Time, Timekeeping and History

Paper for Kingston Philosophy Café (presented at meeting on 22 February 2023)

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1. Overview.

- According to the Oxford English Dictionary, the most frequently used noun in written English is *time*. Whilst frequency of use is no guarantee of a word's clarity/consistency of meaning, some concept of time together with that of spatial location is indispensible in our daily lives – particularly in connection with the planning/co-ordinating of activities and the recording/dating of events. Specifying *when* and *where* (in terms of an agreed system for their identification) is crucial to purposive human interaction.

- Whilst not without its complications, our conventional system for measuring time – based upon the Earth's spin and its orbit around the Sun – appears generally to 'work' and to pose little in the way of conceptual challenge. One complication is the fact that the Earth's speed of travel *varies* during its solar orbit, causing the length of 'true' solar days also to vary (very slightly) over a year and resulting in the adoption, for civil time-keeping purposes, of a *mean time* system which averages out the variations and treats all days as being of exactly the same length. Another complication – met in the mean time system by the very occasional addition of a 'leap second' to the last minute of pre-selected days – is a gradual but detectable slowing down in the speed of the Earth's rotation and solar orbit.

- Objects have no *absolute* spatial position, only position *relative to one another*. *Motion* comprises *change of position* and is thus equally relative. Over a given period of time, the position of an object will be unchanging relative to some objects whilst *simultaneously* changing (in different directions and at different speeds) relative to others.[1] Whether and, if so, how far/fast an object moves can thus be determined only in relation to *another* object chosen, for the purpose, as a fixed point of reference.

[1] Sitting in a train, for example, we remain stationary relative to the train but at the same time share in its motion relative to the Earth's surface, that of the Earth relative to the Sun, that of the Sun relative to other bodies in the Milky Way Galaxy and that of the Milky Way Galaxy relative to other galaxies.

- Determining *simultaneity* of occurrence and *speed* of movement requires a measurement of *time* which in turn requires a *clock* i.e. something displaying changes of state deemed *regular* and *unvarying* in their periodicity (e.g. the oscillating energy states of Caesium-133 atoms upon which are based the leap second adjustments to mean solar time). Not only is change basic to how we *measure* time, it also appears constitutive of how we *conceive* it. As physicist Ernst Mach states: "time is an abstraction at which we arrive through the changes of things".

- Change is intrinsic to the concept not only of *time* but also to that of an *event*. If literally *nothing* about the world has changed, in what meaningful sense can an event be said to have occurred? Also key to the concept of an event is *direction* of occurrence – crucial if any meaning is to be attached to causation, memory and history. Only by conceiving time as 'arrow-like' can sense be made of past, present and future. Whilst the so-called 'laws' of physics generally view micro-physical processes as time-*reversible*, an exception is the second law of thermodynamics according to which differences in energy levels within an enclosed system *level out over time* until a state of uniform disorder or *entropy* is reached. As stated by physicist Stephen Hawking: "The increase of disorder or entropy is what distinguishes the past from the future, giving a direction to time."

- Relativity theory holds that different observers, depending upon their *inertial frame of reference* as determined by their motion relative to what they observe, may disagree about how far events are distanced in *space* and, separately, in *time* and even about their *order of occurrence* but will all agree the combined *spacetime* distances involved. The concept of spacetime is central to relativity theory but appears to unite two distinct and fundamentally different 'things'. Its application (including its representation in the form of 'Minkowski' diagrams) requires *time* dimensions to be multiplied by *speed* (that of light), thereby converting them into *spatial* dimensions. To avoid the paradox that the observed order of events may contravene causal necessity (e.g. that a space satellite may appear to explode *before* the missile which destroys it is launched), it is further required to measure the spacetime distance between events using a 'negative' version of Pythagoras' formula (i.e. defining the square on the hypotenuse of a right-angled triangle as equal to the *difference* between, rather than the *sum* of, the squares on the other two sides). The convoluted nature of what is required suggests a need to revisit and revise, perhaps fundamentally, the theories upon which the spacetime model is based.[2]

- A temptation not always resisted is to view spacetime in Newtonian terms i.e. as some sort of *absolute* framework in relation to the four axes of which everything has a determinate position. It is commonly pictured in the form of an *array* of *events* within which *objects* (including human objects) trace *worldlines* along which are strung the particular events they happen to encounter en route. Physicist Brian Cox, for example, suggests that "spacetime can be pictured as a four-dimensional blob over which we move, encountering the events on our worldline as we go" and speculates that events and the objects associated with them might exist *permanently* in spacetime (e.g. that an idyllic afternoon spent playing as a child in his family garden "is still there, all those people, all those moments, always and forever, somewhere in spacetime"). He relates this speculation to the concept of a *Block Universe* in which "all events that can happen and have happened in the history of the Universe are, in some sense, 'out there'". Obvious questions without obvious answers include:
  - What determines how events are spread out within the array?
  - What determines the particular route taken by any particular object? Is it entirely random?
  - If an event involves *something changing*, what existence has it independent of that something?
  - How can events as we know them (i.e. as *happenings* which are both time-*extended* and time-*limited*) exist 'always and forever' at points in spacetime conceived geometrically (i.e. as having position but no dimension)?

[2] This is suggested, in any case, by the apparent conflict between general relativity theory and quantum theory.

- The model of reality outlined in the last paragraph, it has to be said, smacks more of metaphysics than physics – in particular its portrayal of ourselves as spirit-like objects adrift in a cloud of events (starting, presumably, with our 'birth event' and ending with our 'death event'). The nature of our 'encounters' with such events (some of which feature *ourselves*) is entirely obscure. Crucially, in some of the events in which we feature, our role appears to be not that of passive observers but *active agents* whose conscious choices affect the nature and content of the events concerned. In this paper, the coherence of the model is examined and called into question. A major source of confusion, it is argued, arises from a failure to establish from the outset what exactly *is* an 'event' or an 'object'.

- The Block Universe model views all things and all events associated with them as existing both *eternally* and *in parallel*, thus ruling out any causative connection between them and any scope for human agency. The *Growing Block* model, by contrast, envisages a universe with an ever-advancing 'frontier of existence', thus providing the scope for agents active at that frontier (constituting the *present*) to shape *new* events (which then continue to exist in what, relative to the frontier comprises the *past*). *Presentism* rejects both models and denies that anything exists, in an *ontological* sense, other than in the present. This accords with much of our commonsense view of reality (e.g. that, as we eat *today*'s breakfast, the event of our eating *tomorrow*'s breakfast has yet to happen whilst that of eating *yesterday*'s breakfast has happened and now exists only as a memory). The present moment is, of course, a moving target, today being both yesterday's tomorrow and tomorrow's yesterday. Problematic is how far we can narrow down the present moment before it vanishes into a durationless *nothing*. The notions of a 'thick now' and of a 'salami-slice' universe are examined in this paper.

- Although some physicists claim that time-travel is *theoretically* possible, none can suggest how it might be achieved *in practice*. Time-travel thus remains largely the stuff of science-*fiction* which does, at least, provide a vehicle for exploring its conceptual coherence. Particularly problematic is the scope that time-travel would appear to give us to *alter* past or future events e.g. to go back in time and do something which renders impossible our own birth event or forward in time and, by observing an event we don't like, return to the present and do something which ensures that it doesn't happen. The film *Back to the Future* and Charles Dickens' story A *Christmas Carol* illustrate the conundrums involved. The notion of a *multiverse* (comprising an *infinity* of parallel universes) introduces additional complications. Influencing events in the one we occupy can make no difference to what happens in any other.

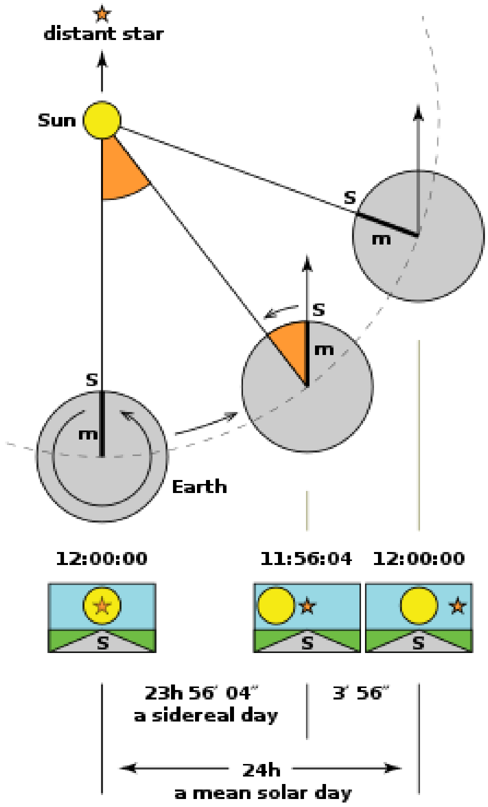
- Our attitudes towards time are affected by the nature of the *changes* we associate with its passage. On the one hand, are processes involving growth and development; on the other, are those involving decay and loss. Time has thus been described as both 'a great healer' and as 'the destroyer of all things'. Some see it as an arbitrary and implacable force, others as the provider of opportunity to realise human and perhaps 'divine' purposes. It is stated in the Bible (Ecclesiastes 3), for example, that there is "a time to every purpose under the heaven". Naive determinists (amongst whom must be included the proponents of a Block Universe) deny any scope for human agency. All we do, supposedly, is 'encounter' events which exist 'always and forever' and which, confusingly, must include the 'encountering' events *themselves*. In practice, we do *not* regard the events of history as existing in this way. To do so would be to deny the *directionality* of change and the meaningfulness of *causation*, *memory* and *history*. History, essentially, is the playing out of human societal purposes and its events are inexplicable other than in terms of human intentionality. It is subject, of course, to continual re-interpretation. As historian E. H. Carr argues: " "Modern man is to an unprecedented degree self-conscious and therefore conscious of history. He peers eagerly back into the twilight out of which he has come, in the hope that its faint beam will illuminate the obscurity into which he is going; and, conversely, his aspirations and anxieties about the path that lies ahead quicken his insights into what lies behind. Past, present and future are linked together in an endless chain of history".

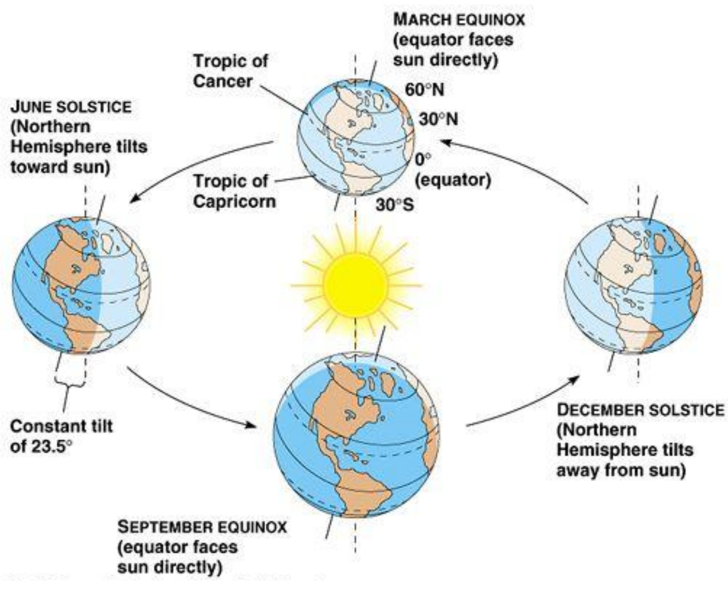
2. Keeping time by the Sun: practicalities and complications

- The rotation of the Earth can be measured in relation to the *stars* (giving *sidereal* time) or the *Sun* (giving *solar* time). The stars, due to their immense distance (the nearest is about 25 trillion miles away)[3], can be regarded for time-keeping purposes as fixed in position relative to the Earth and thus as ideal points against which to measure its rotation. The distance between the Sun and the Earth, by contrast, averages a 'mere' 93 million miles. As the Earth orbits the Sun, moreover, their relative position changes continuously (evidenced by the apparent movement of the Sun against the backdrop of stars, the path it follows each year being known as the *ecliptic*).

- In one orbit of the Sun, the Earth completes 366¼ (approx.) rotations relative to the *stars* but only 365¼ (approx.) relative to the *Sun*. The difference arises from the fact that when the Earth has completed a single rotation relative to the stars, it has progressed in its solar orbit and thus has to turn a bit more before completing a full rotation vis-à-vis the Sun (see diagram on right). A sidereal day is thus about 4 minutes shorter than the average length (24 hours) of a solar day.

- A complication with measuring time by the Sun is that the orbit of the Earth is *elliptical*, not circular. As a result, the speed of its travel around the Sun *varies* (being faster the closer they are) and thus the time it takes to rotate fully relative to the Sun *also* varies. Solar days *average*, but are generally a bit *more* (by up to 30 seconds) or a bit *less* (by up to 20 seconds) than 24 hours. To include such variations in a standard time-keeping system would be confusing and so the one we conventionally use (and which is displayed on our clocks/watches) treats all days as *exactly* 24 hours long (i.e. their *average* length over a year) and is thus called a *mean time* system.





- The fact that, despite its complications, our conventional time-keeping system is solar rather than sidereal, reflects the vital importance to human life of the Sun. Our body rhythms are conditioned by the alternation of light and dark and much of our activity is affected by when the Sun rises and sets, how high it rises in the sky (reaching its maximum elevation midway between sunrise and sunset) and how this changes with the seasons, themselves the result of the 23.5^0 tilt of the rotational axis of the Earth relative to the plane of its orbit around the Sun (see diagram on left).

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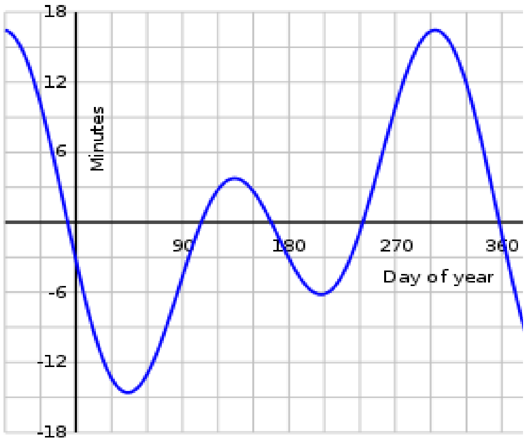
[3] Proxima Centauri, at present the nearest star to our Sun, is about 4.25 light-years away. Despite its name, a light-year is a unit of *length* defined as the distance (about 5.88 trillion miles) which light travels in a vacuum in one Julian year (365.25 days). Proxima Centauri is thus about 25 trillion miles distant from the Sun. Note: a trillion is a *million million* (i.e. 10^{12}).

- From the viewpoint of Earth-bound observers, the daily west→east rotation of the Earth translates into a daily east→west transit of the Sun (and of all other celestial bodies) across the sky. The *meridian* for an observer's location is an imagined line in the sky running north↔south between the Earth's axial poles and passing directly overhead. The Sun reaches this line *midway* between its rising and setting, achieving at this point its maximum elevation (and thus casting the *shortest* shadow on a sundial). A location's *true* midday occurs when the Sun crosses this meridian. So-called *apparent solar time* (aka 'sundial time') relates to this 'true Sun' i.e. to the Sun's *actual* appearance in the sky, including its *actual* crossing of the meridian – which it does at *non-uniform* intervals due to the combined effect of the varying speed and axial tilt of the Earth in its solar orbit.

- In contrast to apparent solar time based upon the *true* Sun, *mean* solar time (aka 'clock time') is based upon a fictitious 'Mean Sun' which crosses the meridian at *uniform* 24 hourly intervals, thus ignoring real (albeit minimal) differences in the *actual* length of days. Over a year, the two measures of solar time *diverge*, one running sometimes *ahead of* and sometimes *behind* the other. The varying extent of this divergence is shown by the so-called *equation of time* (see below)[4] which shows, for each point in the year, the result obtained by subtracting its mean time from its apparent time. If at a given point, for example, sundials indicate the apparent time to be 12.00 noon (the Sun being on the meridian) when clocks indicate the mean time to be 12.10, the equation's value at that point will be *minus* 10 minutes. It can be seen that at only four points in the year do the two measures of solar time *exactly* coincide. In the early part of the year, the mean time at any point exceeds (i.e. indicates a *later* time than) the apparent time, the disparity being greatest about mid-February. Towards the end of the year, the converse applies, the disparity being greatest in early November.



