# <u>Lecture 3</u> The Direction of Time

## 1. Introduction

Last time, we looked at paradoxes that arise from the idea that time *flows*. While some of these problems arose, in part, because of the need for some kind of temporal asymmetry, the problems of flow and direction are strictly distinct. For one thing, it is possible to think that time is asymmetric without thinking that it has flow or is dynamic.

Independent of the matter of flow, there are reasons to think that time has an objective asymmetry. Future events seem unsettled, and past events fixed, but never vice versa. As time 'passes' from past to future, ice in hot water melts but lukewarm water never separates into ice and hot water, gas particles spread out to disperse evenly in a room but never independently come together to form a localised mass of particles. So many of the universe's processes seem to go in one particular direction, namely the past-to-future direction, and never go in the other. But if the laws are time-reversal invariant, as so many of the laws of physics are, then how come events occur in this systematically asymmetric fashion? It cannot be because of the laws themselves, so it must be that time itself is asymmetric.

Since we have reason to think that time is asymmetric, the following question arises: what gives time its asymmetry? What makes time directed? Or, as Eddington put it, what explains the "arrow" of time? We'll look at a few different proposed answers to this question.

# 2. The Arrow of Causation

One popular answer to this question is that it is the direction of **causation** that underpins the direction of time (Reichenbach 1958, Grünbaum 1963, Mellor 1981, van Fraassen 1992). Or, if you like, time's arrow arises from causation's arrow.

We'll rehearse Mellor's argument for this position in particular. He begins by noting that we have an **experience** of time's succession. That is we have experiences as of some events occurring earlier than other events. Take our experience of seeing a hand on an analogue clock: we see the hand pass '1' (call the event of the hand's passing '1' e), and see the hand pass '2' *later* (call the event of the hand's passing '2' f). But, the mere fact that one experience occurs after the other does not in itself suffice to tell me that f occurs later than e.

a succession of feelings, in and of itself, is not a feeling of succession. And since, to our successive feelings, a feeling of their own succession is added, that must be treated as an additional fact requiring its own special elucidation (James 1890: Vol. 1, 628–9, cited in Mellor (2009)). As Mellor puts it, if by the time I experience f, I've forgotten about experiencing e, the mere fact that the experience of f came after the experience of e won't tell me anything about the order in which the events occurred. So, for us to have an **experience of succession** (rather than merely successive experiences), it must be the case that my experience of f is "*affected* by" (Mellor 2009: 453, my emphasis) my experience of e. This shows us that our experience or perception of the direction of time comes from the direction of causation; the causal relations between the two experiences lead us to experience e as preceding f when our experience of e precedes our experience of f.

This explains how causation gives our *concept of time* a direction. Now we require an argument for thinking that time *itself* shares this direction. I.e. for thinking that our concept of time accurately reflects the objective nature of time. Here, Mellor argues that the fact that we can perceive only the past and affect only the future gives us the reason we need to bridge this gap. Perceptions are *effects* of that which is perceived. That means, in the case of perceiving events (and indeed, all other effects) **causes precede effects** (NB: this is a descriptive claim about causes; not (at this point) a conceptual claim). Similarly for our actions and their effects. These are facts that "identifying time order with causal order immediately explains" (454). If we identify these two 'arrows' then it immediately follows that the causes of our perceptions could only be in the past and the results of our actions could only be in the future. Thus we have reason to think that the objective direction of time is nothing other than the **order of cause and effect**.

# OBJECTIONS

- This rules out backward causation by fiat
- Some causes are simultaneous to their effects
- This cannot help us to order causally unrelated events in time
- This is inconsistent with B-Theory
- This conflicts with physicalism (i.e. the position that "that the abilities the world grants us, and restrictions it imposes on us, are determined ultimately by physics" (Price and Weslake 2009, 416))

#### 3. The Arrow of Entropy

Another candidate explanation of time's arrow appeals to the asymmetry of **entropy**. These explanations make reference to the

**Second Law of Thermodynamics**: there is [a] quantity, called entropy, which in some changes remains constant, but in other changes increases, whereas it is impossible that this quantity ever decrease. Irreversible processes are those in which entropy increases. (Reichenbach 1956: 50, cited in Savitt 1996: 352)

Think of entropy roughly as the level of organisation (or lack thereof) in the arrangement of particles in a system. So, a **low-entropy** state is organised but improbable; and a **high-entropy** state is more disorganised but also more probable. To see this, imagine there are only 10 molecules of some gas in this room. Consider all of the position in the room each molecule could be in, and all of the possible combinations of those positions of the 10 molecules relative to one another. Only very few of those are configurations where all 10 molecules are in the upper north-west corner of the room; there are many many more configurations where the 10 molecules are scattered in much less organised fashion. The former would be a low-entropy state of the system, and the latter a high-entropy state.

