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CLOSED SPACE AND CLOSED TIME*

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Alcmaeon says that people die simply because they
cannot join beginning to end

MANY have benefited from John Ackrill's tellingly accurate analyses of textual and philosophical problems, and have been saved by him from error. I am sure that my earlier views on the present subject were in error, although I shall do no more here than present the main outlines of a different view. I shall return to complete the details on another occasion.¹

Closed space

If space were finite, what would happen at the boundary? This question constitutes the most severe objection to the finitude of space, and it was already put in a sharp form in the fourth century BC by the Pythagorean Archytas.² The Pythagoreans, we shall see, were particularly imaginative about space and time. The modern answer is to say that space could be finite without having a boundary. That is what is meant by closed space. But the difficult thing is to show how that is possible. I shall merely try to offer a clear statement of the type of explanation that has been given by others.³

If space were infinite in every region and direction, a rocket ship that went on travelling in a straight line should get for ever further away from its starting point. Is it conceptually inevitable that that would happen? Let us imagine ourselves stepping into a space rocket

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¹ Richard Sorabji, *Necessity, Cause and Blame* (London, 1980), 115–19, contained the mistaken discussion. I hope to present a more detailed view in *Matter, Space and Motion* (in preparation for publication by Duckworth).

² Archytas, *apud* Simplicium, in *Aristotelis Physica commentaria* (in *Phys.*) 467. 26–35.

³ See Stephen F. Barker, 'Geometry', in *The Encyclopedia of Philosophy*, ed Paul Edwards (New York, 1967).

erected outside our window in London, or wherever we are. And let us make sure, once under way, that the rocket ship travels in a straight line. We shall have to consider what is meant by 'straight'. According to a definition as old as Plato, the straight line is the line of sight,⁴ which we now know to be the line taken by light, although we must guard against refraction or reflection. It is also the shortest route between two points. Let us make sure, then, that our path is straight by all three criteria. The rocket ship will emit a coloured wake, and, looking back, we shall note with satisfaction that, in the absence of any wind, the wake corresponds to the line of sight. We shall send out ahead a laser beam, and radio signals will warn us if the spacecraft deviates from the line of the light ray. Finally, we shall make sure that we are taking the shortest route in the direction of travel between any two points. We shall do so by taking measurements with a light-ray gun, equipped to time the return of bounced light signals. We shall want to measure the distances between points successively reached *A*, *B*, and *C*. If light signals take one minute to bounce back and forth between *B* and *A*, and one minute to bounce between *C* and *B*, then they should take two minutes to bounce between *C* and *A*, or the route through *B* will not be the shortest.

Suppose we have assured ourselves that our path is straight by all three criteria. What is there to prevent the cabin boy, who is looking through the front window, from shouting, 'Ahoy, there! I see something that looks remarkably like London'? After all, there is nothing but habit to connect the shortest line, the line of sight, or the line of light with the view from the front window. There is no conceptual link which dictates what the view will be for one who has followed such a line. And it is this lack of conceptual link which makes it conceptually possible that a traveller following a straight line should not get for ever further away from his starting point, but should return to it. Whether he would in fact return depends on empirical facts about the universe and in particular on the distribution of matter. Relativity theory does not determine whether he would return, but allows for the possibility. And it was already anticipated by Riemann that his Geometry, in which this possibility is implied, may be true of the space we live in.

But we must be careful how we formulate our description of what we have imagined. The entire case will be thrown away, if we allow the cabin boy to say, 'we have come round in a circle'. Of course a *circle* comes back to where it started, but that only invites us to think that

⁴ Plato, *Parmenides* 137c boils down to this.

there is space *outside* the circle. The point on which we must insist is that it is a *straight line* that has come back to its starting point. And how would that suggest finitude? Well, if even a straight line does not get for ever further away from its starting point, there is no other line that will get further. The distances in the universe then seem to be finite. And yet they are finite without the universe having an edge (that is what makes space closed). For on our journey we did not come to a boundary where we had to change direction. The journey was finite without that.

The claim to have taken the shortest route needs to be qualified. For between any two points on our track there will be *two* routes, and only *one* of them will be the shortest. It may therefore be thought better to say that our track represents the nearest available analogue of a straight line.