- The table below[5] shows, for selected days in 2021, the *mean/clock* times of London's sunrises and sunsets and of the mid-points between them representing *true* solar midday. It can be seen that the *mean/clock* time of *true* midday on 15 February was 14 minutes *later*, and on 1 November 16 minutes *earlier*, than 12 noon. Also shown are 15 April, one of the four days when apparent and mean solar time *coincide*, and 21 June and 21 December, the days with the *longest* and *shortest* lengths of daylight (representing the northern hemisphere's summer and winter solstices).

Date in 2021:	London *mean/clock* times of: Sunrise	Sunset	*True* solar midday	Length of daylight (h/m/s)	Distance of Earth from Sun (million miles)	
15 Feb	7.14	17.15	12.14	10.01.52	91.859	
15 Apr	*5.04	*18.57	*12.00	13.52.54	93.267	
21 Jun	*3.43	*20.21	*12.02	16.38.21	94.466	(summer solstice)
1 Nov	6.54	16.33	11.44	9.38.53	92.259	
21 Dec	8.03	15.53	11.58	7.49.44	91.443	(winter solstice)

* For ease of comparing dates, the times marked with an asterisk are *not* adjusted for British Summer Time. In practice, clocks in 2021 were put *forward* at 1am on Sunday 28 March, and *back* again at 2am on Sunday 31 October, by *one hour*.

[4] The graph shows the divergence applying at the *Greenwich meridian* – the baseline for the UK's mean time system. For each degree of longitude *east/west,* true midday occurs 4 minutes *earlier/later* than at Greenwich. On 15 February 2021, for example, the *mean/clock time* of Cardiff's *true* midday (i.e. when the Sun was on *Cardiff's* meridian) was 12.26 compared with London's 12.14. Cardiff lies about 3^0 to the west of London, which explains the 12 minutes difference in the timing of their true middays.

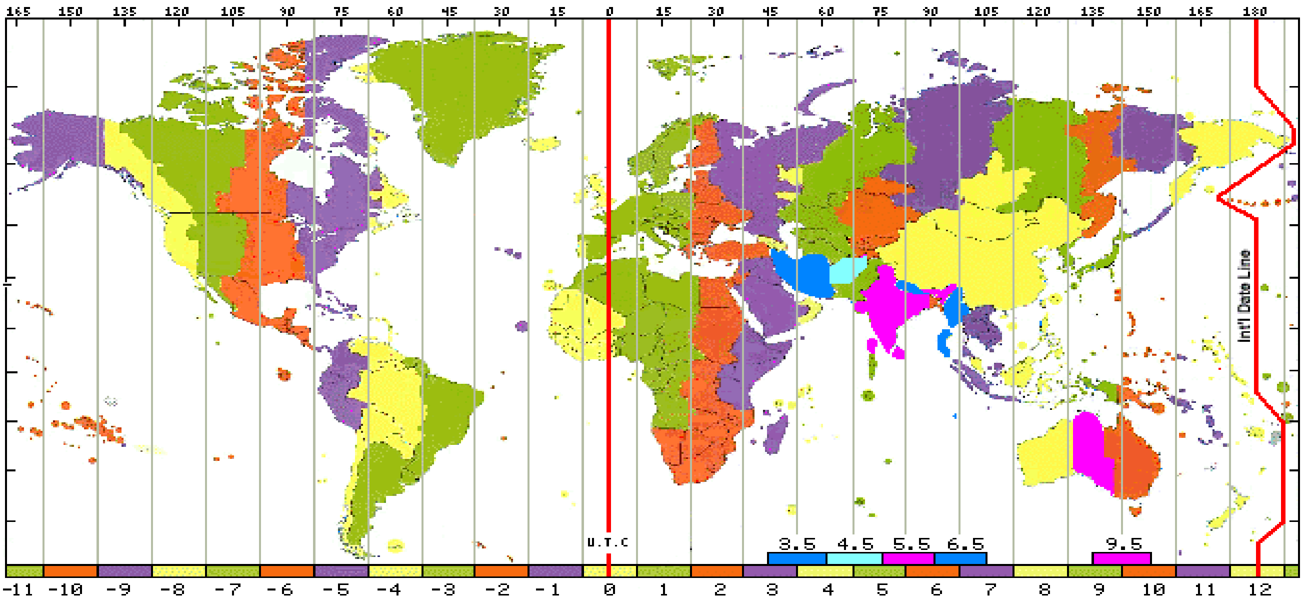
[5] Source of data: https://www.timeanddate.com/sun/uk/london

- For most of human history, communities have kept their own *local* time based upon the position of the Sun in the sky *as viewed from their own location*, midday being the point at which it appears on their location's meridian. Locations with different longitudes have different meridians and thus different apparent (i.e. *true*) middays.[6] Differences between the times kept in different places (including towns and cities within the same country) became an increasing problem as the extent and speed of travel between them increased, particularly with the advent of railways in the 19th century and the need for common timetabling. Another factor was the development of telegraphy/telephony enabling near instant messaging over long distances. In 1884 an International Meridian Conference was held to discuss the choice of *"a meridian to be employed as a common zero of longitude and standard of time reckoning throughout the world"*, many countries by this date having already adopted their own standard meridians for timekeeping purposes. The Conference proposed *inter alia* that: a) Great Britain's *Greenwich Meridian* (established in 1721 and based on star sightings made at the Greenwich Observatory[7]) be recognised internationally as representing zero degrees longitude, the position of all places to be measured in degrees longitude (0^0 to 180^0) east or west of it; b) all countries observe a *Universal Time* (UT) system based upon a 'universal day', this being a *mean solar day* commencing at midnight Greenwich mean time and counted on a 24 hour clock; c) *time zones* covering whole or sub-divisions of countries be adopted, all places within each zone observing the same clock time.

Meridian line at Greenwich Observatory

World time zones

West Degrees longitude East



Hours behind or ahead of Greenwich Mean Time / Coordinated Universal Time (UTC)

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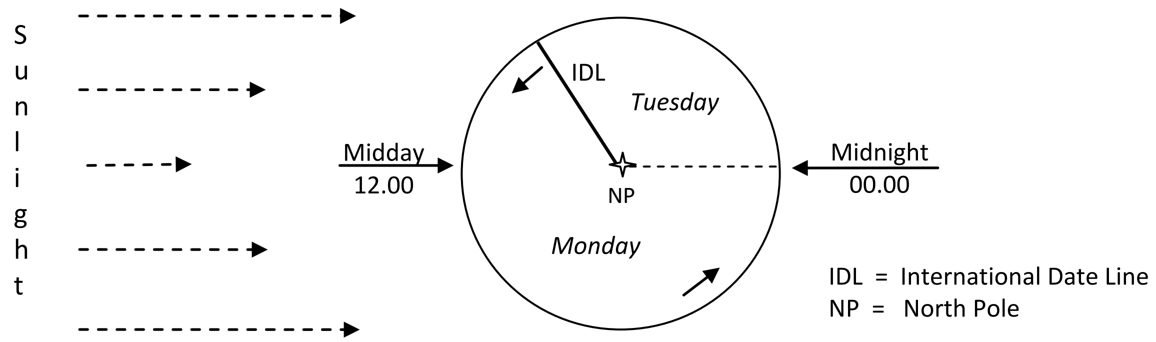
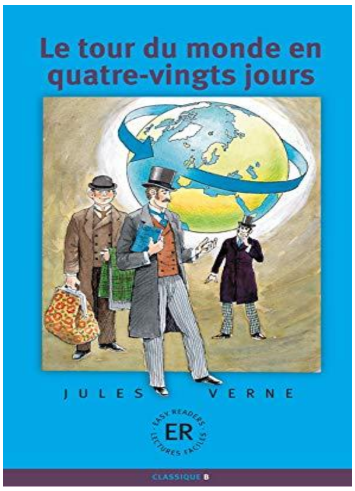
[6] The timing of the middays of locations differs by 4 minutes (i.e. 24 hours ÷ 360^0) for each degree of longitude by which they are separated. A separation of 15^0 longitude thus makes a difference of one hour.

[7] The exact position of the line has been shifted marginally a few times due to more accurate star measurements. The one currently marked on the ground at Greenwich Observatory was calculated in 1851 by Astronomer Royal, Sir George Airy. However, new calculations in 1984 identified the correct position to be about 100 metres to the east – its only current marker being a fortuitously sited litter bin!

- The world time zone map shows the mean time at longitude 0^0 (the Greenwich Meridian) to be 11 hours *ahead* of that at longitude 165^0 *west* and 12 hours *behind* that at longitude 180^0 *east*. By convention, days are deemed to start and finish at *midnight*. This leaves open the question as to which longitudinal line on the Earth's surface should be deemed the *first* to commence a new calendar day (e.g. to go from a Monday to a Tuesday) by passing, as the earth rotates, the midnight point shown on the diagram below. The International Date Line (IDL) – which corresponds roughly to longitude 180^0 east or west but zigzags to avoid land masses – has been adopted as this line and, in effect, divides one calendar day from another. As locations on the Earth pass the midnight point, they enter what is for them a new day (e.g. a Tuesday) whilst those following behind and yet to pass it are still completing the previous day (in this example, a Monday). A consequence is that a traveller who crosses the IDL going *eastwards* instantly *reverts* to the previous day (e.g. from a Tuesday to a Monday) whilst one who crosses it going *westwards* instantly *progresses* to the next day (e.g. from a Monday to a Tuesday). In no sense, of course, does this represent any form of time travel. It arises simply from our system for the naming and numbering of days/dates.



- The difference which travel can make to our experience of time is graphically illustrated by French writer Jules Verne (1828-1905) in his novel *Around the World in 80 Days* (1872). The time effect which is central to its storyline does *not* involve the International Date Line – which had yet to be adopted when the novel was written – but the consequence of *circumnavigating* the world. The story's hero, Phileas Fogg,[8] bets £20,000 against friends at London's Reform Club that he can travel around the world in 80 days or less, returning to the Club no later than 8.45pm on Saturday 21st December. He keeps a daily journal to record his progress and keep count of the days as they elapse. After various adventures and some mishaps he manages to get back to England on what, by his reckoning, is the 80th day. Circumstances, unfortunately, conspire to delay his arrival in London and he misses the deadline by 5 minutes. Without entering the Club, he resigns himself to having lost the bet and goes home. Later the next day, his servant Passepartout is sent out on an errand and discovers that the previous day was *Friday 20th*, not *Saturday 21st*, December. Fogg hastens to the Club and arrives just in time to win the £20,000 – although he calculates that the cost of his journey has consumed all but £1,000 of it! It transpires that, despite his meticulous nature, Fogg had failed to register a crucial consequence of circling the world in an *easterly* direction. As is explained: *"Phileas Fogg had, without suspecting it, gained one day on his journey, and this merely because he had travelled constantly eastward; he would, on the contrary, have lost a day had he gone in the opposite direction, that is, westward. In journeying eastward he had gone towards the sun, and the days therefore diminished for him as many times four minutes as he crossed degrees in this direction. There are three hundred and sixty degrees on the circumference of the earth;*



[8] The character is loosely based on real-life American writer/traveller/adventurer, William Perry Fogg (1826-1909).

and these three hundred and sixty degrees, multiplied by four minutes, gives precisely twenty-four hours – that is, the day unconsciously gained. In other words, while Phileas Fogg, going eastward, saw the sun pass the meridian eighty times, his friends in London saw it pass the meridian only seventy-nine times."

- It should be emphasised that the time phenomenon described in Verne's novel is *real*, not an illusion created by a system devised for the naming and numbering of days. It arises regardless of the existence or otherwise of any internationally recognised date line or where such a line might be drawn. By the end of his journey, Fogg really *had* experienced one more sunrise and sunset (and thus one more day) than had his friends back in London. Travelling *eastwards* (i.e. in the direction of the Earth's rotation) we see our next sunrise *sooner* than had we remained where we were and thus experience a *shorter* day. Conversely, travelling *westwards* (i.e. *against* the direction of the Earth's rotation) we see it *later* and thus experience a *longer* day. Travelling right around the world, we experience one day *more* going *eastwards* and one day *fewer* going *westwards* than do those who remain back at home – the *average* length of our days over the period being *shorter* or *longer*, respectively, than theirs. This is the case regardless of how long it takes to complete the journey. Fogg would have experienced one more day than his friends back in London regardless of whether his journey around the world took more or less than 80 days. The first circumnavigation of the world took *three years* to complete. In September 1519, five Spanish ships under the command of Ferdinand Magellan set sail across the Atlantic Ocean in search of a western route to the spice islands of South-East Asia – the already established eastern route being monopolised by the Portuguese. Although suffering losses on the way, the expedition managed to sail around South America, cross the Pacific Ocean and reach the South-East Asian archipelago. Magellan, however, was killed there in a skirmish with natives and only one ship eventually went on to achieve the circumnavigation – crossing the Indian Ocean, sailing around Africa and returning home to Spain in September 1522. Throughout the expedition, a careful log was kept of the passing of the days. The crew of the ship were thus surprised to discover that the date as estimated by themselves was one day *behind* that recorded in Spain i.e. that over their three years away and as a direct result of going around the world in a *westerly* direction, they had experienced one day *fewer* than had their compatriots back at home.

NB - Magellan left Seville on 10 August 1519 and sailed down-river to the coast but did not *put to sea* until 20 September.

- From the foregoing, it can be seen that the time-keeping system used worldwide for civil purposes is based upon observed regularities in the behaviour of *macro-physical* phenomena – i.e. the Earth's rotation and its orbit of the Sun. Also relevant is the Moon's 28-day orbit of the Earth – the basis for the lunar Hijri (Arabic) calendar and the assumed origin of our grouping of days into *months* (although in different calendars these have varied in number and length) and *weeks* (7 days being a quarter of a lunar month). By contrast, our division of a day into 24 hours, an hour into 60 minutes and a minute into 60 seconds dos *not* relate to any observed phenomena and has its origin, seemingly, in the preference of the ancient Egyptians and Babylonians for counting in multiples of, respectively, twelve and sixty. Defining the length of an hour, a minute and a second as fractions (1/24, 1/1,440 and 1/86,440 respectively) of the length of a day, makes *sidereal* hours, minutes and seconds *shorter* than their *solar* equivalents (a sidereal day being shorter than a solar day – see page 4). A problem for both sidereal and solar timekeeping is that the phenomena to which they relate are subject to both short and long term *variation*.

- The need for a measure of time unrelated to variable astrophysical phenomena led in 1968 to the redefinition of the *second* in the International System of Units (SI)[9] as: *the time duration of 9,192,631,770 periods of the radiation corresponding to the transition between the two hyperfine levels of the fundamental unperturbed ground-state of the caesium-133 atom*. The number of periods was deliberately chosen to make the length of the 'new' second, when it was introduced, the same as that of its predecessor, the so-called 'ephemeris second' based on the duration of the Earth's solar orbit (the definition of a second up to 1952 having been based on the mean duration of a solar day). *International Atomic Time* (TAI) counts the passing of SI seconds and is maintained as a weighted average (to allow for variable gravitational effects) of 400 atomic clocks (mostly caesium) distributed worldwide. Whilst atomic time provides the basis for the extremely precise time measurements required for scientific work and for the synchronisation of telecommunications, it remains the case that our daily lives are conditioned by the alternation of day and night and by the passing of the seasons. Our *civil* time-keeping system, therefore, would seem inevitably tied to the period of the Earth's rotation and solar orbit, regardless of how much this might change in the future. A version of UT (see page 6) known as *Coordinated Universal Time* (UTC) is calculated upon the basis of TAI and thus 'ticks' *atomic* (i.e. *SI*) seconds. Maintaining its equivalence to mean solar time, however, has required the very occasional addition of a *leap second* to the last minute of pre-selected days (such minutes containing *61* rather than 60 seconds). The need has arisen due to marginal *slowing* of the Earth's rotation, making mean solar seconds fractionally *longer* than SI seconds.[10] In effect, when a leap second is added, UTC 'marks time' for that extra second, being thereby 'brought back' into alignment with mean solar time. If the Earth were to rotate *faster*, making the length of days *shorter*, it would be necessary to *subtract*, rather than add, leap seconds (allowing UTC to 'catch up' with mean solar time). UTC provides the basis for the broadcast time signals (including those of the BBC) of participating nations.

