Chapter Six

Instantaneous Change Without Instants

David S. Oderberg

1. Introduction

In this essay, I first set out the principles of change, paying particular attention to the need for a support for all changes and to the need for prime matter. I then discuss the nature of time, arguing that time is not actually composed of durationless instants but that instants can be understood as limits to an infinite process of potential division. I then give a definition of instants in terms of intervals and propose a way of modeling them. In the next section I bring together the two previous sections by explaining change as an instantaneous process that does not involve actual instants. In the final section I draw out a larger metaphysical moral that emphasizes the role of potentiality and sees the potentiality in change and the potentiality in time as but different aspects of the same radical potentiality in nature.

2. Principles of Change

Change is an indisputable reality. All natural bodies are mutable or subject to change. Change or mutation is the passing of a thing from one state or condition to another. In traditional terminology, change is a *transition* (*transitus*) from potentiality to actuality. All things (and I now restrict the term *thing* to natural bodies) are finite and as such are a mixture of potentiality and actuality: what they *are* and what they *may become*. A child is potentially an adult and as such is *in potentiality* with respect to adulthood, though it is *actually* a child. A brown table is potentially a red table; a bronze statue of Hercules is potentially a bronze statue of Demeter; a cabbage is potentially food. Not only are all things a mixture of actuality and potentiality and hence subject to *becoming*, but one might tentatively argue a priori that they are in constant *process* of becoming something else. The reason is that being in potentiality means being in a state of readiness to enter one of a range of new states; but to be prepared for this, an object needs to be in a constant state of motion or kinematic reconfiguration in order to receive or enter one state or the other; which means a constant process of change.[1]

A posteriori, it can be seen from current physical theory (which I shall accept for the purpose of argument) that it is impossible for an object to be cooled to absolute zero.[2] Absolute zero is by definition a state of absolute non-motion of the object and its parts. If an object were at absolute zero it would be in a state of zero entropy

or disorder and zero energy, which would be sufficient for it not to be able to reach any new state. This is said to violate Heisenberg uncertainty since the object would have definite zero position and momentum. A crucial assumption of the claim that every thing is in process of becoming is that space and time (or at least time[3]) are continuous and so are not structured in a way that allows discrete jumps from state to state with no intervening periods of change involving preparedness to receive the new state. Quantum theory allows for discrete, quantized change – in levels of energy, for instance – but only against a background of continuous space and time in which other continuous processes, such as electron revolution, are still taking place.[4]

The claim that every thing is in the process of becoming something else is not equivalent to the Heraclitean doctrine that everything is change. The latter, taken at face value, implicitly denies that there are substantially unchanging subjects of change: the very idea that there could be a single, persisting object O which changes from F to G runs counter to the Heraclitean doctrine, since it posits a substantially unchanging subject. It was no misunderstanding for Cratylus to have considered too weak (if not inconsistent) Heraclitus's claim that one cannot step into the same river twice, instead preferring never to say anything but only wave his finger. Heraclitus ought to have said that one cannot even step into a river *once*.[5] Indeed the very idea that *everything* is change (rather than that every *thing* is in process of change) is incoherent because the very concept of change entails the existence of *that which* is changing. At the extreme, we might say that everything within the universe is change – but we must still posit a single, substantially unchanging universe that is changing in respect of its characteristics, in virtue of whose persistence through change it can coherently be supposed that everything within it is change. Change requires a subject of change and by definition that subject does not itself change *qua subject.*

There are four basic kinds of change. A thing can change quantitatively, which involves changes of size, dimension, mass, volume, shape, and so on (these not being mutually exclusive, of course); qualitatively, which involves the loss or gain of qualities such as color, temperature, texture, taste, or more generally causal powers, material constitution, and so on; and it can change in respect of place, via motion (local change). These are *accidental* changes.[6] But there is also substantial change, in virtue of which a substance, conceived as an ontologically independent entity,[7] changes into another kind of substance, such as: the digestion of a plant into nutrients capable of metabolism by an animal; the hydrolysis of water into new chemical compounds; the decomposition of water by electrolysis into hydrogen and oxygen; the transformation of a carbon atom into a boron atom by electron capture;[8] the change of a living body into a corpse. All of these kinds of change involve the same fundamental process consisting of five elements: (i) a thing to be changed, whether substantially or qualitatively (I will use the traditional term "accidentally"); we can think of this as the *initial state*, as long as we remember that the state is a state of some thing.[9] It is from the initial state that the change (or movement, in the broad sense) begins; (ii) the thing resulting from change, which we might call the terminal or resultant state,[10] in which the change or movement

finds completion; (iii) a subject of change, best understood as a substantial support of the change; (iv) an agent or force which produces the change; (v) an actual *transition* or movement in which the change essentially consists.[11]

The first and second elements should be acceptable enough but something needs to be said in defense of the other three. As to the need for an agent or force to produce change – in short, an efficacious cause – we need to note that this requirement derives from the very fact of change understood as the actualization of some potentiality or other. The presence of a state of passive potentiality – and here the term "passive" must be brought in as a qualifier[12] since we are not talking about active potentiality or the power of a thing to act or behave in a certain way but the power of a thing to receive an alteration – involves the correlative absence of the actualizing principle which is the terminal state of the change (in Aristotelian terminology, the *form*). And the actualizing principle or form cannot be said to be already *in* the potentiality, since this would be tantamount to denying change altogether; it is not right to say that greenness is already *in* the potential of a red wall to become green. Greenness is nowhere in the red wall before it receives a coat of green paint: all we can correctly say is that the red wall has the potential to become green. But then if the new form (the resultant of change) is not in the potentiality of the thing to be changed, but is truly absent, there is no way that potentiality can *of itself* produce greenness – for, as the axiom goes, *nemo dat quod non habet*: you cannot give what you do not have. Hence there must be an efficacious cause, such as a painter, which operates to turn the red wall green, his paint and a paintbrush working in the appropriate way. The same goes for all kinds of change: whatever changes or moves is changed or moved by another.[13]