There are other descriptions which share the defect of the cabin boy's exclamation, 'We have come round in a circle'. It is often said that space may be curved, or that the geometry of such a universe is like that of a sphere. These statements have their point, but they do not enable us to see how space could be finite. For they invite the question what is beyond the curve, or outside the sphere. And that is why it is better to describe the situation in terms of a straight line, or the closest analogue to it.

But how much would our imaginary experiment establish about finitude? Some caveats are needed. We should not rule out the possibility that space, though finite, might expand indefinitely. Nor, I believe, should we exclude the possibility that there are spaces which bear no spatial relation to our space or to each other, and which have different dimensions from ours. Further, before deciding that our space is finite, we should need to make sure that it is not finite merely in certain directions or in certain pockets. But it might be urged that the experiment suffers from a more radical shortcoming. For why would it be rational to suppose that we have returned to London itself, rather than reached an exact replica of London, or, if London had perished in our absence, of the earth?

I think this could be made the subject of physical experimentation. Riemannian Geometry is a consistent system which permits the straight line to return on itself. If we find that the space we travel through has yet other features of Riemannian Geometry, it will be more credible that our space is Riemannian than that London and the earth is duplicated. By sending our astronauts out on little detours

from the main spacecraft, we could get them to take paths that formed a triangle with the main path, and we could get them to measure the interior angles of those triangles. If the interior angles differed from two right angles in an appropriate way, we should have confirmation that we were following a straight line in Riemmanian space, and that it was London we had reached.

One feature of the spatial experiment will later become relevant to the question of closed time, and that is that we can think of London as both in front of and behind itself. As we departed in our spacecraft, we left London behind, but the straight line led us to find it in front of the city we left behind.

I have deliberately over-simplified by mentioning space-time as little as possible, and by treating space as a wholly distinct entity. We might have lived in a universe in which space was indeed a distinct entity, and in which the notion of space-time had no special utility. My account of how space could be finite should apply without modification to such possible universes. But in our actual universe, according to relativity theory, four-dimensional space-time is the fundamental structure, and it is only on some models of the distribution of matter that one can separate out such a thing as space, in order to ask if it is finite. In Gödel's model, for example, which I shall discuss below, one can separate out time, but not space. It might therefore seem easier to consider the finitude not of space, but of space-time. But that too would have its complications. For it is only on some models that there would be a unitary answer to the question whether space-time was finite. On other models, there would be different answers corresponding to different frames of reference.⁵ I believe that my account of closed space could be adapted to fit those models of space-time in which space is a distinguishable structure. But I shall leave this task to those better qualified and move on to consider time.

Endless repetition

I shall first touch briefly not on closed time, but on a rival theory, also pioneered by the Pythagoreans, according to which history is endlessly repeated with the same persons and things recurring in linear time. I have discussed this theory elsewhere.⁶ It appealed not only

⁵ I am grateful to Arthur Fine and David Malament for introducing me to these issues.

⁶ Richard Sorabji, *Time, Creation and the Continuum* (London, 1983), 182–90.

to certain Pythagoreans, but also to the Stoics and to the Neoplatonists. But there were variations according to whether the repetitions of history were thought of as exact. Various Stoics, for example, felt a need to avoid exact repetition, and Aristotle's pupil Eudemus of Rhodes had already objected to the Pythagoreans that the theory of an exact repetition of history would collapse into the acknowledgment of a single occurrence.⁷ I presume he was relying on Aristotle's definition of time as the number, or element which can be counted, in terms of before and after in motion. If repetitions were exact, the motions would be the same, hence so would be the countable element in the motions, in other words, time. The conclusion which follows from that is not drawn explicitly in the report of Eudemus, but if the time is the same, there will have been no repetition after all, and history will have occurred but once. The report runs as follows:

One might be puzzled whether or not, as some people say, the same time recurs. For sameness is spoken of in different ways, and it does seem that a time the same in kind recurs, for example summer, winter and the other seasons and periods. Similarly, motions (*kinēseis*) the same in kind recur, for the sun will accomplish its solstices, equinoxes and other journeys. But if one were to believe the Pythagoreans' view that numerically the same things come again, and I will talk staff in hand to you sitting like this, and everything else will be alike, then it is plausible that the time too will be the same. For when the motion (*kinēsis*) is one and the same, and similarly there are many things which are the same, their before and after is one and the same, and hence so is their number. So everything is the same, which means that the time is as well.