- Short-term variation in the speed of the Earth's rotation is only slight and can be adjusted for, in the calculation of UTC, by the occasional addition (or subtraction) of leap seconds. The long-term prospect (over millions of years), however, is a substantial slowing in the speed of rotation and correspondingly big increase in the length of mean solar days. Solar hours, minutes and seconds comprise *fixed fractions* of such days and thus the *number* of them in a day (i.e. 24, 1,440 and 86,440 respectively) will remain the same whilst their *length* will increase significantly. By contrast, the length of *SI seconds*, being fixed by the seemingly unvarying behaviour of sub-atomic phenomena, will remain unchanged whilst the number of them in a mean solar day will increase substantially. Thus if, for example, mean

[9] There are seven 'base' SI units, three of which comprise the *second* (measuring *time*), the *metre* (measuring *length*) and the *kilogram* (measuring *mass*). Hours and minutes do *not* comprise units of time in the SI system.

[10] The difference is tiny but can accumulate to the point where it exceeds a second. To keep any difference between UTC and mean solar time to less than a second, a total of 27 leap seconds have had to be added to UTC since 1970.

solar days eventually double in duration, their length as measured in *SI seconds* will *also* double. There is, of course, nothing 'god-given' about our division of solar days into solar hours, minutes and seconds. Completely different sub-divisions could be chosen or, alternatively, the existing ones could be retained but the fractions of a day which they represent altered. The 'Republican Calendar' adopted in post-revolution France in 1793 (but abandoned by 1805) divided a day into 10 decimal hours, a decimal hour into 100 decimal minutes and a decimal minute into 100 decimal seconds (making their duration respectively 2.4, 1.44 and 0.86 times that of their standard equivalents). The year was split into 12 months, each comprising three 10-day weeks (the tenth day of each week being assigned for rest/festivity). Five or six 'complementary days' were added at the end of each 12-month period in order to approximate the calendar's year to a solar year. In this respect it resembled the calendar of the Ancient Egyptians (although their year started at the *summer solstice*, the Republican Calendar's at the *autumn equinox*).

Face of a 'French Revolution' clock displaying decimal hours and minutes (inner circle) together with their standard equivalents (outer circle).

3. The concept of time. Reversibility, non-reversibility and entropy.

- Whether or not a phenomenon (e.g. the Earth's rotation) used to measure time behaves in a regular and unvarying way, can be judged only by comparing it with some *other* phenomenon which *is* so judged. The wider the range of phenomena appearing to 'march in step' with one another, the more are we encouraged to view them as activated in common by some hidden source of regularity – even if we have no idea what it might be. In practice, all we can do is observe and compare different micro-physical and macro-physical phenomena and test the predictive powers of the models we construct to simulate how they behave. A key problem is 'factoring out' extraneous influences including the effect of postulated forces such as gravity (which appear to impact at sub-atomic as well as supra-atomic level) and to allow for seemingly *random* behaviour (crucial in quantum mechanics). The holy grail (chimera?) is a model which, even if it doesn't amount to an *explanation*, at least accurately *describes/predicts* the behaviour of *anything* existing *anywhere* and at *any time*. The possibility of *multiple* universes raises particular problems. If more than one exists, none comprises 'all that there is'. A universe could be defined instead as a *set of phenomena* existing in *total isolation from* any other such set (if one were to *interact* with another, they would, on the basis of this definition, comprise *sub-sets* of the *same* universe). In a multiple-universe reality, any 'complete theory of everything' would be limited in its application to the content of the universe containing the theorising beings who formulated it.

- Just how far we are from achieving a complete theory of everything (including *ourselves*) existing in the past, present or future of the only universe of which we are aware, is evidenced by the fundamental *disjunction* regarding the *nature and role of time* in our modelling of micro-physical and macro-physical phenomena. As described by systems theorist Howard Pattee: "the microscopic equations of physics are time-symmetric and therefore conceptually reversible. Consequently the irreversible concept of causation is not formally supportable by microphysical laws, and if used at all it is a purely subjective linguistic interpretation of the laws."[11] At the macro-physical level, by contrast, *order/direction of occurrence* ('time's arrow') seems intrinsic to the world and without it we can make no sense of the phenomena we encounter on a daily basis. A clear example of this is provided by the geological

[11] Pattee, H.H. (2001) *Causation, control and the evolution of complexity*. In P. B. Anderson, P. V. Christiansen, C. Emmeche & M. O. Finnerman (Eds.) *Downward causation: Minds, bodies and matter*, Aarhus University Press

processes which have led to our present-day land forms. If we want to 'see' millions (even *tens* of millions) of years at a glance we could do little better than to observe an expanse of exposed rock strata such as that at Stair Hole in Dorset (see picture below). All that we see, of course, exists *now*. The present-day composition and structure of the rock material, however, is *inexplicable* other than as the result of millions of years of *'one-direction-in-time'* physical events. The harder limestones fronting the

the sea-cliffs were formed in warm coastal lagoons and swamps towards the end of the Jurassic period around 145 million years ago. They were subsequently overlain by softer limestones and other types of sedimentary rock and the entire series was uplifted and folded about 20-25 million years ago as part of a related set of land movements which included the raising of the Alps and which has thus become known as the *Alpine orogeny*. The rock strata were exposed relatively recently (geologically speaking) as a result of the breaching by the sea of the protective wall of harder limestones and the ensuing hollowing out of the softer strata behind and above them. The same processes were responsible for the creation of the adjoining and almost circular Lulworth Cove.

- As indicated above, the crucial difference in how we treat time in our modelling of micro-physical and macro-physical phenomena concerns the *reversibility* or *non-reversibility* of the processes involved. At either level, *some* concept of time appears unavoidable and it has proved impossible so far to 'do the physics' without bringing time into the equation. In the SI system (see footnote 9), the *second* (s) measuring *time*, the *metre* (m) measuring *length* and the *kilogram* (kg) measuring *mass* are three of the seven 'base units' which, variously combined, produce a range of 'derived units' including *speed/velocity* (m/s), *acceleration* (m/s^2), the *newton* ($kg{\cdot}m/s^2$) measuring *force/weight* and the *joule* ($kg{\cdot}m^2/s^2$) measuring *energy/work/heat*. Time is thus a key component of many of the factors which feature in the so-called 'laws' of physics. One such law is the *second law of thermodynamics*[12] which asserts that differences in energy levels within an enclosed system will *level out over time* until a state of uniform disorder or *entropy* is reached. The Earth, of course, is *not* an enclosed system (any more than are humans or other life forms). Transfers of energy from the Sun can stabilise or even reduce the Earth's level of entropy – albeit at the cost of an increase in the Sun's. The entire universe, on the other hand, *can* be conceived as an enclosed system and, assuming it is finite in size, must contain a finite amount of energy. As argued by Isaac Asimov (a professor of biochemistry and a science writer, although best known for his science-fiction): "If the entropy of the universe (which is the measure of its unavailable energy content) is continually increasing, then eventually the unavailable energy will reach a point where it is equal to the total energy. Since the unavailable energy cannot rise beyond that point, the entropy of the universe will have reached a maximum. In this condition of maximum entropy, no available energy remains, no processes involving energy transfer are possible, no work can be done. The universe has 'run down'." Asimov wryly concludes the first of his three-volume guide to physics[13] as follows: "We began with the Greek philosophers making the first systematic attempt to establish the generalisations underlying the order of the universe. They were sure that such an order, basically simple and comprehensible, existed. As a result of the continuing line of thought to which they gave rise, such generalisations were indeed discovered. And of these, the most powerful of all the generalisations yet discovered – the first two laws of thermodynamics – succeed in demonstrating that the order of the universe is, first and foremost, a perpetually increasing disorder." Of particular significance in the present context, is the fact that entropy is one of the few quantities in the physical sciences that requires time to be *arrow-like* i.e. to be *directional*. As Stephen Hawking states: "The

[12] A short (about 4 minute) video explaining the second law of thermodynamics can be viewed via the following link: https://www.youtube.com/watch?v=mGDJO2M7RBg

[13] Isaac Asimov (1966) *Understanding Physics: Volume 1 - Motion, Sound and Heat*

increase of disorder or entropy is what distinguishes the past from the future, giving a direction to time."[14]

4. Abandoning time as a stand-alone factor. The concept of spacetime.

- The complications surrounding the concept of time have encouraged some to suggest its abandonment as a factor within our models of microphysical and macro-physical reality. Mathematician Marcus du Sautoy, for example, writes that "no physicist has satisfactorily pinned down what we mean by time" and suggests that "perhaps the best strategy is to eliminate it altogether".[15] To do so, however, would appear a tall order (to put it mildly) given that time is a crucial factor in so many of the formulas we use to define and quantify fundamental aspects of the world as we experience it – aspects such as speed, acceleration, force and energy (see previous page). Time, moreover, is not alone in displaying conceptual ambiguity. A significant problem arises from *circularity* of definition. *Force*, for example, can be defined as *whatever it is* which causes a body possessing *mass* to accelerate whilst *mass* can be defined as *whatever it is* which causes a body to resist the effect of a *force* (acceleration being directly proportional to force and inversely proportional to mass). Any ambiguity concerning the concept of force inevitably extends to that of energy (which relates to the application of force over distance) and entropy (which relates to the distribution of energy within a system). The elusiveness of the concept of energy was recognised by American physicist Richard Feynman (1918-88) when he said: "It is important to realize that, in physics today, we have no knowledge of what energy *is*".

- If the concept of energy is elusive, then so also is that of mass. Apparent violations of the first law of thermodynamics – which stipulates that the amount of energy within a closed system is *conserved* – can be explained only by accepting that *mass is a form of energy* and that the two are *interchangeable*, their relationship being summed up in Einstein's famous equation $e=mc^2$ (also expressible as $m=e/c^2$) and evidenced spectacularly in the explosion of a nuclear bomb. Time is key to the definition and measurement of both *e* (energy) and *c* (the speed of light) – two of the equation's three components – but is itself conceptually ambiguous. In relativity theory it is treated as a fourth dimension to be added to the three dimensions of space, the four together comprising 'spacetime'[16]. Points within this conceived four-dimensional configuration possess, as in Euclidean geometry, *position* but not *extension* i.e. they are themselves *dimensionless*. The three dimensions of space which we conventionally distinguish are all measured in units of length and differ only in *direction*.[17] Time, although commonly conceived in linear terms (as is reflected in our language when we speak not just of the *duration* but the *length* of time) is measured not with a ruler but a clock (see Annexe A for examples) i.e. anything used to measure processes (e.g. flows of sand in an hour glass, swings of a pendulum, alternations in the energy state of an atom) which are assumed to behave in a regular and unvarying way. Whether measuring spatial length or temporal duration, we are confronted with the same problem – that of *precision*. The marks on a ruler have dimension. The 'ticks' of a clock have duration. The more precise

[14] Stephen Hawking (1988) *A Brief History of Time: From the Big Bang to Black Holes*, Bantam Dell Publishing Group
[15] Marcus du Sautoy (2016) *What We Cannot Know*, Penguin Books.
[16] In his *ABC of Relativity* (1925), Bertrand Russell (1872-1970) describes spacetime as "from a philosophical and imaginative point of view, perhaps the most important of all the novelties that Einstein introduced" and goes on to argue that "relativity demands the abandonment of the old conception of 'matter', which is infected by the metaphysics associated with 'substance', and represents a point of view not really necessary in dealing with phenomena". He suggests that "all the facts and laws of physics can be interpreted without assuming that 'matter' is anything more than groups of events." He does not explain how 'events' (conceived as instant 'happenings', such as a flashes of light, assignable to *dimensionless* points in four-dimensional spacetime) could form into 'groups', what determines which events join which groups or what might link them together.
[17] The fact, as expounded by Descartes, that the position of anything in space can be uniquely specified in relation to three axes set at angles to each other, does not mean there is any unique orientation for those axes i.e. there is no particular direction in space constituting 'up' or 'down'.

our measurement, the closer we get to a point which lacks dimension and thus appears to vanish into nothingness. This is most obvious when we talk about the 'present *moment*', the 'present *instant*' or 'the *now*'. Do we mean the present *second*, *millisecond*, *microsecond* or what? The smaller the time interval, the closer we get to a point of *zero* duration – meaningful, perhaps, in terms of mathematical abstraction but at odds with our commonsense notion of time. Our mental time-lines by which we both *differentiate* and *connect* past, present and future (and trace the course of our own lives from birth to death) become nothing more than strings of abstract infinitesimal points lacking all *content* and thus any basis for their *interconnection* or *order of occurrence*.

- The fact that mathematical abstractions may be counter-intuitive, of course, does not make them invalid or without application. As long as they are based upon empirical observation, they can be indispensible in their predictive power and instrumental value. Indeed, as long as they 'work' when applied practically, it does not matter, strictly speaking, whether or not they fully accord with some underlying but unknown reality. As Russell (1925) states: "The physicist, who knows nothing of matter except certain laws of its movements, nevertheless knows enough to be able to manipulate it. After working through whole strings of equations, in which the symbols stand for things whose intrinsic nature can never be known to us, the physicist arrives at last at a result which can be interpreted in terms of our own perceptions, and utilised to bring about desired effects in our own lives. What we know about matter, abstract and schematic as it is, is enough, in principle, to tell us the rules according to which it produces perceptions and feelings in ourselves; and it is upon these rules that *practica*l uses of physics depends." The *relative* nature (Annexe B provides an example) of both *position* and *motion* (motion comprising *change* of relative position) is not itself counter-intuitive, being consistent with our everyday experience i.e. that things (including ourselves) are stationary relative to some things whilst *simultaneously* moving relative to others. René Descartes (1596-1650) recognises this when he states that "in relation to different bodies we may say that the same thing is both changing and not changing its place at the same time" and gives the example of a sailor who is stationary with respect to his ship but in motion relative to the shore. He further argues that there are no "genuinely fixed points to be found in the universe" and that "nothing has a permanent place, except as determined by our thought."[18] However, the inclusion of *time* in the equation – unavoidable, it would seem, if we are to determine *speed* and *simultaneity* of changes in relative position – raises complications, particularly with regard to what constitutes the *same* time for bodies in relative motion. It appears easier to escape the mental straightjacket of a conceived absolute *spatial* framework determining the *position* of things than that of a conceived absolute *temporal* framework determining their *timing*.[19]

- It is undoubtedly the case that the concept of *spacetime*, which is fundamental to relativity theory, may lead us to conclusions which *are* counter-intuitive, in particular the conclusion that not just the *timing*, but the *order* of events can vary for different observers depending upon their relative position and motion. Particularly challenging is the idea that, if two clocks are moving relative to one another, time as measured by one will run 'faster' or 'slower' than time as measured by the other. Reference to 'observers' has been the cause of much confusion as it appears to imply that relativity is a *subjective*

[18] René Descartes (1644) *Principles of Philosophy* (Part 2; Paragraph 13)

[19] In his *Philosophiæ Naturalis Principia Mathematica (Mathematical Principles of Natural Philosophy)* (1687), Isaac Newton (1642-1727) attributes *absolute* and *independent* existence to both time and space, arguing that "absolute, true and mathematical time, of itself, and from its own nature flows equally without relation to anything" and that "absolute space, in its own nature, without relation to anything external, remains always similar and immovable." In his *Critique of Pure Reason* (1781), Immanuel Kant (1724-1804) includes time and space (conceived in Newtonian terms) as *'a priori'* forms of perception which are somehow 'hard-wired' into us and thus inescapable. Gottfried Leibnitz (1646-1715) takes a contrary view, arguing that "space…is something merely relative, as time is"; that space is "an order of coexistences as time is an order of successions" and that regarding time as "a substance, or at least an absolute being" is "a fancy." But *of what* is time an order of successions? To define it as *an ordered succession of ordered states of coexistence* would appear circular. What can *coexistence* mean other than existing *at the same time*? And what then are the criteria for *simultaneity* of existence?

matter. Russell emphasises that an 'observer', in the context of relativity theory, refers to *anything* which records an event from a given 'point of view'. He states: "The philosophical consequences of relativity theory are neither so great nor so startling as is sometimes thought... Some people think that it supports Kant's view that space and time are 'subjective' and are 'forms of intuition'. I think such people have been misled by the way in which writers on relativity speak of 'the observer'. It is natural to suppose that the observer is a human being, or at least a mind; but it is just as likely to be a photographic plate or a clock. That is to say, the odd results as to the difference between one 'point of view' and another are concerned with 'point of view' in a sense applicable to physical instruments just as much as to people with perceptions. The 'subjectivity' concerned in the theory of relativity is a *physical* subjectivity, which would exist equally if there were no such things as minds or sense in the world."

