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Absolute becoming, relational becoming and the arrow of time¹

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The first and main claim of this paper is that physics cannot provide, *empirical* evidence for the objectivity (mind-independence) of *absolute* becoming, for the simple reason that it must presuppose it, at least to the extent that a classical (i.e., non-quantum) spacetime theory presupposes *a priori* an ontology of events. However, the fact that a theory of absolute becoming must be situated in the abstract realm of metaphysics does not make becoming completely irrelevant for physics, since my second claim will consist in showing that *relational* becoming, once appropriately defined and understood, properly belongs to the tangled set of issues usually referred to with the label “the arrow of time”.

The paper is divided into three parts. In the *first* I will strike a blow against the traditional, received views of becoming, typically requiring *the unreality of the future* as a necessary condition for the objectivity or mind-independence of temporal passage. After having severed the misleading link between the concept of becoming and the unfortunate debate between presentism and eternalism, in the *second* part I will offer a much needed, clear explication of becoming, given in terms of the simple *occurrence of events*. I will then defend this approach to becoming from foreseeable objections, especially concerning its faithfulness to the time of our experience. After having crucially distinguished between absolute and relational

becoming, in the *third* part I will bring spacetime physics to bear on the explication of becoming. In particular, I will show why the definability of a becoming relation in terms of the relation of past causal (or chronological) connectibility of Minkowski spacetime gives us no clue as to how we should use physics to establish the mind-independence of the former relation.

§1 What becoming is *not*

As is sometimes the case in philosophy, one way to solve a problem is to dissolve it, that is, to show that what had so far been considered a substantial debate is in fact not genuine at all. The debate I have in mind is between those who claim that the future and the past are as real as the present (the *eternalists*, or block-view theorists) and those holding that only the present, properly speaking, is real or exists (*presentists*). In part fueled by this debate – and often without having a clear idea of what becoming really meant or entailed – in the last few decades there have been various attempts to find out whether becoming, whatever that meant, was compatible with, or definable within, physical theories like the special or the general theory of relativity.

Despite the confusions afflicting the literature, the prevailing idea seems to have been that becoming (or the flow of time) is connected to *ontological* issues, i.e., issues of the kind debated by presentists and eternalists. In particular, for quite some time, and by virtually all the authors engaged in the debate, *the unreality of future events* has been regarded as the main, necessary condition for an objective, *ontological* (non-merely subjective) becoming. This unreality is typically either mirrored by that of past events, as presentists have it, or contrasted with the reality of the past, as “empty view theorists” or “possibilists” have it (see Dorato 1995 and Savitt 2001).

¹ I thank two anonymous referees for their precious comments to a previous version of this paper.

Quite significantly, despite their disagreement on how to interpret the ontology of Minkowski spacetime, Putnam (1967), Rietdijk (1966), Weingard (1972) and Stein (1991), just to name a few, seemed to presuppose that the crucial issue at stake in trying to understand whether the time of our experience conflicts with special relativistic time involved the issue of the *ontological* status of future events. So, while Putnam claimed that in virtue of the relativity of simultaneity the future in Minkowski spacetime had to be regarded as “real” and “definite” as the past and the present, according to Stein, given certain hypotheses, for any point P of Minkowski spacetime, the reality of becoming is equivalent to the claims that as of any event P , events in the past light cone of P are all “definite”, while the future light cone of P and the spacelike-related region contain only events that, as of P , are “indefinite”.² Note that, following Maxwell (1985, p. 24), by “definite” Stein means “ontologically fixed” (1991, p. 148) and in the present context the key word for me is “ontologically”.

While for a more thorough attack on the meaningfulness of the debate between presentists and eternalists I refer the reader to Savitt (MS), and Dorato (2005), here it will suffice to remark that once we distinguish between a tensed and a tenseless sense of existence, there is no more room for disagreement between those who claim that only the present *is* real – and therefore can conceive, allegedly, that future events can become real in the present – and those that must deny that such a becoming can occur, since for them future, present and past events *are* equally real.

DEF₁ **Tensed existence.** Event e “exists” in the *tensed* sense of “existence” iff it exists now.

This definition is to be contrasted with the following:

² For the sake of precision, Putnam (1967) was more interested in claiming that special relativity entails the reality of the future than in using this conclusion to argue that becoming is incompatible with Minkowski spacetime. Stein (1991), on the other hand, did not defend becoming explicitly, but simply its compatibility with Minkowski spacetime. But they certainly disagreed about whether in Minkowski spacetime the future is to be regarded as real as the present and the past.

DEF₂ **Tenseless Existence** For all present moments, event e “exists” in a *tenseless* sense of “existence” iff it has existed, exists in the present or will exist.³

The utility of DEF₂ is in its contrast with *abstract* existence: the difference between a *set* of desks (if it exists) and *my* desk is, respectively, the difference between a non-spatiotemporally extended object and something that occupies some space and lasts for some time. I will now show why, on the minimal assumption that some event will occur after the present – i.e., that the world will not come to an end after now – presentism becomes either *trivial* or *inconsistent*, depending on whether the thesis of presentism is formulated by using a *tensed* or a *tenseless* sense of existence. Let us first explore the two alternatives defined above as if they were exhaustive. The possibility that there is a third sense of existence, *existence simpliciter*, put forth by Sider (2001 and 2004) and Crisp (2003, 2004) will not be discussed in full here, as I think it has already been rejected in my (2005).⁴

Consider the typical claim that any future (past) event does not *exist*. In the previous sentence, the verb “exist” is either *tensed* or *tenseless*. In the former alternative, the presentist is claiming that future (past) events do not *now* exist, and this is a triviality to which any eternalist would subscribe. On the other hand, if the “exist” in the first sentence of the paragraph is tenseless (*tertium non datur*, on the current hypothesis), since events exist tenselessly just in case they either have a past, or a present, or a future existence, by denying that *any* future (past) event E tenselessly exist (as we are now supposing), the presentist is caught in a contradiction. Since, in virtue of DEF₂, the fact that E will occur (or has occurred) means that it exists tenselessly, one cannot assert that E does not (tenselessly) exist because it is non-present.

