# Explaining Time’s Direction.

Robert Barber

June 2021

Submitted to the University of Hertfordshire in partial fulfilment of the requirement of the degree of MA by Research.

# Table of Contents

## Abstract

The characteristics of the tenseless theory of time do not account for the direction of time that we experience at a global or local level. There have been several attempts by scientists, and philosophers, to account for what underpins time's direction. But all of these accounts fail to give a full account of time's direction, most commonly in accounting for the direction of time at a local level. I put forward that Lewis's asymmetry of counterfactual dependence, when adapted to be underpinned by the asymmetry of quasi-miracles, accounts for time's direction, at both a global and local level. Lewis introduced quasi-miracles to solve a different problem in his asymmetry of counterfactual dependence. But, I believe that by recognising the extraordinariness of certain events helps to explain why the explanation of some local events occurring appears to be time's reversal, when in fact the event is just following the laws of nature. I further argue that this account for time's direction should be combined with the Past Hypothesis, which gives us a new understanding of what should be considered a fundamental law of nature, so that we do not require lots of extraordinary events to account for the way our world is.

# Introduction

This discussion is concerned with the tenseless theory of time establishing a consistent explanation for what underpins the direction of time. To account for time's direction the following will be discussed:

- §1 will state that the tenseless theory of time is compatible with scientific theories, such as Einstein's Special Theory of Relativity. However, there is nothing in the characteristics of the tenseless theory which accounts for the global and local experience of time.

- §2 will introduce different scientific theories, such as the laws of thermodynamics, which, could be argued, underpin time's direction. However, this discussion will show that no scientific theory alone can explain time's direction.

- §3 states arguments about how causation could underpin the direction of time. This discussion will demonstrate that any explanation for time's direction should be unaffected by causal loops, and backwards causation, regardless of whether are possible, or impossible.

- §4 makes progress on explaining time's direction by turning to Lewis's asymmetry of counterfactual dependence. This states that change (not literal or actual change but only possible) is possible towards the future based on the present situation, but is not possible towards the past. In other words, the past is fixed and independent of the present, whereas the future is open and dependent on the present. This account will be further developed and underpinned by the asymmetry of miracles. However, Elga will argue that Lewis has not reconciled his theory with the laws of thermodynamics. This means that Lewis has not fully explained the local experience of time's direction.

- §5 introduces the Past Hypothesis (PH), which states the fact that the early universe was in a state of low entropy, is a fundamental law of nature. This is combined with an adapted asymmetry of counterfactual dependence. The adaptation being that counterfactual dependence is underpinned by the asymmetry of quasi-miracles. This account will solve problems, like Elga's, because they are striking and extraordinary cases which follow the laws of nature but appear to be explained by another means. In Elga's case it is following the laws of thermodynamics but appears to be appealing to a time reversal explanation.

This will lead to the conclusion that the tenseless theory of time accounts for time's direction by it being underpinned by the asymmetry of counterfactual dependence. This in turn is underpinned by the asymmetry of quasi-miracles. The PH is combined with this account as it explains why the early universe was in a state of low entropy without having to appeal to an extraordinary and striking explanation.

**1.1 Tensed theories:**

McTaggart (1908) distinguishes two ways in which things can be ordered in time, which he calls the A-series and the B-series. The A-series orders events in terms of their being past, present and future. Theories of time which take this way of ordering as fundamental are known as tensed theories, since these relations between events change over time. For example, for someone located in 1890, World War I is in the future, it becomes their present (between 1914 – 1918), and then past (after November 1918).

Tensed theories of time hold that the qualities of being past, present or future are objective features of reality. In other words, these terms do not merely indicate one's perspective in time. With this way of ordering things in time, the temporal location of each of these events is not permanent, as they move from being in the future, into the present, and then into the past.

McTaggart explains that no event can have more than one of these qualities at any given moment, since that would be contradictory. For example, the present date for me as I write this is 29/06/2021. It does not make sense to say that today also has the quality of being future or being past. As time passes, the quality will change, but that moment cannot have more than one of those qualities at any moment.

There are different understandings of the tensed theory of time. For example, there is Presentism (e.g. Bourne (2006)), where the only actual time is the present time; No Futurism (e.g. Tooley (1997)), where the past and present exist but not the future; and Branching Futurism (McCall (1994)), where the past, present and future exist, but as time flows many future possibilities cease to exist. There are other versions of tensed theories, other than these. What is important is that, in all versions, there is an objective present moment. For the tensed theory of time, the necessity of an objective present moment being a feature of reality is problematic, as will become apparent in §1.3.

**1.2 Tenseless theories:**

The B-series orders events in terms of their being *earlier than*, *later than* and *simultaneous with* each other. Theories of time which take the B-series relations to be the fundamental way in which things are ordered are known as the tenseless theories of time, since the relations between events do not change over time. For example, World War I is always earlier than World War II and the Vietnam War is always later than World War II.

There is no unique objective present moment in the tenseless theory. Terms such as 'past', 'present' and 'future' are indexical, and subjective, terms. For example, if I said, "I am present”, ‘present’ just marks the moment in time at which I said these words. Similarly, anyone else in history who has uttered a similar statement is just referring to their own temporal location at that moment.

Similar to the tensed theory of time, there are various versions of the tenseless theory. But the version I take to be a paradigm example is Mellor (1998).

**1.3 Relativity of Simultaneity:**

A key feature of the tensed theories is the proposal that there is a unique objective present. However, this feature seems to be incompatible with certain scientific theories; in particular, Einstein's Special Theory of Relativity (STR) and Minkowski's space-time.[1]

According to STR, the speed of light is a constant (c). In other words, it does not matter what one's frame of reference is, the speed of light will always remain the same. According to the relativity postulate, the laws of nature for one person are the same as the laws of nature for another person. But, when the laws of nature are in combination with the law of the constancy of the speed of light, there is the consequence that the ordering of events is relative to one's frame of reference. For example, Einstein (1905) imagines a train moving at ½c (relative to the track) when two lightning strikes, X and Y, hit the train simultaneously. If person A stands outside the train at the midpoint between the two lightning strikes, then those lightning strikes will appear to be simultaneous, due to the speed of light being a constant. However, for someone at the midpoint between the strikes in the train, person B, strike Y will appear to occur first followed by strike X (see Figure 1.3.1).

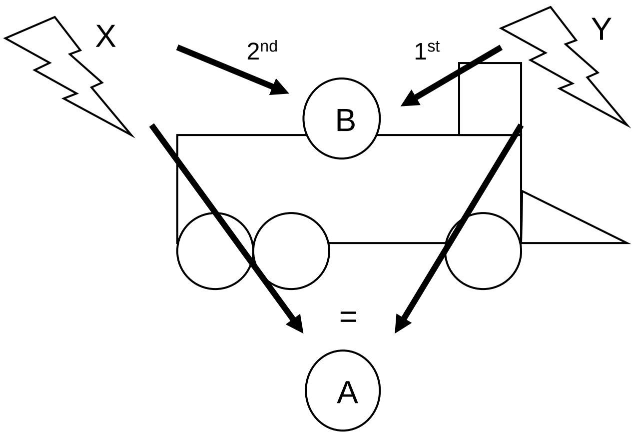


Figure 1.3.1

Understanding why this is the case can be illuminated using Minkowski's explanation of the implications of STR. Minkowski (1908) states that time and space are not two separate dimensions. Instead, as a consequence of Einstein's STR, they can be understood as aspects of one underlying structure known as space-time. Space-time's structure can be understood in terms of light-cones. It is a consequence of the

[1] Putnam (1967) is the first influential statement of this argument. However, Putnam's argument leads him to the conclusion that there are no longer any philosophical problems only scientific ones. This conclusion, I believe, may be too strong, but the criticism he makes of the tensed theory, as I explain, needs resolving by philosophical supporters of tensed theory.

constancy of the speed of light, together with the relativity postulate, that the speed of light is the limit at which things can travel. So, a light cone shows the limits of causal connections between events.

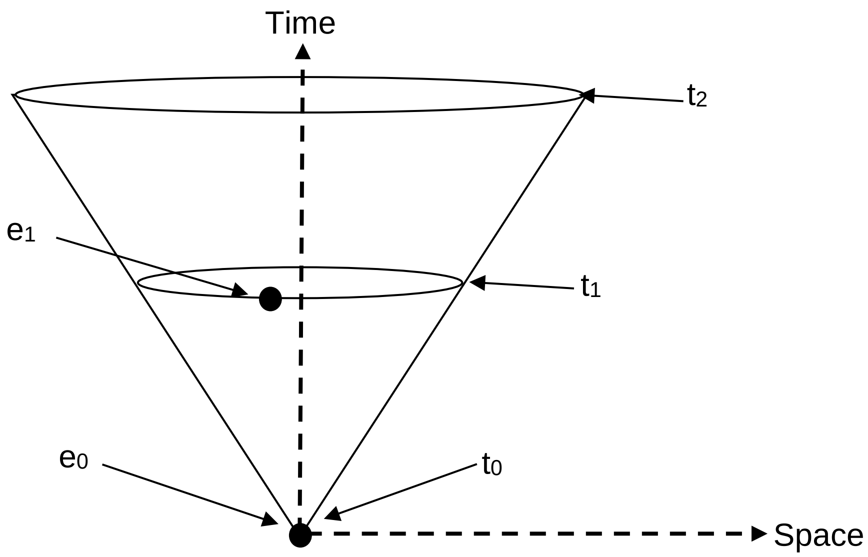


Figure 1.3.2

Figure 1.3.2 shows an event, $e_0$, in space at time $t_0$. At time $t_1$, the lines show how far light could travel between $e_0$, at $t_0$, and $t_1$. As event $e_1$ falls within, or on, these lines it means that $e_1$ can be, but not necessarily is, causally connected to $e_0$. Any event which lies beyond the lines cannot be causally connected to $e_0$. This is because, for there to be a causal connection between $e_0$ and an event outside the lines, it would require the causal connection to have interacted faster than the speed of light. According to Einstein's STR, this is not a possibility.

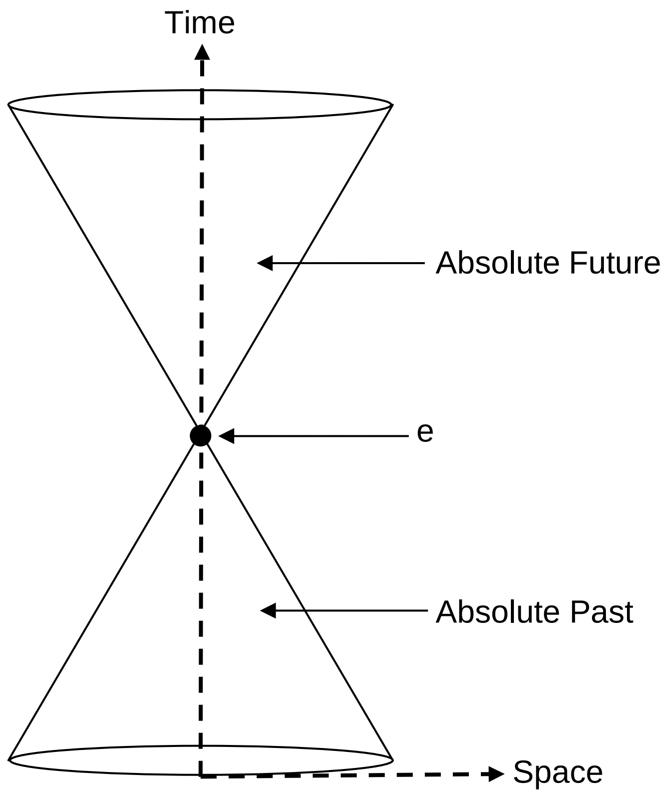

Figure 1.3.3

Figure 1.3.3 shows two light cones. One shows the limits of causal connection between event e and any other future event which lies within this light cone. This cone is known as the ‘Absolute Future’. The other cone shows the limits of causal connection between e and any past event which lies within this light cone. This cone is known as the ‘Absolute Past’. Any event which lies within the Absolute Future is in the future of e in all frames of reference. Any event which lies within the Absolute Past is in the past of e in all frames of reference. However, any event which lies outside the light cones may be earlier, or later, than e depending on one’s frame of reference, as shown in Figure 1.3.4.