- Russell stresses that the theory of relativity does *not* hold that everything in the physical world is relative to an observer. He states: "Perhaps the name is unfortunate; certainly it has led philosophers and uneducated people into confusions. They imagine that the theory proves everything in the physical world to be relative, whereas, on the contrary, it is wholly concerned to exclude what is relative and arrive at a statement of physical laws that shall in no way depend upon the circumstances of the observer. It is true that these circumstances have been found to have more effect upon what appears to the observer than they were formerly thought to have, but at the same time the theory of relativity shows how to discount this effect completely. This is the source of almost everything that is surprising in the theory." The theory of relativity is concerned, essentially, with the way in which different phenomena in the universe 'present themselves' to one another, particularly where they are in relative motion and where the means of intercommunication approach or reach the speed of light – a key condition being that the speed of light (along with other forms of electromagnetic radiation) should, *as measured by observers* and regardless of the speed/direction of their *own* relative motion, be *constant*.

- Speed, conceived as *rate of change of relative position*, appears meaningful only as a feature of spatially related *things*. However dismissive Russell (see footnote 19) and others might be of the concept of 'substance', *some* notion of macro and micro physical entities (down to 'fundamental' particles such as electrons and to 'packets'/quanta of energy) seems inescapable – even if we accept that our conceptualisation of them represents, to use Locke's words, "an uncertain supposition of we know not what".[20] We don't observe motion as something distinct from *things* moving relative to *other things*. Equally, we don't observe speed as something distinct from the *rate* at which such movement occurs. Identifying rate of change in relative position appears to demand *some* concept of time. But *what* concept? Time seems very different in character from the things we conceptualise as possessing three-dimensional extension and relative position. Time, indeed, does not bear the hallmarks of an existent 'thing' at all. Leibnitz is surely correct in saying that to regard time as "a substance, or at least an absolute being" is "a fancy" (see footnote 19). Instead, it could be argued, time has to be viewed as an *aspect* of things, the nature of which is suggested by the way in which we in practice *measure* time – i.e. by observing *physical change* (e.g. in the position of the Sun in the sky, the position of the hands of a clock or the energy levels of an atom). Such change may be viewed as not just measuring but *constitutive* of time as we conceive it. As stated by physicist Ernst Mach[21] "time is an abstraction at which we arrive through the changes of things". This view of time is reinforced if we imagine a *total void* (i.e. the complete *absence* of things) or a universe comprising substantial but entirely *unchanging* things (i.e. where literally *nothing* about them alters – relative position, composition, energy levels or whatever) and then consider what, in either case, could possibly constitute the passing of time.

[20] John Locke (1689) *An Essay concerning Human Understanding.* [Book 1; Chapter 4; Section 18]
[21] Quoted by Marcus du Sautoy (2016)

- Whilst the ways in which things change include *spatial* changes (including changes in size and relative position), time is not viewed conventionally as spatial in nature. In the geometrical/mathematical formulation of spacetime, however, it is treated as a fourth dimension which can be analysed *on the same terms as* the three dimensions of space. But how is this possible if time differs from space in both its nature and units of measurement? Two physicists recognise and answer the problem as follows: "If distance in space is measured in metres and distance in time in seconds, how can we even begin to contemplate combining the two? It is like adding apples and oranges, because they are not the same type of quantity. We can, however, convert distances into times and vice versa... [they] can be interchanged using something that has the currency of a speed... We can then measure time in metres provided we take any time interval and multiply it by our calibrating speed... this trick of interchanging time and distance is very common in astronomy, where the distance to stars and galaxies is often measured in light years, which is the distance light travels in one year... In the astronomy case, the calibrating speed is the speed of light."[22]

- The treatment of time *as if* it were spatial in character (even if it isn't) is fundamental to relativity theory and the calculations associated with it. In spacetime *diagrams*, time is generally assigned to the vertical (y) axis, the three dimensions of space being displayed, for graphical purposes, as just one or two and assigned to the horizontal (x) axis/axes (see 'Minkowski' diagrams below).[23] It is important to emphasise that neither of the two diagrams represents any form of *absolute* spatial/temporal framework. They illustrate a given 'observational frame of reference' or 'point of view'. Different observers, depending upon their relative position/motion, may have different frames of reference (which may be differently 'angled') and disagree about the spatial or temporal distances between events (and even about their order of occurrence). They should all be in agreement, however, about the *combined* (i.e. *spacetime*) distances involved.

'Minkowski' Spacetime Diagrams

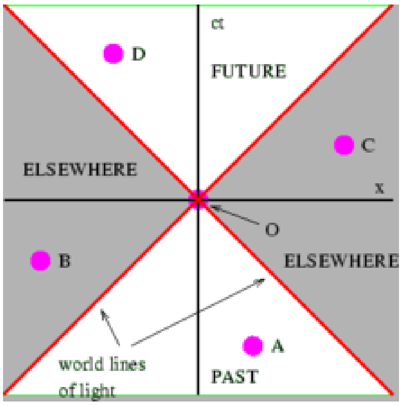


Diagram 1

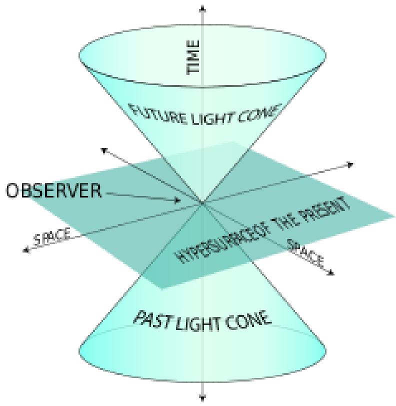


Diagram 2

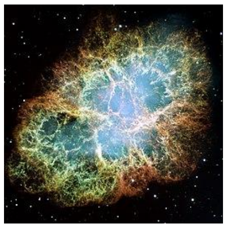
- In both diagrams, the 'calibrating speed' relating time to space is the speed of light and both vertical and horizontal axes are measured in the same units. The 45^o diagonals thus represent the trajectory of anything moving at the speed of light to/from a given spacetime *point of observation* – the zero point of the vertical and horizontal axes. The past, *from the observer's perspective*, is represented by the area below the horizontal axis and the future by the area above it. If nothing is communicable faster than

[22] Brian Cox & Jeff Forshaw (2009) *Why does E=mc^2?* Da Capo Press

[23] Polish-born mathematician Hermann Minkowski (1964-1909) proposed the concept of spacetime (in which time is treated as if it were a spatial dimension) as the most instructive way to represent the relationship between time and space implied by the special theory of relativity introduced in 1905 by Albert Einstein (who was a pupil of Minkowski at the Swiss Federal Institute of Technology in Zurich). When delivering his address on *Space and Time* at a scientific conference in 1908, Minkowski stated: "The views of space and time which I wish to lay before you have sprung from the soil of experimental physics, and therein lies their strength. They are radical. Henceforth space by itself, and time by itself, are doomed to fade away into mere shadows, and only a kind of union of the two will preserve an independent reality."

the speed light, then past events which could be evidenced in some way *at the point of observation* are limited to those arising in/on the lower un-shaded triangle of diagram 1 (e.g. at point A) or the lower light cone of diagram 2. Evidence of events arising elsewhere (e.g. at point B in diagram 1) could not reach the observer's spacetime location without exceeding the speed of light. An event arising at the observation point itself (e.g. a signal triggered by the observer) could be detected in the future only at spacetime locations in/on the upper un-shaded triangle of diagram 1 (e.g. at point D) or the upper light cone of diagram 2. Only if faster than light communication were possible, could it be detected elsewhere in spacetime (e.g. at point C in diagram 1).[24]

- The fact that an event may occur so far from us in spacetime that no sign of it could, without exceeding the speed of light, reach us at our *present* point of observation, does not mean that it could not reach a point we occupy in the *future*. In 1054, Chinese astronomers recorded the sudden appearance of a star so bright that it could be seen in daylight. It remained visible for several weeks before fading from sight. What they appear to have observed was the supernova explosion which produced the Crab Nebula (visible only with a powerful telescope and not identified until 1731) located about 6,500 light years from Earth in the constellation Taurus. Thus they saw, at the beginning of the 2nd millennium AD, an event which happened halfway through the 6th millennium BC. A prime candidate for a future supernova event (although it may not be as imminent as some have suggested) is the red supergiant *Betelgeuse* in the constellation Orion. The star is about 550 light years from Earth and will thus still appear in our night sky as shown on the left for over half a millennium after it has exploded and ceased to exist. At a more 'local' level, we may note, the photons of light emitted by the Sun take about 8 minutes to reach planet Earth so we never see the Sun as it is *now*, only as it *was* about 8 minutes ago.



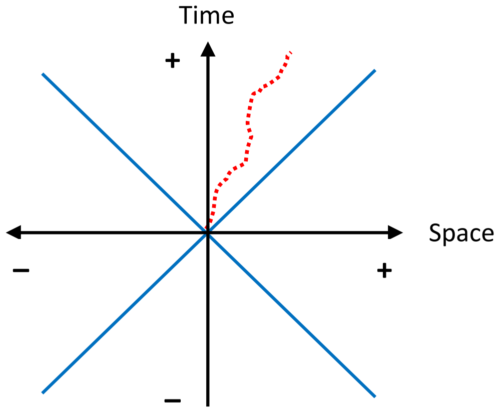
- The meaning, in the context of relativity theory, of an 'event' is ambiguous. It tends to be conceived as something *instantaneous*, the standard example being a 'flash of light'. What is imagined here, however, would appear to be the nature of the *experience of observing* such a flash rather than that of the *physical processes* involved in its occurrence. Such processes include the emission (brief but not without duration) of photons of light from a relevant source, their transmission (sometimes *very* prolonged, as illustrated above) across spacetime and their detection by anything (whether animate such as a human being or inanimate such as a camera) both capable of observing them and positioned in spacetime where such observation is possible. From the premisses that:
  a) an *event* involves some *change* (observed or not) relating to an *object*;
  b) each photon constitutes a distinct object;
  c) events relating to a photon include not just its emission at one point in spacetime and detection at another but also each *infinitesimally small* change of position undergone as it traverses a succession of *dimensionless* points in spacetime;

  it follows that a flash of light, whilst *observed* as a single event, entails a virtual *infinity* of events. The use of the word 'event' in the context of relativity theory is unfortunate as the type of occurrence it appears to denote differs radically from that of the *time-extended* happenings involving complex inter-weavings of processes (sometimes *mental* at least as much as physical) which we commonly call events – including earthquakes, floods, births, marriages, deaths, battles, wars, cricket matches, firework displays, village fetes, music concerts, conferences, parties and 'gatherings' of all kinds.

[24] The triangles/cones should be conceived as extending infinitely 'downwards' into the 'past' and upwards' into the 'future'.

5. Objects and their worldlines.

- Ambiguity attaches as much to the concept of an 'object' as to that of an 'event'. Objects might best be defined as *individuated* and thus *countable*, entities which, as long as they preserve continuity of *identity*, may be deemed to remain the *same* things – even though they may undergo changes in their composition/configuration and are c*ontinuously changing their spacetime position*. In physics, the path traced by an object in spacetime is called its *worldline*. An example is shown in the diagram below as a dotted red line. Each dot, it must be stressed, does *not* mark an individual event. If points in spacetime are *dimensionless*, there can be no gaps between them and the paths of objects must be conceived as a *continuums*. Apart from photons (zero-mass 'quantised' electro-magnetic force carriers), objects to which worldlines may be ascribed include mass-bearing particles and the hierarchy of entities formed by their combining together, such entities thus representing 'convergences' of the world lines of the particles concerned. An atom, for example, might be viewed as the convergence of the worldlines of its constituent sub-atomic particles.



- If the convergences described above are to comprise anything more than just momentary and random 'comings-together' of the worldlines of particulate matter, some binding agent would appear necessary to give them a degree of endurance. The four fundamental forces recognised in particle physics (in descending order of strength: strong, electromagnetic, weak and gravitational) are deemed variously, at different levels of aggregation, to perform this function. The most difficult bonds to break are evidenced at the micro-physical level (e.g. those binding *quarks* into *protons* and *neutrons*, protons and neutrons into *atomic nuclei* and atomic nuclei and *electrons* into *atoms*). The scope for atoms to form *molecules* depends upon their capacity to share elections (this being determined by the structure of their outer electron 'shells'). The strength of bonding between molecules depends upon their atomic make-up and, in particular, upon their behaviour at different levels of energy 'excitation' – determining whether, at a different temperatures, they appear in solid, liquid or gaseous form (in the case of H_2O molecules, for example, whether they appear as ice, water or steam). The weaker the bonds between the component parts of objects, the less enduring will they be and the more easily split into smaller objects which are then free to pursue their own independent worldlines.

- The size of objects to which worldlines may be legitimately ascribed is ambiguous. The larger the object, the greater the scope for it to shed existing and acquire new material as it 'journeys' through spacetime. Complex issues of *identity* arise in the case of such an object. How can it be deemed to remain the *same* object if its component material is subject to partial and even *complete* change? Each one of us, to bring the issue close to home, constitutes just such an object. On our spacetime journey from conception/birth to death/disintegration, our bodies are constantly adding new and discarding old material and thus, at different ages, comprise partially or, if the time gap is big enough, *completely* different sets of cells, molecules, atoms and sub-atomic particles. Such continuity of identity as we possess is essentially a *system*, not material, identity and is realised through the 'instructions' which control the physical form we take and how we function as sentient/cognitive beings. Any worldline tracing the spacetime path of the *ever-changing* body in which such a system is realised, thus represents an *association* of the worldlines of its particulate sub-components, such association being only *temporary* as they join/leave the body, before and after pursuing their own separate worldlines. The 'before and after' worldlines of the material composing our bodies depends in large measure upon where we source our food and dispose of our body waste during life and what is done with our bodies after death (e.g. if cremated, where our ashes are scattered). In theory if not practice, the worldlines of particulate matter may be traced indefinitely back into the past – potentially to the 'singularity' hypothesised to exist at the time of the so-called 'Big Bang' (if 'time', in this context, has any meaning) and forward into an unknown future (perhaps to another 'singularity', whatever that might be).

- Without considering the complexities outlined above or what constitutes *personal identity* for *continuously changing* human 'objects', physicist Brain Cox[25] ascribes to himself a worldline very much like that shown on the previous page. In his version of the diagram, the zero point of the time/space axes represents the spacetime location of his 'birth event' (3 March 1968 – Oldham Royal Infirmary), relative to which the spacetime locations of all of his subsequent 'life events' are measured. Such events include an idyllic afternoon in August 1972 spent paddling in a pool in his parents' garden about 4 kilometres from his birthplace and a 21st birthday celebration on 3 March 1989 on a tour bus (as a member of a rock band) in Florence, Italy, about 2,000 kilometres away. The characterisation of these and similar examples as unitary events which may be pinpointed in spacetime, must be questioned. Conceptual issues include the following.
    a) The events cited by Cox do not comprise 'instants'[26] but *complex* and *time-extended combinations* of physical/mental processes.
    b) Such combinations are *observer-specific* and will vary from one observer to another.
    c) The sentient/cognitive *experiences* of observers constitute events as much as any physical occurrences to which they might be related.
    d) Many events are *meaningless* except in terms of individual or collective human intentionality. They may have *no* physical manifestation (e.g. an uncelebrated birthday) or involve physical activity which is *inexplicable* other than in terms of the intentional states of human participants and the socially constructed rules/norms governing their behaviour (e.g. football matches).