³ In another oft-quoted formulation, e exists tenselessly iff it occupies, or is identical with, a point-like or finite region of spacetime, where the latter’s existence must presumably be independent of both tensed and tenseless existence. See below for difficulties of this formulation

⁴ See also Ludlow (2004)

If the pendulum of presentism oscillates between peddling tautologies and contradictions, one may wonder what motivates its followers. My diagnosis is that presentism gains some credibility because eternalism has been saddled with absurdities that our definitions above avoid. Two of these absurdities are worth reporting. The first would make us believe that the claim that past, present and future events *are* equally *real*, or *exist* on a par, means that they are all simultaneous. However, “existing on a par” does *not* entail co-existing in a *Totum Simul*: events in a “block universe”, with which the eternalist metaphysics is often associated are, exactly as in the standard presentist’s metaphysics, *temporally separated*. No possible disagreement here!

The second trap is easily stated: even though it is *always* true to assert that “*F* occurs at t_F ”,⁵ such an eternal *truth* about event *F* in no way implies the *eternal existence* of the event *F*. Also in this case, there cannot be any disagreement between those who claim that the future is real and those who claim that it is not. The distance between presentism and eternalism is made even closer by the remark that even though the relation “tenselessly co-existing with” trivially coincides with the universal relation in any spacetime – namely with the relation linking any event *e* with any other event – *each event*, from its own spatio-temporal “perspective”, *exists*, either tensedly or tenselessly, *only when it occurs*.

In order to further deflate the metaphysical dispute I have been sketching, I think it is fair to recognize an important role to *both* senses of the word “existence” defined above. According to our different purposes, we rely on the tensed sense of existence, and then we take a *perspectival* attitude toward existence; some other times, for different purposes, we rely on a tenseless sense of existence, and we look at reality from “nowhen”. Both senses are well-grounded and useful. The main point, however, is one that Carnap made long ago: *a*

⁵ For the sake of the argument, we can forget relativistic complications raised by t_F , to be handled below.

pragmatic difference of this kind commands only a linguistic choice, and should not be transformed into a difference about ontological commitments.

This point also sidesteps an ingenious arguments put forward by Sider (2004) with the intent of claiming that the disagreement between the presentist and the eternalist is genuine. Sider notes that translating “dinosaurs existed” with “it was the case that dinosaurs exist”

$$(1) \quad P((\exists x) (Dx))$$

does not generate an existentially committing sentence for the presentist, unlike the eternalist’s “there exist dinosaurs and they are located before us”

$$(2) \quad ((\exists x) (Dx \ \& \ Bxu))$$

which implies that “there exist dinosaurs”. Since in the present context I have to be brief, I will just note that the meaning of such an alleged, third, generalized sense of existence, given by the existential quantifier *simpliciter*, is going to depend on what our descriptive purposes are: the *interpretation* of the logical symbol \exists , which is what matters, will differ accordingly. While formula (1) clearly uses \exists in a tensed sense, it is tenseless existence that is presupposed in (2). In any case, difference in logical form (granting that the first formula is not a quantified one) need not boil down to a difference in existential commitments, since both presentists and eternalists agree that “dinosaurs existed” and that “they do not exist now”. In conclusion, there is not a single sense of existence, over and above the tensed, the tenseless and the abstract sense, since one can always analyze this alleged generalized sense concluding, with a paraphrase of Aristotle, that “existence can (and should) be spoken of in many ways”.

§2 What is, then, becoming? Absolute becoming and the happening of events

If I am right in arguing that there cannot be any disagreement about any of the metaphysical claims stated above, it follows that *becoming should not to be regarded as the becoming real, determinate, definite or fixed in the present of previously unreal, indeterminate, indefinite or unfixed events*. This argument already gives evidence to a claim that is of paramount importance because it has been much too neglected in the past: *if there is becoming, the asymmetry it imposes on the structure of time should not be cashed ontologically, that is, as involving the difference between the real and the unreal, but simply physically, in strict connection with the various asymmetries constituting the arrow of time*⁶.

In order to further defend this claim, in what follows I will introduce another distinction which also contributes to clarify in a decisive way some problems that in the past have been conflated, namely a distinction between *absolute* and *relational* becoming. It is in particular the latter notion that expresses what we intuitively mean by *temporal becoming*.

DEF₃ Absolute becoming. The claim that an event e “becomes” in an absolute sense (or “comes into existence”) at a certain time-place simply means that e *occurs* or *happens* at that time-place.⁷

DEF₄ Relational becoming For any pair of events x and y belonging a spacetime S and a binary relation of becoming B , the claim that x and y are related by B (xBy) means that x has become as of y .

Let me stress at the outset that relational becoming presupposes absolute becoming, a fact which will be of paramount importance for the main claim of this paper, and on which I will

⁶ For a recent survey on the arrow of time, see Albert (2001). Despite an insistence on the geometrical condition of temporal orientability, which in my opinion is necessary but not sufficient to the existence of a global arrow of time, this view of becoming is not unrelated to that advocated by Maudlin (2002).