As to the substantial support of change, we can see that in the case of accidental change – qualitative, quantitative and local – the support is precisely the bearer of the accidents: when a red wall is painted green, it is the wall which supports the change; the same goes for micro-level change, for instance the ionization of an atom, where it is the atom that undergoes accidental change. The same applies to local change, where the support is the thing which moves;[14] and again, this applies as much at the micro-level as at the macro level – the emission of an alpha particle[15] from an atom of uranium 238 involves the movement of the particle. But what about the case of substantial change, such as the hammering of a wall into a pile of rubble or the transformation of the atom of uranium 238 into thorium 234 as a result of alpha decay? Here it is not so obvious that there is a substantial support, but it is also by no means clear that the notion of support can be done away with in this type of change. This can be brought out by means of a general argument. There are three alternative ways of explaining substantial change.

Firstly, one might do away with talk of supports altogether. When the wall is hammered into rubble, what changes? The wall pure and simple, it might be said. But to say that the wall itself changes is ambiguous as between substantial and accidental change; the wall also changes when it receives a coat of green paint over its red surface. So how then can we distinguish between the two kinds of change? One might say that when the wall is hammered into rubble it *turns into* something else; but that will not do, since the red wall turns into a green wall when it is

painted; and a child turns into an adult but there is only one human being. Alternative locutions will either inherit the ambiguity of the verb "change," so we will need a new locution to mark the distinction or else we will have to deny the distinction altogether. Denying the distinction is problematic, for what does it mean? Are we to say that all substantial change is really accidental, or that all accidental change is really substantial, or that there is simply unqualified change? The first two options deny the existence of evident facts: some things just do survive change and others do not, so it is incumbent on the opponent to come up with a theory of unqualified change that does not distinguish between survival and non-survival or at least assimilates every change to one or the other. Perhaps certain kinds of process philosophy take this approach, but they are of doubtful coherence if they invoke the concept of a process while refusing to answer questions such as: What is it that undergoes the process? Does anything survive a process? As usually understood, process philosophy denies fixed realities in nature and so might be thought of as advocating only substantial change; but the process philosopher does not want to invoke the concept of substance, even substance that is short lived, since substances are fixed realities. Yet it cannot be only accidental change that the process philosopher believes in, since accidental change entails the existence of a fixed subject of change. The concept of a process is subject to just the same sorts of concern as that of a change insofar as gain or loss of existence is in view.

On the other hand, marking the distinction between substantial and accidental change with a new locution does not explain the phenomenon, it merely names it. So the denier of a support for substantial change has to find an alternative metaphysical account of what is going on when one substance turns into a numerically distinct substance. And the only way, it seems, is to speak of *creation and annihilation*: when the wall is hammered into a pile of rubble, the wall is annihilated and replaced by a newly created pile of rubble. The problem with this account, however, is that in nature there is no pure creation and annihilation. The sorts of phenomena we speak of when we speak of creation and annihilation are ones in which prior material is turned into something else (where we do *not* assume by "turned into" that the prior material *survives* the change – on that question see below): hence the creation of a human being by reproduction is properly called procreation rather than creation *simpliciter*, since the previously existing gametes are the material out of which the child is formed. Similarly, when the wall is reduced to rubble it is the previously existing matter which is turned into rubble. Creation and annihilation, strictly speaking, are out of nothing and into nothing, respectively. In physics it is a fundamental truth that energy can neither be created nor destroyed (the first law of thermodynamics). This simply reflects the metaphysical truth that since all changes in nature require natural causes, and since those causes are finite, and since finite causes cannot create something out of nothing or turn something into nothing, a natural substantial change is not a series of creations and annihilations. Positively speaking, a substantial change is an actualization of the potentiality which some substance has with respect to some new substance: walls can be turned into rubble but not into fish. It is the potentiality which stretches across the change, becoming actualized by it, and so there

cannot have been pure annihilation and creation when one substance is turned into another.

The first way of explaining substantial change is therefore ruled out. The second way appeals to an apparently obvious fact: that when the wall is turned into rubble, it is the *matter* of the wall which survives the change and acts as support. So why can't we simply posit matter as the support of substantial change? The reason is that the support used to explain substantial change cannot be something whose existence during the change is not guaranteed. When the wall is hammered into rubble, some matter survives in the rubble but other matter is dispersed to the winds. The matter of the wall undergoes all sorts of atomic and molecular changes as a result of the hammering: if the wall is pulverized, are we to say that the heap of fine powder before us is the same matter as that of the wall? Even if it is, the fact is that substantial change can occur without the preservation of sensible matter: the matter can undergo radical molecular change, as when flesh is burned to ashes. Is it the quarks that persist? Or some other as-yet-undiscovered particle? According to current physical theory, even quarks can be substantially transformed into other quarks: for example, a quark triplet of (bottom, top, top) can, in virtue of the strong nuclear force, be changed into a triplet of (down, top, top); indeed the bottom quark could also have been changed into a strange or charmed quark. This is held to be consistent with the conservation laws, and according to quantum theory, quark transformation must eventually occur. So we do not yet have any conceptual assistance at the micro-level and there is no reason to think that new particles yet to be discovered will behave any differently. So we must accept the possibility of *total material conversion*. But we must also avoid an infinite regress of substantial changes with no support, which not only makes no progress on the previous predicament of distinguishing substantial change from creation and annihilation but is itself of no explanatory force since the explanation of change must come to an end.