- At most, Cox's worldline traces the spacetime path followed by the constantly-changing assemblage of cells, molecules, atoms and sub-atomic particles comprising his body (from the form it took at birth through to its present-day composition/configuration) along with the sentient/cognitive system (also subject to change) realised within it. A product of such a system is a sense of *self* – this self being differentiated from other selves and its associated body from other bodies. As argued above, the events Cox associates with himself (whether as active participant or passive observer) are *not* unitary in nature. His idyllic afternoon in August 1972, for example, comprises a mishmash of happenings – splashes of water, buzzes of bees, scents of grass, etc. Their combination into a single 'August 1972 afternoon event' (vaguely bounded in time) is entirely of his own mental construction. He goes on to speculate that this event – which is *unique to himself* and will differ in countless ways from the equivalent afternoon as experienced and remembered by other people (including anyone with him in the garden at the time and thus sharing, very nearly, the same spacetime location) – might have a *permanent existence* in spacetime. He relates this speculation to the concept of a *Block Universe* – the idea that, as he puts it, "spacetime can be pictured as a four-dimensional blob over which we move, encountering the events on our worldline as we go". He explains: "If we take Einstein's theory at face value, there is no sense in which the past has happened and the future is yet to happen... [It raises] the question of whether all events that can happen and have happened in the history of the Universe are, in some sense, 'out there'." Whilst recognising the counter-intuitive nature of this scenario – questioning "Is the Block Universe actually real or just an artefact of Einstein's model?" – he is attracted by the notion that both the past and the future might have a permanent existence and that, although he could never revisit it, his idyllic afternoon (including family members associated with it) exists not only in his memory but "is still there, all those people, all those moments, always and forever, somewhere in spacetime." Less attractive is the thought that if *happy* events have such an existence

[25] Brian Cox (2016) *Forces of Nature*, William Collins (with the BBC)
[26] Cox earlier defines an 'event' as "something that happens at a particular location in space and at a single instant in time."

then so also do *unhappy* ones, including those associated, for example, with wars, genocides and famines and involving the extremes of human suffering.

- Cox's suggestion that relativity theory renders untenable a distinction between past, present and future events is reminiscent of the words of Albert Einstein in a letter of condolence he sent to the family of a lifelong friend upon learning of his death: "Now he has departed from this strange world a little ahead of me. That signifies nothing. For us believing physicists, the distinction between past, present and future is only a stubbornly persistent illusion."[27] Relativity theory, however, does not exclude *any* distinction between past, present and future. It recognises the meaningfulness of such a distinction as long as it is made within the confines of *a given inertial/observational frame of reference*. Moreover, a concept of temporality – distinguishing, crucially, between *before* and *after* – appears intrinsic to any concept of *causality*. If event *a)* is to cause event *b)*, it seems necessary for it to *precede* it – i.e. for event *a)* to be in event *b)*'s *past* and, conversely, for event *b)* to be in event *a)*'s *future*. It is precisely in order to reconcile
  i. Einstein's basic postulate (one of two[28]) *that the laws of physics are the same in all inertial frames of reference* (which requires that the order of all causally-connected events conforms to a *single* model of causality), with
  ii. the possibility that different observers with different frames of reference might disagree about the *order of occurrence* of such events,

  that it appears necessary to measure the spacetime distance between paired events using, counter-intuitively, a *negative* version of Pythagoras' theorem i.e. defining the square on the hypotenuse of a right-angled triangle as equal to the *difference between*, rather than the *sum of*, the squares on the other two sides. As illustrated in Annexe C, the effect of applying this method to the 'Minkowski' spacetime model is to limit cases of apparent non-reconciliation to those where the separation between paired events is 'spacelike' i.e. where they occur outside each other's past or future light cones and thus where, if nothing can exceed the speed of light, no causal relationship could, in reality, exist between them.[29]

- The pair of events used for illustrative purposes in Annexe C are *a)* the launch of a missile and *b)* the destruction by that missile of a space satellite. We can agree, presumably, that *a)* causes *b)* and not the other way round. To an observer in motion relative to the Earth and depending upon the relative velocity[30] involved, however, it might appear that *a)* occurs *after b)* i.e. that the missile's launch *follows* the destruction of the space satellite. The fact that the two events, *as so observed*, could have no causal connection unless faster-than-light communication were possible, does not make such an observation unimportant. Crucially, it forces us to recognise the possibility of a disjunction between *appearance* and *reality*. To cause the space satellite's destruction, the missile's launch *must* precede it. If the events appear, from the perspective of a particular inertial frame of reference, to occur in the reverse order, then that appearance has to be *false*. The distinction between appearance and reality is fundamental to relativity theory. It is worth re-stating here the words of Bertrand Russell (quoted on page 14): "The theory [of relativity] is wholly concerned to exclude what is relative and arrive at a statement of physical laws that shall in no way depend upon the circumstances of the observer. It is true that these circumstances have been found to have more effect upon what appears to the observer

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[27] Einstein, it should be noted, believed in neither a Creator God nor a personal afterlife. In *The World as I See It* (1935), he states: "I cannot conceive of a God who rewards and punishes his creatures, or has a will of the type of which we are conscious in ourselves. An individual who should survive his physical death is also beyond my comprehension, nor do I wish it otherwise; such notions are for the fears or absurd egoism of feeble souls."
[28] The other is that *the speed of light in a vacuum is the same in all inertial frames of reference*.
[29] A 'timelike' separation, on the other hand, applies where two events are located *within* each other's light cones and, therefore, one *could* have a causal impact upon the other.
[30] Velocity combines *speed* and *direction*.

than they were formerly thought to have, but at the same time the theory of relativity shows how to discount this effect completely. This is the source of almost everything that is surprising in the theory."

6. Observation and the coherence of our models of macro/micro-physical reality.

- Distinguishing between appearance and reality by discounting for the effects of the circumstances of the observer, demands clarity as to what observation involves. At the risk of stating the obvious, any process of observation requires something to be observed (X) and something to do the observing (Y).[31] How X appears to Y depends crucially upon:
  1. the nature of X (a broad distinction can be made between physical *objects/stuff* and physical *events*, the latter comprising things which *happen to*, and thus entail some *change to*, the former);
  2. the gap in space and time between X and Y;
  3. how this gap is bridged by a flow from X to Y of something affected by, and thus potentially revelatory of, features pertaining to X;
  4. the nature of Y (humans provide the most obvious examples of observers but are clearly not alone amongst animals in observing their surroundings and acting upon what they perceive);[32]
  5. the process of *pattern-seeking* by which Y translates the sensory impacts attributable to X into the *perception* of something of a given *type*.

- We all distinguish, broadly speaking, the same *types* of objects/stuff. This is unsurprising given our sensory/cognitive systems are much the same as are the sorts of things we encounter from birth onwards. The commonality of our 'type-distinction' is not just evidenced in our use of words but is a *prerequisite* for verbal or any other form of communication – although the ability to differentiate features of our environment (and particularly, if we are to survive, distinguish the safe from the unsafe) is not itself language-dependent. Humans, we may assume, could distinguish lions from antelopes and act appropriately, long before they had words to act as signs for them. Such an ability extends to non-human animals. Dogs don't need words to recognise cats, or vice-versa.

- Although differing widely in type, all physical objects/stuff are observed by us to be:
  a) *extended* and thus potentially *divisible*;
  b) *structured* i.e. having an identifiable *form* and *composition*;
  c) *resistant to penetration*, varying in degree between solids, liquids and gases;
  d) *positioned* relative to other objects/stuff;
  e) *moveable* i.e. capable of *changing* their relative position.

  Our observation of the extension and relative position of things would seem to be the basis for our common conception of *three-dimensional space*. Our observation that the extension, structure and relative position of things can *change* would seem to be the basis for our common conception of *time*. Kant argues that the nature of human perceivers is such that we cannot interpret our sensory experience of the world other than in terms of subjective *a priori* (i.e. existing *prior* to such experience) *forms of perception*, specifically the forms of *space* and *time*. For Kant, space and time are *empirically real* (i.e. exist as *real* features of things *as we perceive them*) but *transcendentally ideal* (i.e. exist otherwise only as *a priori* concepts, not as real features of things as they are 'in themselves'). With regard to time, for example, he says: "once we abstract from the subjective conditions of perception, it is nothing at all and cannot be attributed to the things in themselves."[33] Whilst it is clearly the case that our brains work in such a way as to convert sensory input into the perception of spatially and

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[31] Observers, of course, may also be the *objects* of observation (by other observers).

[32] Recorders such as cameras and clocks might also be regarded as 'observers' (see Bertrand Russell quote on page 14) but what they record acquires meaning only as interpreted by their human designers.

[33] Immanuel Kant, *The Critique of Pure Reason*, 1781.

temporally located things/stuff, however, it does not thereby follow that such perceptual experience is necessarily subjective in the sense of being causatively unrelated to how things are 'in themselves'. Körner makes the point as follows. “One can agree with Kant’s view that the matter and form of perception are distinct, without sharing his view that the form is subjective. Thus even a realist, who believes that the thing he perceives exists just as he perceives it, could adopt the Kantian distinction without inconsistency. Moreover, he could hold with Kant that the matter cannot be perceived except under the form, because the separation of perceptions from their situation in space and time is only possible (as is, for example, the separation of the shape and colours of perceived patches) in thought, but not in fact”.[34]

- Wholly consistent with physical things (including our own bodies and body parts) having the attributes listed at the start of the previous paragraph, are the following facts about how they *appear* to us as observers.
    - Things appear differently from different angles/distances and under different ambient conditions.
    - If things are moving relative to ourselves, the speed of movement can affect their appearance.
    - How things appear is affected by the nature/acuity of our senses and the focus of our attention.
    - Changes in the appearance of things not attributable to the *processes* by which we receive and interpret physical signs relating to them, are suggestive of changes in the things themselves.
    - Generally speaking, differences/changes of appearance are mutually consistent, explainable and exactly what we would expect.
    - We are mostly aware, through our senses, only of *surface* appearances.
    - *None* of the appearances of things tells us everything about them.
    - We sometimes, although *rarely*, mistake the nature of things.
    - Most mistakes occur due to adverse conditions (e.g. viewing things from a distance or when the light is poor), often concern only matters of detail and are usually corrected on closer examination.

- Our observation of a physical object is generally *superficial* and always *partial* but this does not, in practice, cause us to doubt the existence of the parts (usually the *bulk* of the object) which we do not currently observe and may *never* observe. If we look at an apple whilst turning it over in our hands (and are thus receiving a continuum of visual and tactile information relating to the surface of its skin), we are not liable to doubt the existence of its subsurface components (e.g. its flesh, core and pips) despite the fact that they are not currently perceived by us and, indeed, have *never* been perceived by *anyone*. Our implicit assumption that the apple is much like any other (including ones we have eaten) could, of course, be mistaken. We might be handling a very realistic and convincing *imitation* apple. The fact that, *without further examination*, we do not currently *know* for sure whether or not this is the case, however, does not mean that there is *nothing* below the surface of the object i.e. that things exist only as long as they are perceived. To assume so would be to confuse an *epistemological* issue with an *ontological* one. It would also bring into question the existential status of an observer not currently observed by *another* observer – i.e. the existential status of unobserved observers!

- To a limited extent, we can enhance the acuity of our senses with a variety of aids – in the case of sight, for example, by using a microscope. The revelation which such use provided of previously unperceived structures (viz. Robert Hooke's *Micrographia* published in 1665), served to reinforce the long-standing hypothesis that what we observe through our senses is divisible into smaller and yet smaller components, the key question being whether there is any limit to such divisibility. Greek philosopher Democritus (c. 460-370 BC) hypothesised the existence of *indivisible* particles of which everything is ultimately composed and which

Hooke's drawing of a flea, as seen through his microscope.

[34] Körner, S (1955) *Kant*. Penguin Books

became known at *atoms* (from the Greek word 'atomos' meaning uncuttable). Although atoms are no longer conceived as indivisible, our current 'standard model' of particle physics envisages their subdivision into *fundamental particles* which are so conceived and which comprise *leptons* (which include electrons), *quarks* (which come in six 'flavours') and *bosons* (which include photons). Also envisaged are *anti-matter* counterparts of such particles. The display of *both* particle and wave-like behaviour by photons of light, has led to the *probabilistic* approach of *quantum mechanics* to the nature of observed 'reality', a key issue being that if the very act of observing anything at the sub-atomic level *itself* determines what is being observed, then objective knowledge of the world appears impossible.[35] Inevitably, we are dealing with phenomena way beyond the scope of direct observation via our senses and are limited to interpreting the observable output of measuring devices designed on the basis of a given theoretical model of the nature of the reality under investigation. As physicist Werner Heisenberg argues: "Our actual situation in research work in atomic physics is usually this: we wish to understand a certain phenomenon, we wish to recognise how this phenomenon follows from the general laws of nature. Therefore, that part of matter or radiation which takes part in the phenomenon is the natural 'object' in the theoretical treatment and should be separated in this respect from the tools used to study the phenomenon. This again emphasises a subjective element in the description of natural events, since the measuring device has been constructed by the observer, and we have to remember that what we observe is not nature in itself but nature exposed to our method of questioning."[36]

- The counter-intuitive direction in which theorising about reality at the sub-atomic level can take us, is explored at some length in another paper.[37] Particularly challenging is the possibility of so-called 'quantum entanglement'[38] whereby two or more particles resulting from the decay of a 'parent' particle must, *between them*, conserve the quantum properties of the original particle. This implies that measuring a property of one of the particles must instantly collapse the wave function for the same property in the other*, regardless of how far apart they may be*. This opens up the possibility of instant communication at a distance but appears to contravene the principle – central to relativity theory – that faster-than-light communication is not possible. Equally challenging is the postulated existence of 'dark' matter/energy comprising most of the universe but seemingly *unobservable*. The concern of relativity theory with discounting for the circumstances of the observer, would thus seem irrelevant to any changes/events affecting all but the small proportion of the universe's matter/energy which appears, potentially at least, to be observable. In practice, of course, the vast bulk of even this small proportion is *never* observed (viz. the apple example on previous page).

[35] The so-called Copenhagen interpretation of quantum theory (arrived at by physicist Niels Bohr and others in 1927) envisages an *either* particle-like *or* wave-like reality, our knowledge of which can be expressed only in terms of *probability*. Which aspect is observed will be affected by the nature of our observation. Such observation, in effect, *collapses the probability function* delivering a particular outcome for the particular bit of reality we seek to examine. "The observation itself changes the probability function discontinuously; it selects of all possible events the actual one that has taken place." [Werner Heisenberg. *Physics and Philosophy: The Revolution in Modern Science*. 1962. Penguin Classics reprint, 2000].

[36] See reference in footnote above.