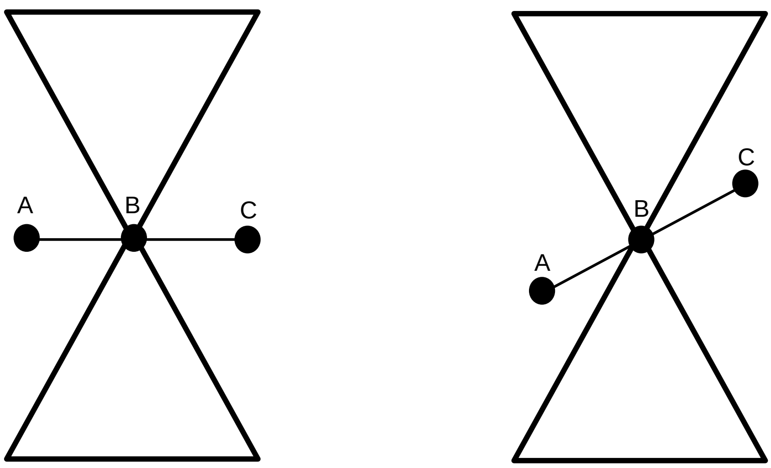


Figure 1.3.4

Figure 1.3.4 shows three events, A, B and C, from two different frames of reference. A, B and C are not causally connected, as each falls outside the others' light cones. The line connecting the events together is the present perspective from the point of view of the observer. The left-hand diagram represents the frame of reference of an observer who is stationary and in which the three events are simultaneous. The right-hand diagram represents a frame of reference in which an observer is moving (at, for example, ½c), with respect to the first observer and so A appears to happen earlier than B, and C appears to happen later than B. Similar to Einstein's train example, there is nothing in the physics of the situation to privilege one frame of reference over the other.

STR, and space-time, thus poses a problem for tensed theories because simultaneity between spatially separated events is relative; and so there is no universe-wide objective plane of simultaneity and so no universe-wide objective present moment. As stated above, the objective present moment is a common key feature of the different versions of tensed theories. Therefore, tensed theories seem incompatible with this scientific theory. Even though this problem, or any other problem that the tensed theory has, may not be insurmountable, nevertheless, it does still need explaining.[2]

[2] There are ways that supporters of tensed theory have tried to surmount the problem of its compatibility with STR. Sklar (1977) and Stein (1991) argue to accommodate for the dynamic qualities of the tensed theory without having to reject the key principles of STR – both have approached this argument in different ways. Tooley (1997) argues for an incompatibilist approach, which would reject STR in its standard form and, as a consequence, would then make it compatible with tensed theory. Bourne (2006) argues that the problem is in Einstein's definition of simultaneity, instead he offers an alternative understanding and definition to resolve the problem.

The tenseless theory, however, does not have the same problem with STR, and space-time. This is because the tenseless theory does not require a unique objective present. In other words, when one states an event is earlier or later than another event, one is only stating this for one's own frame of reference. Given this initial compatibility of the tenseless theory with STR, I am going to focus the rest of this discussion on whether this theory of time is able to account for the direction of time.

Even though Minkowski's diagrams represent the limitations of causality, they do not tell us, let alone explain, the direction of causality between two or more events. It may appear intuitive for one to say that an event within the Absolute Future light cone comes after e, where e is the cause of the event in the Absolute Future light cone. However, this could just be convention due to one's frame of reference. Therefore, if one wants to show that causality determines time's direction, then one needs to show that there is a causal asymmetry. In what follows, I will look at some existing proposals for what underpins the direction of time and show that they fail. This will put us in a better position to see what an adequate account of time's direction would have to achieve.

**1.4 Section Summary:**

- Tensed theory of time explains the direction of time because it is the change of a moments quality from being in the future, to the present and finally being in the past.

- The tensed theory is problematic when considering its compatibility with scientific theories, such as STR. This is because depending on one's frame of reference will effect whether an even will appear to be earlier than, simultaneous to, or later than another event. This means that an event may have more than one quality at any time of being past, present or future, which it cannot have.

- The tenseless theory of time does not have the same compatibility issue with the scientific theories, such as STR. However, there is nothing about the tenseless theory of time which explains the direction of time which we experience.

- The following sections are going to look at the different possibilities for what could underpin time’s direction. I will conclude, that by using a Past Hypothesis understanding of the laws of thermodynamics, time’s direction is underpinned by the Lewis’s asymmetry of counterfactual dependence with the adaptation that that is underpinned by the asymmetry of quasi-miracles.

## Theories of Time's Direction

Any theory of time's direction needs to pass two tests, as argued by Mellor (2012). First, the global test: it needs to explain a global direction of time; that is, the universe-wide direction of time. Second, the local test: it needs to explain a local direction of time; that is, the experience of time at the local level. By passing these two tests, any theory of time's direction will explain why the universe's direction of time and our personal experiences of the direction of time seem to go in the same direction.

Scientists, such as Hawking (1988), argue that the global direction of time is underpinned by the laws of thermodynamics. It may be intuitive to conclude that the laws of thermodynamics also underpin the local account of time's direction. However, this intuition does not necessarily follow and needs further investigation. Before explaining why this might be, I think it is important to consider other possible theories and why they do not need to be considered as seriously as the laws of thermodynamics. I will briefly explain the arguments for radiation and the expansion of the universe underpinning the direction of time before arguing that these do not give a sufficient account.[3]

### 2.1 Radiation:

Radiation is a wave which, as it progresses, will become more spread out. Light radiation is an example of this. Radiation could underpin the direction of time if two conditions are met. First, that the radiation wave always spreads out from an emitter in concentric circles (known as 'retarded waves'), but the waves never move inward towards the emitter (known as 'advanced waves'). Second, the radiation waves continue to spread out and never converge.

Price (1996: 49–77) argues that the first condition is contentious. The first condition is problematic because Maxwell's theory of electromagnetism mathematically allows for both retarded and advanced waves to be observable in nature. Wheeler-Feynman Absorber Theory states that the reason one never observes an advanced wave is

[3] Le Poidevin (2004: 206), Mellor (1998: 119) and Price (1996) all examine these scientific theories as possibilities for the direction of time before arguing that they are insufficient.

because the source's advanced wave is cancelled out by the advanced wave of the absorber particles, so one only sees a retarded wave. An analogy for this is a computer screen. When looking at one from a certain distance, one sees a complete image. However, the closer one looks, the more the image breaks up and becomes pixelated. For radiation, this means that on a macroscopic level – analogous to the computer screen – only retarded waves are observable. But, at a microscopic level – analogous to the computer pixels – one can observe both retarded and advanced waves. One could ask of Price's criticism why it is not good enough to explain the global direction of time in terms of being a macroscopic phenomenon. But I am not going to take this question any further, at this stage, because even if Price does have a response, the second condition stated above is still contentious.

As Mellor (2012) argues, the second condition for radiation underpinning time's direction is also contentious. The second condition, that a wave must continue to spread out and never converge, is problematic. This is because by using a convex lens a radiation wave would begin to converge on itself. One may argue that this would only impact a local area of the wave and the wave as a whole could compensate for this convergence and continue to spread out. But this still means that radiation does not pass Mellor's local test for a theory underpinning time's direction. This is because if radiation did underpin time's direction then, at local level, one may expect to experience time symmetrically rather than asymmetrically.

### 2.2 Expansion of the Universe:

For the expansion of the universe to underpin the direction of time, it would mean that the universe must never begin to collapse in what might be referred to as big crunch, as described in Gold's Universe.[4]

The idea of Gold's Universe is not popular because cosmologists believe it would lead to inconsistencies with current predictions on how the universe will continue to expand.[5] However, Price argues that arguing for inconsistencies in Gold's Universe is appealing to a double standard within science. Price (1996: 79-81) states that the early

[4] Gold Universe is named after Thomas Gold due to his 1962 publication of 'The Arrow of Time'.
[5] Gold's Universe would require the end of the of the universe to be smooth and homogenous, but not so much that a collapse would not begin.

universe was "distributed in an extremely smooth and homogenous way, with almost the same density everywhere." The chances of the early universe exhibiting characteristics as those described is 1 in $10^{10^{123}}$.[6] Why did the early universe exhibit such unlikely characteristics? Importantly for this point, why is it more improbable that the end of the universe would not exhibit similar, unlikely, characteristics? These two questions have not been explained by scientists and until they are, it does not seem unreasonable to maintain Gold's Universe is a genuine possibility. The possibility (whether actual or not) of Gold's Universe is enough to mean that time's direction cannot be identified with the expansion of the universe, because if the universe collapsed then time would not go backwards. To make sense of a collapse, time's direction would have to be maintained independently of this process in order to articulate the process of expansion and then collapse.

Even if science could conclusively prove that Gold's Universe is not a possibility, then the expansion of the universe still does not underpin time's direction because it cannot pass the local test. Mellor (2012: 208) states "For just as a child's growth is a fact about its whole body, not about any one of its cells, so the universe's expansion is only a fact about all of it, not about any point or thing within it." In other words, the expansion of the universe can only underpin time at a global level. There is nothing about the expansion of the universe which explains our experience of the direction of time. So, the expansion of the universe does not pass the local test and does not underpin time's direction.

**2.3 Thermodynamics:**

As stated above, for scientists, the popular theory for underpinning time's direction is to use the laws of thermodynamics. In particular, the second law which concerns entropy. The second law of thermodynamics dictates that entropy, or disorder, tends to increase over time. Whether an isolated system can be considered to be in a state of high (disordered), or low (ordered) entropy is relative in comparison to another isolated system. As time progresses, the entropy of an isolated system will increase.[7] In other words, things move from being ordered to less ordered. For example, compare

[6] Calculated by Penrose, R (1979) cited in Price (1996:83).
[7] See Dainton (2001), Atkins and Jones (2004), Atkins (2010)

one isolated system of a glass of water on a table in comparison to another isolated system where there is a broken glass of water on the floor. The glass of water on the table has low entropy and the broken glass of water has high entropy. This is because, in comparison to the broken glass on the floor, the glass on the table is structured and the water is contained, whereas the glass on the floor has lost its structure and the water has spread out on the floor. The proposal is that entropy could give time its direction, because time's direction would be determined by the measure of an isolated system going from low to high entropy. However, Price (1996: 29–31), using the consequences of Boltzmann's work on entropy, argues that the law of entropy is symmetrical rather than asymmetrical at a global and a local level. It therefore does not pass either test.

North (2011: 320-2) explains, by using statistical mechanics, that in any specified macro state there will be many different compatible microstates. In other words, there will be many different arrangements of a system's particles which can give rise to the same macro features. This can be explained in terms of phase space. Phase space is a mathematical concept which represents all the possible fundamental states of a system. Rather than the standard three dimensions used to describe space, phase space has six dimensions. There are three values to specify the location of a particle on the *x*, *y*, and *z* axes, and three to specify the velocity of a particle through the *x*, *y*, and *z* axes. Any point in phase space represents a possible microstate for the system. A macrostate corresponds to a region in phase space, within which each point picks out a microstate that realises the macrostate. For example, the phase space of a gas is where each point represents the different possible arrangements of positions and velocities of the particles in the gas. Imagine a gas filling up half of a room. There are different arrangements the gas can take so that it fills up half of the room. For example, one could swap some the gas particles’ positions, or change their velocities, but the gas would still fill half of the room. Boltzmann showed that the entropy of a given system is a function of how many different arrangements of the system's particles are compatible with its macrostate. This is because there are more ways for a gas to be arranged when spread out around a room, which would show a state of high entropy, than there are arrangements for a gas concentrated in a small part of room, which would show a state of low entropy. This suggests that we can understand entropy increase as the progression toward more and more probable macrostates. Add to our theory a natural seeming probability assumption, that a system is as likely to be in any one of its possible microstates as any other, and we get that high entropy, large volume occupying macrostates are overwhelmingly more probable than low entropy, small volume ones.

At this point, it may appear that the laws of entropy are actually asymmetric. However, North (2011: 315–7) states dynamical laws are symmetric. For example, a baseball flying through the air will obey the laws of nature acting upon it. If you were to invert those laws of physics one would see the reverse of the event. North (2011: 323–4) states that when combining the symmetric dynamical laws with the laws of entropy one finds that there are just as many entropy increasing states as there are entropy decreasing states for a system to evolve into from its current state. This means that it is equally probable to have entropy increasing towards the future as well as the past. In fact, using statistical mechanics, it is more probable that entropy increases towards past than decreases. However, this is not what one finds. Instead, one finds that entropy decreases towards the past. Consequently, statistical mechanics states that it is extremely unlikely that any of our evidence for the world's low entropy past is reliable. Therefore, Price (1996) asks 'why does the past start in a state of relatively low entropy?' According to Price, this is a question left unanswered, and ignored, by scientists. Price states that by scientists leaving this unanswered, and ignored, they appeal to double standards. In other words, the laws which state that one should expect high entropy in the future should apply the same to the past. Thus, entropy does not explain the global asymmetry between the past and future, and thus does not explain time’s direction.

Entropy also fails to give time's direction at a local level. Following the explanation of statistical mechanics above, imagine an ice cube and what it would be like five minutes into the future. One would expect it to be have partly melted. Imagine then what the state of the ice cube would be like five minutes into the past. One would expect it to be frozen, potentially in a less melted state. However, statistical mechanics states that actually it should be more melted, similar to five minutes in the future. The statistical mechanical explanation for entropy increase lacks the resources for explaining why there is increase towards the future but decrease towards the past. The statistical mechanical explanation for entropy contradicts our experience of the world at a local level. The laws of thermodynamics fail to pass either the global or the local test required to underpin time's direction. Nevertheless in §5, I am going to return to these ideas because, while I do not think the laws of thermodynamics solely underpin the direction of time, I do think that they are part of the solution.

**2.4 Section Summary:**

- Any explanation which attempts to underpin the direction of time needs to pass both the global test and the local test.

