its probability distribution, and they lack any necessary empirical correspondence.

But is the doctor's cognitive representation then merely fantasy? The problem here is with the question, not its answer. Being locked-in, the doctor's diagnosis will be efficacious unless there are specific reasons for it not to be such as insufficient locking or a locking by extraneous contingencies. The chain of independent emergent constructions is no reason for skepticism, for in pragmatic terms the doctor's mental state is ultimately locked by the heart's actual state so that diagnosis can well result in cure.

5 The Transcendence of Being

If the ontology of process is a becoming, its nature is to transcend probable being to yield something that is therefore improbable in relation to it. In epistemological terms this improbable outcome is viewed as being "novel" in relation to an existing actuality if it could not have been entirely predicted from it. It is subjective surprise. Because in this paper an outcome is the actualization of objectively real probabilities, a better term is "emergence" (Wilson 2002; Wong 2006). This is because it usefully implies that the relation of being and becoming is subject to explanation.

In this paper, all processes are emergent in the sense that outcomes are to some degree improbable in relation to existing actualities even in the case of dissipation. While reductive explanations enjoy ever greater success in natural science, their measure of success is not unequivocal prediction, but whether prediction falls within a Gaussian standard deviation. This is true of the most accurate of all sciences, quantum electrodynamics. To a significant extent the success of reductive explanation is also an effect of ever greater specialization and a narrower framing of problems.

Emergence comes in two flavors: a weak and a strong emergence (Chalmers 2006). In weak emergence outcomes deviate from what is defined as being probable either by the existing actualities in an evolutionary symmetry group or by the actualities of the revolutionary and exogenous groups in the course of a revolutionary phase. In either case, a full and accurate knowledge of existing actualities provides knowledge of the probable outcome. While a historical trajectory is unpredictable in the long run because there is a compounding of improbabilities, in the short run it is to some degree subject to a one-sided approximate causal explanation. For this reason weak emergence appears less problematic. In sharp contrast, strong emergence bears no relation to existing actualities. Because its outcome is entirely independent of them it is often viewed as irrational, supernatural, or quixotic. It defies the reason and logic that are an artifact of cognitive closure.

5.1 Weak emergence

A standard definition of (weak) emergence is "the arising of novel and coherent structures, patterns and properties during the process of self-organization in complex systems" (Goldstein 1999, p. 49).

This definition unfortunately raises difficulties. Most importantly it is a description without venturing to explain beyond a question-begging reference to self-organization and complexity. Rather than being caused, a weakly emergent outcome “arises”, but what then accounts for it? Herbert Simon’s answer seems to have become conventional. He suggested that emergence arises from complexity, “not in an ultimate metaphysical sense”, but only in the “pragmatic sense” that it is not easy to infer the emergent properties of a whole from its parts (Simon 1962, p. 468). Here explanation yields to description and ontology to epistemology—a costly retreat. Complexification simply refers to the N-body phenomenon that a multiplication of factors makes prediction impossible although the underlying process nevertheless remains deterministic. As the result, it fails to explain improbable emergence and reduces it to subjective surprise.

Another weakness is the definition’s reliance on entity foundationalism’s “systems” perspective. This framework has certainly been useful, for it supported the rise of sciences addressing emergent phenomena such as embryology, geology and political economy. In this scheme properties that do not reduce to the properties of base constituents are assigned to an emergent “system level”—a reified carrier of the emergent properties. It is analogous to traditional philosophy’s positing substance as the carrier of intrinsic properties. Each level in a hierarchy of levels becomes the emergent effect of the next lower level. Because infinite regress would betray explanation, the base level cannot be defined as emergent. It is presumed to be directly knowable because its intrinsic properties are unequivocally manifest in sensory phenomena (Ernst Mach, Edmund Husserl).

That a base level nevertheless supports the emergence of a higher level is attributed to its having some unobservable variable that escapes unequivocal determination. As Alexandre Koyré once suggested, “it is not by following experiment, but by outstripping experiment, that the scientific mind makes progress” (Koyré 1968, p. 80). Today it is understood that scientific knowledge depends on theoretical constructs that do not reduce to observables (Churchland 1988; Pickering 1986). If a broad generalization be allowed, the idea that emergence must involve something more than meets the eye has been pursued either by appealing to an idealist or supernatural ontological category or by expanding upon ontological monism by adding to it real unobservables.