[37] See paper entitled *Substance* (especially section 4) on the KPC website, accessible via the link: Substance.pdf (e-voice.org.uk)

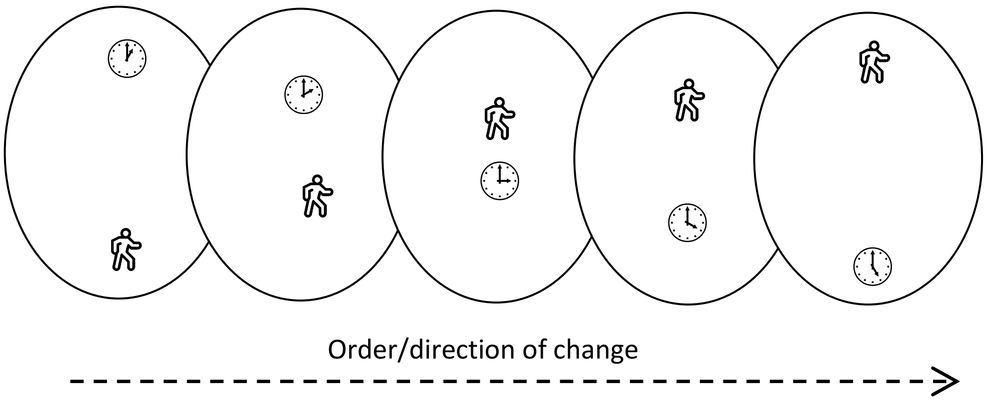
[38] That entanglement is entailed by quantum theory was first postulated in 1935 by Albert Einstein and American physicists Boris Podolsky and Nathan Rosen. They presented it, however, as a *paradox* (named the EPR paradox after its originators) that calls into question the coherence of quantum theory itself. They did not regard entanglement as an actual possibility. Over the last few years, however, experiments have been carried out that are claimed to evidence its existence. In 2016, China launched the world's first quantum communications satellite (named Micius after an ancient Chinese philosopher/scientist) designed to demonstrate the feasibility of quantum communication between Earth and space and to test quantum entanglement over large distances. A report in the 16 June 2017 issue of *Science*, claimed that Micius had detected quantum entanglement involving a 2-photon pair 1,203 km apart.

7. Are there limits to the divisibility of time? Is a 'salami-slice' or a 'block' universe meaningful?

- The supposed existence of *fundamental*, and thus *indivisible*, particles of *matter* has caused some to question the limits, if any, to the divisibility of *time*. Back in the 14th century, French philosopher Nicholas of Autrecourt (c1298-1369) speculated that time is 'granular' i.e. that it comprises a succession of individual and *indivisible* 'instants'. If we define an instant as the fundamental unit of time, however, we need to explain what determines the *minimum length of duration* which it represents. For practical purposes – e.g. identifying, as we accelerate in our cars, the speed at which we are travelling at any given *point* in time – we treat time as *infinitely divisible*. Any such a point has to be conceived as *non-zero* (in zero time we travel zero distance, our speed thus also being zero)[39] but *infinitely small*, our speed being identifiable by applying the mathematics of *calculus*.

- Physicist Julian Barbour[40] argues that time should be conceived not as a dimension comparable to the three dimensions of space, but as a phenomenon attributable to successive change from one physical state (definable as a given quantum configuration) to another – cf. Mach's view (see page 14) that "time is an abstraction at which we arrive through the changes of things" and Leibnitz's view (see footnote 19 on page 13) that "time is an order of successions". Whilst *appearing* continuous, such change is thus realised, supposedly, through a succession of *discrete*, and individually *static*, quantum configurations (a tempting but questionable comparison is with the appearance of motion produced by the rapid succession of the 'still' frames of a movie film – see Annexe D). Unclear is the *content* and *extent* of the configurations envisaged by Barbour. Do we inhabit a 'salami slice' universe and, assuming the slices cannot be *dimensionless* and so *non-existent*, just how *extensive* and *thin* are they?

A 'salami slice' universe



- The diagram shows five 'on-the-hour' slices of a universe containing a person and a clock, their relative position changing from one slice to another. What are shown, of course, are a bare sample of slices in between which lie 'on-the-minute', 'on-the-second', 'on-the-millisecond', 'on-the-micro-second' slices, and so on. But is there no limit to such slicing? Unless time is infinitely divisible, there must be a *finite* (albeit immense) number of slices covering the changes of position displayed. The question (to which

[39] This is the basis of the 'arrow paradox' identified by Greek philosopher Zeno of Elea (490–430 BC). "In the arrow paradox, Zeno states that for motion to occur, an object must change the position which it occupies. He gives an example of an arrow in flight. He states that in any one (duration-less) instant of time, the arrow is neither moving to where it is, nor to where it is not. It cannot move to where it is not, because no time elapses for it to move there; it cannot move to where it is, because it is already there. In other words, at every instant of time there is no motion occurring. If everything is motionless at every instant, and time is entirely composed of instants, then motion is impossible." https://en.wikipedia.org/wiki/Zeno%27s_paradoxes

[40] Julian Barbour (1999) *The End of Time: The Next Revolution in Our Understanding of the Universe*. Oxford University Press
Barbour explains his theory in a couple of interviews which can be accessed via the following links:
Julian Barbour - What is Time? Aug 2014 (approx. 8 minutes) https://www.youtube.com/watch?v=K49rmobsPcY
Julian Barbour - The End of Time Aug 2019 (approx. 20 minutes) https://www.youtube.com/watch?v=GoTeGW2csPk

there is no obvious answer) is what is the least possible difference between the content of one slice and that of another? Just as obscure, if quantum configurations are wholly random and probabilistic, is:

a) why they should bear any *relationship* to one another;

b) why their *sequencing* should be such as to give the impression of *meaningful continuous change*;

c) what determines the *direction* of their sequencing (see the issue of entropy and the 'arrow of time' raised on page 11);

d) if the 'playing' of a sequence of quantum 'stills' gives the appearance of continuous change, to *whom or what* does it present this appearance?

Barbour speculates that our brains are 'time-capsules' which blend quantum *instants* into a continuous flow experienced in the form of a 'stream of consciousness'. But is this coherent? Barbour, it would seem, must accept that our bodies (including our sensory systems and *brains*) are *themselves*, along with everything else, nothing but phenomena which arise, in an unexplained way, out of a succession of *timeless* instants. In a salami-slice model of the universe, our brains must figure as mere *smears* (the thinnest possible without being non-existent) on the slices – although how a particular smear on one slice would relate to a particular smear on another, and thus relate to the *same* brain, is totally obscure. Barbour recognises, but does not resolve, the issue (see page 17) of the *persistence of identity* (including *personal* identity) which is raised if all physical phenomena are subject (particularly at the micro-physical level) to *constant* and *random* change. He also recognises the difficulty of avoiding time-related words when arguing for the *elimination* of time from our conceptual toolbox. As suggested above, this is particularly acute when trying to explain the basis for the *order of occurrence* of supposedly *discrete* and *mutually independent* quantum configurations.

- When theorising about the nature of physical reality, it is all too easy to forget that *we* are as much part of it as anything else. Thus if quantum indeterminacy is a fact of micro-physical reality, we have to accept that it 'infects' not only the scientific instruments we use to explore that reality but also but *ourselves* including our own *brains* i.e. the very 'instruments' we employ to generate our scientific theories, including those associated with particle physics, quantum mechanics and relativity. The tendency to regard ourselves as observing 'from the outside' a reality of which we are at least semi-independent, seems as prevalent amongst physicists as amongst anyone else. For example, Cox (see page 18) suggests that "spacetime can be pictured as a four-dimensional blob over which we move, encountering the events on our worldline as we go" and relates this to the concept of a *Block Universe* containing all that ever has happened or ever will happen. He appears to imagine the 'we' to whom he refers, as not just disembodied 'spirits' traversing a landscape of 'events' but as wholly *passive* spirits devoid of all *agency*. We are portrayed as *encountering* events, not as *determining* any of their occurrences. Supposedly, for example, we don't *choose* to organise a birthday party, we just 'encounter' the birthday party event. Cox recognises, but appears complacent about, the implications of a Block Universe for the possibility of our possessing any freedom of choice. "On the downside, there is no free will in the Block Universe. All the events in our future 'exist', waiting for us to barrel along our worldline to intersect them. I don't care personally whether I have free will or not. It makes no difference to me." As described earlier, Cox finds comfort in the thought that happy events in his past, whilst he could never revisit them, might have a permanent existence in spacetime – forgetting that, if true, the same must also apply to *unhappy* ones.

- If, as the proponents of a Block Universe appear to theorise, *all* events (regardless of whether we place them in the past, present or future) have some form of permanent and parallel *co-existence*, no meaning can be attached to their relative *duration*, *order of succession* or *causal connection.* Conceived, it would seem, as *point-like* and *timeless*, they clearly bear no relationship to events as we know them – i.e. *transient, time-extended*, *sequential* and *causally-connected* happenings realised in the form of physical and/or mental activity. What we identify as events, of course, depends upon our *level of focus*. A football match, for example, can be counted as a single event but may also be divided into two – a first half and a second half. Or, if we like, we can count each pass of the ball, goal, free-kick, etc. as a separate event. What counts as an event is *observer-dependent* in the sense that it depends upon how we choose to divide up *continuums* of physical/mental activity. Consequently, it is usual to identify events within events. This is clearly true of the events of history – the Battle of Britain and the D-Day Landings, for example, may be regarded as 'sub-events' of the overall event we call the Second World War. We should note here that in a Block Universe where, it is hypothesised, 'the past, present and future exist *all at once*',[41] *history* and *memory* can have no meaning. If, to quote Cox (see page 18) "all events that can happen and have happened in the history of the Universe are, in some sense, 'out there'", then all the events of the Second World War and, indeed, all the events of our own lives (including our births and deaths) exist 'all at once' – i.e. *at the same time*. Conspicuous here is the inability of those who hypothesise the existence of a Block Universe to avoid using in their arguments the very concept – *time* – which their hypothesis would render *meaningless*. The same applies to Cox's speculation that the 'event' comprising the idyllic afternoon which he recalls happening in August 1972 "is still there, all those people, all those moments, always and forever, somewhere in spacetime." He fails to question what meaning, if any, can be attached to calendar dates and divisions of the day (such as afternoons) if all events and everything associated with them, exist *'always and forever*'.

- The conceptual confusion discernible in the Block Universe hypothesis stems, it would appear, from a failure on the part of its proponents to define clearly, with relevant examples, what 'events' *are* and to differentiate such events from the *processes* evidencing their occurrence and their character. Whilst, for example, photons of light may provide *evidence* of a supernova event (see page 16), they do not *constitut*e it – any more than does the background radiation deemed evidence of the 'Big Bang' to which the birth of the universe is attributed in any way *constitute* that hypothesised event. The same applies to the event identified by Cox as an idyllic afternoon spent by him in August 1972 together with its innumerable sub-events (splashes of water, buzzes of bees, scents of flowers and grass, etc.). Cox may have been encouraged in his speculation that such events and the things (including people) associated with them could somehow exist 'always and forever' by the thought that they would be evidenced, to an extent at least, by photons of light which, having no mass, could journey indefinitely through spacetime. A central concern of relativity theory is the role of electro-magnetic radiation in providing observers with information about the occurrence/nature of events/things. Much of such information, however, comes via *other* processes including kinetic ones (e.g. the air vibrations associated with sounds) which fade out over relatively short distances. In any case, whatever the means by which events/things are evidenced, such evidence (as argued above) in no way *constitutes* the events/things themselves. Moreover, neither the dark matter/energy hypothesised to comprise most of the universe nor any events associated with it, are evidenced by *anything* we can observe and most of the matter/energy which appears at least *potentially* observable is, in practice, *never* observed (e.g. the bulk of whatever underlies the surfaces to which our observation is largely confined).

8. Time-travel and competing models of reality.

- Apart from providing a popular theme in science fiction – viz. H.G. Wells' novel *The Time Machine* (1895), the TV series *Doctor Who* (1963-) and the film *Back to the Future* (1985) – *time-travel* is viewed by some physicists/mathematicians as a serious possibility, at least in theory if not in practice.[42] What appears to be envisaged is not the *unremitting*, *unidirectional* and *involuntary* temporal change to

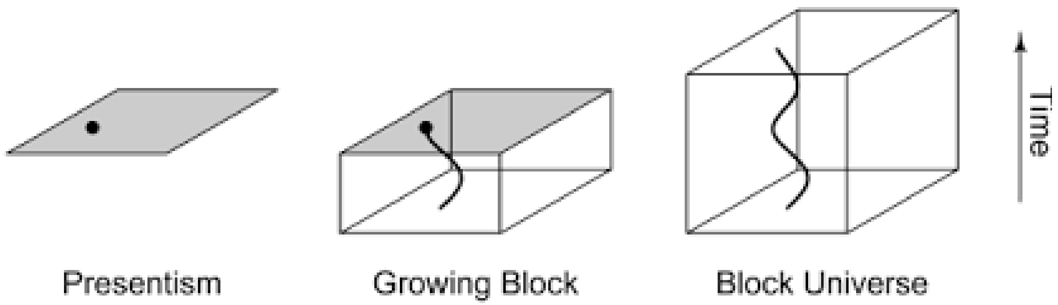
[41] Time: Do the past, present, and future exist all at once? | Big Think Sep 2020 (13 minutes approx.) https://www.youtube.com/watch?v=5vzymaIabWI

[42] See, for example, David Deutsch and Michael Lockwood (1994) *The Quantum Physics of Time Travel*, Scientific American. The paper is sub-titled *"Commonsense may rule out such excursions – but the laws of physics do not*". The full text can be accessed via: https://www.academia.edu/6059479/The_Quantum_Physics_of_Time_Travel

which all objects (including *ourselves*) appear subject – as represented in diagrammatic form by the progress of their 'worldlines' (see page 17) up the vertical (time) axes of spacetime diagrams – but *leaps* in time which may *vary in direction* and be made *by choice*. Generally imagined also are changes in *spatial* position – so the 'time machines' featured in science fiction would be better described as '*spacetime* machines'.

- The major challenge for anyone seeking to render plausible the possibility of time-travel is to identify a model of reality which is not just consistent with the postulates of particle physics, quantum mechanics and relativity theory but which is also *logically valid* and *conceptually coherent*. The most obvious requirement, if we are to travel back/forward to past/future points in spacetime and encounter the events/objects associated with them, is for them to *exist*. An attraction of the Block Universe hypothesis for those who take seriously the possibility of time travel, is its contention that all events (and their associated objects) enjoy some form of *permanent* existence – i.e. that they exist, 'always and forever, somewhere in spacetime' or, put another way, that 'the past, present and future exist all at once'. If all events so exist (i.e. exist *in parallel*), however, no obvious meaning can be attached to their *order/direction* of occurrence and thus to going '*backwards*' or '*forwards*' in time. Indeed, the distinction, in the first place, between past, present and future events loses all meaning.

- Competing with the Block Universe hypothesis are two alternative models relating to the existence of events/objects in spacetime – *Presentism* and the *Growing Block* (see diagrams below).



Presentism (in its *ontological* sense[43]) maintains, as the name implies, that nothing exists other than in 'the present'. It rejects the notion of 'the past' or 'the future' as realms of existence, thereby, also rejecting, it would seem, the possibility of time-travel. An obvious problem for Presentism is the ambiguous nature of what constitutes the *present* i.e. what we mean by *now*. Do we mean (as questioned on page 13) the present *second*, *millisecond*, *microsecond* or *what*? The more we narrow it down, the closer it gets to a point of *zero duration* where it vanishes into *nothingness*. We might choose to define it as an infinitely small but *non-zero* point in time (perhaps calling it a *'thick now*') but this only begs the question of its precise duration. As *observed* by us, events/objects appear to have an *extended* existence in time whilst also being subject to *change*. Presentism could explain this, perhaps, as merely the effect upon observers of the successive replacement of one 'now' by another, the content of each differing in some way from that of its predecessor (cf. the 'salami slice' model of reality described on page 23). The passage of time might thus be viewed as comprising an ongoing succession of 'nows'. Rather than "tomorrow, and tomorrow, and tomorrow", arguably, Shakespeare's Macbeth might just as well have said "*Now, and now, and now,* creeps in this petty pace from day to day, to the last syllable of recorded time" (see Annexe E). Unclear, however, is what, if anything, connects the content of one 'now' (conceived as an infinitesimally thin 'slice of time') to that of its successor. Highly problematic is the nature of *observing* things (such as *ourselves*) if they, as much the things they observe, exist only as features of such slices (comprising, perhaps, quantum configurations) – features

[43] The word is also used to refer to the making of moral judgements about *historical* events/people by applying *present-day* ethical standards.