- Neither radiation nor the expansion of the universe can be used to underpin time's direction as neither explain the direction of time at a local level. Both theories also seem to be contentious at a global level.

- The second law of thermodynamics has been proposed to explain the direction of time. In other words, time follows the direction of systems moving from states of low to high entropy.

- However, the statistical mechanical explanation of the second law of thermodynamics seems to be problematic because, if it does explain the direction of time then there needs to be an explanation for (i) why the universe started in a state of low entropy when statistical mechanics would suggest it started in a state of high entropy, and (ii) why, at a local level, we do not experience cases of high entropy towards the past as statistical mechanics would predict.

- These scientific laws alone do not underpin the direction of time.

## **Causal Asymmetry**

Minkowski's light cones, in §1.3, showed the limits of what could be causally connected. As discussed above, there is nothing about the light cones which necessitates that the interaction between two events means that the earlier event is the cause of the later event. However, there could be something about the nature of the cause and effect relationship which means the cause necessarily is the earlier event, and the effect necessarily is the later event. If so, the causal asymmetry could underpin the direction of time. In this section, I am going to present three different arguments to demonstrate causal asymmetry. Each of three of the arguments are going to be problematic, but the arguments are useful to show what is required of any theory which tries to explain time's direction.

### 3.1 Fork Asymmetry:

Fork Asymmetry is often used by philosophers and scientists to underpin the causal asymmetry. This analyses causal asymmetry in terms of physical asymmetry, which is shown in the laws of nature, such as the laws of thermodynamics. Reichenbach (1956) argues that causal asymmetry, in terms of physical asymmetry, is shown through the Principle of Common Cause (PCC).[8] Reichenbach explains that PCC is where two events, A and B, are correlated but neither is the cause of the other. Reichenbach states that A and B must have a common cause, C, which preceded them. For example, if A is smoke and B is heat, neither of them is the cause of the other but as one increases, or decreases, so will the other. A and B both need the same cause; so, in this example, C is fire.

Price (1996: 140–2) states that there are two problems with fork asymmetry - Reichenbach's PCC:

> 1st Problem: many common causes are too rare and too insignificant to give rise to correlated effects. In other words, one only finds the correlated effects when the cause is big and frequent enough to cancel out background noise, and this does not happen often enough.

[8] PCC is Reichenbach's term for fork asymmetry.

Price, when arguing for common causes being too rare and insignificant to cancel out background noise, tells us to imagine a world where we witness the only fire ever to have occurred. Price then tells us to imagine a heater and smoke machine which produces more heat and smoke than the fire. They produce so much that the amount of heat and smoke produced by the fire would seem insignificant. From what we know, it would be absurd to say that the fire did not cause the heat and smoke. However, why would one conclude the fire is the cause of the heat and smoke, as the fire seems insignificant. Price (1996: 140) states: "The causal facts seem to be quite insensitive to the amount of actual correlation of the kind required for the fork asymmetry." Price concludes that the fork asymmetry provides, at best, a partial distinction between the cause and effect that fork asymmetry is meant to show.

> 2$^{nd}$ Problem: asymmetric macroscopic events are dependent upon a huge number of symmetric microscopic components. The microscopic components of the laws of nature, which are used to understand time's direction, are symmetric. Price (1996: 148-52) uses this to argue that there is no fork asymmetry in microphysics.

Price imagines an outgoing radiation wave from a single atom source, i. To measure the difference between the presence and absence of i at time t, and because i is a source rather than a sink, the difference would be observable after t. After t, it is possible to determine whether i had been present by the presence, or absence, of an outgoing ring of correlated changes in the field. To see the pattern of correlation, one would need to correct for background noise; in other words, know the state of the field before t. If we know this and know i is the only variable, then for us i is over-determined by the later state of the field. However, what applies to the atom source, i, equally applies to an atom sink, i*. To measure the difference between the presence and absence of i* at time t*, the difference would be observable before t*. After t*, it is possible to determine whether i* had been present by the presence, or absence, of an incoming ring of correlated changes in the field. To see the pattern of correlation, one would need to correct background noise; in other words, know the state of the field after t*. If we know this and know i* is the only variable, then for us i* is over-determined by the earlier state of the field. There is only asymmetry at a macroscopic level because of an imbalance between big coherent sources (too many) and big coherent sinks (too few). But, at a microscopic level, the physical processes are symmetric. Price explains that the fork asymmetry disappears the more closely you observe the microstructure of the physical process. Like the example in §2.1, when looking at a computer screen, one sees a pictorial image. However, the closer you look at a computer screen the more the pictorial image disappears and is replaced with individual pixels. This is comparable with the fork asymmetry. One observes fork asymmetry on a macro level. However, at a micro level one observes the symmetry of physical processes.

Price's criticism of fork asymmetry may be contentious, because he assumes that the direction of time is more than just a macroscopic phenomenon. I will return to this criticism in §3.5, because I believe that Price does not make the same assumption about his own argument. By doing this, Price creates a double standard. However, for now, I am going to continue as if Price's criticism is correct and move onto Mellor's explanation for what underpins causal asymmetry.

**3.2 Symmetrical and Asymmetrical Connotations of Causation:**

Mellor (1995: 67–78) argues that every cause raises the chances of its effects. By this, Mellor means that an effect's chance of occurring, in the relevant circumstances, with the cause, is greater than the effect's chance of occurring without the cause.[9] For this to be true, the cause must be evidence for, and explain, the effect that it is raising the chance of, in the relevant circumstances. Mellor argues that there are four connotations of causation which demonstrate how causes give rise to their effects. Two of these connotations are symmetrical and two are asymmetrical. Mellor does not argue that the causes determine their effects. But, the two asymmetrical connotations of causation do underpin causal asymmetry, and are used to argue that the cause-effect relationship is not a convention.

- Symmetrical Connotations

Before explaining the asymmetrical connotations, I will explain Mellor's symmetrical connotations. The symmetrical connotations are contiguity and evidential

[9] Mellor (1995: 67)

connotations. These two connotations, because of their symmetrical nature, explain the impression that the cause-effect relationship is nothing more than convention.

1. Contiguity

   It is clear that causes are contiguous to their immediate effects. Mellor (1995: 60) states “An immediate effect of a cause C is an E, such that C causes E but not by causing any D that causes E.” In other words, for example, the fact that a match was lit means that the immediate following fact is that a camp fire started to burn. So, one could say the match being lit caused the camp fire to burn. However, the fact the camp fire started to burn means the immediate preceding fact is that the match was lit. So, by these standards, one could equally say that the camp fire starting to burn was the cause of the match being lit. Thus, contiguity cannot provide the required asymmetric relation between cause and effect.

2. Evidential Connotation

   Mellor (1995: 61–3) argues that causes may be evidence for their effects. But equally an effect can be evidence for its cause. For example, falling off a cliff may be evidence for the faller’s death. Equally though, the effect of having lung cancer may be evidence for the person being a smoker. When applied to fork asymmetry, as discussed above, one will find that the effects of the common cause provide evidence for each other. For example, heat and light are effects of a fire and from one effect, one can justly infer the other. So, if one has evidence for one effect, light, and evidence for the cause, fire, then one can infer the other effect of heat is also present. Hence, the evidential connotation does not provide the required asymmetric relation between cause and effect.

- Asymmetrical Connotations

As previously stated, Mellor argues that every cause raises the chances of its effects. The symmetrical connotations do help to show that causes give rise to their effects. However, they do not show that effects cannot give rise to their causes. Mellor argues that it is the asymmetrical connotations of explanation and the means-end relationship which demonstrate that effects cannot give rise to their cause. This results in him stating that it is these two connotations which underpin the causal asymmetry and in turn time’s direction.

1. Explanatory Connotation

Effects can be explained by their causes, but causes cannot be explained by their effects. Using Mellor's example of a man falling to his death, if one asked 'why did the man die?', then one can answer 'because he fell.' So, in this example, the effect can be explained by the cause. But this connotation shows asymmetry in causation because the effect cannot explain the cause. Using the same example, if one asked 'why did the man fall?' then it is not explained, in this situation, by answering 'because he died.'

2. Means-End Relationship Connotation

Mellor (1995: 79) states that the most useful of the connotations to explain causation is the means-end relationship connotation. He says "causes are [a] means of bringing about their effects … In other words, bringing about a cause is always a way of bringing about its effects." Mellor uses the example of a man falling to his death. If a man's falling will cause him to die, then it follows that his falling would be a means to that end.

The means-end relationship connotation is asymmetric because there is nothing about the end which will bring about, or raise the chances of, the means, in the way that the means does for the ends. Mellor (1998: 107) gives the example of Jim winning a race because he is the fittest man. Jim's fitness gives the means for him winning the race (as well as the explanation). However, the opposite is not true. Jim winning the race is not a means to him getting fit.

Mellor's connotations show that there are aspects of causation which are symmetric, but there are asymmetric aspects too. Mellor thinks these connotations can be used to explain time's direction. But, the most that Mellor has demonstrated so far is that there is an asymmetry in the causal relation, he has not demonstrated that causes must occur earlier than their effects. So, Mellor needs an argument to show why causes must occur before their effects, before the causal asymmetry can underpin time's direction. Mellor thinks this is provided by his argument against the possibility of causal loops, which would be possible if backwards causation were possible.

**3.3 The Impossibility of Causal Loops and Backward Causation:**

To demonstrate that causal asymmetry underpins time's direction Mellor needs to argue that causes must occur before their effects. To do this Mellor argues against the possibility of causal loops and backwards causation. A causal loop is where C causes E and E causes C.

Black (1956) argues that causal loops are impossible due to an argument he presented called the Bilking Argument. The Bilking Argument states that by trying to justify backward causation, or causal loops, one ends up with paradoxes and inconsistencies. For example, imagine that B is earlier than A and that B is supposed to be the effect of A and consequently that A is the cause of B. If this is the case, then, so the Bilking Argument goes, it is possible to have a series of events which could intervene preventing A from causing B. However, this means that A could not be the cause of B. The Bilking Argument concludes that the cause of B has to be something which occurred earlier than it, and that backward causation is not possible.

Dummett (1964) argues that backward causation is still logically possible. Dummett imagines a tribe whose huntsmen go on a five-day hunting expedition. It takes the huntsmen two-days to reach the hunting ground, one day to hunt and then a further two days to return. Every day the huntsmen are away the tribal chief does a ritual so that the huntsmen will be brave and have a successful hunt. On the last two days of the expedition it would seem logical that the ritual no longer has a causal connection to the hunt, because the huntsmen will have already been successful, or unsuccessful. However, whenever the chief has previously not done the ritual on all the days the huntsmen have been away, the hunt has been unsuccessful. Dummett states that as long as the chief does not have any epistemic access to whether the huntsmen have been successful on their hunt, until they return to the tribe, then it is logical to believe that backward causation has occurred.

Mellor (1998) argues in line with the Bilking Argument. Mellor argues that causal loops are inconsistent because any example of a causal loops leads to the possibility of an event intervening and breaking the possibility of a loop. Mellor uses the example of the Grandfather Paradox. Imagine a time traveller (Dr Who) deciding that he hated his grandfather and that he wanted to go back in time to a point before his own birth, or his father's birth, to kill his grandfather. To do this, Dr Who travels back from 2045 to 1945. He leaves at time f and arrives at time g. According to TARDIS time (Dr Who's personal time), time g is an hour later than time f. From a perspective outside the TARDIS (external time), time f is 100 years later than time g. From the external time perspective, there are events where the means to an end in 1945 occurred in 2045. The explanation for any such 1945 event would also be in 2045. So, for both of Mellor's asymmetric connotations a causal loop would be problematic because they demonstrate events where the cause occurs after the effect.

Mellor, however, argues that such causal loops are impossible. For example, if Dr Who succeeded in killing his grandfather before he was born then this would prevent him from being born in order to decide to kill his grandfather, hence causing a paradox. Mellor (1998: 125–35) states that there are three common responses to the argument that causal loops are impossible. But each of these responses is unsuccessful against the argument that causal loops are impossible.

1. The first response is to tell the tale twice. First before the time travel and then after it. Imagine time-travelling dinosaur hunters. On the first telling, the hunters say that they are going to be hunting dinosaurs, which could have consequences similar to the Grandfather Paradox. However, the second telling says that before the hunters went back in time, a reconnaissance team went to find out when the dinosaurs would naturally die. By doing that, it could be arranged so that the hunters would only kill dinosaurs that were going to die naturally in the next moment, that way avoiding any future time related consequences similar to those described in the Grandfather Paradox. Mellor states that this response makes things worse for causal talk, because by saying that a dinosaur's death was from both being and not being shot, it replaces a possible contradiction with an actual one.