The same conclusion, that history occurs once, would follow for those present-day philosophers who accept in a suitable form the principle of the identity of indiscernibles. If we try to imagine an exact repetition of history, events will be qualitatively the same as before, and the time of their occurrence will also have nothing to distinguish it from the earlier time. The principle of identity of indiscernibles would then dictate that the time was after all the same, and there was no repetition. For in the relevant version, the principle says that in order for two things, for example two times, to be distinct, there must be some feature that differentiates them. It has been argued that the Stoics would be committed to the same conclusion by principles of their own.⁸ So long as events are numerically the same (and for some

⁷ Eudemus, *apud* Simplicium, in *Phys.* 732. 26–733. 1.

⁸ Jonathan Barnes, 'La doctrine du retour éternel', in *Les Stoiciens et leur logique*, ed. Jacques Brunschwig (Paris, 1978), 3–20, esp. 12.

Stoics they are), time too will have to be the same, since time for the Stoics has no existence independent of events. All these arguments turn on *logical* considerations. No *empirical* test for reduplication is suggested, parallel to the measuring of interior angles, which was used above in the discussion of space, to decide whether a traveller had reached a duplicate of London.

If the hypothesis of a finite history endlessly repeated in linear time can be collapsed, we might expect the result of collapse to be a finite history, occurring only once, and having its events arranged in a linear sequence with a beginning and an end. If time depends on the occurrence of events, it too will be finite, and indeed that result would follow from the identity of indiscernible times, or from the other logical arguments used above. There would be no distinct times, according to the identity of indiscernibles, outside the span of history, because there would be nothing to distinguish such times. But could history and time be viewed as circular rather than linear? That is, they would be finite without having a beginning or an end, in the manner of a circle whose length is finite, but which lacks beginning or end. That would be a form of what is called closed time, and A. A. Long has suggested that if the Stoic idea of endless repetition can be collapsed we should think that what the Stoics and perhaps the Pythagoreans were really expressing was the idea of closed time.⁹

Closed time

I am grateful to Long for reopening the issue, because I had previously argued that the idea of closed time was incoherent, and a number of others have thought the same.¹⁰ But on the other side, a very simple imaginary situation has been described in which we might be motivated to think of time as closed.¹¹ We have already imagined that there might be only a finite sequence of qualitatively distinguishable

⁹ A. A. Long, 'The Stoics on world-conflagration and everlasting recurrence', *Southern Journal of Philosophy*, supp. vol X, ed R. Epp (1985).

¹⁰ Richard Sorabji, above n 1, 115–19; W. C. Kneale, 'Time and eternity in theology', *Proceedings of the Aristotelian Society*, LXI (1960–1), 91–2; J. R. Lucas, *A Treatise on Time and Space* (London, 1973), 57–60; Jonathan Barnes, above n 8, 19 n 64.

¹¹ Bas van Fraassen, *An Introduction to the Philosophy of Time and Space* (New York, 1970), elucidating Adolf Grunbaum, *Philosophical Problems of Space and Time*, 2nd edn (Dordrecht, 1973); cf. W. H. Newton-Smith, *The Structure of Time* (London, 1980), 65–8; Lawrence Sklar, *Space, Time and Space-Time* (Berkeley, Los Angeles, 1974), 303–17; David Lewis, 'The paradoxes of time travel', *American Philosophical Quarterly*, XIII (1976), 145–52.

events, and we have seen that, on the postulate of identity of indiscernibles, the sequence could occur only once. Now suppose that in this single sequence no event looked like a first or last, but on the contrary each appeared to be caused in a perfectly normal manner by its predecessors. The sequence of events would then appear to form a seamless, closed circle. No event could be assigned to a later or earlier end of the sequence, because the seamless circle of events would not permit the distinction of an earlier or later end. And that would mean that time itself, as well as events, would be seen as forming a circle. The talk of a circle, which was unsatisfactory in connection with space, would not raise the same problems here, because no comparable question arises about what lies outside the circle.

I do not see why this situation should preclude talk of earlier and later, past and future. But each event would be seen as lying *equally* in the past and future, just as, from a point around a clockface, twelve o'clock can be seen as lying equally in the clockwise and the anticlockwise direction. For all that, twelve o'clock does not occur more than once on the clockface. And similarly an event and its time would occur only once. One of my previous objections to the idea of closed time, that each event would be before and after itself, has its analogue in the spatial situation, where London proved to be in front of and behind London. That turned out to be the natural consequence of a perfectly intelligible situation, and its temporal counterpart should not deter us. In talking of past and future, before and after, I am not withdrawing the claim that there would be no earlier or later *end* of the sequence. The point is that there would be no ends in the sequence, and therefore no earlier or later ends, even though any event could be viewed as both earlier and later than any other.