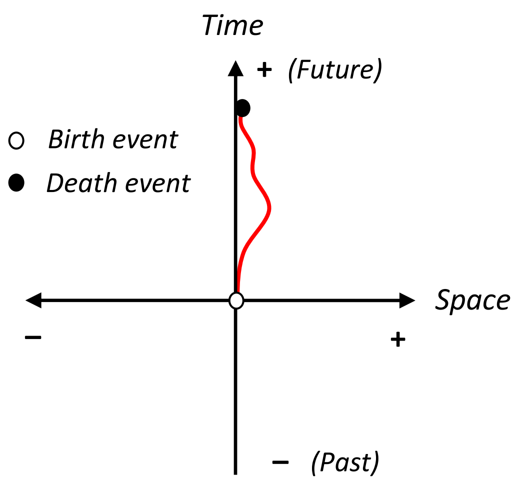
which, whilst subject to *random change*, retain (at least over a limited succession of 'nows') sufficient *continuity of identity* to still count as the *same* things.

- Regardless of how 'thick' or 'thin' it might be conceived, 'now' presents a *moving target*. If conceived as vanishingly small in duration, it cannot be pinpointed, let alone named, before it has become 'then'. In practice, what we mean by 'now' tends to be *fuzzy* and the word is often used to refer to relatively *extended* periods of time which may be *imprecisely bounded* (e.g. as when we use the word 'now' to mean 'nowadays'). Regardless of the duration attributed to it, however, 'now' remains a moving target as one micro-second, second, minute, hour, day or whatever gives way to the next. Presentism, it may be noted, does not render meaningless *any* notion of the past or the future. Relative to whatever we take to be the *present/existent* moment in time – i.e. whatever we identify as '*now*' – the past can be taken to refer to all the *no-longer-existing* moments *preceding* it, the future to all the *yet-to-exist* moments *following* it. The *relative* or *perspectival* nature of how we commonly use the terms 'past', 'present' and 'future', is evidenced by the fact that which we apply to a given event *varies* depending upon its *order of occurrence* relative to that of *another* event. Thus, for example, we view the coronation of Queen Victoria as occurring in the *past* relative to that of Elizabeth II but in the *future* relative to that of Elizabeth I. Similarly, we view 'today' as both 'yesterday's tomorrow' and 'tomorrow's yesterday'.

- The Growing Block may be seen as a half-way house between the Presentism and Block Universe models of reality. It depicts 'the present' as an ever-advancing 'frontier of existence' – *nothing* existing before it but everything which comes into existence as it edges forward in spacetime *remaining* in existence – and thus would seem to rule out the possibility of time-travel *forward* to the *future* but not *back* to the *past*. Unlike the Block Universe, which portrays ourselves as passively encountering *already existing* events (including our own *deaths*) as we 'barrel along our worldlines', the Growing Block leaves open the possibility of our actively *shaping* events as they arise in the present. Presentism also allows for this possibility but, unlike the Growing Block, denies that such events then continue to exist in 'the past'. Both, in so far as they provide scope *for human agency*, are consistent with our everyday experience of making choices and taking actions, both individually and collectively, which can change the world around us and affect the course of future events. Presentism, arguably, accords most closely with our common conception of events as *happenings* which are essentially *transitory* and have no existence either before or after they occur – a view reflected in the essentially *tensed* nature of our language. An issue for Presentism is that events, as commonly conceived, comprise *time-extended* not *instantaneous* happenings, rendering ambiguous the meaning to be attached to the 'present' moment in time. The time-extended nature of events is also an issue for the Block Universe and Growing Block models. It appears to render incoherent the notion of events as existing 'always and forever somewhere in spacetime'. If they are *time-extended*, what can be the nature of such existence? In what meaningful sense, for example, can it be claimed that the event comprising the 1966 World Cup Final match between England and West Germany (including its players, spectators, officials, etc.) exists permanently in spacetime? Such existence would appear to require the game to be played over and over again, forever and forever, as if on some 'existential time loop' – whatever that might be.

- All three models, it can be seen, raise issues which call into question their coherence. The conceptual confusion which seems to be involved stems, arguably, from the *ambiguous* nature of *events* (see page 16), *objects* (see page 17) and *observers* (see page 20) together with the treatment of time as if it were *spatial* in character and so analysable on the same terms as the three dimensions of space (see page 15). Such treatment may be expedient for the purposes of mathematical modelling but nonetheless constitutes a form of *analogy* and analogies (like metaphors), if stretched too far, are liable to result in confusion, if not incoherence. With any theoretical model, it is all too easy to mistake the *model* for the *reality* it is supposed to represent. The fact that physical processes may be symbolised/modelled mathematically, does not mean that they *consist* of mathematical symbols, formulae, etc. – any more than the fact that they may be verbally described means that they *consist* of words. In the case of the Growing Block and Block Universe models, the portrayal of spacetime as *box-like* is liable to encourage its misconception as an *absolute* spatial/temporal framework within which events occur and objects follow their worldlines. Events and their associated objects, it must be remembered, have only *relative* location i.e. relative to *one another* (as illustrated in Annexe B). Crucially, it is important to recognise, worldlines are nothing but *theoretical* constructs/abstractions. 'Out there' in the real world, there are no worldlines along which objects 'barrel'. All such talk is at best *metaphorical*.

- Strung out along an object's worldline, supposedly, are the events it 'encounters' during its existence. At one end is the event of its *becoming existent,* at the other that of its *ceasing to exist*. In the case of *human* objects (at least with regard to their *bodily* existence), these two events are generally assumed to comprise, respectively, their *births* and their *deaths.* The diagram below illustrates such a worldline, the individual's birth event being positioned at the zero point of the vertical (time) and horizontal (space) axes and thus indicating the inertial frame of reference to which the diagram relates. Starting at this point, the worldline progresses *continuously upwards* relative to the *vertical* axis, the succession of events thus being *uni*directional in *time*. By contrast, the distance in *space* between the location of the birth event and that of subsequent events may increase, decrease or stay the same from one event to another – the worldline's path thus being *bi*directional relative to the *horizontal* axis. In this example, it can be seen, the person returns not long before their death to a place near to where they were born.[44]



Any event located above the horizontal axis lies in the birth event's *future*, any below it in its *past*. The location of such events in *time* may thus be regarded as either *positive* or *negative* relative to that of the birth event. Wholly obscure, however, is what kind of reality would be represented by an event located in the area to the *left* of the vertical axis of a spacetime diagram i.e. located *negatively* in *space* relative to the birth event. Throughout its length, it can be seen, the world line stays within the upper right-hand segment of the diagram, all events encountered by the person during their lifetime thus being *positively* located, relative to the birth event, in *both* time and space. Instead of a person's *birth*, it should be noted, their *conception* (about nine months earlier and, almost certainly, at a different location in space) might be deemed the event which brings them into existence as a human being – disagreement on the subject being at the heart of debate about abortion rights and the rights, if any, of the human foetus.

- Humans possess not just a *body* composed, ultimately, of fundamental particles bound in fields of force but also a *mind* comprising the *sentient/cognitive system* which is realised in the workings of the *brain* and is evidenced in the various forms of *mental experience* subsumed under the general term *consciousness*. Both body and mind are subject to *constant change,* a key issue being how much can occur before their possessor is deemed to constitute a *different* individual. If we adopt *spatio-temporal continuity of existence* as our criteria of *bodily* identity, then humans may be deemed to possess the *same* bodies from birth to death, regardless of all the changes they undergo in-between. If, moreover, we regard the phenomenon of consciousness as inextricably linked to brain activity,[45] then a worldline

[44] The worldline of philosopher Immanuel Kant (1724-1804) would suggest a rather unadventurous spirit. He is reputed to have spent his entire life in or not far from the city where he was born (then the Prussian city of Königsberg, now the Russian city of Kaliningrad). His worldline, therefore, would run pretty well straight up the vertical axis of a spacetime diagram.

[45] The inseparability in time and space of human bodies/brains and their associated mental activity, is recognised by John Locke (1632-1704) when he argues: "Spirits as well as bodies cannot operate but where they are ... Everyone finds in himself that his

such as that shown above represents the spacetime path of an object identified not just as a material thing but as a *thinking and feeling* material thing. A key feature of the mental experience connected with the activity of our brains is a *sense of self* – i.e. *awareness* of oneself as a conscious being which, as long as it exists, remains identifiably the *same* individual (despite undergoing all sorts of bodily and mental change) and exercises a limited *power of agency* (i.e. the ability to make choices and take actions which can impact upon other individuals and the world at large). Also a product of human brain activity, however, is the common conception of the self as an *immateria*l thing, the existence of which is *distinct* from that of the body – the classic exposition of the *substance dualism* which this entails being that of René Descartes (1596-1650).[46] The obvious problem (unresolved by Descartes or anyone else) is what could possibly connect two fundamentally different types of substance and how or why an *immaterial* mind/spirit should find itself shackled during its earthly existence to a *material* body. Particularly obscure are the following:

a) how immaterial spirits, unless *eternally* existent, come into and go out of existence;
b) how a particular immaterial spirit becomes attached to a particular material body;
c) the fate of spirits after the bodies to which they are attached stop functioning and disintegrate;
d) if spirits are *reincarnated* (i.e. become attached to *new* bodies), whether they retain any memory of their former incarnation(s);
e) the nature of the sensory/cognitive experience of any human spirits reincarnated through attachment to a *non-human* body (e.g. the body of a *cat*) and, if such experience is indistinguishable from that of anything else with such a body (e.g. is *entirely* cat-like), in what sense they can be said to still exist as human spirits;
f) whether *more than one* spirit (including *non*-human ones, if there are such things) can be conjoined at the same time to the same human or non-human body;
g) the nature of the wholly *immaterial* life which spirits must lead when no longer joined to a material body (believers in an 'afterlife' appear incapable of imagining it other than in *material* terms).

The above provides more than a flavour of the conceptual problems arising from substance dualism. Perhaps wisely, physicists (including those of a dualist persuasion) are silent on the subject of how they might be resolved. Human worldlines, for example, are assumed to terminate with the dissolution of the human bodies to which they relate. Unexamined is the applicability of spacetime and worldlines to the lives which human spirits are widely believed to pursue, once disembodied, in a wholly *immaterial* realm (perhaps split into a 'heaven' and a 'hell') where they may encounter (amongst others) previously departed partners, lovers, relatives, friends, enemies and even pets.

- Apart from its entertainment value, *science fiction* provides a vehicle for exploring (if in general only superficially) the conceptual issues which present themselves when we theorise in the field of the natural sciences – such as when we theorise about the possibility of *time travel*. In their paper *The Quantum Physics of Time Travel* (see footnote 42), two mathematicians/physicists recognise a potential conflict between what the *laws of physics*, on the one hand, and *commonsense*, on the other, may or may not rule out. What is considered to be commonsense, however, can vary from one person to another. An alternative distinction which might be made is between *physical* possibility and *logical* possibility, the 'rules' of logic being as much a product of human theorising as the 'laws' of physics. Logic is concerned essentially with the 'internal' validity of *reasoning* involving the manipulation of the verbal and mathematical signs which enable us to 'point at' and examine the objects of our awareness.

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soul can think, will and operate on his body in the place where that is; but cannot operate on a body or in a place an hundred miles distant from it. Nobody can imagine that his soul can think or move an object at Oxford whilst he is in London; and cannot but know that, being united to his body, it constantly changes place all the whole journey between Oxford and London, as the coach or horse does that carries him" *Essay Concerning Human Understanding* (1689) Book 2; Chapter 21; Sections 19-20.

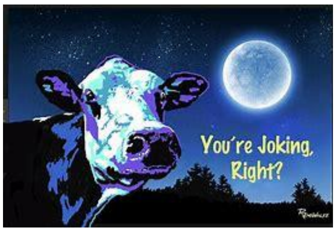
[46] "If we perceive the presence of some attribute, we can infer that there must also be present an existing thing or substance to which it may be attributed... each substance has one principal property which constitutes its nature and essence and to which all its other properties are referred. Thus extension... constitutes the nature of corporeal substance; and thought constitutes the nature of thinking substance". *Principles of Philosophy* (1644) Part 1; Paragraphs 52-53

Such objects include not only physical phenomena but also the *mental constructs* (e.g. governments, laws and money) which form our *social/institutional* world. The central concern of classical *deductive* logic is the *validity* of *inferences* drawn from *premisses* each of which, it is assumed, may be *true* or *false*. That time travel is possible is a *logically* valid inference to draw from the following two premisses which are stated both in words and in symbolic form, where V stands for 'either...or' (which in formal logic, unlike in common usage, includes the possibility of *both*[47]*)* and ¬ for 'it is *not* the case that'.

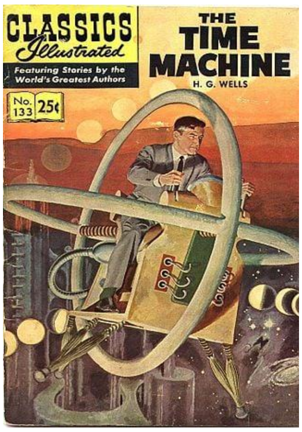
Premiss 1:	either time *travel is possible* (*q*) or *pigs can fly* (*p*)	$q \vee p$
Premiss 2:	pigs cannot fly	$\neg p$
Inference:	time travel is possible	q

The table below shows the four possible combinations of truth value for *q* and *p* and the corresponding truth values for the premisses and for the inference. According to the rules of logic, an inference is valid as long as there is no possible situation in which all of the premisses could be *true* but the inference *false*. It can be seen that in the single row in the table where both premisses are true, the inference is *also* true. The inference is thus *logically* valid. The purpose of this example is *not* to suggest that logic can prove or disprove anything about the real world – quite the opposite. The concern of deductive logic is essentially with whether or not an inference must be true *if* all of the premisses upon which it is based are true – *never mind how realistic or fantastic those premisses might be*. Thus if *q*, in the above example, were to stand for *'cows can jump over the moon*' rather than *'time travel is possible*' – with *p* still standing for '*pigs can fly'* – the inference that cows can perform so literally incredible a feat of saltation would be logically valid although, as an assertion of *material fact*, would be patently absurd. In a similar way, if *q* were to stand for *'god exists*' then such existence would be a *logically* valid inference to draw from the two premisses but would say nothing about the *actual* existence or non-existence of whatever might be meant by the word 'god'. Expressing logical arguments in purely symbolic form *generalises* them and converts them into abstractions capable of mathematical treatment. There is a danger, however, that in manipulating abstract/mathematical symbols we may lose sight of whatever, in a *particular application*, they supposedly represent. We have seen that issues raised by scenarios such as flying pigs, moon-jumping cows and putative gods, relate not to their *logicality* but their *reality* and *conceptual coherence*. Scenarios involving *time- travel* are no exception.

q	*p*	$q \vee p$	$\neg p$	*q*
T	*T*	*T*	*F*	*T*
T	*F*	*T*	*T*	*T*
F	*T*	*T*	*F*	*F*
F	*F*	*F*	*T*	*F*



- As already pointed out, the time-travel portrayed in science fiction is not the involuntary 'petty-paced creep' from one moment to the next which we all experience but involves backward or forward *leaps* (usually made *deliberately*) to *distanced* points (such points then being experienced by the time-travellers involved as their *present* point in time). Such temporal leaps usually involve the use of some sort of 'time-machine', although how such a device might work is left entirely obscure. Physicists who argue that time-travel is *theoretically* possible have yet to identify how it might be achieved *in practice*. Any device involved must be able to time-shift not only its human occupants but also *itself* along with whatever else it might contain – including, if they are not to arrive naked at their new spacetime location, the time-travellers' clothes! An issue for the proponents of time-travel is the nature of the change, if any, to which such a



[47] Thus, if having afternoon tea with a logician and only two cakes remain on the plate, beware of saying: "feel free to choose either". This might be interpreted as an invitation to take *both*!

device and its human/other contents, might be subject between leaving one point in spacetime and arriving at another. If heading *back* in time, for example, do time-travellers whilst on their journey (assuming they experience it as *time-extended*) observe everything to occur *backwards* (the hands of clocks, for example, to run *counter*-clockwise), levels of entropy to *decrease* rather than increase (see page 11) and their own ageing processes to go into reverse? In science fiction such possibilities are generally ignored and time-travellers are portrayed as arriving *unchanged* at their new points in spacetime (including ones preceding the point of occurrence of their birth event or following that of their death event) and as retaining all of the memories they had at the start of their journey. Perhaps most challenging to the notion of time-travel is the scope it would appear to give time-travellers to *alter* the course of events occurring before or after the moment when they take their leap backwards or forwards in time. A major conceptual challenge, for example, is posed by scenarios such as these:

1. We go back to a spacetime location pre-dating our parents' first meeting and do something which causes them *never* to meet, thereby rendering impossible our own birth event;

2. We go forward to a spacetime location where we see our 80-year-old self die in a cycling accident. Returning to what, at the start or our journey, constituted our present moment in time, we vow to give up cycling before our 80th birthday, thereby rendering impossible the accident we have just witnessed.

