CHAPTER I

The Measure of All Things

> Philalethes: Our measurement of time would be more accurate if we could keep a past day for comparison with days to come, as we keep measures of spaces.
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> G. W. Leibniz, *New Essays on Human Understanding*

Incident at Greenwich

On the evening of 15 February 1894, a man was discovered in the park near the Royal Observatory at Greenwich in a most distressing condition: it appeared that he had been carrying or otherwise handling some explosive which had gone off in his hands. He later died from his injuries. The fact that he had been in Greenwich Park naturally provoked speculation: was he attempting to blow up the Observatory? Around this puzzling and ambiguous incident Joseph Conrad constructed, in *The Secret Agent*, a story of a double agent who had been instructed by a foreign power to blow up 'the first meridian'—i.e. the Greenwich Observatory—and so provoke outrage at what would be perceived as an attack on science or technology itself, the idea being that this would be a much more subtly unsettling attack on society than any assault on a prominent individual or group of innocent people.

By 1894, Greenwich had acquired a peculiar significance: it not only marked 0° longitude, it also stood for the standardization of time. For much of the nineteenth century, different towns in Britain kept their own time, and travellers from one place to another would often have to reset their portable timepieces on alighting. But the development of the railways made it increasingly important to dispose of these local variations, and 1852 saw the introduction of a standard 'Railway Time', as it was called. Finally, in 1880, Parliament passed the Definition of Time Act, which introduced a universal time, this being defined by the time on the Observatory clock at Greenwich. This, as we might imagine, could well have induced in some quarters the same resentment as the idea of a single European currency does in others today, though whether feeling ran sufficiently high as to motivate the blowing up of the Observatory is a matter for debate.

The idea of a standard time implies a standard timepiece, which raises the question of what it is for a timepiece to be entirely accurate. I discover that the grandfather clock is slow by noticing a discrepancy between it and my 1950s wristwatch. But on comparing my wristwatch with your digital watch, bought only last week, I discover that my watch is losing a few minutes every day. And were we to judge your timepiece against the standard of a caesium clock we should no doubt discover some further discrepancy. But this process must have a limit. Eventually, we arrive at a means of measuring time that we take to be as accurate as anything can be, and we take this to be our standard, according to which all other timepieces are to be judged. Now, does it make sense to inquire, of this standard, whether it is truly accurate? This may strike one as a strange question. Surely, one can ask of any means of time-measurement whether it is truly accurate or not, a truly accurate clock being one that judges two adjacent periods (for example, successive swings of a pendulum) to be of the same duration when and only when they are indeed of the same duration. But here we come up against a problem. There is simply no way of telling, for certain, that anything meets this requirement. We can only compare one timepiece with another.

How in fact do we decide that a particular means of measuring time is accurate (at least to an acceptable degree)? Here is one method. We can take a particular timepiece and reproduce it a number of times. We should take care to make the replicas as close to the original as possible in terms of their dimensions and physical composition. We should also ensure that they are placed in the same environmental conditions (one timepiece, for example, should not be in a much hotter place than another, or subjected to greater vibration, pressure, etc.). Then we should synchronize them and set them going. Finally, we should note whether they tend to stay synchronized, or whether they end up out of step with each other. If after, say, a few days they are very significantly out of step with each other, then we know that this particular means of measuring time is not particularly reliable. But if instead they remain perfectly in step with each other, if—to use the technical expression—they remain *congruent*, then we can be confident that we have found a reasonably accurate timepiece. The longer they remain congruent, the more accurate the method.

However, we can still, it seems, entertain the possibility of a timepiece remaining perfectly congruent with its replicas for years on end, and yet not keeping perfect time. For what it is to be completely accurate is not, we suppose, merely to be in agreement with a standard, but to measure time itself correctly. We take it for granted that the intention of the clock is to measure time. But perhaps this familiar notion is, after all, a rather peculiar one when we pause to scrutinize it. What is it for an instrument to measure *time*? The oddity of the idea of measuring time is well captured by a story of

O. K. Bouwsma's, 'The Mystery of Time (or, The Man Who Did Not Know What Time Is)'. The hero of the story is puzzled by clocks. He has been told that they measure time, but although he has seen them at work doing their measuring, he has not yet been able to see what it is that they measure. With other kinds of measuring instruments there is no problem. A tape-measure, for example, can measure a length of cloth, a pair of scales can measure a quantity of flour, a jug a volume of water, and so on. What is being measured in these cases is plain to see. But clocks seem to be able to register something that does not affect our senses at all. Perhaps there is some invisible, ethereal fluid flowing through these instruments, making the hands go around the dial? Or perhaps there is nothing at all, and the mechanism operates without any external prompting. Our hero begins to suspect it is all a con trick. In effect, the story is an inverted version of the Emperor with no clothes—there is in fact no trick: the clocks genuinely are measuring something that cannot be seen.