⁷ This view has been independently reformulated by both Dorato’s (2002) and Savitt’s (2002) contributions to Callender C. (ed.) *Time, Reality and Experience*. Cambridge University Press, Cambridge, but originates in Broad (1938). Recently, also Dennis Dieks has independently come to defend it.

return below. The adjective “absolute” in DEF₃ refers to the fact that here we are abstracting from the spatial and temporal relations that an event e bears to other events – relations that are crucial in DEF₄ – so that we could have absolute becoming also in a universe with just one event. As soon as we have more than one event and we add spatiotemporal structure to the universe, we have relational (temporal and spatial) becoming, and the kind of structure we have is going to depend crucially on the kind of spacetime we are considering.

DEF₅ **the temporal becoming** of a pair (a set) of temporally separated events consists in the fact that *such events occur successively*, or at different instants of time.

DEF₆ **the spatial becoming** of a pair (a set) of spatially separated events consists in the fact that *such events occur* at different locations in space.

Clearly, we can have different forms of relational becoming, depending on the constraints imposed by the various spacetime structures: temporal becoming can either be a *complete* order (as in Newtonian spacetime or in some highly symmetric models of general relativity), or a *partial* order (in the special theory of relativity). In Newtonian spacetime, *spatial* becoming is the relation of *co-occurring at the same instant* of absolute time, a relation that is made possible by the existence of an absolute relation of simultaneity. In the special theory of relativity, due to the relativity of simultaneity, *temporal* becoming is either frame-dependent and global, and therefore non-invariant or else, as we will see in §3, simply incompatible with spatial becoming. Consequently, *if there is invariant temporal becoming* in Minkowski spacetime, *it must be strictly local* (becoming along worldlines), and spatial becoming is ruled out, despite the fact that spatial becoming, were it real, would be invariant for all inertial frames, given that the relation of “being spacelike-related” is invariant.⁸ In the general theory of relativity, which here I will not discuss, the completeness of the order of temporal

⁸ Notice that, in light of the above section, the claim that if there is temporal becoming no two spacelike related events can have become one relative to the other should *not* be taken to mean that such events do not exist one relative to each other.

becoming *might* be reestablished by those cosmological models admitting a cosmic time function. Finally, following the previous distinctions, we should also distinguish a *tensed* form of *becoming* from a tenseless form. In the former case, an event e occurs or happens *now* or *in the present*; in the latter case, e occurs or happens *at some time-place* or at some point-region of spacetime

I will now discuss four related points raised by my definition of absolute becoming and which concern: (a) the status of events in their relation to spacetime; (b) a defense of the plausibility of linking “becoming” and “happening”; (c) the possible contrast class of the definition, namely the sense in which we could claim that a physically possible universe could *lack* becoming altogether, something which will also help us to see the sense in which physics *must* presuppose absolute becoming; finally (d) the sense in which the proposed explication is faithful to the passage of time in our experience. Let me examine these four important points in turn.

(a)

DEF₃ above regards *physical events* as the protagonists of becoming. Events, which in ordinary language metaphysics are entities with temporal parts, when sufficiently idealized or pointlike, are also the very building blocks of any spacetime theory, whether Newtonian or relativistic. The proposed definition of absolute becoming has rather interesting consequences: if physical events are what is denoted by the points of the mathematical manifold that is used to represent them, and if we can admit the occurrence of events in a certain space-time S , then we *can* talk about events becoming in S . Furthermore, it would seem that we have the legitimacy of such a talk, so to speak, for free, or *a priori*, since the ontology of any spacetime theory *presupposes physical events*. Absolute becoming is presupposed by physics and trying to use an empirical science to provide *empirical evidence*

for it simply amounts to putting the cart before the horse. However, is the definition acceptable? What kind of notion of event is it relying on?

Luckily, it is not necessary to complicate the simplicity of DEF₃ with complicated questions about the metaphysics of events. Certainly, it is an immediate consequence of the definition that *there cannot be becoming where there are no events*, so that it might seem that empty spacetime *cannot* be the locus of becoming. This conclusion, however, follows only from the thesis that events should *not* be identified with regions of spacetime; more precisely, within this context we should consider three different possibilities, among which there is no necessity of choosing.

a1) If *events* just *are*, à la Quine (1986), *regions of spacetime*, then according to DEF₃, becoming just *is* the coming into being of those regions. However, there is nothing absurd in this option, which would be very close to a form of spacetime substantivalism: after all, in contemporary cosmologies, “the expansion of the universe” *is* in some sense the expansion of spacetime itself, since galaxies clearly do *not* expand in a pre-existing spacetime.⁹ With the passage of cosmic time, the occurring of events would simply be identical with the coming into being or the addition to the previous spacetime of new regions.

a2) If, on the contrary, events are to be distinguished from spacetime – which in this case could be regarded, à la Leibniz, as a set of spatiotemporal *relations* – then we can simply suppose that events *are* the physical primitives of our ontology, and we can understand them in terms of the typical textbooks examples: a sufficiently “small” region of an electromagnetic or a gravitational field¹⁰, an oscillating charge, a flash of light, a measurement result in quantum mechanics, and so on. In this option, we cannot have regions of the spacetime manifold where there are no physical events at all, i.e., *regions in which*

⁹ I owe this remark to Avshalom Elitzur, for which I thank him.

¹⁰ In this case, fields are to be understood as entities definable independently of spacetime regions!

nothing changes or there is no becoming, since events exemplify spatiotemporal relations but are not in spacetime.

a3) As a third possibility, it might be noted that *if*, against a1), it did not make sense to talk about spacetime itself as becoming and if events, as it is supposed in a2), were distinct from existing spatiotemporal regions, it would be too restrictive to limit the scope of becoming to non-empty regions of spacetime where there are events. However, consider that the metric field of general relativity is certainly *not* to be identified with empty spacetime, and therefore we should not worry too much about the “restriction” is question. For example, a hole of matter in a curved spacetime with a metric field defined on it *can* certainly have events in it, and therefore according to DEF₃, can host becoming. The manifold of general relativity (empty spacetime), of course, cannot by itself host becoming, since we would also need the metric field, but then we should ask why, given the consequences of the hole argument, we should identify physical spacetime with the bare manifold.¹¹ Finally, note that the “vacuum” of quantum field theory is certainly not devoid of “interesting events”.