2. The second response tries to avoid contradiction by placing Dr Who's arrival, or the dinosaur shooting, in another possible world rather than our own world. However, for Mellor this causes three concerns. First, it may mean that the journey turns the actual world from one where it has not occurred into one where it has. In other words, Dr Who leaves our world $W_0$ and arrives in another world $W_1$. In $W_1$ there has been no journey taken by the Dr Who of $W_1$. So, $W_1$

has both a Dr Who who has and hasn't taken the journey. This is the same contradiction as above, because $W_1$ cannot both contain and not contain Dr Who in 1945. Second, nothing that is logically impossible in our world can occur in any other possible world. If one does argue it is possible in another world, it is just another way of saying that it is possible in our own world. Third, the world where Dr Who arrives in 1945 must be different to the world he leaves in 2045. But this is another way of saying that backwards time travel cannot occur within any one possible world, and so in particular cannot occur in ours.

3. The third, and final, response, just requires time travel stories to be consistent, as all tales must be if they are able to be true. So, if Dr Who did leave in 2045, then he can do nothing in 1945 which could stop himself leaving in 2045. This is possible because there are lots of things Dr Who could do which would not cause his time-travel tale to be inconsistent. However, Mellor argues that it overlooks the existence of real contingent possibilities. Dr Who does not need to do anything in 1945 which could stop him leaving in 2045, but he could. For Mellor, this is as much a fact about Dr Who, at that time, as any other fact about him. This means that this, and any, time travel tale is inconsistent, because nothing can be contingently possible and necessarily impossible.

Thus, Mellor argues, causal loops lead to inconsistencies. This leads Mellor to the conclusion that causal loops are an impossibility. However, there are also accounts of causal loops or backwards causation, such as Dummett's, which seem to be consistent. The discussion of the possibility of causal loops, and backward causation, is about whether it is possible to intervene so that an effect is caused by a cause which is earlier than the effect, rather than a cause which is later than the effect. If, one agrees with the Bilking Argument, and Mellor, and believes that intervention is possible then causal loops, and backwards causation, are inconsistent and impossible. But, if like Dummett argues, one believes that there are consistent accounts where intervention is not possible, then causal loops, and backwards causation, are consistent and possible. There is more which can be said from both sides on this discussion on causal loops and backwards causation. Further discussion may result in one, or both, sides demonstrating that the arguments raised are not insurmountable criticisms. However, I think for my discussion on what underpins time's direction, the better argument would be one that does not rely on causal loops being consistent or inconsistent. The remaining arguments for what could underpin time's direction will be ones that are not affected by whether causal loops, or backwards causation, are a possibility or not.

**3.4 Perspectivism accounting for Causal Asymmetry:**

Price (1996) does not rule out the possibility of causal loops, or backwards causation. So, in this section, I am going to present Price's account of agency asymmetry and how he argues that this asymmetry underpins the direction of time.

Price (1996: 166–8) argues that the asymmetry that one sees in time's direction comes from our perspective of the world. Price imagines a train on a single track from Perth to Sydney. The train is unable to turn around, so anything that is passed on the journey the train is unable to return to and revisit. This example is analogous to our experience of time's direction. Like the passenger, we experience events, and can possibly see/predict events coming, but they will pass and we are unable to experience that same event again. From our perspective in experiencing the direction of time, it is objectively true that a cause is always earlier than the effect, or that the past is fixed rather than the future. However, it is not an objective truth about the world that time is asymmetric. The asymmetry is a feature of the agent's perspective, rather than a feature of time.

Price (1996: 155–60) states that the asymmetry of agency is underpinned by the knowledge asymmetry.[10] The knowledge asymmetry is that one tends to know more about the past than the future. Imagine placing a bet on a horse to win the Grand National. The way you decide which horse is bet on, at least if you want to stand a chance of success, would be to use previous knowledge about the horse, jockey and trainers to make an informed decision. We do not have access to any knowledge about what happens in the future that would help us make a decision on this bet.[11] This knowledge of the past and lack of knowledge about the future, from our perspective,

[10] Price is using and adapting the knowledge asymmetry which Horwich (1987) argues for.

[11] Even if we had information that the race had been rigged, that information is about past events to set up the rigging. In the future there are a number of different variables which could alter the success of a rigged bet. Such as, you being unaware of an honest jockey reporting the attempted rigging.

gives us the impression of an actual causal asymmetry in the world. Importantly, we all share this same perspective. In other words, any talk of causation, and causal asymmetry, is based on the agent's projection of the perspective we have on the world, based on the asymmetry of knowledge.

Price argues that the asymmetry of agency needs only to appeal to a macroscopic explanation, because we are macro creatures and can give only a perspective of the macro world. This is where I believe Price's account becomes problematic. I believe he may be granting his theory an assumption which he has not allowed other theories and results in creating a double standard.

**3.5 Price's Double Standard:**

In §2 and §3.1, I explained theories which have been argued could underpin the direction of time. However, each theory has been criticised by Price in a very similar way: that the micro-explanations of the different theories, such as statistical mechanical understanding for entropy, shows symmetry rather than asymmetry. Price then presents his own theory of perspectivism which states that asymmetry of agency underpins time's direction. Asymmetry of agency is underpinned by the asymmetry of knowledge. Time's direction and causal asymmetry is a projection of our internal asymmetry due to having more knowledge about the past than the future which we can deliberate on. Importantly, the asymmetry of agency does not need to appeal to the micro world because we are macro creatures.

The problem is that it is not clear why it is not good enough to explain the direction of time in terms of being a macroscopic phenomenon in the previously considered accounts of time's direction. And it is not clear why the symmetry at the microscopic level trumps the asymmetry manifested at the macroscopic level. Price may state that the answer is that the macro-world is underpinned by the micro-world. So, there needs to be an explanation of the micro-world which demonstrates asymmetry. But that then needs to be applied to his own theory. Our macro perspective of the world is going to be underpinned by the micro-world. I think that Price either has to allow the direction of time to be a macroscopic phenomenon or explain how his own theory can be underpinned by the micro-world. Whichever option Price takes, it means that he needs to hold his own theory and those he criticises to the same standard.[12]

There is more that can be said about Price's view and criticisms of other theories. But Price's points are contentious, because he has not demonstrated that time's direction is not just a macro phenomenon, which is an assumption he grants his theory but not the theories he criticises.

**3.6 Section Summary:**

- Causal asymmetry could be used to underpin time's direction. However, from the discussion in §1.3, light cones do not necessitate an earlier event, of two connected events, being the cause. So, if causal asymmetry does underpin time's direction then one must establish what underpins causal asymmetry.

- Fork asymmetry has been used to underpin causal asymmetry because later correlated events can have the same cause, whilst one does not find two correlated earlier events with the same effect. However, Price criticises this view for being asymmetric on a macro level but symmetric on a micro level.

- Mellor's causal asymmetry is underpinned by the means-end relationship and the evidential connotation. However, this only demonstrates that there is an asymmetry in the causal relation. Mellor must demonstrate that causes must occur earlier than their effects. To do this Mellor argues that causal loops, and backwards causation, are impossibilities.

- The Bilking argument, and Mellor, argue that causal loops and backwards causation are impossible because any account is inconsistent. This is because any example where an effect has a later cause has the possibility of intervention so that the effect has an earlier cause. However, Dummett argues that there are cases which are consistent examples of causal loops, and backwards

[12] Even if Price could argue that his theory is not appealing to double standards, there is still a problem when considering what would be predicted about the past, such as in the statistical mechanical case. It seems that Price's account would predict that we would try to bring about those things we do not know have happened, and wouldn't try to bring about those things we know will happen. But that's not what we do.

causation, because it is not possible to intervene and demonstrate the effect has an earlier cause. Either side may not find any criticism insurmountable. However, the remaining arguments for what underpins time's direction will not be effected whether causal loops, or backwards causation, are a possibility or not.

- A perspectivism view on causal asymmetry underpins time's direction because the asymmetry is constrained by the agent's view of the world. However, Price's account of this assumes that time's direction is a macro phenomenon, which is an assumption he is not willing to grant other theories. If he does grant that assumption, then he has no argument against the other theories on that score.

## Asymmetry of Counterfactual Dependence

The theories of time's direction which scientists tend to appeal to, such as thermodynamics, expansion of the universe and radiation, at least do not pass the local test. Due to the discussion on Mellor's causal asymmetry, any theory on time's direction needs to be consistent whether causal loops are a possibility or not. While the discussion on Price has demonstrated that time's direction needs to give a consistent explanation at a macro or micro level. I think some progress can be made on these points by considering Lewis's account of what underpins time's direction.

Lewis (1979: 458-62) argues that what underpins the direction of time is an asymmetry of counterfactual dependence. A counterfactual is a conditional statement whose antecedent is contrary to fact. Counterfactuals are statements about hypothetical situations. They are not necessarily just about what would happen, but can also be about what might happen. An example of a counterfactual is, if I had struck the match, it would have lit.

Lewis (1979: 461) states "what we can do by way of 'changing the future' (so to speak) is to bring it about that the future is the way it actually will be, rather than any of the other ways it would have been if we acted differently in the present." This is similar to change but not a literal change. Lewis is making the distinction between what actually happens and what possibly happens. The past cannot be changed no matter what we do. This means that the past is counterfactually independent of the present. However, the future is counterfactually dependent on the present. The many different possible futures are dependent upon various counterfactual suppositions about the present. The one actual, fixed past is the one past that will remain the same under those counterfactual suppositions. Lewis states that the causal asymmetry, between an unfixed future and a fixed past, is there because of the asymmetry of counterfactual dependence.

Lewis (1979: 464–5) states that "a counterfactual is true if every world that makes the antecedent true without gratuitous departure from actuality is a world that also makes the consequent true." Lewis further explains that a counterfactual is true if and only if some world where both the antecedent and consequent is true, is more similar to our actual world, overall, than is any world where the antecedent is true but the consequent is false. In the following section I will look at what Lewis's criteria is to decide what the most similar possible world is. As well as what underpins the asymmetry of counterfactual dependence.

**4.1 Comparative Similarity of Possible Worlds:**

Lewis (1979: 467–72) acknowledges the future similarity objection, by philosophers such as Fine. To make this objection clear, consider the following counterfactual:

'If Nixon had pressed the button, there would have been a nuclear holocaust.'

The objection is that, using Lewis's account, the counterfactual would be false. This is because the world which would be the most similar to this world would be one where the antecedent is true and the consequent is false. One would need only to consider a situation where a change occurs which prevents the holocaust but does not require a big divergence from reality. For example, the signal failing to trigger the launch of missiles after the button was pressed by Nixon. However, Lewis argues that this would not be the case. Lewis gets us to think about four possible worlds to show what needs to be considered when deciding on similarity between worlds:

Consider a deterministic world, where Nixon does not press the button at t, and no nuclear holocaust occurs. Call this $W_0$.

Then consider $W_1$. This world is the same as $W_0$ up until just before t where a small miracle occurs and the two worlds diverge forever. Lewis uses the term 'miracle' to mean that what happens in $W_1$ could not happen in $W_0$, since such an event would be a violation of $W_0$'s laws (although not a violation of $W_1$'s laws). So, in $W_1$ it may be a few extra neurons firing causing Nixon to press the button. $W_1$ is similar to $W_0$ up until the small miracle occurs. So, worlds without small miracles, causing a divergence, would be more similar to $W_0$ than $W_1$.

In $W_2$ no miracle takes place; and the deterministic laws of $W_0$ are followed. $W_2$ differs only from $W_0$ in that Nixon presses the button. However, using the definition of determinism, it is clear that these worlds are either always alike or never alike throughout time. Lewis argues that it would be unlikely that these two worlds could remain so similar for long without little differences occurring, which would result in big differences over time.

$W_3$ is the same as $W_1$ until t, which is a point shortly after Nixon presses the button. After t, another small miracle occurs which results in there being no nuclear holocaust. However, Lewis argues this small miracle does not remove the left-over effects of Nixon pressing the button, other than there being no Holocaust. For example, the wires have been heated up, there is a fingerprint on the button, Nixon's memoirs change and anyone reading those memoirs may be affected differently. This is not an exhaustive list, but anyone of these examples could lead to a big divergence.

$W_4$ is the same as $W_1$ until t, which again is a point shortly after Nixon presses the button. After t there is a big miracle which removes any possibility for divergence. For examples, fingerprints are removed, memories are altered, etc. For this to happen, one would need lots of small miracles to happen to guarantee that $W_4$ converges back to being similar to $W_0$.

Lewis (1979: 472) states that these four possible worlds tell us the features of similarity between worlds in order of importance as follows:

1. One should avoid big, widespread, diverse miracles.
2. One should maximise spatio-temporal regions of perfect match of particular facts.
3. One should avoid small miracles.
4. One should not bother too much to secure approximate similarity of particular facts.

This ranking then determines which world is most similar to $W_0$. It also allows a better understanding for Lewis's account of the direction of causation.

This use of Lewis's ranking can be further seen in Lewis (1986b: 56–8), when he examines an example he calls Bennett's World. Bennett's World is similar to $W_1$. It has the same laws governing it before t as $W_0$. At t there is a small miracle which diverges it away from $W_0$. However, unlike $W_1$, there is a small miracle just after t which causes convergence back to $W_0$. The small miracle which causes the convergence is of the same nature as the one which caused the divergence. However, Lewis argues that Bennett's World is "deceptive". Lewis states that the pasts of $W_1$ and $W_0$ are different. In the past of $W_0$, there are traces of determinants which determined the event at t. In the past of $W_1$, there are traces of determinants which determined that worlds events at, and after, t. For Lewis, one cannot confidently say that the histories of the two worlds are the same for long. In other words, when you look at Bennett's World, or $W_1$, it quickly becomes $W_2$. As already discussed, $W_2$ cannot be the most similar world to $W_0$.