Hence the third way of looking at substantial change, involving the much derided but still sound Aristotelian doctrine of *prime matter* as the true support. Prime matter is not actually a kind of matter but a *wholly indeterminate substrate* underlying substantial change. It is, in other terminology, *pure potentiality*, the something which can be transformed by an actualizing principle into anything which nature allows. It is the raw material of the universe, so raw in fact that it is not in any familiar sense material at all. But it must exist to support substantial transformation, and its existence is a corollary of the very *finiteness* of the natural world and everything in it. Much more can be said, both for and against prime matter, but it is not our principal concern here. It will, however, make a return to the explanatory stage later when the accounts of time and change defended in this essay are brought together and the root of their unity is briefly explored.

Finally, change requires a genuine *transition* from one state to another.[16] The standard contemporary definition of change is therefore inadequate; for instance, "An object undergoes a change if, and only if, it possesses a property at one time and does not possess this property at an earlier or later time."[17] Not only does this formulation fail to cover substantial change but it makes no mention of the need for a transition and hence is consistent with the notion of change as mere *replacement*,

for example, by annihilation and creation. Of course, on a tenseless theory of time it is hard to see how change could be considered to be anything *other* than replacement, but the topic of the A-theory versus the B-theory cannot be explored here. I am taking it as self-evident that change is not mere replacement, that when a red wall is painted green it really does *move*, in a broad sense, from one state to another; that our locutions such as "become," "turn," "develop," and so on, are not mere figures of speech or relics of a stone-age metaphysic; and that any approach which denies this would leave the phenomenon we call change miraculous at best, utterly inexplicable at worst.

How are we to understand the concept of a transition from state to state? We can only do this via a consideration of the role of time in change, and it is this which will now be the focus of our concern.

3. Time and Instants

Time is generally thought, by both philosophers and physicists, to have the topology of the real number line. As it is for the continuum of real numbers, so it is for the continuum of time, which is considered to be constituted by a succession of instants totally ordered by the *earlier than*/*later than* relation. It is arguable that at least parts of classical mechanics can be modeled using time as merely dense and not continuous,[18] but standard models of both classical and quantum physics take time to be continuous; if it were dense this would not affect the argument to be presented here. Further, no standard theory takes it to be discrete.[19] The question to be considered is whether time is made up of durationless instants.

The short answer to the question is that it cannot be, for the reason Zeno originally proposed in respect of lines: if a temporal interval or a line segment were composed of durationless instants or points of zero length respectively, then neither the interval nor the segment could have a length greater than zero. The usual approach to the problem now is to invoke the mathematical consistency of proposing finite sums to series of infinite numbers, but this does not dissolve the paradox since infinite series never literally sum to a finite number, they only *converge* on it as a *limit*. (For instance, the series $\frac{1}{2} + \frac{1}{4} + \frac{1}{8} \ldots$ converges on 1.) Similarly, when derivatives are invoked to model motion at an instant, they are only ever *limits* to an infinite series of measurements: instantaneous velocity, for instance, is no more nor less than $v = lim\ (dt \rightarrow 0)\ dx/dt$. While it is convenient to ignore talk of limits when calculating using such concepts as instantaneous velocity, and while such concepts may be mathematically consistent, the ontological truth is that limit concepts do not denote actual entities. And an instant, conceived of as durationless (not as a fleeting "chronon" or "instanton" of some physical speculation), is just such a limit concept – it is not an actual something, it is an actual *nothing*. And no number of nothings can ever make up a something, no matter what sorts of mathematical technique are invoked.

Yet it has seriously been suggested by David Bostock (or perhaps semi-seriously, as we shall see) that continuum-many points can be constructed into a line. The passage is so striking it is worth quoting in full:

> How *can* we conceive of a line as made up of nothing but points, which cannot touch one another? Imagine that you have an inexhaustible supply of points to hand; how could you 'put them together' (as it were, 'one at a time') so as to make a line out of them? Well, we can say nowadays that the answer is this. First set down a denumerable infinity of points that is dense in the line, for example by putting down the two end-points of the desired line, and then by setting down a further point in the middle of any stretch between two points already set down. (Note that we do *not* try to put the points down 'in succession' from left to right.) When you have finished this (!), then consider all the Dedekind cuts in the points already set down, in other words all ways of separating those points into two groups, with all of one group to the left of all of the other. For each such cut, put in a further point to be the point at which the separation is made (if you do not have one already – that is, if there is not either a rightmost point of the left group, or a leftmost point of the right group). We may note, incidentally, that to complete this stage you will in fact need more than a denumerable infinity of points (so it may take you a little longer than the first stage), but when you have done it you are through. The result is now a continuous line. But although we have a proof of this fact, must we not still admit that it is absolutely amazing? No point that has been put down touches any of the others, and yet the result is a line with no gaps in it anywhere! No wonder that Aristotle could not see how such a construction of the line could succeed. *Indeed, I think I would admit that I cannot exactly 'see' it myself* [emphasis added].[20]

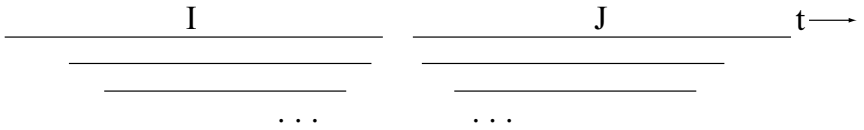
One wonders, with all the scare quotes, exclamation marks, "as it weres," "amazings," "little longers," and the final, rather damning admission, just how serious the author was when he penned these words. The first thing to note is that Bostock takes it for granted that it is possible to construct a completed infinity – all he does is to show you how. Nevertheless the very idea that one can "traverse the infinite," to use the terminology of Aristotle and the medieval philosophers, is highly questionable.[21] Bostock's language (if he is being serious) makes it clear that he believes one can, quite literally, complete an infinite totality. He might as easily have said that you can count to infinity simply by starting with zero and counting one number larger than any number you have counted. Easier said than done, you might retort, and you would be within your rights to do so. Secondly, and perhaps more importantly, is the fact that Bostock appears to have missed the whole point (if one may excuse the pun) of Aristotle's objections. It is not simply the concern that the points will not touch and so not form a genuine continuum; but that they cannot touch because they are *indivisible nothings*! Hence it makes no sense to "put down end-points" or any other points, whether from left to right, in some other sort of succession, or in any way whatsoever. The task is equally impossible for the construction of a dense line as for that of a continuous one.