I hope this is sufficient to show that no matter how we interpret the relationship between events and spacetime – events are spacetime regions regarded as being capable of becoming, as in (a1), events exemplify spatio-temporal relations and are therefore distinct from spacetime regions, as in (a2), events are not spacetime regions and the latter don’t become, as in (a3) – we can accommodate becoming.

(b)

I must now show that DEF₃ above is highly plausible, that is, that there is a strong, yet so far neglected, conceptual connection between the occurring and happening on the part of events on the one hand, and their becoming or coming into existence on the other (coming into being and becoming here are treated as synonymous).

¹¹ For more arguments in this direction, see Dorato and Pauri (2006).

First of all, I take it to be uncontroversial that the *being* of an event just amounts to its *happening*, so that the meaning of the word event¹² somehow contains in itself the germs for a reconciliation between a Parmenideian philosophy of being and an Heracliteian philosophy of passage, depending on whether we insist on the static-sounding “being located” or simply “being” of the event, or on its dynamical-sounding “occurring”. As in the case examined before concerning presentism and eternalism, we find good reasons to overcome a sterile, age-old opposition between the friends and the foes of becoming. On the one hand, eternalists and enemies of becoming will probably complain that there is no point in using in DEF₃ the verbs “to occur” or “to happen”, since this makes becoming sound more dynamic than it is: the verb “to be” is what is required.¹³ On the other hand, since “being” and “occurring” for an event are one and the same thing, presentists and the friends of becoming will complain for the opposite reason. Once again, DEF₃ irenically accommodates the best intuitions of both sides, showing at the same time that by accepting DEF₃ the debate about absolute becoming in some sense dissolves.

Despite etymology, what might still be controversial, of course, is the assumption that an event’s *happening* at a time-place is equivalent to its *coming into being* at that time-place, or simply to its *becoming* at that time-place. By focusing on temporal, rather than on simple absolute becoming, it is easy to build a simple argument that establishes the “only if” part of the equivalence, namely that temporal becoming logically or conceptually implies the happening of events. For those who regard this link as self-evident (as I do), the argument will still be helpful in pointing out the sense in which the view of becoming advocated here is committed to the age-old claim that time implies change.

(1) The reality (mind-independence) of temporal becoming entails the reality (mind-independence) of time;

¹² “Event” comes from the Latin word *eventus*, the substantivization of *e(x)-venire*, “to come from”.

- (2) The mind-independence of time entails the mind-independence of change;
- (3) The mind-independence of change entails or is equivalent to the mind-independence of the occurring of events.

Combining these three conditionals we have what we wanted, namely the fact that the notion of an objective temporal *becoming* entails an objective *occurring* of events. Of course, temporal becoming is a temporal notion and its reality requires the existence of time: I take it that (1) is uncontroversial. If time requires change (2), change requires events, because any change *is* an event, and events must *occur* by definition of the word event (3), where “occur”, “happen” and “take place” are *primitive, non-analyzable verbs*. Using the contrapositives of these conditionals, it is even easier to understand the chain of reasoning: if there were no occurring of events there would be no change; without change there would be no time, and without time there would be no becoming.

The weak part of the above chain might be (2), due to the ambiguity of the notion of “change”. Define change_1 as the possession of two incompatible properties by the same continuant at different times, as in “the traffic light became red”. Change as it is used in (2), call it change_2 , is *not* the qualitative change in time given by change_1 , but rather a coming into being, an occurring, a happening on the part of an event, as it is specified by (3).¹⁴ If time requires change_1 then the argument would still go through, because changes in continuants (substances) are in any case events, and events occur. If time did not require change_1 , one could claim that it implies change_2 , a position that possibly requires a relationist view of time or spacetime. While I cannot give further arguments for this claim here, I think that the view that the happening of events is essential to the reality of time is quite plausible and should be further explored.

¹³ This worry was expressed by one of the referees.

¹⁴ For the difference between these two notions of change, see Broad (1938, p. 280) and Savitt (2002, p. 159).

In order to prove the “if part”, namely that the *occurring* of events is sufficient for *absolute becoming*, we must recall that the event’s being at some time place (t, s) is its occurring then and there, and conversely, an event e occurring at (t, s) is e ’s being or existing at (t, s) . This is sufficient for our derivation of the if-implication: take any future token event e ; since the token event in question e has never occurred before, when it occurs it trivially comes into existence, or comes to pass by simply happening.

This “proof” of “if-part” may seem too quick. Everyone agrees that there is a clear sense in which all events exist tenselessly at their respective spacetime locations. How can we claim that events do not simply tenselessly exist but in addition “come into being” at their location? Doesn’t tenseless existence (the block view) imply by itself that events tenselessly exist or are *without* coming into being?

The reply to these objections is simple: the point of the DEF₃ is simply to deflate the metaphysics of becoming *and* the metaphysics of being, by stressing that “coming into being” (becoming) and “being” or “existing” for events must be regarded as one and the same thing, and then insisting that an event cannot exist without happening (this is further developed in point (c) below). We are not adding anything to the essence of an event by saying that it comes into being or that it becomes, but we are simply saying that it takes place. As Broad already put it in his (1938), this absolute becoming is not to be understood analogously to acquisition of a property on the part of a “pre-existing” event.