Since, according to the Second Law, entropy never decreases, the direction of entropic increase is **asymmetric**. (Strictly speaking it isn't true that the Second Law is an asymmetric law. There is a very *very* small chance that entropy can decrease in a system. For present purposes, though, we can accept this rough characterisation of the nature of entropy.)

Now, it is certainly the case that, in our neck of space-time, the asymmetries of entropic increase and time coincide. Entropy seems to increase in a past-to-future direction. But that doesn't suffice to show that time's arrow is caused by or identical to the entropic arrow. Positing this to be the case would seem to do some explanatory work (e.g. it would explain *why* these asymmetries coincide). However, there is a problem. This is due to *Loschmidt's reversibility objection*. The details of the objection aren't important for our purposes; it will be enough for us to understand its conclusion. And that is that "for an isolated system with no beginning and end **there is no statistical asymmetry in thermodynamic behaviour**" (Savitt 1996: 352, my emphasis).

So, in order for thermodynamic laws to do the work we want them to do, we also have to posit a kind of beginning or "**boundary condition**" as it's called. That is, we need the following assumption:

**Past Hypothesis**: At a point in the distant past, the universe was in a state of very low entropy.

Only with this assumption in place is it the case that there is a statistical asymmetry in thermodynamic behaviour such that entropy (almost) always increases.

## OBJECTIONS

- The fact of global entropic increase does not guarantee the *local* entropic asymmetry that we observe. So the claim about the asymmetry of entropic increase in the global system does not explain why our local systems exhibit the asymmetric behaviour that they do, let alone why those systems seem to increase in entropy *into the future* rather than into the past.
- Relatedly, we have just as much reason to suppose a kind of **Future Hypothesis** according to which the state of the universe in the very distant *future* is a very low-entropy state.
- The Past Hypothesis is *incredibly* unlikely.

# 4. The Arrow of Counterfactual Dependence

According to David Lewis (1979) the asymmetries of both time and causation should be understood in terms of the (contingent!) asymmetry of counterfactual dependence at this world. Recall that, on Lewis's view, one event B counterfactually depends on a distinct event A iff:

- (1) If A were the case, then B would be the case; AND
- (2) If not-A were the case, then not-B would be the case.

A counterfactual like (1) is true (on Lewisian semantics) iff **all the closest possible A-worlds are B-worlds**. Now, how do we rank the closeness (or similarity) or worlds? According to the following ordered rules:

- (I) Avoid big, widespread, diverse violations of law.
- (II) Maximize the spatio-temporal region throughout which perfect match of particular fact prevails.
- (III) Avoid even small, localized, simple violations of law.
- (IV) It is of little or no importance to secure approximate similarity of particular fact, even in matters that concern us greatly.

As it happens, Lewis argues, at our world, when we rank other possible worlds in terms of their similarity to ours using these rules, it is always the case that the antecedent of the counterfactual precedes the consequent in time. But this is a merely contingent fact! It could very well be that, at other possible worlds, counterfactuals aren't asymmetric in this way.

It is a contingent fact about our world that there are many more *future determinants* of past events than there are *past determinants* of future events. A **determinant** is "a minimal set of conditions jointly sufficient, given the laws of nature, for the fact in question" (1979: 474). You can think of these like *traces*. Consider an event like my breaking an egg. The traces that this leaves include things like:

- the change in the particles in the air caused by the vibration of the egg striking the side of the pan
- the memory I have of the egg's breaking.
- the various bits of egg shell that are projected in particular directions because of the exact way the egg struck the pan
- the change in arrangement of the yolk and white in the shell because of the strike
- the slight movement of the pan caused by the force of the egg on its edge

Each of these *individually* is a determinant for the event of my breaking the egg. However, there are far fewer determinants of that event earlier than the breaking.

Thus, this asymmetry of determinants provides a (contingent!) asymmetry between past and future at the actual world. That is, it can explain the asymmetry of time.

# OBJECTIONS

- This does not do enough to explain *why* there is such an asymmetry at our world
- This makes the asymmetry of time merely contingent
- There is reason to think Lewis is wrong about the asymmetry of counterfactual dependence (cf. Elga 2001)