Initially, we smile at the man's innocence. He is simply mistaken in thinking that whatever is being measured must be capable of being seen. He takes the materialist outlook too far. But the problem goes rather deeper. The clock registers the passage of time in virtue of being a temporal process. We, too, register time's passing as we age. The cycle of the seasons is another change which cannot but indicate the rushing onward of that ever-rolling stream. Clocks are simply a peculiarly regular kind of change, and, like us, they register change by themselves changing. But now we begin to see what is so odd about the idea of clocks measuring time: unlike the kitchen scales, they are not entirely independent of what they are measuring. For when people talk of time, are they not simply talking, in an abstract way, of change? Consider how we experience time. I glance out of the window and see the branches of the horse chestnut gently swaying in the breeze; a bird alights on one of the branches for a moment and then flies off; I catch the droning of a passing motor car in the lane; and in the distance the striking of the church bell tells me that it is three o'clock. And if I shut my eyes and block my ears, I still register my fleeting thoughts. All these things press on me the passage of time. I experience time, in other words, through the experience of change. So perhaps time is neither more nor less than change. Moving objects, changing feelings, chiming clocks: all these *are* time. Or so we may naturally think. Hence the oddity of the idea that clocks measure time: they are what they measure. But then we return, and this time with greater puzzlement, to the question of what it is to measure time correctly—or *in*correctly. If a timepiece is measuring its own change, among other things, how can it get it wrong, so to speak?

At this point, we need to impose a little discipline on our rather rambling train of thought. Three questions need to be addressed: What is it for a timepiece to be accurate? Is time the same thing as change? What, if any, is the connection between these two questions? The remainder of this chapter will be concerned with the first of these questions. We will leave the others until Chapter 2.

Metric, Convention, and Fact

At one point in the preceding discussion we noted that, although we could perform a test that would show some kinds of timepiece to be more accurate than others, it was impossible to tell whether an instrument was 100 per cent accurate since all one had to judge accuracy by was other instruments, whose accuracy could always be called into question. We could not survey time itself, independently of all the changes that took place in time, to see if an instrument was measuring it correctly or not. Indeed, it was not entirely clear that we could make sense of time existing independently of these changes.

There are two responses to this limitation of ours. The first response is to deny that it is any kind of limitation at all. Once we have selected our standard—whether it be a caesium clock or a sundial—it makes no sense to ask *of the standard* whether it is accurate or not. It is accurate by fiat. The very act of selecting the standard confers upon it total accuracy. All instruments are judged by the standard: an instrument is accurate if and only if it agrees with the standard. It follows from this that the standard cannot fail to be accurate (or perhaps that it makes dubious sense to apply the concept of accuracy to the standard). Since the choice of standard is a matter of convention, though not completely arbitrary convention, this viewpoint is known as *conventionalism concerning the metric of time.* It is important to distinguish this rather controversial position from the obvious and unexciting observation that our choice of a particular unit with which to measure time is a conventional matter. The fact that we divide up days into hours, minutes, and seconds, for example, is not something divinely ordained, but simply a matter of convenience. (It is interesting to note that in this age of decimalization, where pounds and ounces have given way to grammes, yards to metres, and—in Britain—shillings to five pence pieces, we still have twenty-four hours in a day. There have, however, been attempts to impose a decimal system on time—in France after the Revolution, for example—and some decimal clocks still exist, although confined to museums.) What, according to conventionalism, is a matter of convention is not merely the choice of unit, but whether two given successive intervals of time are of the same duration or not. Take your last three heartbeats. Was the interval between the second and third the same as that between the first and second? According to one method of timing those intervals, they were the same; according to another, they were not. But were they *really* the same? The conventionalist has no use for such a question. It is like asking whether this toadstool is *really* poisonous: it will be so for some creatures, but not for others. (Of course, whether a toadstool is poisonous for a given creature is not merely a matter of convention!)