Nevertheless we do want to assign *some* sort of reality to instants. They might not be actually anything – but they are *potentially* something. They are the potential limit of division of a time interval. In other words, to say that time is divisible into instants is to say that it is *potentially infinite*: there is no actual metaphysical terminus to division, but division can really go on indefinitely. Like prime matter itself, instants are not themselves actual: they are, quite literally, *formless*. But they are a kind of reality, namely potential, and without them the very structure of time

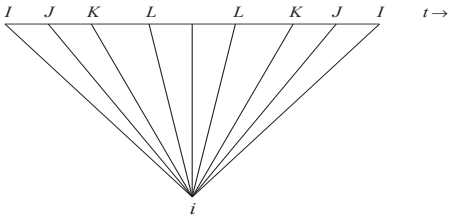
could not be explained any more than motion and its derivatives. Similarly, although there are no actual infinities, the world is full of *potential* infinities.[22] This is clearly the position of Aristotle when he says, "nothing is actually infinite (*energeian … apeiron*) but only potentially so for the purpose of division (*dunamei … epi tēn diairesin*)".[23] We cannot banish instants as limits from our ontology any more than we can banish limits in general. We cannot say, of the function $f(x) = {}^{1}/_{x}$, that it does not *really* approach infinity as x approaches 0, unless we want to abolish the function altogether; a somewhat extreme step. The function really does have a limit. But this does not mean that *f(x) actually reaches* infinity, by which we mean that the line is not actually infinitely extended in the *f(x)* direction. We can never actually get to *f(x)* = infinity because the line never actually stretches that far. This natural way of talking is, I claim, also the correct way of talking. And as far as the mathematics goes, we know that *f(x)* never actually approaches infinity in the sense of the line's being actually infinitely extended, because for $x = 0$ *f(x)* is *undefined*, not *infinity*: the latter value would create mathematical havoc, as is well known. Hence potentiality, in the form of the limit, is built into the very fabric of mathematical thinking. And so it is as far as time is concerned: to posit actual durationless instants as the constituents of the time interval leads to as much absurdity as positing *f(x)* = infinity for $x = 0$ when $f(x) = {}^{1}/_{x}$.

But if instants are to be granted a reality as potential entities, the resultants of a process of division that can never actually be completed, how are we best to understand them? I propose that we take *intervals* to be the primary reality – the actual entities that exist as constituents of larger intervals – and define instants in terms of these, using only the basic concepts of mereology and temporal ordering.[24] Informally, the proposal is as follows. Every interval is made up of parts which are themselves intervals. Every interval can be divided into three parts, one of which is an *inner part*[25] and the others of which are *outer parts*. One of the outer parts *entirely precedes* the inner part (that is, with no temporal overlap), and the other outer part *entirely succeeds* the inner part. Both outer parts are *contiguous* with the inner part in the following sense: there is no interval *entirely between* either of the outer parts and the inner part (entirely succeeding the outer part and entirely preceding the inner part, or entirely preceding the outer part and entirely succeeding the inner part) and no interval *overlapping* (in the mereological sense) either or both of the inner and each outer part and containing a part entirely succeeding the outer part and/or entirely preceding the inner part, or entirely preceding the outer part and/or entirely succeeding the inner part. From this it is evident that for any interval the two outer parts and the inner part *wholly constitute* that interval (without repetition or remainder) and are present in that interval in the order of outer part–inner part–outer part.

Since every interval has an inner part, every inner part of any interval has an inner part since inner parts are themselves intervals. We can then think of instants initially as *infinite nested sequences of inner parts of intervals*.[26] But not any sequence will do, since we want to rule out the following sequences as instants:



The reason is that we will not then have a unique sequence for each instant – it will be possible to converge on the same limit from different directions, to put the matter informally. So we need to stipulate[27] that the inner parts need to be *symmetrical*, in the sense that dividing the initial inner part in half splits the interval into halves consisting of half of the inner part plus each outer part; and similarly for every inner part. Hence the outer parts must be equal in size, but not necessarily equal to the inner part. So we can then define an instant as an *infinite nested sequence of symmetrical inner parts of an interval.* Indeed the sequence must be *maximally* infinite in the sense that it contains every symmetrical inner part of the given interval. For practical purposes this is all we need, since we are defining the instant *i* relative to a given interval *I*. Once given *I*, there is a unique nested sequence that defines a unique instant *i* within the interval. Nevertheless we have not secured uniqueness in an absolute sense, since there are still an infinite number of nested sequences defining *i* relative to an infinite number of other intervals:[28]



What unites the nested sequences in the above diagram is that they can be ordered from smallest to largest by the *part* relation, and for one sequence *s* to be part of another sequence *t* is for *s* to have an initial interval which is a symmetrical inner part of the initial interval of *t*. The maximal nested sequence will have all the other smaller ones as parts but will not itself be part of any other. It is this *maximally infinite class of maximally infinite nested sequences of symmetrical inner parts of intervals* which is the unique abstract entity that defines an instant.