Despite the fact that each event could be seen as lying equally in the future and in the past, I see no reason why there should not be a direction for the flow of time. The static question of where events *lie* in the circle is not the same as the dynamic question of when we *reach* them. Given any three events, there would still be a fixed order in which, starting from one, we could reach the other two. The same would apply to causal influence: there would be a fixed temporal order in which we could influence the other two. And besides the temporal order, there might be a causal order, in that the first event was a necessary condition for the third only *because* it was a necessary condition for the second. The event we were reaching would

admittedly lie in the past as well as in the future, and the event we were leaving would lie in the future as well as in the past.

The possibility of temporal direction would be challenged by someone who thought that temporal direction could be reduced to some unidirectional physical process like entropy (a process in which physical differences are increasingly levelled out). The circle of events would not allow a unidirectional process, because the circle would require that all changes should eventually be reversed. However, I do not myself see that the direction of time can be reduced to any unidirectional physical process, any more than the direction of clockwise motion can be reduced to a physical process distinct from itself.¹² Nor would the absence of such a process rule out the talk of past and future, or of events being earlier and later than each other.

The fact just mentioned, that in circular time all changes would need to be reversed eventually shows that circular time would require a different physics. A tree could grow, so long as it shrank or disappeared in time to grow. It could lose a branch, so long as it later had the same branch with the same particles. If the particles stayed in existence in the interim, they would need to be assembled from wherever they had got to. It might be simpler if the particles went completely out of existence, and if qualitatively indistinguishable ones were generated out of nothing.

Circular time has implications for immortality. Suppose the universe lasted a total of forty years. Then a living being which lasted forty years without having a beginning or an end during that time would be immortal. However, human beings all have a beginning when they are conceived. So how would they fare in a circular system of forty years? They might die within the forty years, or they might dwindle into the sperm and ovum from which they were generated. In either case, despite the death or dwindling, they could, in a sense, enjoy survival after death. For whenever they died or dwindled, there would still be life ahead of them. Any particles scattered at the time of death or dwindling would need to be in their former positions later on through assembly or creation *ex nihilo*. Although death or dwindling

¹² The issue is, of course, controversial. John Lucas has argued against the possibility of direction in circular time, and hence against the possibility of circular time itself, on the basis of the absence of suitable physical correlates for directions (above n 10, 59–60). For discussions of the direction of time, see e.g. Lawrence Sklar, above n 11, 351–414; John Earman, 'An attempt to add a little direction to "the problem of the direction of time"', *Philosophy of Science*, LI (1974), 15–47.

would involve an interruption in human life, it would deal with the fear of permanent extinction, of having no more future, which for some people is the most horrifying aspect of death. And it would deal with it, without relying on the need for an infinite future.

To some people an infinite future would be preferable. But others would find a positive advantage in a guaranteed future that was finite. For the length of experience would not then be a source of tedium such as some philosophers have feared in immortality.¹³ For the people described would live at most forty years, some of them less. It should not be thought that they would live the same forty (or fewer) years again and again; they would live it only once. For the principle of identity of indiscernibles, which was invoked to establish that there would be only one cycle, would equally imply that there was only one *experience* of the cycle. Boredom might come from another source, if the fact that all their experience is past (as well as future) leaves them with no surprises. But if their memory or attention is selective, or if for those who die or dwindle it is eradicated, there will be plenty of novelty to surprise them. In general a different psychology would be needed, just as much as a different physics, if life was to be tolerable.

In some respects, circular time would have the same effects as endless repetition. People would have to accept the prospect which Augustine found so repulsive in endless repetition, that any progress would be undone. I have discussed his reaction and alternatives to it elsewhere.¹⁴ One alternative would be to seek pleasure in activity while avoiding concern for its outcome. Those who lived right through a cycle might try so to pattern their lives that decline in one field (golf) was balanced by progress in another (chess-playing).

It would be desirable that memory or attention should be imperfect, not only to prevent boredom, but also in order that a person might avoid terror or guilt at the thought of what he was going to do. In so far as he did recall unpleasant events, he might need to cultivate an attitude of resignation, although pleasant things could be recalled and anticipated gladly. Imperfect memory or attention would also make it possible for a man to deliberate, and it would free him from the inhibition of thinking of future action or inaction as certain and as fruitless, or redundant.