Here is another objection to the definition of becoming that I have provided. Part §1 has argued that the tenseless existence of an event e simply means that the event has existed, or exists now or will exist at some time-place. Suppose that event e is future so that, on the basis of DEF₂, it is always true, and therefore true also at the present moment, that “ e tenselessly exists”. One may wonder how can e come into being in the future when and where it will occur if also in the present moment it is true to say that e exists tenselessly. However, we

should not forget that the tenseless existence of e does not entail its present existence or its sempiternal existence: *relative to its own spacetime location, e exists only there and then*, because it *is* or *takes place* where it is located. In a word: e exists tenselessly because it will exist at some future time. But if it will exist and does not exist now, then we can say that it will come into being by occurring.¹⁵

These objections depend on an equivocation about the nature of future events in the block universe, or in the eternalist's perspective. We can *represent* events as "being all there", *as if* all events had already happened, but we should not forget that this is only a representation, since the real, represented things are in time. Consequently, if the spacetime structure allows for some form of temporal becoming, the events occur one after the other; therefore, once we are given a temporal location, relative to that location, whether it is occupied by a sentient being or not, there is (tenselessly) and objectively a past and a future.

In conclusion, relative to any point in space-time p , there are (tenselessly) events occurring before and events occurring after p . Since the existence of events is presupposed by the ontology of any classical spacetime theory, such an occurring must be regarded as a real, fundamental and non-analyzable feature of the universe. Finally, since *temporal becoming is* the successive occurrence of events, we will see that there is temporal becoming in any spacetime theory admitting timelike-separated events in its geometrical structure (see §3 below).

c)

However, one could attempt to individuate a class of worlds to be contrasted with those that become as follows: call a physically possible world becomingless if and only if events in that world only *appear* to happen. That is, if becoming or the occurring of events were an

¹⁵ These replies meet some objections raised by a previous, anonymous reader of this paper.

illusion or a mind-dependent phenomenon, then we should say that events “simply are”, that really “they do not occur or happen”, but only appear to do so.

Interestingly enough, two of the founding fathers of the theory of relativity have defended this view, claiming that relativity entails that the *occurring* of events is a “secondary quality” like color or tastes, due to the encounter of sentient beings with a timeless reality.¹⁶ The process of “secondarization” – which begun with the ancient atomists and which consist in putting in the mind properties that apparently belong to the external world – here would come to its radical completion. After the secondary qualities of Galilei, Boyle and Locke (colors, tastes, odors, sounds), after the “secondarization” of space advocated by George Berkeley, with Eddington and Weyl (and Gödel) we would arrive at claiming that relativity requires us to treat *also* time – in the form of the occurrence of events – as a purely “subjective” phenomenon:

[In relativity], *events do not happen; they are just there*, and we come across them. “The formality of taking place” is merely the indication that the observer has on his voyage of exploration passed into the absolute future of the event in question (Eddington 1920, p. 51, emphasis added).

The objective world simply is, it does not happen. Only to the gaze of my consciousness, crawling upward along the life-line of my body, does a section of this world come to life as a fleeting image in space which continuously changes in time (Weyl 1949, p. 116, emphasis added).

I take it that in these frequently misunderstood passages, not only are Eddington and Weyl implicitly telling us what becoming *is*, but are also arguing against it: according to them, there could be no occurring of events without conscious or sentient beings, and there is an important distinction between the being of events and their happening, because the latter feature is a mind-dependent phenomenon. Certainly, if coordinate time is an identifying factor for the occurring of an event, as in Kim’s conception of events (1976), and coordinate time is frame-dependent, it would seem that the occurring of an event also becomes frame-dependent and therefore relative, if not merely subjective.

¹⁶ Clearly, “timeless” does not mean “tenseless”.

Despite the authority of Eddington and Weyl, however, for the reasons given above I take it that a distinction between the being of an event and its occurring (due to our mind) is highly implausible. If we regard, as we should, “occurring” or “taking place” as primitives, or as not further analyzable verbs, it seems to me that the fact that events “occur”, “take place”, or “happen” is an undeniable part of the very meaning of the word “event”. Here is a quotation illustrating this view, and quite evidently addressed to the two quotations referred to above: «Taking place is not a formality to which an event incidentally submits – it is the event’s very being. World history consists of actual concrete happenings in a temporal sequence» (Williams 1951, p. 106, my emphasis).

Notice that if we accept that the being of an event, its being located somewhere in spacetime, and its occurring, are one and the same thing, as Williams’ quotation above shows, then we have two remarkable consequences. The first is that even though there is a clearly defined contrast class to the DEF_3 – the contrast would be between the reality of the happening of events and its mind-dependence or illusory nature – it is logically impossible that this class has elements, so that the distinction in question cannot apply to events. The second consequence follows from the first, and it is even more remarkable: the existence of absolute becoming in any spacetime theory must be admitted *a priori*. If “happening” is part of the meaning of “event”, i.e., if an event’s being just is its taking place and taking place is absolute becoming, then absolute becoming is *a priori* real in any spacetime theory, since such theories assume an ontology of real, mind-independent events..

This conclusion provides what I regard as a definitive argument in favor of the first and main claim of this paper: physics cannot provide *empirical* evidence for the reality of absolute becoming because it presupposes it, at least to the extent that it presupposes an

ontology of events.¹⁷ If events cannot but happen, and the happening of events is tantamount to their absolute becoming, physics is irrelevant to establish whether there is absolute becoming, since it must take it on board *ab initio*. This is true, of course, as soon as physics embarks, as it must, on the project of explaining and predicting things that “happen out there” And as we will see in section §3, if we replace coordinate time by proper time, the difficulty raised by Weyl and Eddington about the relativity of events’ times to frames, vanish altogether.

d)

I now have to face the question that seems the most complicated of the four: the view of becoming that I am advocating seems a far cry from the intuitive notion of the passage of time of our experience. Is the becoming that I am defending here, like Dennett’s free will in his (1984), “worth wanting”?