**4.2 Asymmetry of Miracles:**

The size of a miracle, which causes divergence or convergence, helps in us deciding how similar a world is to our own. Lewis (1986: 55–6), when discussing miracles, states that he does not agree with the definition that big miracles are other-worldly events that break many laws of nature, whereas little miracles break only a few laws of nature. Lewis says that one should not be counting violated laws. Instead, one needs to distinguish lawful events from unlawful events. Lewis uses pair annihilation, in relation to radiation, as an example of this. Pair annihilation is where the two opposite particles of a positron and an electron are attracted to each other and annihilate each other when they meet, producing radiation. So, Lewis says a miracle in the pair annihilation example would be the two particles unlawfully and quietly disappearing without a trace. Lewis states that these unlawful events can be considered in the same way as lawful events. In other words, in the same way that lawful events can be spread out, or be localised, so can unlawful events. In whatever way one can distinguish one simple event from many simple events, one can also distinguish one simple unlawful event from many simple unlawful events. For Lewis, a big miracle consists of many little miracles together, preferably not all alike. However, what makes the big miracles more of a miracle is not that it breaks more laws. Instead, big miracles are divisible into many and varied parts, any one of which is on a par with a little miracle.[13]

[13] Lewis does not specify or make clear how many little miracles, or how many varied parts, are required to make a big miracle. There may be an answer to this but it is not one that will be considered further here.

Lewis (1979: 473-5) states that the asymmetry of counterfactual dependence comes from the asymmetry of miracles, which itself is based upon the asymmetry of overdetermination. Any particular fact, in a deterministic world, is predetermined throughout the past and postdetermined throughout the future. For a fact to be predetermined, it must have a determinant prior to the fact, and for it to be postdetermined, it must have a determinant after the fact. A determinant is a minimal set of conditions, jointly sufficient, given the laws of nature, for the fact in question. Every fact requires only one determinant. However, a fact can have more than one determinant. If a fact does have more than one determinant, then it is over-determined. The asymmetry of overdetermination is then found in the fact that there is considerably more overdetermination with respect to the past than there is with respect to the future. In other words, to diverge from the future of $W_0$, one only needs to break one determinant (or cause one small miracle). However, to converge back to a similar future of $W_0$, one would need to break many determinants (or cause a big miracle). This account of the asymmetry of miracles is what underpins the asymmetry of counterfactual dependence, and in turn underpins the direction of time.

It is Lewis's theory of the asymmetry of counterfactual dependence which I believe does underpin the direction of time. However, it is not without criticism. The next section is going to look at one criticism which is problematic when considering the local test.

**4.3 Elga's Criticism of Lewis:**

Elga (2001) argues that Lewis's account of the asymmetry of miracles does not ground the asymmetry of counterfactual dependence, and therefore does not underpin the direction of time. Elga demonstrates this by showing the consequences of Lewis not reconciling the asymmetry of counterfactual dependence with the laws of thermodynamics.

Elga starts by giving the example of $W_0$, where Gretta at 8:00 cracks open an egg onto a hot frying pan. By 8:05 Gretta has a cooked egg sitting in the frying pan. Elga asks which of the following counterfactuals are true:

1. If Gretta had not cracked the egg, then at 8:05 there would not have been a cooked egg on the pan.

2. If Gretta had not cracked the egg, then at 7:55 she would not have taken an egg out of her refrigerator.

Using Lewis, Elga states that for one of the counterfactuals to be true then the closest no-crack world would be one in which:

A. The history before 8:00 is almost exactly like the actual history before 8:00.
B. The history before 8:00 differs significantly from the actual history after 8:00.

If the no-crack world meets those conditions then statement 1 will turn out to almost always be true, and statement 2 will turn out to almost never be true.

Using Lewis's asymmetry of miracles, one knows that only a tiny miracle before 8:00 is required to prevent Gretta cracking the egg. But to ensure that Gretta does not crack the egg after 8:00 would require a larger miracle. Elga (2001: S315-S317) supposes that: $W_0$ is the actual world and is where the egg gets cracked and is cooked. $W_1$ is where Gretta does not crack an egg and no laws are violated. $W_2$ is where a tiny miracle occurs, causing a small violation in the laws of nature just before 8:00, which results in the egg not being cracked. From this moment, $W_2$ diverges from $W_0$. Elga states, by following Lewis's account, that only $W_2$ meets the conditions above (A and B), so $W_2$ is the closest world to $W_0$. However, suppose $W_3$ is a world where a miracle shortly after 8:00 occurs, causing convergence with $W_0$. For Lewis, $W_3$ requires a very big, diverse, widespread miracle to achieve the desired convergence and so cannot be the closest world. But, Elga argues, $W_3$ does not necessarily require a large miracle and, by still following Lewis, one could conclude that $W_3$ is as close as $W_2$ to $W_0$.

Elga states that one is able to specify the state of the world at a time in terms of the position and the velocity of all the particles that exist at that time. $S_0$ is the state of the world at 8:00. $S_1$ is the state of the world where the egg is in the pan and has been cooked. The process of going from $S_0$ to $S_1$, following the laws of nature, can be described as follows: "the egg oozes out of the cracked shell and down towards the pan, where it splats on the pan, making a noise, slightly heating up the surrounding air, and setting up some vibrations in the pan. Then the egg cooks by absorbing heat from the pan."[14] Starting at $S_0$ and having time pass for five minutes results in $S_1$. Similarly, starting at $S_1$ and having time pass backwards for five minutes results in $S_0$.

[14] Elga (2001: S318)

The $S_0$ to $S_1$ process describes the state of $W_0$ with time in the direction we experience, and the reverse process, $S_1$ to $S_0$, describes time in the reverse direction of our experience.

Elga asks us to think what the $S_0$ to $S_1$ process would look like in reverse. To avoid confusion, let's refer to the time-reversed process as $Z_1$ to $Z_0$. $Z_1$ is the velocity reverse of $S_1$. In other words, it is the result of reversing the velocities of all the particles in $S_1$. Like $S_1$, $Z_1$ is a state in which the cooked egg sits on the pan. But the egg uncooks and jumps back into its shell. This resulting state is $Z_0$, which is the velocity reverse of $S_0$. To show that the first process is sensitive to certain small changes in $S_1$, it is enough to show that the second process is sensitive to certain corresponding changes in $Z_1$.

Following the statistical mechanical explanation of entropy, as discussed in §2.3, there are more possibilities in phase space where the future of the egg sits in the pan and cools, than possibilities where the egg jumps back into the shell. Elga (2001: S320) states that this would require either a slight change in the states of many particles or a slight change to the states of just a small, localised bunch of particles. This second type is what he calls a "small miracle change". Using this, Elga imagines two different timelines for the egg. The first timeline is the $Z_1$ to $Z_0$ process where the egg finishes back in the shell. The second timeline is where, at $Z_1$, there has been a small miracle change to the position of the pan molecules. Those molecules' trajectories would then differ from the $Z_1$ to $Z_0$ process molecules' trajectories. This disruption would continue to spread. For example, the air molecules would hit the pan in a slightly different way causing other air molecules' trajectories to change. The result being an interference with the motion needed to form inwardly directed airwaves. In this second timeline, the egg just sits in the pan. Elga's example shows that $Z_1$ is sensitive to slight changes, which shows how sensitive the $S_1$ to $S_0$ process is. Elga (2001: S321) states: "Suppose that a small miracle change gets from $Z_1$ to $Z'_1$, a state with a future in which the egg just sits on the pan. Then a corresponding change gets from $S_1$ to $S'_1$, a state with a past in which the egg just sits on the pan. In other words, the past history of $S'_1$, is one in which the egg was never cracked onto the pan." Elga now states that there is no asymmetry of miracles, and consequently no asymmetry of counterfactual dependence.

The example that Elga describes is $W_3$, and has demonstrated that only a small miracle would be required to cause convergence with $W_0$. However, as $W_3$ converges with $W_0$, $W_3$ contains false traces of Gretta cracking an egg. In §4.1, Lewis argues that it is these small traces which show that a world with a converging miracle is not as similar to $W_0$ as a world with a diverging miracle. However, the effect of Elga's 'small miracle change', in the process of $Z'_1$ to $Z'_0$, will continue to expand outwards impacting on other microscopic particles. The result being that one has the false traces (i.e. memories) of Greta cracking the egg. Elga concludes that you do not need a big, widespread miracle to achieve convergence in $W_3$, contrary to Lewis's view.

Elga's example is a problem for Lewis, because it shows that owing to Lewis not reconciling his argument with the laws of thermodynamics there is no asymmetry of miracles. If there is no asymmetry of miracles, then there is nothing underpinning Lewis's account of asymmetry of counterfactual dependence. Elga's criticism needs resolving if it is going to be concluded that Lewis's account, with the required amendments, is the correct account of what determines the direction of time.

**4.4 Section Summary:**

- The asymmetry of counterfactual dependence underpins time's direction because any counterfactual statement demonstrates that what we are able to change (not a literal, or an actual, change but a possible one) about the future is based upon what actually occurs in the present. However, the past is not dependent on the present in the same way. There is nothing that can be counterfactually stated about the present which changes the past, that demonstrates a world more similar to our own. In other words, the past is fixed and independent of the present, whereas the future is dependent on the present state.

- The asymmetry of counterfactual dependence is underpinned by the asymmetry of miracles. A miracle can either cause divergence from our world or convergence towards our world. The most similar world to ours is one where there is divergence because this only takes a small miracle, whereas convergence requires a big miracle, or lots of small miracles. Divergence supports the idea that the future is open and dependent on the present. Convergence supports the idea that the past is closed and independent of the past.

- Lewis has not reconciled the laws of thermodynamics with his asymmetry of counterfactual dependence. This is problematic because Elga shows that, by following the laws of nature, there could be cases where convergent worlds are more similar than divergent worlds. This means that the past may not be fixed and independent of the present. Elga’s problem needs resolving if the asymmetry of counterfactual dependence is to underpin the direction of time.

## The Past Hypothesis

In §2.1, it was stated that Boltzmann's statistical mechanics showed that, in a series of microstates, entropy is symmetrical, rather than asymmetrical. This is a problem for both scientists and philosophers when accounting for time's direction. I propose that one adjusts our understanding of the laws of entropy and assume a boundary condition in the past, as argued by Albert (2000 and 2015) and Loewer (2007). The same, or similar assumption cannot be made about the future. I believe by arguing for this, an account can be formed which passes the global test for explaining the direction of time.[15]

### 5.1 Albert and Loewer:

Loewer (2007: 300–2) proposes that two claims should be added to the fundamental dynamical laws. First, the Past Hypothesis (PH): the macro state of the early universe was a state of low entropy. Second, a uniform probability distribution (PROB) over the physically possible initial conditions compatible with the PH. These should be considered laws, rather than mere facts about the world. Loewer states that according to Lewis a law is "a contingent generalisation entailed by the Best System of the world."[16] For it to be considered the "best" then it combines simplicity, informativeness and fits better than other generalisations. In other words, PH and PROB explain features of the world which have to do with time's direction, in a better way than other explanations.

[15] The work of Albert and Loewer are building upon arguments made by scientists, such as Einstein, Feynman, Schrodinger and Boltzmann, who argue that the low entropy state of the early universe is a necessity.