¹³ Bernard Williams, 'The Makropulos case: reflections on the tedium of immortality', in his *Problems of the Self* (Cambridge, 1973); discussion in Richard Sorabji, above n 6, 181–2.

¹⁴ Sorabji, above n 6, 188–90.

Problems of memory raise the question what form memory would take in a forty-year cycle. While watching a tree being planted, someone might find that planting familiar because he had had this very same experience forty years earlier. The familiarity would be a case of memory because it was due to the experience's being past, not to the fact of it also being present or future. He could also remember the forty-year-old remembering, although it would be wrong for him to add forty years to forty years and conclude that the planting had occurred eighty years earlier.

A different physics would deal with the objection that circular time is impossible, because it would lead to self-defeating situations. In a forty-year cycle, somebody somewhere, by design or accident, will surely kill his mother. Would not that prevent him from being around to be her killer?¹⁵ The simplest answer is that, since a different physics will anyhow be required, we should expect one which permits his mother to return from the dead in time to give him birth.

In some ways a cycle of millions of years would be easier to accommodate than a cycle of forty years. There would be ample time for the murdered mother to be born. In general a person would have more influence on his remote past and less on his recent history (I shall touch on backward causation below). A long cycle would immediately solve the problems connected with memory, because we should die after occupying a small portion of the cycle, and could expect our memories to be eradicated when our birth came round in the future. The length of the cycle would not reintroduce the threat of tedium, because our lives would occupy only a fragment of the time. Finally, we know we are not part of a forty-year cycle; whereas with a cycle of millions of years we may begin to wonder whether we are part of one, and whether our physics is after all compatible with it.

Gödel went very much further in the direction of investigating whether our actual situation is compatible with closed time.¹⁶ He considered the question only in relation to the personal time of

¹⁵ See Samuel Gorovitz, 'Leaving the past alone', *Philosophical Review*, LXXIII (1964), 360-71; John Earman, 'Implications of causal propagation outside the null cone', *Australasian Journal of Philosophy*, I, (1972), 222-37; David Lewis, above n 11; Paul Horwich, *Time* (M.I.T., Bradford Press, forthcoming 1986), ch 6, 'Time travel'; Murray Macbeath, 'Who was Dr. Who's father?' *Synthese*, LI (1982), 397-430. The context of Earman's discussion is the possibility of signals travelling faster than light, for which he supplies a useful bibliography.

¹⁶ Kurt Gödel, 'A remark about the relationship between Relativity Theory and Idealistic Philosophy', in *Albert Einstein, Philosopher-Scientist*, ed P. A. Schilpp (New York, 1951), 555-62.

individuals, because, as he pointed out, the theory of relativity does not allow that there is a single time for everybody, regardless of their state of motion. Observers travelling at high velocities in relation to each other do not agree about which events are going on at a given moment, or in what order events occur. Gödel's view was that, on the supposition of a certain distribution of matter in the universe, an individual making use of a rocket ship could find his personal time closed, if only he could attain a high enough velocity. On the other hand, the time of others not so accelerated would not be closed. Moreover, the velocities attainable in practice, given the available fuel, would suffice only to reach the distant past, so that the individual would in fact die before meeting his younger self. Even so, this would presumably ensure a kind of survival after death, for the traveller's birth would always lie in his personal future.

Gödel claimed that closed personal time was compatible with the mathematics of relativity theory. Is he right that it is also compatible with other things? Much has been done to exhibit the idea of time travel by rocket ship as consistent,¹⁷ but problems remain to be discussed. To mention but one, would there be enough molecules to constitute the rocket ship both on and off the ground? The peculiarities of time travel might require its molecules to be in both places at once, if it made a journey backwards through time, rather than simply disappearing and reappearing. Its molecules might also need to shuttle from its landing site at the earlier time to the rock face from which they were mined before the ship was assembled for take-off. If such difficulties can be met and Gödel is right, those who hate the thought of personal extinction might do better to invest in a rocket than in a cooling chamber. For the moment I will only point out that a time cycle such as I have described does not have to confront all the issues raised by Gödel's. Although molecules have to shuttle, there is no question of their being in two places at once. Nor need we face the problem which Gödel was so keen to avoid (although I do not think it an insuperable problem) of a person meeting his younger self. Nor need we make the distinction (although it is an intelligible one and necessary for some purposes) between a personal time and a time common to everyone. Nor (as I shall argue elsewhere) is it so clear that the past would be irrevocable.