I think that this criticism derives from two separate points that must be disentangled. The first, in particular, presupposes a supererogatory view of the task of the philosophy of time *vis à vis* the problem of becoming in physics. This first criticism seems to be based on the idea that a metaphysical interpretation of the ontology of spacetime physics must be capable of handling a psychological theory, so that until we have a metaphysical/physical theory that completely explains our psychological sense of the passage of time, we have not shown that, say, Minkowski spacetime is compatible with the becoming of our experience. The second point is the view that any form of becoming must presuppose a presentist conception of time in which the future is open, indeterminate unreal, and indefinite, in contrast to the closure, determinateness, reality and definiteness of the past. Since I hope to have disposed of the latter objection, I must deal with the former.

¹⁷ Notice that this claim does not depend on any dubious argument about the difficult epistemological problem concerning when and how does a physical theory provides evidence for ontological claims.

I take it that the main aim of the discussions concerning the definability of becoming in Minkowski spacetime was to show that, given a suitable definition of becoming – which, I submit, until very recently was lacking – a physical theory like the special theory of relativity does not contradict our temporal experience, in which becoming clearly plays an essential role. An immediate consequence of a compatibility result would be, of course, that we could *in principle* model our psychological experience of time in a spacetime arena like the one of special relativity. Absence of compatibility between the time of our experience and the time of physics would instead create trouble for physicalism in general, given that the compatibility of two theories is a necessary condition to reduce one to the other, or at least to have some sort of supervenience of one on the other.¹⁸

Therefore, I take it that the main task of the philosophical literature on time that we are critically evaluating is to show that it is in principle possible to find a plausible metaphysical “counterpart”, or a supervenience basis, of our psychological sense of passage and then to show that this counterpart is compatible with spacetime physics. At the current stage of our neuro-psychological inquiry, however, we cannot explain a phenomenological theory of our internal consciousness of time with a physical theory of time

In some sense then, the accusation that DEF₃ above cannot do justice to our experience is unfair. Clearly, the explication of becoming given above cannot do justice to the richness of our experience of time, which can only be arrived at by psychological or phenomenological descriptions. Since we don’t possess a physicalist theory of our conscious experience of time, and since it is possible that such theory could not be achieved in principle, we should be content to evaluate whether DEF₃ or some other similar proposals can constitute the supervenience base on which physiological and psychological laws and predicates could depend. And it seems to me that, from this viewpoint, *the experience of the passage of time*

¹⁸ This fact has been curiously neglected by many philosophers of mind.

must have as a physical/metaphysical counterpart at least a succession of events mind-independently occurring one after the other. This is to be regarded as the physical/metaphysical necessary condition upon which our capacity of experiencing present event, retaining past experiences and anticipating future events, is grounded. Unless we are constantly deluded by our experience, *we could not have any experience of time without this objective fact of the world*, and this statement poses an essential constraint to the possibility of a physical theory that denies the reality of time: such a theory should in any case recover as an approximation the regime of classical theories of spacetime, in which change is real because events happen in a real succession!

In a word, we cannot ask to an explication of becoming that tries to solve the problem of the compatibility of the time of our experience with the time of physics to reproduce all the details of our psychological experience of time. Admittedly, though, there is one essential feature of our experience of passage that needs to be further discussed, namely the directionality of time, which, however, we can capture only by going to *relational becoming*.

§3 Relational becoming and the arrow of time

Distinguishing between absolute and relational becoming has the aim of establishing whether, given a particular event or a class of events, it is possible to consider some events as having become with respect to it, and some that haven't. While the coming into being of an event e involves only the occurrence of e , and is in this sense intrinsic, absolute and real in any spacetime theory assuming an ontology of events, we must now look into the consequences of regarding becoming as a relation between events: $xBy =_{\text{def}}$ "y has become as of x". While absolute becoming is not sufficient to establish the directionality of becoming,

we will see how relational becoming establishes a rather unexplored connection with the issues surrounding the so-called question of the arrow of time.

The spacetime I shall be considering in this paper is Minkowski's, and the reasons for this restriction are two-fold: 1) all field theories (except gravitational ones) can be written by considering Minkowski spacetime as the arena in which events and processes occur;¹⁹ 2) as we are about to see, the definability of a becoming relation in Minkowski spacetime has been proved rigorously and it is important to base our inquiry on solid results.

In virtue of its meaning, a relation of becoming *B* holding between pairs of physical events must be regarded as *reflexive*; in addition, if we want objective, i.e. invariant (intersubjectively valid) descriptions of the world, we must also require that *B* be *transitive* for observers intersecting at a point (or at a sufficiently small region of spacetime). In order to establish a compatibility result, following Stein (1991) and Clifton and Hogarth (1995), we need three more hypotheses:

- (i) *B* is non-universal: this means that for all events x of spacetime, there are events y such that $\neg xBy$, which means, in its turn, that for all events x of Minkowski spacetime, there are other events y that have *not* become with respect to x . As we will see, it is important to keep in mind that this hypothesis is in fact equivalent to *assuming* becoming;
- (ii) for some pair of events such that y is in the causal past of x , $xK_p y$, *then* it is also the case that xBy , i.e., with obvious symbolism, $xK_p y \rightarrow xBy$;
- (iii) *B* is invariant under all automorphisms preserving a temporal orientation of Minkowski spacetime, ensuring that if we parallel transport any timelike vector

¹⁹ It is controversial whether the introduction of a cosmic time function in general-relativistic models suffices to construe becoming as more than a purely "local" notion, in the sense of "local" that will become clear in the following. For arguments in favor of the "locality" of becoming even in cosmology, I refer the reader to Dieks's paper in this issue.

pointing in the future while keeping it timelike, it will remain future-pointing everywhere in spacetime.