[16] Loewer (2007:305)

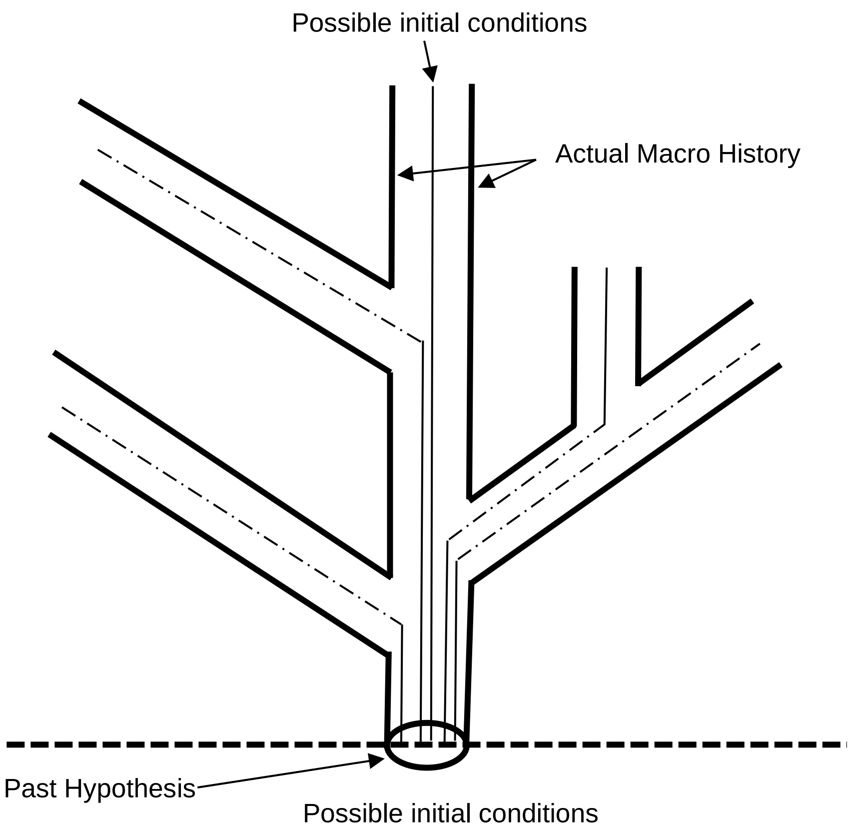


Figure 8.1.1

Figure 8.1.1[17] shows the possible evolutions of the micro and macro states where PH has been assumed. The thin lines represent all the possible micro histories, with the one straight thin line being our actual micro history. The circle represents the special low entropy macro state postulated in the PH. The circle only occupies a small space of all the possible initial conditions of the universe. The cylinders represent the different possible macro histories, with the actual macro history being the cylinder which contains the actual micro histories. Nearly all micro histories which start within the cycle evolve towards a state of maximum entropy. However, there are some microstates which do not evolve towards maximum entropy, or at least do not always maintain an evolution towards maximum entropy, which is in accordance with statistical mechanics. Loewer states that although the evolution of micro histories are governed by deterministic laws, macro histories appear to evolve indeterministically. In other words, the probability distribution specifies the probability of the histories which realise that macro state. The branching of the macro states represents the indeterminism of the macro states. From the central macro state there will be

[17] From Loewer (2007: 301)

branching in both temporal directions. However, there will be more branching in the direction away from the PH. This is because of statistical mechanics, which, as discussed above, states that there are more ways for states of high entropy to be realised in phase space than there are states of low entropy.

Albert (2000 and 2015) states that having the assumption of the PH allows for the production of localised macro records of the past but not of the future. Loewer (2007:303)[18] gives the example of footprints in the sand, to explain Albert's point. A footprint on the beach at $t_2$ is a record of someone walking on the beach at an earlier time. One is able to assume something about the state of the beach, at an earlier time, from the inference made from the footprint being placed there by a walker. The assumption being that the sand was soft and damp at $t_1$. Without this assumption, one would not be justified in making the inference. The soft and damp sand acts as a 'ready condition' which makes the productions of inferences, or 'records', possible. The PH acts as a 'ready condition'[19] for the universe. If one does not have the PH as a ready condition for the universe, the retrodictions about macro states become inaccurate. For example, if one used the laws of thermodynamics, in particular the second law of entropy, and statistical mechanics to predict the future of an ice cube ten seconds from now, then one will say that the ice cube should be melting. But, a retrodiction, using the same method, on the state of the ice cube ten seconds ago will say that it was also melting then, which one should be able to confidently say is not the case.

Loewer (2007: 304–5) states that to consider the PH and PROB as contingent is a mistake. The PH and PROB, with the dynamical laws, need to be considered as fundamental laws. PH and PROB underwrite many of the asymmetric generalisations which are considered laws, such as the laws of thermodynamics. They can only give lawfulness if they themselves are laws, and if PROB can be considered a law then the probabilities it posits, in statistical mechanics, are objective. Loewer argues that the Lewis account of laws is compatible with the notion that PH and PROB are laws. As stated above, a law is "a contingent generalisation entailed by the Best System of the

[18] Albert (2000 and 2015) uses the example of a billiard ball on a frictionless table, where the ball was moving 10 seconds ago but stationary now. From this one can posit that there was a collision at some point during those 10 seconds.
[19] Albert (2015: 38) refers to the PH as "the mother of all ready conditions."

world." Treating PH and PROB as laws, according to Loewer, makes a system a little more complicated and "vastly" more informative than a system which only has the dynamical laws.

**5.2 Responding to Elga:**

In §4.4, I discussed Elga's argument that the asymmetry of miracles could not underpin the asymmetry of counterfactual dependence. Loewer (2007: 315) acknowledges Elga's criticism of Lewis, but believes it is not a problem if the PH and PROB are considered laws. Considering PH and PROB as laws means that when considering the similarity of worlds, the different worlds would have to conform to these laws in the same way that they need to conform to the dynamical laws. Therefore, Elga's $W_3$ cannot be considered as similar to $W_0$ as $W_1$. This is because to conform to the laws, which include PH and PROB, a big miracle is required. This means that the miracle would have to make sure the egg did not get cracked, as well as causing entropy not to increase and the removal of all other traces.

PH and PROB does appear to resolve Elga's criticism. However, let's consider the two tests which need to be passed to demonstrate time's direction; namely, that any argument, or explanation, trying to underpin the direction of time needs to do so on a global and a local scale. Currently, one may argue that global asymmetry has been shown by having the PH and PROB as fundamental laws of the world. However, it still needs to be shown that there is a direction to time at a local level. At a global level, entropy is increasing; but, at a local level, one can observe events where entropy may decrease as well as increase. Decreasing entropy, such as an everyday occurrence like water freezing into ice cubes (or Elga's egg example), may not affect the increasing entropy of an entire system. However, it does mean that, at a local scale, PH cannot solely show the direction of time without further explanation. Albert and Loewer each have their own arguments for showing the local account of time's direction. In §5.3, I discuss Albert's account of causal handles. In §5.4, I discuss Loewer's account of decision counterfactuals. However, using Frisch, I will argue that both of these accounts are problematic. In §5.5, I will then argue for my own account for what underpins time's direction which will adapt the work of Lewis from §4.

**5.3 Causal Handles:**

Albert (2000: 125–30)[20] argues that there are more, what he calls, causal handles on the future than there are on the past. In other words, Albert argues that the future counterfactually depends more on what we do now than the past does. The reason for this is due to the fact that there is PH but no future hypothesis. This asymmetry shows "that the present determinants of the past are (as it were) enormously less *amenable to our control* than the present determinants of the *future* are."[21] To demonstrate this, Albert gives the following example:

Imagine a frictionless billiards ball table with twenty-one numbered balls, plus the cue ball, on it. Ball 5 is currently stationary but we know that ten seconds ago ball 5 was moving. The knowledge of the ball moving ten seconds ago is a simple example standing in for the PH. Whether ball 5 is involved in a collision over the next ten seconds is determined by the present condition of all the balls on the table. Whether ball 5 has been involved in a collision over the last ten seconds is entirely down to the present condition of ball 5. In other words, there can be numerous hypothetical alterations to the present condition of all the balls to alter whether ball 5 is involved in a collision over the next ten seconds. But there can be no hypothetical alterations to the balls, unless one is hypothetically altering the present velocity of ball 5, which would alter whether ball 5 has been involved in a collision over the past ten seconds. Albert also states that another consequence is that "there are perfectly imaginable present conditions of this collection of balls in which certain small hypothetical alterations of *any physical feature you choose* of any particular *one of these balls you like* would alter the facts about whether or not ball number 5 is be involved in a collision over the next ten seconds".[22] But, there are no hypothetical small alterations which can be made to the present condition to any of these balls which will alter whether ball 5 was in a collision over the past ten seconds.

Albert concludes, from this example, that there are a far wider variety of "routes" to influence the future of ball 5. In other words, there are more causal handles on the future of ball 5, than there are on the past.

[20] See also Albert (2015)
[21] Albert (2000: 126)
[22] Albert (2000: 126–7)

Albert (2000: 128–30) acknowledges that the above example is very specific and needs to be applied more generally to our world. If one postulates the PH on all possible macro evolutions, then this does not impose any further restrictions on future macro evolutions. But any other possible present macro state still must have evolved from the same actual macro past. In other words, the PH restricts all possible macro histories so that there are more causal handles on the future than there are on past. Using the example of Nixon pressing the button, causing a nuclear war, one may argue that the things of which one has "unproblematic and unmediated control" are features such as hands, feet, tension in muscles, the electrical firing in various motor neurons, or conditions in various regions on the brain. The difference between a world where the nuclear button is pressed two minutes from now, or is not pressed, may be small alterations to the present position of Nixon's right hand. But there are no alterations to the present position of Nixon's right hand which will alter whether the nuclear button was pressed two minutes ago. For Albert, this account of causal handles demonstrates how the PH can be applied to our local account to underpin the direction of time.

Frisch (2014: 217–9) argues that the asymmetry of causal handles is problematic, especially when it is applied more generally in comparison to Albert's specific examples. Frisch (2014: 218) states "Many records or traces of the past do not determine the occurrence of the events of which they are records but only raise the probabilities of their occurrence. Thus, the general definition of a causal handle is as follows: A macro event *C*(*t*) is a *causal handle* on an event *E*(*t'*) exactly if the occurrence of *C* (significantly) affects the probability of *E*." Following Albert, one evaluates the consequences of small hypothetical changes to the present by keeping the present macro state fixed, except for the hypothetical alteration, then determine how the counterfactual macro state evolves in accordance with the constraint of the record (PH). Albert also assumes that, in addition to the macro record being fixed, one also holds fixed any known memories one might have of the event. For Albert, this means that these records act as a screening off process, which means that there are rarely, if any, causal handles on the past.

Frisch (2014: 218–9) argues that from Albert's conclusion – that there are almost no causal handles on the past is equivalent to a screening off process – easily fails. Frisch uses Albert's example of the Galton board to show that the additional evidence for an event's occurrence can alter the probability of that event.[23]

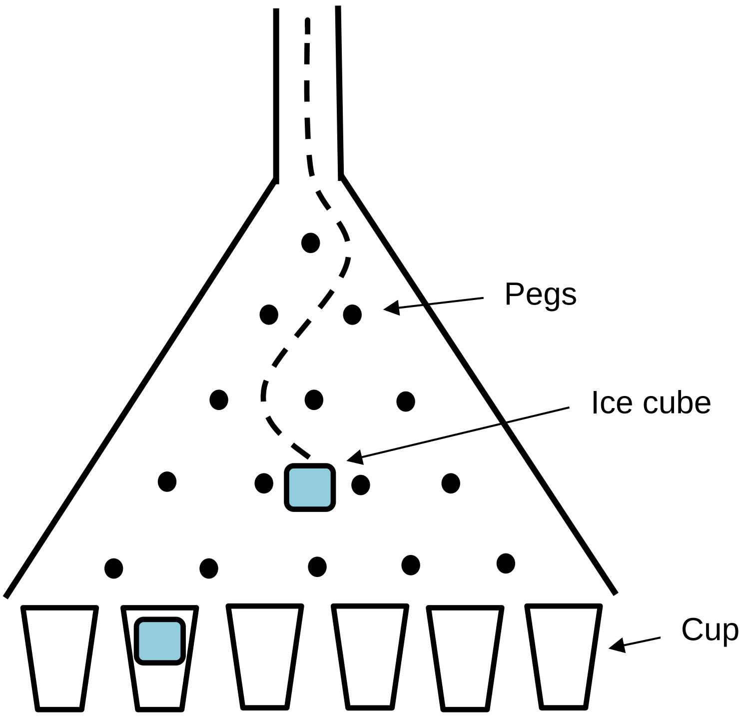


Figure 5.3.1

Figure 5.3.1 shows a Galton Board. As an ice cube is dropped onto the board it will hit a peg and either fall to the left or to the right. As each ice cube proceeds to fall down the board, it will indeterministically evolve into different macro states. This is shown by the distribution of the ice cubes in the cups at the bottom of the board. As more ice cubes proceed down the board, one should notice the amount of the ice cubes in each cup forming a bell curve. At the end of the experiment, all the ice cubes are emptied into a single bucket. Over the entire experiment the ice cubes' states have evolved differently but their individual states do not affect the final state they all share in the bucket. The purpose of this part of Frisch's argument is to come to the same

[23] There are different interpretations of probability (i.e. epistemic probabilities, chances, credences). However, neither Albert, Loewer nor Frisch define which type of probability they are referring to. Mellor (1995) argues that what matters in whether an example counts as a genuine case of causal handle is whether the probabilities are chances and not merely epistemic. Taking this into account may alter the presented discussions and responses. However, without Albert, Loewer or Frisch specifying what is meant by probability this discussion will have to dealt at another time.

conclusion which Elga does. In other words, that the PH does not account for the local direction of time we experience.[24]