I have given only an outline account of how circular time might be possible. The issues which remain would require at least as much

¹⁷ The most lucid account I know of is by Murray Macbeath, above n 15.

space as those already broached, and I am deliberately postponing them to another occasion. But I will say which ones currently seem to me the most important and what my current view is about them, without giving my reasons. First, would circular time require causation to work backwards from future to past in an objectionable sense? No; in a small time circle, I could indeed plant a tree tomorrow, in order to give shade to my house yesterday. The difficulties of backwards causation have been made prominent by Michael Dummett, who defended its possibility, but they have all been discussed in the context of ordinary linear time.¹⁸ I believe it becomes much easier in the context of circular time to show that any difficulties there may be can be overcome.

Another urgent question is whether everything that happened would always have been inevitable. Here I would correct my previous views;¹⁹ I do not think it need have been, although this requires detailed argument. The question of inevitability relates (although not in the ordinary way in circular time) to the question whether we would be morally responsible, and to the question whether we would be free. A perfect memory of what was going to happen would indeed inhibit us, but the inhibition would come from the memory, not from the circularity of time itself. Given an imperfect memory, I do not believe that we need lack freedom.

It should also be asked whether, in a forty-year cycle, an individual could enjoy a personal time longer than forty years, living his first decade simultaneously with his fifth in juxtaposed older and younger bodies. I believe that for living, moving individuals who, like us, changed their constituent molecules over time, this would be a possibility. But the consequences for the concept of a person would be considerable.

¹⁸ Two papers in favour of backwards causation by Dummett have led to the replies listed below. Michael Dummett, 'Can an effect precede its cause?', *Proceedings of the Aristotelian Society*, supp. vol XXVIII (1954), 27–44; with reply in the same volume by A. Flew; Dummett, 'Bringing about the past', *Philosophical Review*, LXXIII (1964), 338–59; Max Black, 'Why cannot an effect precede its cause?', *Analysis*, XVI (1956), 49–58; A. Flew, 'Effects before their causes? Addenda and corrigenda', *Analysis*, XVI (1956), 104–10; id., 'Causal disorder again', *Analysis*, XVII (81–6); Michael Scriven, 'Randomness and the causal order', *Analysis*, XVII (1957), 5–9; D. F. Pears, 'The priority of causes', *Analysis*, XVII (1957), 54–63; Samuel Gorovitz, 'Leaving the past alone', *Philosophical Review*, LXXIII (1964), 360–71; R. G. Swinburne, 'Affecting the past', *Philosophical Quarterly*, XVI (1966), 341–7; Richard M. Gale, 'Why a cause cannot be later than its effect', *Review of Metaphysics*, XIX (1966), 209–34; id., *The Language of Time* (London, 1968) ch 7; D. H. Mellor, *Real Time* (Cambridge 1981), ch 10.

¹⁹ Sorabji, above n 1, 115–19.

There is a final question that has been well discussed in the literature.²⁰ The case for describing that situation in terms of circular time rather than in terms of endless repetition rests at the moment on the flimsiest of logical considerations. It rests chiefly on a certain application of the principle of the identity of indiscernibles. That application will appeal to some philosophers, but it is by no means irresistible. Can we not imagine an empirical test that would tell in favour of the circular description? I think we may be able to. But if not, the description in terms of circular time will remain viable, even though it may turn out to be merely equivalent to the description in terms of endless repetition.

I have said enough to return to A. A. Long's suggestion that circular time may be what the Stoics and perhaps the Pythagoreans intended. If they did, they ought not to retain the language, tempting though it is, of endless repetition: of events occurring 'again', or 'recurring', or being 'repeated', nor of a succession of 'worlds' (in the plural). For events, we have seen, would occur only once, and be experienced once. The Stoics would have also to work out a drastically altered physics and set of attitudes to life. They would have to reconsider their views on causation, freedom, and responsibility. I see no trace of this in them myself. The Stoic theory that each cycle of history ends with a disastrous conflagration might even preclude their arguing for circular time in the way suggested above. For that particular argument depended on there being a seamless circle of events, none looking like a first or last, and each caused in a normal way by its predecessors.