If the relation of becoming B satisfies reflexivity, transitivity and the three premises above, then one can prove that B is co-extensive with the relation of *past causal connectibility* (K_P): for all x and y , xK_Py iff xBy . As the knowledgeable reader will have noticed, except for the replacement of Stein's unclear and misleading relation of "ontological definiteness" with a relation of temporal becoming that is devoid of *any* ontologically asymmetric assumptions – as mandated by the first part of this paper – this is essentially the result of Stein's theorem, which has three interesting consequences.

1) If we accept Stein's hypotheses, in Minkowski spacetime *spatial becoming* (i.e., becoming relating only spacelike-separated events) is absent, so that an invariant temporal becoming is strictly *local*: the physical present of an event is just the event itself. In the special theory of relativity, as announced above, *temporal becoming* is either frame-dependent, global and therefore non-invariant or else, if invariant, as it should be in order to be *objective*, simply incompatible with *spatial becoming*.

2) As a consequence, our "natural" belief in the spatial extendedness of the present (spatial becoming) is strictly speaking *wrong*, and the special theory, together with few psychophysical findings, can explain the origin of our "mistake". To use an expression of Minkowski's, "space by itself" (1908), regarded as the order of coexistence, is a shared construction of our brains, due to the existence of a finite threshold for discriminating two light-signals as temporally successive on the one hand, and the relatively "amazing" speed of light on the other. Given a threshold of approximately 15 ms – below which we cannot tell apart *two* light signals presented in front of us in a screen – light can travel 4500 km. Call the first of the two signals A and the second B, and imagine that A is emitted on the surface of a sphere whose radius is 4500 km, while B is emitted where we are, in the center of the sphere,

just 15 ms *after* A. Because of the perceptive threshold of 15 ms, for us A and B are simultaneous and every light signal C that is emitted after A but before B will be perceived simultaneously with A and B. If we want to represent our psychological present along our four dimensional worldline, we must consider that we are “temporally long and therefore large” and “spatially thin” (as Stein more or less put it)

3) In virtue of §1, we must conclude that for any event e of Minkowski spacetime, any *future or spacelike-related* event tenselessly coexist with e , despite the fact that, *if* there is temporal becoming, all such events relative to e have not become. In fact, *if* there is becoming, Stein’s result tells us that, relative to any event e of Minkowski spacetime, only events in the past light-cone of e have become, and becoming is strictly local. Clifton and Hogarth (1995) have strengthened Stein’s result to chronological becoming, namely becoming along worldlines. *In both theorems*, however, we should note a consequence of extreme importance, that so far has been completely neglected: *temporal becoming involves the issue of an asymmetric causal or temporal relation, and therefore the complex question of direction (arrow) of time, but has nothing to do with allegedly ontic asymmetries between past present and future.* This is the second, main result of my paper.

It is interesting to ask ourselves why this simple consequence has so far escaped us. The reply is immediate if we consider Grünbaum’s (1973) argument for the conceptual separation between the issue of becoming and that of the arrow or direction of time. For Grünbaum, becoming or the flow of time involves the reality of tenses and the “moving now” conception of time, a thesis that, in fact, *is* conceptually independent of the structural difference that irreversible phenomena impose on the two directions of time. Structural difference, or as Grünbaum puts it, anisotropy, means that in one such direction we find the entropy of most closed systems going up, radiation waves diverging from a center, kaons decaying in a certain way, and galaxies receding from one other, while in the other direction of time (the one we

call from later to earlier) entropy mostly goes down, waves converge and the universe (supposing it will expand forever in what we call the past-future direction) will re-collapse to the big bang. If nowness were mind-dependent, and becoming involved a moving now, as Grünbaum has it, we could have an arrow of time (a structural distinction between the two directions guaranteed by physics) and yet no mind-independent becoming at all.

This claim is correct as long as we hold for true the wrongheaded theory of becoming espoused by Grünbaum: becoming as I see it does not involve the question of the reality of tenses. In order to evaluate Grünbaum's objection to the conceptual connection between becoming and the arrow of time, I must take a stand on the question of the nature of the present and its alleged "flow". What I have written so far has completely ignored these difficult problems and with good reasons: the question whether the presentness of an event is an objective, mind-independent feature of the event itself – or is rather to be regarded as an *indexical* like "here", "I" and "she", expressing the temporal position of the speaker relative to the event – is completely *irrelevant* for understanding the issue of the ontological status of the future or the past *vis à vis* the present. The fact that an event *E* is present may well be an *objective* mind-independent fact, and yet future and past events (relative to *E*) are to be regarded as existing in the *tenseless sense* required by DEF₂, namely as being capable of future or past occurrence. The advantage of recognizing both a tensed and a tenseless sense of existence is that we can leave on a side the question of the nature of the present or the reality of tenses. In my view, being present for an event just means for it to occur, to exist, from its own temporal "perspective"; if an observer happens to be situated where the events occur, her calling it "present" is another way of affirming the fact that the event is occurring simultaneously to her perceiving it. I don't think that treating "being present" as an indexical as I do makes the fact that an event is occurring at a certain spatiotemporal location less objective.