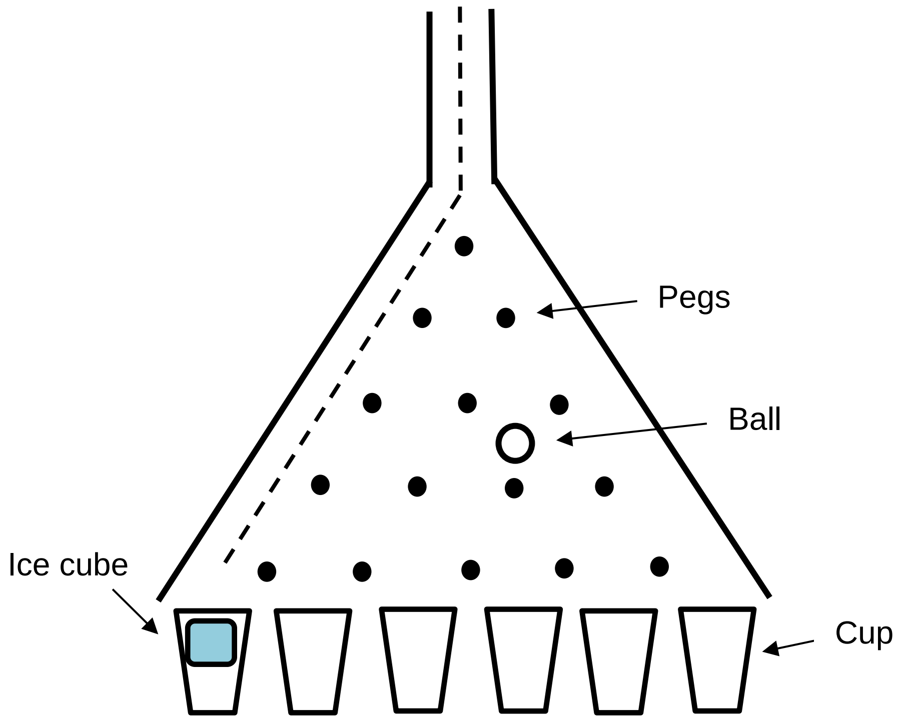


Figure 5.3.2

Figure 5.3.2 shows a Galton Board with an ice cube which, when released and hits the first peg, dislodges a ball. This ball then starts to fall down the board and as it hits a peg will either fall to the left or to the right. The ice cube being in the cup, furthest to the left, constitutes a trace that when the ice cube hit the first peg it slid to the left. Where the ball ends up also acts as a record of the ice cube's path down the board. Frisch argues that one can set up the probabilities so that both the ball's present position and the ice cube's position, in the cup furthest to the left, come out as causal handles on the path of the ice cube past the first pin. In other words, while keeping the present condition of the ice cube in the cup fixed, there can be many alterations in the

[24] Frisch further comments that, rather than the tree like structure in Loewer's analogy, it is a web like structure. However, I believe that Frisch's web analogy is misleading. Instead, I propose that one needs to amend Loewer's tree analogy. The tree is the global asymmetry which is underpinned by the PH. When looking closer at the tree on some of the branches, at a local level, one will find Witches Brooms. At this local scale on the tree, one will find divergence and convergence as well as periods of increasing and decreasing entropy, but this does not change the whole systems increasing entropy.

present condition of the ball which would alter the probabilities about whether the ice cube would slide to the left, or the right, of the first pin.

Frisch states that there is nothing unusual about the example he has given above. He argues that there are many cases in which additional evidence affects the probability of past events. This is in line with Albert's account, so would count as a causal handle on the past. Frisch concludes Albert's causal handles may appear intuitive, but it rests on at least one of the following assumptions. First, it is true that traces with the PH, nomologically determine the event's occurrence. Second, that each event leaves many traces, which when taken individually, only marginally affects the probability of the event's occurrence. However, as Frisch argued above, the latter assumption is often false because there are many events which leave no, or only a few, traces in the future. This leads Frisch to the conclusion that Albert's causal handles cannot underpin the direction of time.

**5.4 Decision Counterfactuals:**

Loewer (2007: 316–7) believes that to demonstrate a local account of time's direction one needs to evaluate counterfactuals in connection with statistical mechanics. Loewer argues for a statistical mechanical conditional (SMC), which is compatible with the dynamical laws, PH and PROB. The SMC is linked to an asymmetry of our ability to make decisions. Loewer states that it takes the form of "If P were to decide to A then the probability of B would be x."[25]

Loewer states that he makes two assumptions when explaining the SMC. First, that the decisions are local microscopic events in a person's brain which has a positive probability. Second, that the decisions are correlated with macroscopic motions of the body. Loewer then asks us to suppose two things. First, even if we live in a deterministic world, a person still has control over what decision they make. Second, that the various decisions which are available to a person are all equally likely to be chosen. Loewer argues that decisions are therefore indeterministic relative to the macro state of the brain, and the surrounding environment, before and at the moment of making the decision.

[25] Loewer (2007: 316)

Loewer (2007: 317) imagines that person P has a decision to make between two choices, $D_1$ and $D_2$. Loewer states that if one knows the statistical mechanical probability of each decision, then one would know the objective probabilities of $D_1$ and $D_2$. SMC tells us information about the objective probabilities of the $D_1$ and $D_2$ leading to an event. Loewer argues for this by giving us the following conditional example, “if I decide to bet on the coin landing heads, then the chance I would win is 0.5.”[26] Loewer states that is true iff the statistical mechanical probability of winning given the macro state and my decision is 0.5. So, this is the sense in which statistical mechanics is objective. Statistical mechanics requires objective probabilities for SMCs to plausibly work.

Loewer argues that decision counterfactuals are temporally asymmetric. They “inherit” the direction of time from the statistical mechanical distribution. Microscopic differences in a decision at time t can result into large macroscopic differences. Loewer argues these differences will only affect the probability of macro events after t, and never prior to t. The reason for this is the prior dominance of local macro signatures of the past, but not of the future. Loewer states that it also depends on our biological structure where small differences in the brain can get magnified into differences in bodily movement which then cause big differences in the world, such as Nixon pressing the button.

Loewer (2007: 317–8) raises the worry that there might be events in the past which leave few, or no, macroscopic traces at t. For example, Loewer uses the destruction of Atlantis to show a possible event which could have left no macroscopic traces. Due to the lack of macroscopic traces, one could conclude that Atlantis’s destruction occurring at t was caused by the raising of a my finger at the later time $t_1$. Loewer also raises the concern that, as a consequence of this account, the probability of the past micro state is correlated with present alternative decisions. Due to these concerns, Loewer states three conditions of control to show that decision counterfactuals are still temporally asymmetric:

[26] Loewer (2007: 317)

- 1st condition – when one makes a decision, there is a correlation between that decision and the event occurring.
- 2nd condition – one must have good reasons to believe that such a correlation is achievable.
- 3rd condition – one has control over an event B only if it is part of the content of our decision that B occurs.

Using the example of Nixon pressing the nuclear button, one can see that each of these conditions of control correlate to future events of a nuclear holocaust. Each of the condition cannot be linked to any event in past, such as there is no correlation between Nixon deciding to press the button and him being caused to walk into the room to press the button. For Loewer, this demonstrates that the direction of time is underpinned by the asymmetry of decision counterfactuals. However, Loewer's account for the asymmetry of decision counterfactuals is rather quick.[27] The account still seems to be symmetric rather than asymmetric, as Frisch argues.

Frisch (2014: 219 - 24) states that the asymmetry of decision counterfactuals is built into our account of what a decision is, which would be begging the question. To avoid this, Frisch argues, one needs to treat the asymmetry of decision counterfactuals as analogous to Albert's causal handles. So, this means that when evaluating the truth of a counterfactual, one holds the actual present macro state, as well as our present memories, fixed. Then one puts forward an alternative decision event, which is compatible with the fixed state, and let the conditional probabilities of both future and past macro events be those given by the PH. For Loewer's account to succeed, the alternative decision must make no difference to the probability of the past event.

Frisch (2014: 220) states that the PH does not imply Loewer's account. He states that decisions at t are not completely independent of the macro state of the world prior to t. In other words, many decisions today reflect facts about one's own biography and are strongly correlated to past events. Even though one's biography plays a role in shaping the choices one makes, one consciously only remembers very few events from one's past and few of these events have left completely reliable macroscopic traces. Therefore, the present macro state along with my memories do not screen off

[27] This is a point which Loewer does acknowledge and states that further development is needed.

the past from my decisions. This means that an agent's decisions do make a difference to the probability of macro events prior to the time of one making the decision.

However, the three conditions of control, even in situations like what Frisch describes, are meant to show an asymmetry between the past and future correlations since one cannot have control over events in the past. The first condition of control is problematic for the same reason which is stated above, in §5.3, against causal handles being asymmetric. That being there is a correlation of control between our decision in the present and past events occurring.

Frisch argues that the second condition of control is also correlated to past events.[28] Agents who have the right kind of competences can, in certain circumstances, learn from their decisions, since their decisions act like finely tuned instruments which pick up on cues that are not consciously available to the agent. Frisch (2014: 221) states that if an account like this is correct, then there are correlations between our decisions and past events. Frisch has shown that the first two conditions of control, which are meant to show that decision counterfactuals are asymmetric, are actually symmetric.

One may argue that all of the three conditions need to be met, and while one of the conditions may be understood to be symmetric in chosen situations, the first and second condition cannot both be shown to be symmetric in the same situation. However, Frisch (2014: 222) states that both conditions of controls can be jointly satisfied to show symmetry. Imagine a pianist playing a piece of music but is uncertain whether she has reached a stage in the piece that is repeated for the first or second time. The pianist chooses to play the second ending, since she has learned from experience that when she plays a piece she knows well, her decision to play certain notes are evidence for where she is in the piece of music. The pianist's present decision not to repeat the part constitutes good evidence for a certain past event. The pianist has a vague, and unreliable, memory of having already played that part of the piece once. The decision to play the second ending, then, is additional evidence for the unreliability of her memory. Loewer's conditions are jointly satisfied because, first, one has a good reason for treating the decision as providing us information about the

[28] Frisch uses Halton's (2006) account of agents to make this argument.

past, or past events. Second, the past event in question has left no, or only few, and not reliable traces in the present.

Frisch (2014: 223) raises a concern with Loewer's third condition for how an agent's decisions are temporally asymmetric. As stated above, the third condition is that one has control over an event B if it is part of the content of our decision that B occurs. Frisch argues that one has control over the events that are consequences of our decision, even when the content of our decision is not that these events occur. Frisch gives the example that he may have the desire to get to work for 9AM, and that he has good reason to believe the arrival time is correlated with the time that he leaves home. His decision to leave at a certain time gives him the means of controlling his arrival time. In this situation, the decision is to leave at, say, 8AM rather than deciding to arrive at 9AM. Frisch states "It seems that we can have control that *p* be so by decision, even when our decision is not a decision that *p* be so."[29] Thus, Frisch concludes that the first two conditions of control are correlated to past events, while the third should be rejected on independent grounds.

Loewer's account of the asymmetry of decision counterfactuals are meant to be underpinned by the three conditions of control. These conditions are meant to show that our decisions are correlated towards the future but never the past. However, Frisch's argument has shown that there are problems with each of Loewer's conditions of control. This means that neither Loewer's or Albert's account of the PH can be used to demonstrate time's direction to pass the local test.

**5.5 The Past Hypothesis and Quasi-Miracles:**

The criticisms presented by Frisch (2014) may not be insurmountable for either Albert and Loewer.[30] However, I believe that the better solution to explain what underpins time's direction is to use the PH with the asymmetry of counterfactual dependence. In §4.3, Elga's criticism demonstrated that Lewis had not reconciled the asymmetry of counterfactual dependence with the laws of thermodynamics. I propose, rather than using Lewis's account of the asymmetry of miracles, that instead one uses the

[29] Frisch (2014: 223)
[30] Albert (2015) responds to the criticisms of Frisch.

asymmetry of quasi-miracles to underpin the asymmetry of counterfactual dependence.

Lewis introduces the idea of quasi-miracles to respond to a criticism of his argument for the asymmetry of counterfactual dependence. Lewis assumes in this argument that the world is deterministic. However, physics is not necessarily deterministic; quantum mechanics allows for the possibility of indeterminism. Lewis considers what the consequences of an indeterministic world are for the asymmetry of counterfactual dependence, in particular the consequences for the asymmetry of miracles. Lewis concludes that in an indeterministic world one should replace the asymmetry of miracles with the asymmetry of quasi-miracles. It is this account I will use to underpin the direction of time.

Lewis (1986b: 58-65) argues that an indeterministic world may actually make things easier for divergence. In an indeterministic world one does not require a small miracle to cause divergence. This is because the divergence may arise through chance processes. For example, an extra neuron firing causing Nixon to decide to press the button could be a chance process which causes divergence away from our world. However, Lewis acknowledges that an indeterministic world may make it more difficult for his account of convergence. If chance miracles are possible, as part of normal processes, and if they are common, then it makes it more likely for convergence to naturally happen. For example, a chance process such as another neuron firing in Nixon's brain causing him to forget about what he was doing could prevent him pressing the button and convergence back to our world. To account for a possible indeterministic convergent world not being as similar to our own, as a possible indeterministic divergent world, Lewis argues for quasi-miracles. A quasi-miracle is where the laws of nature are followed; however, due to many chance processes in the way laws of nature are realised in a state, it could result in a different event occurring. As already mentioned, one would only need a small quasi-miracle to cause divergence. However, for convergence one would need a large number of quasi-miracles. The number of quasi-miracles required would be such a large coincidence, and on a scale unlike anything one sees in this world, that it would mean that any convergence would be more dissimilar to our world than divergence. Lewis's description of asymmetry of quasi-miracles demonstrates that quasi-miracles are just as consistent with his account of asymmetry of counterfactual dependence as his argument for the asymmetry of miracles.