Nor does Eudemus argue for circular time. He merely collapses into a finite linear time the supposedly endless repetitions of the Pythagoreans, and that in order to refute them, not to express his own view. It is true that the Greeks and their modern commentators do sometimes describe time as circular. But as I have pointed out elsewhere,²¹ that normally means something very much less than what I have been discussing. Sometimes the point is no more than that *events* repeat themselves in linear time. But sometimes the reference is to time viewed as a system of measurement. The heavens provide a kind of clock, and the longest period marked by this clock is the period in which all the heavenly bodies return to their original alignments. If we

²⁰ See W. H. Newton-Smith, *The Structure of Time* (London, 1980), 65–78, 230–42; Lawrence Sklar, above n 11, 316–17; W. V. Quine, 'Comments on Newton-Smith', *Analysis*, XXXIX (1979), 66–7.

²¹ Sorabji, above n 6, 184–5.

view time as a measure, we ought then to think of it as coming to an end at the end of the cycle and starting up again. But the very word 'again' reveals that there is a further concept of time as not coming to an end, but continuing indefinitely in linear fashion. And this is explicitly acknowledged by Proclus in the lines I have italicized, in some of the very passages where he talks of time as circular.²²

The advance of time is not, as it were, a line that is single, straight and infinite in both directions, but finite and circumscribed. . . .

The movement of time progresses in accordance with the measures of the temporal monad, fitting end to beginning, *and that an infinite number of times.*

The whole of time is contained in a single revolution of the whole universe. . . .

The revolution of the whole has as its measures the entire extent and development of time, and no extension is greater—*unless it be by repetition, for in that way time is infinite.*

Despite all of this, however, I now think that there is at least one passage which tries to express the more rigorous idea of circular time, despite its inappropriate use of concepts like beginning, end, revert, and again. The pseudo-Aristotelian *Problemata* describes and rejects an argument according to which we are earlier (as well as later) than the people of Troy, because things are circular. Unfortunately, the argument supports the idea of our being earlier by postulating a beginning, and suggesting that we might be nearer to it than are the people of Troy. The pseudo-Aristotelian author then has no difficulty, in the closing sentence, in dismissing the argument by pointing out that a circle contains no beginning. And he looks for no other way in which the circular hypothesis might be true. What is very interesting, however, is that he compares a remark of Alcmaeon, the philosopher of the fifth century BC, who was at least a friend of Pythagoreans, if not a Pythagorean himself. Alcmaeon says that people die because they are not able to join beginning to end. This remark has been considered hard to understand.²³ And it has been taken to mean either that the soul will eventually be unable to complete its circling motions,²⁴ or

²² Proclus, in *Platonis Timaeum commentarii* 3. 29. 3–5, 3. 30. 30–2, 2. 289. 14, and 20–3.

²³ Charles Kahn, 'Anaximander and the arguments concerning the *Apeiron* at *Physics* 203b4–15', in *Festschrift Ernst Kapp*, ed H. Diller and H. Erbse (Hamburg, 1958), 19–29, see 26; G. S. Kirk, J. E. Raven, and M. Schofield (eds), *The Presocratic Philosophers*, 2nd edn (Cambridge, 1983), 347; Jonathan Barnes, *The Presocratic Philosophers*, 1st edn (London, 1979), vol. I, 115.

²⁴ J. Burnet, *Early Greek Philosophy*, 3rd edn (London, 1930), 195; A. E. Taylor, *A Com-*

that the body will eventually be unable to complete its physiological cycles.²⁵ But interesting as are the parallel passages about soul circles and physiological circles, when they are viewed as mere parallels, it needs to be considered that Alcmaeon may be making a fresh point here, and one of very considerable philosophical interest. Men would be immortal, if they could only join their beginning to their end, that is, if they could only dwindle into the very seeds from which they came. Of course, the seeds would have to be the very same ones, in order that the ensuing life might be the same life—their own. Alcmaeon need not have worked out what would make that possible, but merely assumed that it was impossible. But the pseudo-Aristotelian author connects Alcmaeon's idea with that of circular time. And the discussion of circular time in the present paper has provided a set of hypotheses under which the immortality which Alcmaeon regards as impossible could come about. For people in the forty-year cycle envisaged above could dwindle into the very seeds from which they came, and in doing so, they would secure a kind of immortality. The passage runs as follows.²⁶

How should we take 'earlier' and 'later'? In the sense that the people in the time of Troy are earlier than us, and the people before them are earlier than them, and as you go higher, the people are always earlier? Alternatively, if there is a beginning, middle and end of the universe, and a man too, when he grows old and comes to his limit, reverts again to his beginning, and things nearer the beginning are earlier, what prevents us being closer to the beginning part? If we are, we will also be earlier. Just as in motion there is a circle for the heavens and for every star, what prevents the formation and destruction of perishable things being such that the same things [reading: *t'auta*] are always being formed and destroyed? They also say that human affairs form a circle like that.