So much for the first response to our inability to compare a timepiece directly with time itself to check its accuracy. What of the second response? This is *objectivism concerning temporal metric,* and for it the question about heartbeats does have a point. Whether or not we can discover if two successive intervals were equivalent, there is, for the objectivist, a fact of the matter as to whether they were equivalent, independently of any conventional choice of a measuring system. (By 'measuring system' is meant here a means of comparing the intervals, not a unit of time.) As objectivism is sometimes expressed, time has an *intrinsic metric* or measure. Again, this does not mean that time is *really* divided up into hours and we have happily stumbled upon the right unit of measure, but rather that, independently of any way of determining it, *this* pair of successive intervals is a pair of equivalent intervals, and *that* pair is not. One of the consequences of objectivism is that there are some facts in the world that remain 'secret'. That is, we can never know for sure whether or not they really exist. And this is not just an accidental limitation, something we could perhaps overcome if we put our minds to it, but something that could not possibly be otherwise. For some people, this is an unacceptable consequence. There is a theory that at one stage commanded a wide following in philosophy, and in one form or other still has its adherents, and that we may characterize as follows: if a given statement about the world is such that we have no possible way of discovering whether or not it is true, however ideally we are situated, then that statement is neither true nor false. This position is one version of *verificationism*. Some verificationists wanted to go further and say something rather stronger: that the statement in question is actually *meaningless* in those circumstances. For the time being, however, we can confine ourselves to the more modest position. To express that position slightly differently: there are no facts about the world which we could not, at least in principle, discover to be the case. No fact is essentially impossible to discover. To the extent that objectivism is committed to such undiscoverable facts, objectivism would be rejected by anyone subscribing to a verificationist view of truth.

Conventionalism offers some comfort to Bouwsma's hero. It tells him that he need no longer search for the elusive thing that clocks measure, for in reality they are measuring nothing. That is, there is no objective feature of the world that is being monitored by the clocks. They are simply mechanisms by which we may order our lives, which enable us to synchronize our meetings, and which may remain or fail to be congruent with each other. That is the end of the matter. I suspect, however, that our intuitions point us in the direction of objectivism. In which case, should we not be worried by the inaccessible facts which objectivism says are out there? Is there no room for the suspicion that, since we have no use for such facts as the putative fact that these two intervals are really equivalent (though we can never prove it) we may as well do away with them?

Those are not meant to be rhetorical questions, whose answer is obvious; they simply raise a worry over what otherwise seems to be the natural assumption that the metric of time—how long things take—is a matter of fact rather than convention. How might we address this worry?

Time and the Laws of Nature

Making a number of exact reproductions of a timepiece and seeing if they remain in step is one way of testing the accuracy of a particular means of time measurement. This method, as we have seen, is ultimately inconclusive. There is, however, another, and that is to see whether or not the deliverances of our timepiece are consistent with the laws of motion. Consider the following:

> A body continues in a state of rest or uniform motion unless acted upon by a force.
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> The acceleration of a body is a function of its mass and the force acting upon it, such that Force = Mass × Acceleration.

These are, respectively, Newton's First and Second Laws of Motion. Both of them make implicit reference to the notion of equal intervals of time. For a body is moving with constant velocity if it covers the same distance in each of a series of equivalent intervals (e.g. a foot every second), and accelerating (or decelerating) if it covers a greater (or smaller) distance in each successive and equivalent interval. We can then set up an experiment in which the rate of motion of a body is measured by the timepiece whose accuracy we wish to test.

Suppose, then, we attach, to a body of known mass, a spring. By means of this spring we can drag the object along the ground at varying speeds. The force exerted on the object can be measured by the extent to which the spring is extended. Having calibrated the spring appropriately, and marked out a series of equivalent distances along which the object is to be propelled, we select the timepiece to be tested. We then conduct a series of tests, exerting a variety of forces on the object, causing it to move at various speeds, and at various rates of acceleration, measuring motion all the while by means of the selected timepiece. We end up with a long series of pairs of values for force and acceleration. If the results are consistent with the previously accepted Laws of Motion, then our timepiece may be considered at least approximately accurate. If the results are not consistent, then we may regard it as inaccurate.

Of course, the Laws will in the first place have been established through the use of timepieces, so our faith in them is not independent of means of measuring time. Nevertheless, the point is that there is a connection between the way in which we measure time, and the laws we discover to govern motion. Some timepieces will point the way to relatively simple laws relating motion and force, some to much more complex ones, and others to no systematic relationship at all. We naturally assume that the world is an ordered place, and that there will be systematic relationships between the forces acting on a body and the subsequent motion of that body. And we will naturally prefer simpler relationships to more complex ones. So we have a way of choosing between competing timepieces. (Of course, the crude set-up described above will not be adequate for distinguishing between timepieces which differ from each other only slightly, but then other tests could be devised.)