Note also that every nested sequence *s* will be *strictly totally ordered:* totally, since for any two intervals i_1 and i_2 in *s*, either i_1 is an inner part of i_2 or i_2 is an inner part of i_1 or else $i_1 = i_2$; strictly, since "*x* is an inner part of *y*" is irreflexive and asymmetric (nothing is an inner part of itself, and for any i_1 and i_2, if i_1 is an inner part of i_2 then i_2 is not an inner part of i_1); and the inner part relation is also transitive. The same applies to the class of nested sequences that defines the instant. Further, the totally ordered set of the instants themselves (that is, the totally ordered set of totally ordered sets of nested sequences) can be shown to be at least dense.[29]

It should, of course, be noted that there are other proposals for constructing instants out of, or reducing them to, other kinds of entity. Russell, for example, construes instants as maximal classes of simultaneous events.[30] Another suggestion

is to define them as equivalence classes of ordered pairs of intervals.[31] For the metaphysician, however, engaged in the central task of understanding the nature of certain kinds of entity, it is not simply a question of choosing, say, an abstract modeling that is the most elegant, or simple, or mathematically satisfying. Nor can the metaphysician rest content with taking certain models to be mere notational variants of each other, an attitude that leads straight to conventionalism about our understanding of reality. The point of grasping and explicating a kind of entity in a certain way is to conform to what fundamental ontology requires; and what it requires is an elaboration of an essentially commonsense view of the world in terms of basic categories, and a correlative appreciation of what entities do or do not have their own reality. That is the main reason why, say, sequences of intervals are to be preferred to Russell's sets of simultaneous events when explicating instants. There is no prima facie explanatory connection between events and simultaneity on the one hand, and instants on the other – *except* insofar as events import into the concept of time simpliciter, the concepts of duration and simultaneity. But there is nothing about events or simultaneity per se that should make us think that we do best to understand instants in terms of them. On the other hand, there is a manifest, commonsense explanatory connection between instants and intervals. But that does not make a definition in terms of ordered pairs of intervals preferable either, since it requires that we take as primitive the relation of *meeting* between a pair of intervals: we can then take the instant to be a set of pairs of meeting intervals. This approach is ontologically inadequate since it seeks to explain what should be fundamental in terms of something less basic. Intervals meet *at a point*; so instants cannot be defined in terms of meeting intervals since the latter are already partly defined in terms of the former, not explicitly but implicitly, as the very concept of a meeting between intervals imports that of an instant. Moreover, the order of understanding would seem to go in the same direction. To try to grasp the concept of an instant in terms of a meeting between intervals is not explanatorily useful, as grasping the very concept of a meeting requires grasping that of an instant to begin with.

There is an essential conceptual connection between instants and intervals, nevertheless. Thinking of the matter pre-theoretically, there is the clear idea that somehow instants are what we reach when we "burrow" into intervals long enough, but that instants do not, on the other hand, *really* exist. Put in this way, of course, the idea sounds faintly absurd to the seasoned ontologist. But this, I submit, says more about the divorce of much contemporary ontology from reality than about the alleged absurdity of our commonsense ideas about the world. Choosing a definition of instants in terms of intervals not only respects common sense in this way; it also lays the foundation for an understanding of change that respects our non-philosophical, intuitive grasp of reality. It is to this that I now turn.

4. Instantaneous Change

Change takes time. And yet in another sense it takes no time at all. It may take an hour to paint a red wall green. But if we ask, "When, *exactly*, did the wall become

green?", what are we to answer? We might say, "When the last coat of green paint was applied." But when, exactly, was that? "When the last lick of paint was applied to the coat." And when, exactly, was that? "When the last drop of paint from the last lick hit the surface of the wall." But we need not stop there. We can get more and more precise, and if we like we can fetch the latest in microscopic instruments to determine when the last molecule of green paint touched the surface of the wall. We might even start doing some quantum theory. But to the determined enquirer, that still will not be enough. Note that the sort of question I am posing here is not the same as the question of vagueness. The latter is a question about, in our example, what counts as the wall's becoming green – is it the first coat of green paint, the last, the last swipe of the brush across the surface, the last droplet of green paint on it? And so on. But even if we stipulate one event or another, and even if the event takes place at the molecular or sub-molecular level, there is still a question about locating the exact time at which the change takes place. This is not a matter of vagueness but of the possibility of ever greater precision.

That precision allows us to move further and further back from the terminal state of an object *x* (let it be the possession of property G), and further and further forward from the initial state (let it be the possession of contrary property F), without there being any obvious stopping point *except* for the putative point at which *x* is both F and G, which, since they are contraries, is impossible. So there simply does not appear to be any stopping point. Or we could say, since we are moving closer and closer together from opposite directions, that the stopping point is the one at which *x* changes *instantaneously* from F to G. But what point is that? It cannot be a point at which F*x*, since, if *x* is genuinely changing at that point, it cannot *be* F, at least not wholly. Similarly it cannot be a point at which G*x*, since if that were the case *x* would have *already* changed. So is it a point at which *x* is *partly* F or *partly* G? But that would only push the problem a stage back and we would have to locate the point at which *x* changed from being F to being partly F or partly G. Could the instant at which *x* changes be the instant at which it is neither F nor G? But now we need to know at what point, exactly, *x* passes from being F to being not-F, since this too is a change, and also the point at which it passes from not-F to G. Further, are we really to suppose that there is an instant at which – to continue with the example of the red wall that changes to green – the wall is neither red nor green? But then what color is it? Not blue or purple. But it cannot be colorless either, since all material objects have to have some color or other.