As for idealism, Nicholas Rescher in the standard philosophical work in English on process seems to rely on Hegel. He defines process as an abstract force of change that is actualized in physical matter (Rescher 2000, Chapter 1). Long ago Henri Bergson appealed to a life force (Bergson 1998), although it is not clear his position was really idealist as is commonly charged. Recourse to idealism in the empirical sciences occurs when improbable emergence is attributed to the constraint of circumstance on a random base constituent, as in quantum fluctuation, thermodynamic molecular motion and genetic mutation. Because randomness is not contingent by definition, it gives rise to an ontological dualism. In the social sciences this random factor is implicitly attributed to the presence in human nature of a creative element of divine origin to explain human free choice: the human is a demi-urgos chipped from the divine block.

Among materialist approaches is the suggestion of structuralism that causal relations somehow acquire an existence that is to a degree independent of their nodes (Worrall 1982). Emergent effects can for that reason be attributed to causal relations, although the question of how they manage to do that is left open. Another materialist approach, now understood to rely on a philosophically unacceptable circularity (Churchland 2005), is functionalism. It assigns an observed emergent property at a higher level to a hidden base level property that accounts for the emergent outcome. An approach less problematic, in principle at least, is the one used in this paper. It holds that emergence is due to a factor that is real, albeit hidden or unobservable because it is not local. For examples see Bohm 1980 and Vervoort 2013, S3-4.

The ontological mechanism of weak emergence was described in the section on action in a symmetry group. It suggested that a “weak emergence” refers to an evolutionary or revolutionary trajectory that has an observable outcome that is to a degree improbable in relation to existing actualities because non-actual probabilities have become actualized by locking in.

5.2 Strong emergence

“Strong emergence” can initially be defined in contrast with weak emergence. Paradoxically, while actualities must be locked in to exist, a strongly emergent outcome is independent of existing actualities and will be characterized as being “radically improbable”. That is, existing actualities will not define the norm against which is measured the relative improbability of a strongly emergent outcome, for it is autopoietic and completely new. Because this might seem to threaten the notions of grounding and locking-in, the first question must be whether strong emergence in fact really exists.

There is no agreement over whether it does and if so how to define it and distinguish it from weak emergence. Because it yields a radically improbable outcome, many have concluded it appeals to the supernatural. Nevertheless there has been a tendency to admit strong emergence as an observed fact in the cases of organic life and human consciousness (unconventionally, the Big Bang should be added here). These have served to distinguish the domain of the physical world from those of the biosphere and noösphere (literally consciousness, although here it is assumed to be an artifact of social being). They are radically improbable in relation to existing actualities and could not have been anticipated however weakly.

Assuming then that strong emergence does exist and is not just a gratuitous accident or inherently mysterious, it has certain implications in relation to this paper’s framework. One is that all emergence relies on improbable possibilities being accessible because of grounding and actualized through locking-in. Locking within a given symmetry group makes the degree of specificity of an actuality probable in relation to the degree of specificity of another, but this does not prevent the group as a whole being radically improbable. Human consciousness is radically improbable and so too then is the Brooklyn Bridge, which is weakly emergent in relation to human capabilities. Neither could have been anticipated however weakly from a knowledge of the physical and biological worlds from which humankind arose.

So what is the source of grounding if not by actualities in some group? It is suggested that it is by a process that is an interface between a strongly emergent symmetry group and an exogenous group that has a contradictory actuality. This appeal to an interface seems warranted by actual cases of strong emergence in which there is a mediation or interface between a strongly emergent and an exogenous process. For example, the relation of a strongly emergent (living) organism and its environment is mediated by membranes without which it cannot live.

The actuality of this interface is contradictory because its maximal probability density is simultaneously defined by a radically improbable actuality in the strongly emergent group and a probable actuality in an exogenous group. However, these are not merely different points along a continuum of probability, for they do not share a common reference; without it they are irreconcilable.

Obviously an example is needed. A tool in hypothetical isolation, which is to say not in use, is only a potential tool, an actuality in the physical world. However, when in use it also becomes grounded by the actuality of radically improbable social being (Preston 1998). While this social being has not been accounted

for here, we do know that there is something radically improbable about it, whether it be consciousness or a kind of social being peculiar to humans.

Because there is no common reference for these two probabilities, the interface cannot reconcile them as one maximal probability density. Assuming that strongly emergent social being is actualized in individuals, they define the tool's maximal probability density in accord with human needs. On the other hand, the maximal probability density of the tool is also grounded as an actuality in the exogenous group. Because of this contradictory maximal probability density, the interface locks the two symmetry groups into a contradictory state in which the strongly emergent process is locked by the interface rather than the dissipating exogenous process. Should the tool cease to function as an interface, it will collapse back to become once again only a weakly emergent actuality in the physical domain or historical artifact.