This connection between our measurement of time intervals on the one hand and the laws of motion on the other was pointed out by the great mathematician Leonhard Euler (1707–83) who held a chair first of physics and then of mathematics at St Petersburg's Academy of Sciences. Euler is regarded as the founder of a branch of mathematics known as *topology.* His suggestion, in his *Reflections on Space and Time,* was that a given cyclical process can appropriately be described as *periodic* (i.e. each cycle in the process takes exactly the same time as every other) if, having defined a unit of time in terms of that process, we find that Newton's First Law of Motion is confirmed.

This may offer the objectivist over temporal metric some ammunition against the conventionalist. First, the fact that we can test the accuracy of different timepieces against what we take to be the laws governing motion suggests that, after all, facts concerning temporal metric may not be inaccessible. So conventionalists are not necessarily on firm ground when they say that objectivists are obliged to suppose that there are facts we can never discern. Secondly, taking the laws of motion to be truly descriptive of the world actually entails objectivism over metric. If it is an objective fact that an object of such-and-such a mass will be accelerated by exactly this much when such- and-such a force is applied to it, then it is an objective fact that some successive intervals are longer or shorter than, or the same as, others.

These are certainly significant considerations, but they are not decisive. To take the first point, our experiment only succeeds in testing the accuracy of a timepiece if we can be sure that our measurements of force and distance are accurate. But we are not entitled simply to assume this. How did we measure equivalent distances? Perhaps by means of a ruler. This certainly makes the measurement of space easier than the measurement of time, since we cannot transport a temporal 'ruler' (such as the interval between two strikes of a bell) from one time to another. But it is no more secure. Did the ruler remain exactly the same size as we moved it from one place to another? We cannot be entirely sure. Given this uncertainty, what we are testing in the experiment is not simply the accuracy of a timepiece, but the accuracy of our whole measurement system. And even if we get the result we wanted, we cannot be sure that the individual measurements are accurate, because it may be that some deficiency in our time measurements are compensated for by deficiencies in our distance or force measurements. However, this possibility becomes more remote the more tests we perform.

The second point against the conventionalist—that taking the laws of motion as objectively true entails objectivism over metric—is more significant, but the conventionalist can simply reply that the laws of motion themselves are simply conventions. They are undoubtedly extremely useful, in that they correctly predict the observed outcome of our experiments with motion, but their usefulness does not entail their truth. When playing chess against a computer, we find it useful to ascribe states of mind to the computer: it *intends* to take that bishop, it is *willing* to sacrifice that knight, it *knows* I wish to attack its queen, etc., etc. Is the computer really in any of these states of mind? Has it a mind at all? Most people would be inclined to answer 'no' to this question, but still find it useful to treat the computer *as if* it had a mind in predicting its moves, this being a much easier method than trying to work out what it will do from a study of electrical impulses through its circuitry. This, the conventionalist may insist, is how things are with the laws of motion. It is convenient to take them as describing things out there in the world around us—equal intervals, equal distances, equal forces—but they are not actually doing so. How plausible is this? The notion of quantity is a very basic, indeed indispensable one, without which we cannot adequately describe our world, act in it, or predict what will happen. It is very hard indeed to believe that a quantitative conception of things does not pick out aspects of reality itself, aspects that would be there whether or not anybody was describing them.

Conventionalism about temporal metric is a view specifically about time, of course; it does not say anything explicitly about other quantities. But what we have seen is that it is not possible to think of conventionalism as applying only to time: it has further, and far-reaching, consequences. We have to treat the laws of motion—*any* laws of motion, not just Newton's—as not truly descriptive of the world, not because they are merely approximations, but because they simply fail to pick out genuine features of the world. Conventionalism, then, is a very bold position indeed.

Someone will complain that so far we have simply been skirting around the question that so puzzled Bouwsma's hero: what *is* it that clocks measure? It is time to tackle this question head on.

Questions

Why might people have found the idea of a 'universal time' so objectionable? Does this tell one anything about how they conceived time?

What would you say to Bouwsma's man who did not know what time was?

If there is no objective truth of the matter as to whether one event is longer than a subsequent event, how is it that some processes are better at measuring time than others?