Here we run up against one of the governing principles of change: the generation of one thing is the corruption of another, and the corruption of one thing is the generation of another.[32] The loss of F by *x* just *is* the acquisition of G; the red wall loses its redness *by* acquiring greenness. This does not imply that the wall is ever red and green simultaneously; what it implies is that actualizing principles – forms – are lost in virtue of being driven out by other forms. Consider our being confronted with a material object that has one among a range of properties of a certain general kind – be it color, temperature, shape, size, quantity, location, configuration of parts – and then loses that property. One way of accounting for

what happens when it loses the property is to appeal to the idea that if an object is capable of possessing a range of properties of a certain general kind, then it *must* possess one of them. If it is capable of being colored it must be *some* color; if it is capable of having a size, it must have *some* size. The idea is, I believe, correct, but spelling it out requires closer attention to the distinction between determinable and determinate qualities than can be given here. We want to say, for instance, that an object capable of being colored must have some color; but not that an object capable of being red must have some shade of red. We want to say that an object capable of having one of the three (normal) states of solid, liquid or gas must be in one of those states; but not that an object capable of being liquid must be in some liquid state or other (boiling, simmering, still, disturbed, and so on). But the general principle is that forms are driven out by forms, not by nothing. So to say that the wall enters a state of non-coloredness at the instant of transition between red and green just does not seem right. It turns a world that appears quite clearly to be fundamentally continuous (even at the quantum level, where quantized change only occurs against a background of continuous change) into one that is full of gaps all over, where macroscopic objects undergoing accidental change jump from accident to accident with no comparable accident in between. Maybe, it might be replied, the jumps are there but they are too small to measure; maybe the world just is like one long movie made up of a sequence of still frames. To which the rejoinder is: why are the jumps *always* so small? Why don't we see, even occasionally, long jumps from state to state over perceptible intervals in which neither F nor G nor any other accident in the relevant range of accidents is possessed? If there is a law of nature making it so it has not been discovered yet; and no metaphysical principle governing size of jump is ready to hand.

I have been using an example of accidental change, but the phenomenon is just as striking, if not more so, in the case of substantial change. For if we are to claim that there is an instant of transition from substance S to substance T at which no substance at all exists – not just something that is neither S nor T – then we must account for what exists at that instant. It cannot be nothing at all, because we would again have the problems associated with jumps or replacements rather than genuine changes, and these have been raised already. Maybe what exists at the putative instant of transition is a bare particular; but a bare particular is also a nothing, at least nothing *actual*. Why not say, then, that it is pure potentiality, pure prime matter? Firstly, it is doubtfully coherent to speak of prime matter as in any way particularized, as though it came in parcels; the parcels could not have spatio-temporal characteristics, since prime matter has *no* characteristics, intrinsic or extrinsic. (How, then, to make sense of the differentiation of pure potentialities among distinct subjects of substantial change is a difficult question which cannot be answered here.[33]) Secondly, to postulate prime matter as what exists in the interstice between S and T is to violate the very principles governing prime matter: (i) prime matter is changeless, and so cannot be either the terminus of a transition from a substance to it or the origin of a transition from it to a substance. This is because prime matter is, by definition, that which supports all substantial change, so for it to be the term of a substantial transition would require positing a further

sub-prime matter, *ad infinitum*, and no substantial change would have an explanation; (ii) prime matter, again by definition, does not exist without form, that is, without actualization as something of some kind or other. This is because prime matter is not nothing, it is a genuine reality destined to unite with actualizing principles to constitute distinct objects of distinct kinds in the natural world. As an entity within nature, it too is subject to the laws and operations of nature. But since it is, in itself, devoid of any characteristics on which the laws and operations of nature could gain a foothold, nature must work upon it *indirectly* through the forms which it takes on. So if nature must act on it, prime matter cannot exist without form.

We seem, then, to run up against serious obstacles in seeking to characterize instantaneous change in terms of an actual instant of change. But perhaps the most serious was already implicitly stated in the previous section: there *are* no actual instants. It is otiose to speculate at too great a length on what things are like at the instant of change if there is no such thing. Rather, we can speak of "change at an instant," but if the earlier considerations are correct then this can only be given the same metaphysical interpretation as "velocity at an instant" or "acceleration at an instant." The instant is a limit, and the limit is only a potentiality, not an actuality: it is the potential result of an infinite process of division, not an actual moment of time at which objects exist in certain states or configurations. But the crucial question now is: how do we reconcile the thought that change is instantaneous with the thought that there are no actual instants? We can take our cue from Aristotle:

> Again, since a thing that changes continuously and has not perished or ceased from its change must either be changing or have changed in any part of the time of its change, *and since it cannot be changing in a moment* [emphasis added], it follows that it must have changed at every moment in time: consequently, since the moments are infinite in number, everything that is changing must have completed an infinite number of changes.[34]

> So that which has changed must have been changing and that which is changing must have changed, and a process of change is preceded by a completion of change and a completion by a process: *and we can never take any stage and say that it is absolutely the first* [emphasis added]. The reason of this is that no two things without parts can be contiguous, and therefore in change the process of division is infinite, just as lines may be infinitely divided so that one part is continually increasing and the other continually decreasing.[35]

> Our next point is that no process of change is infinite: for every change, whether between contradictories or between contraries, is a change from something to something. Thus in contradictory changes the positive or the negative, as the case may be, is the limit, e.g., being is the limit of coming to be and not-being is the limit of ceasing to be: and in contrary changes the particular contraries are the limits, since these are the extreme points of any such process of change … .[36]

There is, on the Aristotelian view, no first stage of change. Change involves limits, and limits involve infinite divisibility; since there are an infinity of instants – understood *only potentially* – everything that changes must have completed an infinite number of changes. It is, I propose, by means of the sketch I have given above of the metaphysics of change and the metaphysics of time that all of these thoughts can be put together into a coherent whole. When an object *x* changes from F to G, or from F to not-F, the period of time in which the change takes place is *full* of forms, and the only forms which are present are the forms of Fness and Gness or the forms of Fness and whatever form entails non-Fness. In the case of substantial change, the forms are substantial forms; in the case of accidental change, they are accidental forms. There is no *void*, no period of any duration during which *x* is neither F nor not-F, neither F nor G; still less is there a durationless instant at which this is the case. But there *is* change *at an instant*, as long as instants are understood derivatively just as motion at an instant or velocity at an instant are understood derivatively, these being in fact just special cases of change. Our model of change is thus:

_____F_____….FFFF……GGGG…._____G_____

where FFFF and GGGG approach each other infinitely – there never being adjacent F and G, there never being a void, and there never being a point of simultaneous, contrary F and G. There is no first moment of change since there is no last moment of F, and by parity of reasoning, no last moment either since there is no first moment of G. Yet Richard Sorabji has argued,[37] with special reference to motion (but of general application), that:

> [t]here can be no first *position* away from the starting point, or last position away from the finishing point in a continuous motion, or in any other continuous change. Hence there can be no first *instant* of being away from the starting point or last *instant* of being away from the finishing point. No such considerations apply to being at the position of rest.[38]

It is, he claims, reasonable to postulate an *asymmetry* between motion and rest because although there is no first position away from the starting point in the case of motion, there *is* a last position *at* the starting point, namely the position of rest itself. The problem here, however, is that the "hence" in the passage just quoted introduces a non-sequitur, inasmuch as it implies that there is a last instant of rest. Rest takes time just as motion does, and time is, as agreed on by both sides, infinitely divisible. So although there may be a final position in space for a resting object, it does not follow that there is a final position in time. This asymmetry between time and space (one of many) undercuts the spatial asymmetry invoked by Sorabji as between motion and rest. If we are to take the temporal dimension seriously then we are unable to find an asymmetry that will enable us to posit a last moment of rest any more than a first moment of motion. Motion and rest will conform to the same general model outlined above.

5. The Unity of Potentiality

Is there a larger metaphysical moral to be drawn from the above analysis of the metaphysics of time and change? I have defined the essence of change as the actualization of a pre-existing potentiality. I have also defined instants as the limits of a process of infinite potential division. It is my contention that these two potentialities are but different aspects of one and the same radical potentiality that lies at the heart of nature itself. Both are necessary for the explanation of change. The actualization of potentiality would not be possible without the potentiality that characterizes time; and if, as I would also contend (without space for a defense here) there is no time without change, the potentiality at the root of time would not be possible without the eduction of form from potentiality that is the essential note of change. In change, form succeeds form: every coming-to-be is a passing-away and every passing-away is a coming-to-be. Change is, then, a continuous process of loss and gain that is without gap and without contradiction. Change is instantaneous: without instants as limits it could not take place. To search for an actual instant of change, however, is to search in vain, for there are no actual instants at all. To search for a transition that does not consist in the actualization of potentiality is to search for a chimera. Transition there must be, and without the exceedingly small there is no transition; but to look for it *in* the exceedingly small is to miss its presence in the process at large. Ultimately the process is unfathomable – as unfathomable as the very potentiality that explains the finitude of the material universe and everything within it. In metaphysics, this is all the explanation we can hope for. In metaphysics, this is all the explanation we need.

Notes

1 This argument assumes that no object is capable of entering only one state, and that this is not just a metaphysical possibility but a physical necessity.
2 Which is equivalent to –273.15 degrees celsius below zero.
3 If current physical theory is correct, there would not appear to be a way of treating space as discontinuous if time is continuous, given their mathematical treatment as dimensions of a single continuous manifold. Be that as it may, there is nothing in the nature of space which suggests a priori that it could be discontinuous if time were continuous, and vice versa.
4 W. H. Newton-Smith, in *The Structure of Time* (London: Routledge & Kegan Paul, 1980), 26–27, argues plausibly against Harré and Boscovitch who claim that there can be no discrete change of a parameter in continuous time.
5 Aristotle, *Metaphysics* IV.5, 1010a10.
6 Note that the technical term *accident* refers to any modification or attribute of a thing; the attribute need not be accidental in the senses of non-essential, contingent or non-law like.
7 For theories of ontological independence as applied to substances, see: J. Hoffman and G. Rosenkrantz, *Substance*: *Its Nature and Existence* (London: Routledge, 1997); and E. J. Lowe, *The Possibility of Metaphysics*: *Substance, Identity, and Time* (Oxford:

Oxford University Press, 1998), ch.6, and his "Ontological Dependency," *Philosophical Papers* 23 (1994), 31–48.

8 An atom of carbon 11 with 6 protons and 5 neutrons, after electron capture into the nucleus, is transformed into an atom of boron 11 with 5 protons, 6 neutrons and an ejected neutrino.

9 In traditional terminology, the *terminus a quo*.

10 Traditionally, *terminus ad quem*.

11 The *transitus*.

12 And will henceforth be used tacitly.

13 As the scholastic principle goes, *Quidquid movetur, ab alio movetur*.

14 In the case of local change, of course, it may be the other relatum which does the moving; but the object with respect to which it moves still bears distinct relational accidents. For the sake of simplicity I am here only concerned with intrinsic change, and hence for example with local change by an object in virtue of its own intrinsic motion.

15 Consisting of two protons and two neutrons, that is, the nucleus of helium.

16 Or from one thing to another; again, this will be taken as implicit.

17 Quentin Smith in *A Companion to Metaphysics*, J. Kim and E. Sosa, eds. (Oxford: Blackwell, 1995), 83. This is typical of the definitions given in the standard reference books.

18 Newton-Smith, *Structure of Time*, 121–26.

19 From the beginning of quantum theory there has been speculation as to whether the space-time continuum should be abandoned because of the limits on measurement imposed by the theory. Even now it is thought that there is a Planck length, currently estimated at 10^{-35} m., which puts a limit on the measurement of space-time intervals. The fact that the estimate of the Planck length has been getting smaller must reflect the improvements in measurement techniques, which in turn suggests that physics has not yet reached the certain position of requiring discrete space-time lengths. And even if it did, this would only be because a theoretical limit on measurement had been discovered, not because an actually indivisible metaphysical unit (a *chronon*) had been discovered. Of course quantum theorists would object to just such a distinction between what is and what can be measured, but I assume a difference for the purpose of this essay and do not have room to explore the broader issue.