Now it is simple-minded to think that those being born are always numerically the same people, but we could more readily accept that they are the same in kind. Thus [sc. on the mistaken view] we ourselves would be earlier, and someone could posit that the order of the series was such as to turn back again to the beginning and to make things continuous and to remain for ever in an identical state. (In fact Alcmaeon says that people die simply because they are not able to join beginning to end—a clever remark, if you take

mentary on Plato's Timaeus (Oxford, 1928), 262–3; cf W. K. C. Guthrie, *A History of Greek Philosophy*, vol. I (Cambridge, 1962), 356.

²⁵ Charles Kahn, above n 23, 26; Charles Mugler, 'Alcméon et les cycles physiologiques de Platon', *Revue des Études Grecques*, LXXI (1958), 42–50.

²⁶ Pseudo-Aristotle, *Problemata* 17. 3. 916a18–39.

him to be speaking impressionistically and do not want to make the saying precise.)

Now if there is a circle, and a circle has neither beginning nor end, people could not be earlier by being closer to a beginning, neither we earlier than they, nor they than us.

Space and time compared

If this passage does express the idea of closed time, there will be an asymmetry in Greek thought, for no one, I believe, expressed the idea of closed space. But this is not surprising. I myself needed the aid of a far from obvious treatment of straight lines in order to make sense of space being closed.

There is a parallel asymmetry in Greek thought concerning reduplicated worlds. Reduplication over time became a commonplace. Reduplication in space was rarely considered. Of the three Presocratic authors, Anaximander, Anaxagoras, and Democritus, who appear to talk of multiple worlds,²⁷ the reports on Anaximander are highly obscure, while Democritus' point is merely that, given the play of chance, one might expect the formation of some worlds indistinguishable from ours, as well as of many quite unlike it. The only one of the three philosophers who might be interpreted with any plausibility as offering a spatial analogue of the temporal reduplication of later theories is Anaxagoras. But whatever Anaxagoras means in his fragment 4, he does not claim an *exact* reduplication. This asymmetry is not altogether surprising, because there is no spatial analogue to the Great Year to encourage speculation on spatial reduplication. The Great Year is the long period within which the heavenly bodies are supposed to return to the alignments they had before. The expectation of such repetition in the heavens encouraged belief in repetition for the whole universe.

In case it seems disappointing that the Greeks did not attain to the idea of closed space, I should say that I think their debate on whether space could be finite in *other* ways was of a high quality. The objection of Archytas, which I mentioned at the beginning, about what would happen at the edge of a finite space, is famous. But there are other

²⁷ Anaximander (for a collection of passages, see e.g. W. K. C. Guthrie, above n 24, vol i, 106–15); Anaxagoras, fr 4 (Diels–Kranz), taken from Simplicius, in *Phys.* 3.4. 28ff with Simplicius' comments 157. 9ff; Democritus, *apud* Cicero, *Academica Priora* 2. 17–55.

heroes practically unsung from later stages of the debate, Cleomedes on the side of infinity and Alexander of Aphrodisias against. Their arguments must wait till another occasion.²⁸

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²⁸ Sorabji, *Matter, Space and Motion* (forthcoming). I have benefited greatly from discussion of closed time with Lindsay Judson, Alexis Belash, Charles Kahn, Michael Stokes, Nicolas Denyer, and with students and colleagues in King's College: Victor Caston, Christopher Peacocke, Alan Lacey, Richard Spencer-Smith, Mark Sainsbury, and above all Christopher Hughes.

* — *Closed space and closed time*: OSAPh IV 1986 215–231. | Greek philosophers, notably the Pythagoreans and certain Stoics, may have conceived of time being closed (i.e., a single series of events repeating themselves endlessly), but no philosopher apparently maintained the idea of closed space, a concept central to many modern theories of space. | 114735