The PH is still important when considering quasi-miracles because it removes the need for a big quasi-miracle, or a lot of small quasi-miracles, by having the low entropy state of the early universe. Similar to Lewis's account of asymmetry of miracles, possible worlds with quasi-worlds should avoid having a big quasi-miracle, or a lot of small quasi-miracles, when looking for the most similar world. Without the PH, there would be a lot of other possible worlds that would need a big miracle to be considered similar to our own. But, with the PH this is not the case as the low entropy state in the early universe had to be, as it is part of a fundamental law of nature.

Quasi-miracles may be compatible with the asymmetry of counterfactual dependence. But the idea of quasi-miracles needs further elaboration to show why they resolve problems that previous theories could not. Bourne and Caddick Bourne (2017: 567–9) explain that "a quasi-miracle is a particular kind of extraordinary and striking event which appears miraculous, even though it is not." Imagine a room of monkeys randomly pressing the keys on typewriters. There are many different, and equally probable, outcomes which the monkeys could produce because there are many different sequences of characters. Some of the sequences may produce words which we recognise. If a meaningful sequence of characters were produced then even though people may understand the actual mechanisms behind how the event occurred, they would still find the event striking and extraordinary, in a way that one would not if any of the equally probable meaningless sequences of characters were produced.

Bourne and Caddick Bourne state that the extraordinariness of quasi-miracles are based on two distinct things: coincidence and design.[31] In certain situations, one can consider the different ways in which the probability of the outcome can be assessed, relative to either the other possible outcomes or to the different possible methods by which the outcome was produced. Given the process of monkeys randomly hitting keys, a given meaningful sequence of words is no less probable than any other

[31] Design refers to a non-accidental process.

particular meaningless sequence of words. Nevertheless, the probability of getting a meaningful sequence of words from randomly hitting keys is much lower than intentionally hitting the keys to produce a meaningful statement.

If one were to encounter a quasi-miraculous event, it would involve giving us the impression of there being a special reason why the event progressed in that particular way, rather than in any other way. In actuality, the event would not really necessitate any special reason. What is striking, and extraordinary, about the event is the fact that this world is very like one in which intention is the explanation, yet we know that isn't the explanation.[32] For example, if there is a page of meaningful writing, one would be struck by how close this case is to one where the explanation for its occurrence is that it has been intentionally created.

Applying this explanation of quasi-miracles to Elga's criticism, one can see that his account is nothing more than quasi-miraculous. The explanation of the event appears to be one that did not actually bring it about. In other words, the egg jumping back has the appearance of being explained by time reversing, when in fact the explanation is the event is following a statistical mechanical understanding of the laws of thermodynamics. This event is striking because it appears that time's reversal is the explanation for it occurring. Quasi-miracles are an account of our experience of the extraordinary and so could be used in an account of our experience of time at the local level (that is, that extraordinary things like this don't happen, otherwise they would not be extraordinary). So, this could at least be part of the explanation our experience of local direction of time (even though it does not explain why the facts are as they are, for example why don't we see eggs jumping back into their shells).

What is key in Elga's example is whether these events *would* happen or whether they only *might* happen. Lewis (1986b) does not explicitly tackle, or resolve, this problem but what he writes does point us to the solution. It is a contextual issue based upon the logical connection between (i) counterfactuals about what would happen, (ii) counterfactuals about what might happen and (iii) counterfactuals about what the

[32] The driving process there should be an alternative explanation will vary depending on the specific example.

chance would be of an event happening. As Lewis states, chance processes are abundant, as there are many different events which may occur which follow the laws of nature, this means that there is some chance of a quasi-miracle. The probability of a quasi-miracle may be very low, and in fact minute, but the probability is not zero. Elga's example is a counterfactual case of points (ii) and (iii) due to the context that one is looking at them in. However, they are not cases of point (i). In other words, they are not examples of counterfactuals about what would happen. Although Elga's egg might jump back into the shell, it wouldn't. Our judgement of whether such events happen are linked to what we judge to be extraordinary. The fact it is found to be extraordinary has not been explained; it is just a fact about the world that it works in a particular way, and we experience it as working in that way, and so we experience events which give the appearance of working in a different way as extraordinary.

Using Lewis's account of asymmetry of counterfactual dependence, with the adaptation of underpinning it, not with the asymmetry of miracles but, with the asymmetry of quasi-miracles, we then have a sound explanation for what underpins the direction of time. This is combined with the PH and PROB to demonstrate how the asymmetry of counterfactual dependence is compatible with the laws of thermodynamics, so that both the global and local tests are passed in explaining time's direction. By holding PH and PROB it means that you do not need a large quasi-miracle, or lots of small quasi-miracles, to account for the early universe being in a state of low entropy.

**5.6 Section Summary:**

- The PH and PROB are fundamental laws of nature. By holding this, retrodictions about past states become more accurate. In other words, it accounts for the fact the universe started in a state of low entropy and that entropy decreases towards the past.

- Even with the PH and PROB understanding of the universe, it does not resolve the issue, which was raised in §2, that scientific laws alone do not account for time's direction. In other words, they do not account for time's direction at a local level.

- Albert’s causal handles and Loewer’s decision counterfactuals have both been used with the PH to underpin time’s direction. However, Frisch has demonstrated that both of these arguments fail to pass the local test.

- Instead of underpinning the asymmetry of counterfactual dependence with the asymmetry of miracles, one should underpin it with the asymmetry of quasi-miracles. Quasi-miracles are events which, if they occurred, would not go against the laws of nature but would be extraordinary and striking.

- The notion of a quasi-miracle can be used to explain Elga’s egg because, if it did happen, then it would be an extraordinary and striking event, but it does not break the laws of nature. What makes this striking is that the explanation for Elga’s egg is so close to a world where the explanation is that time has reversed. Events, such as Elga’s egg, do not actually take place in our world otherwise they would not be extraordinary (it is just a fact of the world that the laws of nature work in a particular way and that we experience them it that way).

- Lewis’s account of the asymmetry of counterfactual dependence, with the adaptation of being underpinned by the asymmetry of quasi-miracles, underpins the direction of time. It is able to explain why we have the experience of time’s direction that we do, at both a global level and a local level, when combined with the PH and PROB. The PH and PROB mean that a large, or lots of small, quasi-miracles are not required to explain the early universe being in a state of low entropy.

## Conclusion

The key points to my argument, to show that the tenseless theory of time can give a consistent account of what underpins the direction of time are:

- The tenseless theory of time is compatible with scientific theories, such as Einstein's Special Theory of Relativity. However, there is nothing in the characteristics of tenseless theory which explains why we experience time's direction, at a global and local level, in the way that we do.

- Scientific laws, such as the laws of thermodynamics, alone cannot explain the direction of time.

- An explanation for time's direction should not be effected by the possibility, or impossibility of causal loops, and backwards causation.

- Lewis makes progress in explaining time's direction when arguing for the asymmetry of counterfactual dependence. This states that counterfactual statements show that changes (not literal, or actual, changes but possible ones) about the future are based on the present. Counterfactual statements about the past are not based on the present. The past is fixed and independent of the present, whereas the future is open and dependent on the present. This account is underpinned by the asymmetry of miracles which states that the most similar possible world to our own is one with divergence rather than convergence. Divergence from our world only requires a small miracle, whereas convergence to our world requires a large miracle, or lots of small miracles. Divergence supports the idea that the future is open and convergence supports the idea that the past is fixed.

- Elga's egg shows that Lewis has not reconciled the asymmetry of counterfactual dependence with the laws of thermodynamics. This means that there are cases of convergent worlds which are more similar to our own than divergent worlds. So, Lewis's current and unadapted theory is unable to give a complete local account of time's direction.

- PH and PROB are fundamental laws of nature. By holding this it accounts for the fact that the universe must have started in a state of low entropy. However, it does not account for local examples where entropy could increase towards the past, such as Elga's egg.

- To resolve problems, such as Elga's egg, Lewis's asymmetry of counterfactual dependence should be adapted so that it is underpinned by the asymmetry of quasi-miracles. Events, like Elga's egg, are striking because they appear to be explained by processes, like time reversing, when in fact they are following the laws of nature (in this example it is following a statistical mechanical understanding of the laws of thermodynamics).

The tenseless theory of time explains the direction of time as being underpinned by the asymmetry of counterfactual dependence, which itself is underpinned by the asymmetry of quasi-miracles. This explanation also holds that the PH and PROB are fundamental laws of nature, this then accounts for the early universe being in a state of low entropy and does not require a large quasi-miracle, or lots of small quasi-miracles.

## Bibliography


Albert, D. (2000), *Time and Chance*, Harvard University Press

_____ (2015), *After Physics*, Harvard University Press

Atkins, P. and Jones, L. (2004), *Chemical Principles: The Quest for Insight,* W.H. Freeman & Co Ltd

Atkins, P. (2010), *The Laws of Thermodynamics: A Very Short Introduction*, Oxford University Press

Beebee, H., Hitchcock, C. and Menzies, P. (eds.) (2009), *The Oxford Handbook of Causation,* Oxford University Press

Bennett, J. (1984), 'Counterfactuals and Temporal Direction', *Philosophical Review*¸ 93, 63 – 64

Black, M. (1956), 'Why Cannot an Effect Precede its Cause', *Analysis*, 16, 49–58

Bourne, C. (2006), *A Future for Presentism*, Oxford University Press

Bourne, C. and Caddick Bourne, E. (2017), 'Explanation and Quasi-miracles in Narrative Understanding: The Case of Poetic Justice ', *Dialectica*, 71:4, 563–579

Callender, C. (ed.) (2014), *The Oxford Handbook of Philosophy of Time,* Oxford University Press

Curiel, E (2019), 'Light Cones and Causal Structures' https://plato.stanford.edu/entries/spacetime-singularities/lightcone.html (accessed on 09/05/2021)

Dainton, B. (2001), *Time and Space (Second Edition),* Routledge

Dummett, M. (1964), 'Bringing about the Past', *Philosophical Review,* 73:3, 338–359

Einstein, A. (1905), *Relativity: the Special and the General Theory*, Princeton University Press

Elga, A. (2001), 'Statistical Mechanics and the Asymmetry of Counterfactual Dependence', *Philosophy of Science*, 68:3, S313–S324

Ernst, G. and Huttemann, A (ed.) (2010), *Time, Chance and Reduction*, Cambridge University Press

Frisch, M. (2010), 'Does a Low-Entropy Constraint Prevent us from Influencing the Past?', in Ernst and Hutteman (2010), 13–33

Frisch, M. (2014), *Causal Reasoning in Physics*¸ Cambridge University Press

Gold, T. (1962), 'The Arrow of Time' *American Journal of Physics*, 30, 403–410

Hawking, S. (1988), *A Brief History of Time*¸ Bantam

Holton, R. (2006), 'The Act of Choice' *Philosophers' Imprint*, 6:3

Horwich, P (1987), *Asymmetries in Time: Problems in the Philosophy of Science*, The MIT Press

Le Poidevin, R. (2004) *Travels in Four Dimensions: The Enigmas of Space and Time*, Oxford University Press

Loewer, B. (2007), 'Counterfactuals and the Second Law' in Price and Corry (2007), 293–326

Lewis, D (1973), *Counterfactuals*, Blackwells Publishing

_____ (1979), 'Counterfactual Dependence and Time's Arrow', *Noûs*, 13, 455 – 476

_____ (1986a), *Philosophical Papers: Volume II,* Oxford University Press

_____ (1986b), 'Postscripts to "Counterfactual Dependence and Time's Arrow"' in Lewis (1986a), 52–66

McTaggart, J.E. (1908), 'The Unreality of Time', *Mind* 17, 457–474

Mellor, D.H. (1995), *The Facts of Causation*, Routledge

_____ (1998), *Real Time II*, Routledge

_____ (2012), *Mind, Meaning and Reality: Essays in Philosophy*, Oxford University Press

Minkowski, H (1908), 'Space and Time' in Curiel (2019)

North, J. (2011), 'Time in Thermodynamics', in Callender (2011), 312–50

Popper, K.R. (1956), 'The Arrow of Time', *Nature*, 176, 538

Price, H. (1996), *Time's Arrow and Archimedes' Point*, Oxford University Press

Price, H. and Corry, R. (ed.) (2007), *Causation, Physics and the Constitution of Reality: Russell's Republic Revisited*, Oxford University Press

Putnam, H. (1967), 'Time and Physical Geometry', *Journal of Philosophy*, 64:8, 12–17

Reichenbach, H. (1956), *The Direction of Time*, University of California Press

Sklar, L. (1977), *Space, Time and Spacetime,* Berkeley, CA: University of California Press

Stein, H. (1991), 'On Relativity Theory and the Openness of the Future', *Philosophy of Science*, 58:2, 147–67

Tooley, M. (1997), *Time, Tense and Causation*, Oxford University Press