As I take it, the question of the motion of the present, its flow, is the question whether it is an objective fact that events occur in succession along one or the other of the two directions of time. To be vivid, call one end of the universe A and the other B, without prejudging which is the beginning and which the end: *if there temporal becoming in one direction rather than the other, it means that the order of succession of events is from A to B rather than from B to A, so that A is the beginning and B the end.* In other words yet, this also entails that the relation “earlier than” is objective, or independent of sentient beings, because while the earlier event has occurred from the perspective of the later, the later one objectively hasn’t, and this is what the directionality of becoming amounts to.²⁰ In a word, if the issue of the direction of time is not to be construed as entailing that “the past is real, the future isn’t”, or as the definability of an asymmetric relation of becoming in terms of the past causal connectibility relation, the coextensionality of the two relations, renders Grünbaum’s objections against a conceptual separation between becoming and an arrow of time irrelevant.

From Stein’s theorem we learn that the issue of becoming in Minkowski spacetime makes us land in the territory of the arrow of causation, possibly connected to other metaphysical and physical “arrows” that mark out our experience of the unidirectionality of time. While absolute becoming is *a priori* and trivially true in any spacetime theory adopting an ontology of events, relational becoming, if it is a property of our universe, seems to be entitled to avoid the muddy banks populated by the metaphysical discussions of presentists vs. eternalist and sail toward the scientifically more significant issues related to the arrow of time.

²⁰ I take it that Maudlin’s position is not too distant from the one espoused here, even though I worry much less

§4 Conclusions

However, one could still wonder whether physics is really relevant for establishing the reality of relational becoming. After all, Stein, Clifton and Hogarth were able to prove their compatibility result only *by assuming that there is becoming*, which amounts to the claim that the relation B is *not* universal (see (i) above). This does not amount, of course, to charging their compatibility result with circularity (if you are interested in establishing a compatibility result then you *must* assume becoming), but might seem to reinforce the main point of this paper, which is that classical spacetime physics cannot provide *empirical* evidence for the reality (mind-independence) of becoming, because it requires both absolute *and* relational becoming *as a priori postulations*. After all, the definition of *relational* becoming presupposes the notion of *absolute* becoming, which, as we have seen, is in its turn presupposed *a priori* in any theory assuming an ontology of events.

In order to explore the epistemic status of relational becoming *vis à vis* classical spacetime physics, there are three options that need to be briefly mentioned. Either (a) the asymmetry of causation is more fundamental than the asymmetry of becoming, or (b) the reverse is the case, or (c) both “arrows” depend on some more fundamental physical or experiential “arrow”. Even though a detailed discussion of these three options here is impossible, in order to argue that classical spacetime physics presupposes *also relational* becoming it might be sufficient to discuss the relationship between the arrow of causation and the arrow of becoming and show that the latter is *more fundamental* than the former.

In fact, if we reflect on Stein’s premise (ii) above, the arrow of becoming is construed as a necessary condition for the possibility that event a causally influences b , whenever a is in the

than he does about justifying a literal *flow* of the present.

causal past of b . If we assume that influence on any event b in Minkowski spacetime can only (or typically) come from an event a in the causal past of b , *then we must also hold that a has become as of b* . In this hypothesis, since is the temporal succession of events (the order of becoming) that confers an asymmetric order to causation, it is more fundamental than the causal arrow. Epistemically this hypothesis seems highly plausible, since if we did not know that a process is already temporally directed from a to b , we could not claim that b is the *backward* cause of a (where “backward” means of course that b is later than a).²¹ In order to distinguish forward from backward causation we must regard the temporal order as something that is given independently of the asymmetry of the causal relationship. And the same is true from an *ontological* point of view: if a process were not already temporally directed from a to b , b could not be the “backward” cause of a .

If we grant the asymmetry of becoming center stage and leave the asymmetry of causation in the background, understanding whether physics presupposes also the order of becoming looks a much easier task. In fact, it is not at all clear how physics could *explain* or *ground* the fact that in the universe *there is* a successive coming into being of events, since such a succession is necessarily assumed *to make sense* of any problem concerning the existence of irreversible physical processes. Certainly, physics could provide evidence as to the reason why we observe that a local (STR) or possibly global (GTR) succession of events is directed from A to B rather than the other way round.²² That is, physics can tell us whether we can associate or correlate some irreversible physical process or law with the order of becoming (say the growth of entropy in one of the two directions, or the expansion of the universe, or the decay of kaons in the weak interactions). But it should be clear that talking about the asymmetry of certain physical processes *in time presupposes the reality of a successive coming into being of physical events, i.e., the reality of temporal becoming*. In this respect,

²¹ I owe this argument to one of the referees.

the deep reason why the search for a master asymmetry in physics presupposes the order of becoming is given by the fact that in order to have real time, we must have a successive coming into being of events in one of its two directions.²³

By looking at some formulations of quantum gravity, one could argue that even though physics cannot ground or explain the arrow of becoming, it could certainly falsify the claim that, at the most fundamental level, there is a temporal succession of happenings. Despite the lack of any empirical evidence concerning quantum theories of gravity, we should be open to this theoretical possibility. However, even granting it does nothing to jeopardize the conclusions we have reached so far: since any theory of quantum gravity should be able to recover classical spacetime theory at a certain level of description, in no way could we conclude that temporal becoming is an illusion: all physical theories we know so far presuppose (in the sense we have seen) that there is an unfolding of events in time (local, or global as it might be in cosmology) and even a no-change theory will have to take this fact into account. After all, when thermodynamics was explained by a deeper, *time-symmetric* theory (statistical mechanics), the irreversibility of thermal phenomena did not certainly go away.²⁴

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²² For the example involving the two events A and B, see above.

²³ Of course, we could have asymmetries in space (say a table being at the same time large at one end and small at the other) but such an asymmetry could never be regarded as temporal.

²⁴ It is interesting to consider the kind of gap that otherwise would originate between fundamental physics and experience: not only would the explanation of the illusion of succession still be an act that takes place in time, but even confirming any such no-change theory would take time. For the problem concerning whether physics could coherently deny the reality of time, see Healey (2002).

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