Of course this scenario begs the question of how strong emergence manages to start in the first place, for its existence presumes its existence. This would properly be the subject of different paper, for it involves a bootstrap operation that engages a variety empirical specifics. But broadly in the case of the tool, the weakly improbable social development of the tool to meet human needs increases the efficacy of labor for the production of a yet more improbable outcome. That improbable outcome is surplus value, the magnitude of the improbability of cumulative ideational and material culture that, to use a popular term, ratchets. This surplus value enhances the improbable action of individual, and as the tool becomes localized in the symmetry group of economic production it comes to produce surplus value rather than merely adapt to circumstances. At that point, a distinctly human social being has emerged in which the individual has acquired radically improbable powers of action.

The persistence if the contradiction of an exogenous and a strongly emergent process helps distinguish strong emergence from a revolutionary weak emergence. Revolutionary emergence is self-negating and ends in an independent weakly emergent evolutionary stage. In strong emergence the revolution is permanent in that the interface depends on and perpetuates an ongoing contradiction. As the Red Queen put it in *Alice in Wonderland*, "Now, here, you see, it takes all the running you can do to keep in the same place". A result the outcome, *ceteris paribus*, becomes ever less rather than more probable, as in speciation or science's ever greater support for improbable action in the world.

In the literature is a belief that strongly emergent processes acquire "autonomy". This word can imply opposite things (Timpanaro 1975, pp. 39-41), one being epistemic and the other ontic. It is frequently seen to result from recursion or complexification (Hauser, Chomsky, and Fitch 2002 provide an example in linguistics). However, there is nothing in unpredictable recursion or complexification that escapes the regime of a causal relation of entities in a dialectical interaction. This leaves emergence a miracle. In social studies autonomy has traditionally been given an opposite and idealist meaning as an independence of consciousness or action from physical determinations. Philosophers have struggled mightily to avoid having a mind-body duality slip naturally into an ontological dualism. Because of its dependence on observables, neither meaning of autonomy is of use here, where it instead refers to a radical improbability in relation to existing actualities.

If the interface were to collapse, the strongly emergent process would become a weakly emergent evolution. For example, should the metabolism enabled by membranes cease, so too would life, and the organism would reduce to a collection of organic molecules. Death here is not so much a collapse in physical complexity as a contradictory relation of an organism with an exogenous process. For humans, if social contradictions deepen, social being atrophies. Human life becomes reduced to biological needs and consciousness

to the genetically determined cognitive world.

6 Conclusion

The paper has tried to define the ontology of process in a way that is naturalistic and can be represented in cognition. This representation is not intuitive, but employs theory arising from past improbable social action enlarged upon by the action of an individual social being in the present. It represents the world as processes that have possibilities grounded by but not in thrall to their “past”. More specifically, a process is a contradictory probability distribution continually in motion because its actuality is locked by other actualities in its symmetry group so that it is simultaneously both more and less probable, is both a being and becoming.

A major advantage of this approach is that it conjoins local specifics with what transcends them; it weds being and becoming without recourse to a reified totality, an ideal essence, or a reduction of the world to nothing more than a subjective construction or semantics. It also provides a basis for choosing among hypotheses on the basis of *both* their relative empirical specificity and their universality without having to presume that the conception has a truth value that somehow corresponds with a world independent of cognition.

This advantage is naturally most apparent in the social sciences where the concern is to explain improbable human action. The issue of the contradictory relation of free (autonomous) individual agents and the determination of reified and persistent social structures has haunted sociology since its inception (Archer 1982; Demerath 1996). It is also critical in western historiography because of the difficulty reconciling casual explanation based on the determination of the particulars of time, place and circumstance with moral responsibility, freedom and creative action (Bambach 1995). Social distinctions need not be viewed as a source of Foucaultian division or in tension with social solidarity, but instead as mutually enabling. This occurs when people act jointly (mutually lock-in) to actualize the strongly emergent possibilities of their social being that arose from society’s productive relation with its natural environment in the labor process. This notion of self-transcendence through social mutuality is hardly new, but traditionally it has relied on the supernatural (Fiske 1965) or does not consider how improbable social value is created in the first place (as in Simone 2008; Kimmelman 2013).

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