20 David Bostock, "Aristotle on Continuity in *Physics* VI," in *Aristotle's Physics: A Collection of Essays*, L. Judson, ed. (Oxford: Clarendon Press, 1991), 179–212, at 186.

21 See, for example, the arguments of William Lane Craig in W. L. Craig and Q. Smith, *Theism, Atheism and Big Bang Cosmology* (Oxford: Clarendon Press, 1993), chs. I and III; and also my "Traversing the Infinite, the 'Big Bang', and the Kalam Cosmological Argument," *Philosophia Christi* 4 (2002), 305–36. Aristotle's term for traversing the infinite is *dielthein*: see *Physics* VI.10, 241b11; *Physics* VIII.9, 265a20. St Thomas Aquinas uses *pertransire*: see *ST* I, q. 46 a. 2.

22 For a series of compelling arguments against actual infinities, see the discussion by William Lane Craig in Craig and Smith, *Theism, Atheism and Big Bang Cosmology*, esp. chs. I and III.

23 Aristotle, *De Generatione et Corruptione* I.3, 318a20 in *Loeb Classical Library* edition, E. S. Forster, trans. (London: Heinemann, 1955). According to David Bostock, there is a "tension" between Aristotle's discussion of infinity in Books III and VI of the *Physics*: "Aristotle on Continuity in *Physics* VI," at 180. I cannot find the tension. In Book VI he says that "everything continuous is divisible into divisibles that are

infinitely divisible" (231b15), and repeats this at 232b23. Again, at 239b8 he says, "time is not composed of indivisible moments any more than any other magnitude is composed of indivisibles." So I find it mystifying that Bostock should say: "But in Book VI he shows no such tendency to be suspicious of the infinite, and apparently accepts without qualms that a line does ('actually') contain infinitely many points, that a stretch of time does ('actually') contain infinitely many instants, and so on." Hence Bostock's suggestion is incorrect that Aristotle solves Zeno's paradox of motion by holding "that one who traverses a finite distance has thereby completed a series of infinitely many distinct tasks, in traversing the infinitely many 'half-distances' contained within the original distance." Bostock cites 233a13ff. and 239b9 in this context, and yet even a cursory reading of these passages demonstrates that Aristotle accepts that the infinitude of the quantities covered in a finite time or length is an infinitude of *potential division only*. Translations from the *Physics* in this note and elsewhere in this chapter are from the version by R. P. Hardie and R. K. Gaye in *The Basic Works of Aristotle*, R. McKeon, ed. (New York, NY: Random House, 1941).

24 My proposal closely follows that of Newton-Smith in *Structure of Time*, 134–38, but was conceived independently. Many of the details of my proposal are, however, not in Newton-Smith, for example, the need for classes of nested sequences. See Oderberg, "The Beginning of Existence," *International Philosophical Quarterly* 43 (2003), 145–57. For a similar approach in respect of points in general, see A. N. Whitehead, *Process and Reality*. Corr. ed. (New York, NY: Free Press, 1978 [1929]), 294ff. See also J. van Benthem, *The Logic of Time* (Dordrecht: Reidel, 1983), ch. I.4, and A. Galton, *Qualitative Spatial Change* (Oxford: Oxford University Press, 2000), 245–46, citing J. Allen and P. J. Hayes, "Moments and Points in an Interval-Based Temporal Logic," *Computational Intelligence* 5 (1990), 225–38.

25 I borrow the terminology from Newton-Smith.

26 Again, I use Newton-Smith's terminology.

27 As Newton-Smith does not.

28 Note that there may be other functions which define differently curved – and hence distinct – sequences. This does not militate against my proposal, because uniqueness needs only to be guaranteed relative to the function chosen. Although I speak of *defining* instants as classes of sequences, this should be regarded as no more an *identification* of such classes with instants than any set-theoretic conception of number should be regarded as *identifying* numbers with certain kinds of set. See P. Benacerraf, "What Numbers Could Not Be," *The Philosophical Review* 74 (1965), 47–73. What I am calling a definition is no more than a theoretical representation of a fundamental metaphysical truth about infinite divisibility. Since it is a central claim of this essay that an instant is no more than a limit, it cannot itself be identified with any kind of class or sequence.

29 Newton-Smith, *Structure of Time*, 137–38.

30 Bertrand Russell, "On Order in Time," *Proceedings of the Cambridge Philosophical Society* 32 (1936), 216–28. Newton-Smith criticizes Russell's proposal for being unable to ensure that time is dense without assuming the controversial principle that there is no time without change.

31 Galton, *Qualitative Spatial Change*, 245.

32 As the scholastic axiom goes, *generatio unius est corruptio alterius et corruptio unius est generatio alterius*. And as Aristotle puts it, "the passing-away [*phthoran*] of one thing is the coming-to-be [*genesin*] of another thing, and the coming-to-be of one thing is the passing-away of another thing": *De Generatione et Corruptione* I.3, 318a25; translation from *Loeb* edition.

33 I discuss the problem of individuation in "Hylomorphism and Individuation," in *Mind, Metaphysics, and Value in the Thomistic and Analytical Traditions*, J. Haldane, ed. (South Bend, Ind.: University of Notre Dame Press, 2002), 125–42.
34 *Physics* VI.6, 237a12–a16.
35 *Physics* VI.6, 237b2–b9.
36 *Physics* VI.10, 241a27–a30.
37 R. Sorabji, "Aristotle on the Instant of Change," in *Articles on Aristotle*, vol. 3, J. Barnes, M. Schofield and R. Sorabji, eds. (London: Duckworth, 1979), 159–77.
38 Sorabji, *Articles on Aristotle*, 161.