Both scenarios, we might note, illustrate the seeming impossibility of conceiving time travel other than in terms of going back to a *past*, or forward to a *future*, point at which *particular events*, within an *ongoing chain of events*, occur. Only if events are attributed with *order/direction* of occurrence (notwithstanding that in a hypothesised Block Universe they supposedly exist 'all at once'), can they be considered to happen *before* or *after* one another and can any sense be made of *causation, memory* or the *dating of events*.

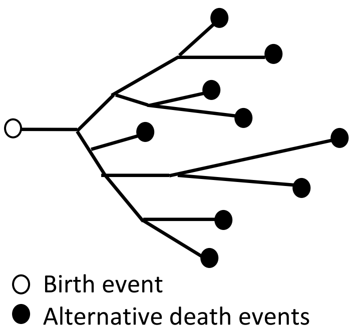
- One response to the apparent incoherence of scenarios such as those above, is simply to rule out their possibility. For example, we might invent a 'law' that travelling in time cannot enable us to do anything which would cause the totality of events affecting our lives to involve *contradictions* (e.g. for our birth event or the event of our death at the age of 80 in a cycling accident to both occur and *not* to occur). A rule of this nature would not, of itself, invalidate a scenario such as that portrayed in the film *Back to the Future* where the character Marty McFly (played by Michael J. Fox) goes back in time and ends up *ensuring*, rather than preventing, the forming of a lasting relationship between his parents – an outcome wholly consistent with his birth event. That this was achieved only by virtue of his time-travelling activity when a *teenager*, however, entails a 'time-loop' the circularity of which brings the coherence of the whole scenario into question. Equally questionable is a scenario where a person's ageing self travels back in time and warns its teenage self about the big mistakes it considers itself to have made as an adult, thereby enabling its teenage self to *avoid* them and thus to enjoy a quite *different* adult life. We could, of course, invent another arbitrary rule – i.e. that travelling in time cannot allow us to meet and communicate with an earlier or later version of ourselves.

- It has been suggested that a way to resolve a least some of the contradictions which appear inherent in the notion of time travel is to postulate the existence of a '*multiverse*' i.e. a virtual *infinity* of *parallel* universes encompassing all possible permutations of events – each differing, if only minimally, from any other and all *equally real*. Thus, supposedly, we may lead very different lives in different universes, experiencing very different sets of events (e.g. in one universe die in a cycling accident, in another get away with only minor injuries and in another have no accident at all). In many universes, of course, our birth events will simply not feature and so neither will we. Rather than helping to resolve conceptual problems associated with time-travel, however, the notion of a multiverse only *compounds* them. Travellers in spacetime are faced not only with the challenge of hopping backwards or forwards within a single universe but also of hopping *between* universes (the so-called 'laws' of physics, perhaps, differing from one to another). Conspicuous in its conceptual naivety is the notion that in different universes a person might lead different (even *totally* different) lives, display different (even *totally* different) physical and mental characteristics and yet still constitute the *same* person. Unless linked to *continuity* of physical/mental existence, personal identity would appear to have no meaning – an issue already identified (see pages 28-29) in relation to putative 'spirits' or 'souls' and the possibility of their reincarnation, whether in human or non-human form. The issue is generally ducked in science fiction. There have so far been *thirteen* incarnations of Doctor Who in the TV series of the same name. Although a 'Time Lord' (benefiting from the possession of *two* hearts) and not a human being, all incarnations have been outwardly human in form. Such appearance, however, has varied widely and in the latest incarnation the Doctor appears as female rather than male. Apart from differing in physical appearance, the Doctor has also differed widely in personality. The cognitive dissonance and crisis of self-identity which this would seem bound to inflict on whatever 'inner being' is thought to be common to all incarnations, has yet to be explored in the series.

Doctor Who Incarnations:

1963-66	William Hartnell
1966-69	Patrick Troughton
1970-74	Jon Pertwee
1974-81	Tom Baker
1982-84	Peter Davison
1984-86	Colin Baker
1987-89	Sylvester McCoy
1996	Paul McGann
2005	Christopher Eccleston
2005-10	David Tennant
2010-13	Matt Smith
2014-17	Peter Capaldi
2018-22	Jodie Whittaker

- The different sequences of events which an individual might experience in life are sometimes portrayed as an array of lines (see diagram on left) dividing off like the branch lines of a railway but with the direction of travel strictly *one-way* (starting with the person's birth). All branches eventually 'hit the buffers' in the form of the death of the individual concerned. Those shown in the diagram, of course, are but a tiny sample of a potential infinity of 'routes of travel'. The model of reality represented in the diagram is consistent with our experience of events (some resulting from our individual or collective *decision-making*) which affect, perhaps profoundly, what follows in our lives. The alternative routes could be viewed as *possibilities* (the identification and assessment of which informs our decision-making), just *one* becoming an *actuality*. Such a view, basic to how *in practice* we lead our lives, is at odds with the quite common belief that everything is somehow *pre-determined* by the 'laws of physics' or perhaps by a putative 'god' who lays down those laws whilst also telling us how we *should* or *shouldn't* behave – thereby implying that we do, after all, have some *choice* in the matter! Such predetermination, if coherent and true, would mean that within a given universe, only *one* sequence of events is possible, the seeming possibility of others being just an illusion. An *infinity* of universes would, by definition, cover all possible permutations of events but, by any meaningful definition of a 'universe' (see page 10), there could be no connection between them. All this has implications for our interpretation of fictional portrayals of time-travel. In Charles Dickens' *A Christmas Carol* (1843), the Ghost of Christmas Yet to Come takes miser Ebenezer Scrooge forward into the future to a time following his death and to a graveyard where his body is buried. The neglected state of Scrooge's grave evidences what has already been intimated to him – that he is to die unloved and unmourned. The story proceeds as follows:"The Spirit stood among the graves, and pointed down



to One. He [Scrooge] advanced towards it trembling. The Phantom was exactly as it had been, but he dreaded that he saw new meaning in its solemn shape.

'Before I draw nearer to that stone to which you point,' said Scrooge, '*answer me one question. Are these the shadows of the things that Will be, or are they shadows of things that May be, only?'*

Still the Ghost pointed downward to the grave by which it stood.

'Men's courses will foreshadow certain ends, to which, if persevered in, they must lead,*'* said Scrooge. *'But if the courses be departed from, the ends will change. Say it is thus with what you show me ...Assure me that I yet may change these shadows ...by an altered life.'*"

Illustration for A Christmas Carol (1843)
by John Leech (1817-64)

Returning to what, prior to his journey into the future, had been for him 'Christmas Present', Scrooge becomes a changed man – kind, caring and generous to all around him. He seeks to make amends to all those he has caused to suffer as a result of his meanness. These include his exploited clerk Bob Cratchit whose disabled son Tiny Tim, it has been revealed to Scrooge, is set to die an early death as a result of his family's impoverishment. By supporting the family, Scrooge secures for Tiny Tim a longer and happier life. In terms of the diagram shown on the previous page, Scrooge's decision to alter his behaviour diverts the course of his own life down a different 'branch line' from the one he otherwise would have travelled and where he thus experiences a different set of events.[48] Crucially, Scrooge needs to know whether the future scenario shown to him by the Ghost represents a pre-determined *actuality* which is thus unalterable or just a *possibility* which could be averted in favour of something better if only he chose to abandon his miserly ways. In a Block Universe where past, present and future supposedly exist 'all at once', even if Scrooge could witness a future actuality he could do nothing to alter it as it would, in effect, already exist.[49] In a universe conforming to either the Growing Block or Presentism models of reality, on the other hand, Scrooge could not observe a future actuality (as it would not yet exist) but his choices/actions could affect the future course of events and he could inform those choices by imagining and evaluating their possible outcomes. In a multiverse comprising an infinity of parallel universes, anything Scrooge might be able to do to improve the fate of Tiny Tim in one universe could make no difference to his fate in any other – in any case, the idea that in different universes a person could display very different characteristics, lead very different lives and yet still constitute the *same* person appears, as already argued, to be incoherent. To conclude this section, we may note that the conceptual ambiguities attaching to portrayals of time-travel in science *fiction*[50] reflect corresponding ambiguities in *science* regarding, in particular, the nature of *objects*, *observers* and *events* and the validity of treating time as if it were *spatial* in character.

[48] Many events involve *interactions* between people. The 'branch line' model thus implies a complex and conceptually obscure relationship between the 'routes of travel' which are available to, and chosen by, different individuals.

[49] In the words of T. S. Eliot (see Annexe E): "If all time is eternally present / All time is unredeemable".

[50] Some (including the novel *A Christmas Carol* and the films *Back to the Future* and *Groundhog Day*) are examined in an intriguing video (approx. 8 minutes long) which can be accessed via: https://www.youtube.com/watch?v=d3zTfXvYZ9s

9. Attitudes towards time and human history. [See Annexe E for fuller text of some of the quotes below]

- As already suggested (see page 14), *change* is fundamental not only to the *measurement* but also to the *meaning* of time. In a universe where literally *nothing* changes, the passing of time has no meaning. An 'event' is equally meaningless unless related to something which changes. To claim that an event has occurred but that *absolutely nothing* has changed is incoherent – unless we can count the *non*-occurrence of something as an event![51] The *nature* and *direction* of the change which we experience in life (in particular, whether it is viewed as positive or negative) inevitably affects our attitudes towards time. Our concerns may extend to the impact of change not only upon human *individuals* but also upon human *societies*, other life forms on planet Earth and, ultimately, all that exists in the Universe.

- Obvious in terms of the natural changes associated with human ageing and varying widely in detail between individuals are: a) a period of growth/development (both physical and mental) from birth into adulthood; b) a period of deterioration/decline in old age ending in death. Inevitably this renders our attitudes towards time ambivalent. Concentrating upon the capacity of humans to grow, develop and heal, we may view time as a *benign* force. According to Greek physician Hippocrates (c. 460-370 BC): "It is time which imparts strength to all things and brings them to maturity". Mirroring this is the common saying that 'time is a great healer'. The curative powers of time may be seen to extend not only to human *bodies* but also to human *relations*. According to French philosopher Blaise Pascal (1623-62): "Time heals griefs and quarrels, for we change and are no longer the same persons. Neither the offender nor the offended are any more themselves". A counter-view is provided by novelist Ivy Compton Burnett (1884-1969): "Time is not a great healer. It is an indifferent and perfunctory one. Sometimes it does not heal at all. And sometimes when it seems to, no healing has been necessary". In the *very* long term, time does not appear to be on the side of *anything* in the Universe. As Isaac Asimov points out (see page 11), the second law of thermodynamics implies that "the order of the universe is, first and foremost, a perpetually increasing disorder" i.e. regression to an entropic 'mush'.

- The happier our earthly life, the less happy are we likely to be for it to end in death. Whether our life is happy or unhappy, the motivation can be strong to imagine its continuation in an unearthly realm (albeit generally conceived in remarkably earthly terms) where all is blissful and inconveniences such as the second law of thermodynamics do not apply. Regardless of any belief in an afterlife, the predominant human attitude towards time appears to one of regret at the loss it brings of all we hold dear combined with a determination, prompted by awareness of "time's wingèd chariot hurrying near", to make best use of it whilst we can – to "seize the day" and to "gather rosebuds whilst [we] may".

Gather ye rosebuds while ye may,
Old time is still a-flying:
And this same flower that smiles today,
Tomorrow will be dying.
To Virgins, to Make Much of Time
from *Hesperides*, a collection of poems by
Robert Herrick (1591-1674)

Herrick's poem was the inspiration for
these two paintings (1908 and 1909)
by pre-Raphaelite artist
John William Waterhouse (1849-1917).

[51] Arthur Conan Doyle's Sherlock Holmes story *The Adventure of Silver Blaze* (1892) centres on 'the curious incident of the dog in the night-time'. As Holmes explains, the incident/event to which he refers is that the dog did *nothing* in the night-time.

- The tendency to view time as a *causative force* (whether benign, malign or indifferent), reflects its association with *change*. The observation of recurrent patterns of change encourages us to suppose the existence of a hidden 'something' which causes them to be the way they are.[52] Time has tended to be associated more with changes involving *loss* than gain and thus widely regarded as a force which, if not malign, is nevertheless implacable and destructive. It has been seen, for example, as "the devourer of all things", as an "ever-rolling stream [which] bears all its sons away" and as lighting "the way to dusty death". Time's association with *death* finds personification in the menacing figure of the Grim Reaper, the harvester of human souls, and also in the related but not quite so grim shape of Father Time whose depiction in the form of a weathervane at Lord's Cricket Ground has not itself escaped the vicissitudes of time having been damaged on three occasions (during the Blitz when it became entangled with the cable of a barrage balloon, in 1992 when struck by lightning and in 2015 when battered by high winds). An image of Father Time looming over a cricket ground might be deemed appropriate. George Bernard Shaw claimed that "the English are not a very spiritual people, so they invented cricket to give them some idea of eternity." Cricket itself, arguably, could be seen as metaphor for life and death. Whilst we might hope, if determinedly optimistic, to achieve 'one hundred not out', we know that the game must eventually come to an end with the final removal of bails and drawing of stumps. Although not obviously a subject for humour and featured most notably in religious art, the Grim Reaper makes an appearance in Monty Python's *The Meaning of Life* (1983) where his about-to-be victims initially mistake him for a local villager looking for some hedge-cutting work![53]

Statue of Death
Trier Cathedral, Germany

Father Time
Lord's Cricket Ground

- In Greek mythology, death is personified by Thanatos – a minor deity imagined in the form of a winged youth. A merciless taker of lives, he is described by the poet Hesiod (pre 650 BC) as follows: "[He] has a heart of iron, and his spirit within him is pitiless as bronze: whomsoever of men he has once seized he holds fast: and he is hateful even to the deathless gods".
  Different aspects of time are personified by the following Greek gods:
  - Chronos – time as *spans* of moments (e.g. from birth to death);
  - Aion – time as *seasonal* and *eternal* (extending into an afterlife);
  - Kairos – time as moments of *opportunity*.

  Reflecting the association of time with opportunity is the common belief that there is a *right*, and correspondingly *wrong*, time for things – expressed most fully, perhaps, in the Bible (Ecclesiastes 3) where it is stated that "to every thing there is a season, and a time to every purpose under the heaven". It also finds expression in, for example, Shakespeare's *Julius Caesar* (Act 4, Scene 3) where Brutus asserts "There is a tide in the affairs of men, Which taken at the flood, leads on to fortune Omitted, all the voyage of their life Is bound in shallows and in miseries".

Thanatos
Temple of Artemis,
Ephesus c. 300 BC

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[52] Too big a subject to pursue here is the idea of *causation* including: a) its *psychological* link, as argued by David Hume, to the observation of 'constant conjunctions'; b) the *existential status* of the 'laws of nature' hypothesised to dictate how all things should be and behave.

[53] The sketch can be viewed via the following link: https://www.youtube.com/watch?v=3UBQFXQUqxE

- The association of time with *progress* entails the belief that there is a *direction* to change which, despite possible short-term set-backs, is *positive* at least in the longer term. Issues raised here include:
  - the length of the time periods under consideration (i.e. what counts as short or long term);
  - the aspects of reality in relation to which changes are considered;
  - the criteria by which changes are judged as being either positive or negative;
  - the perspectives of those who make such judgements.

  As already argued, if current scientific wisdom regarding the entropic tendency of any enclosed system is correct, the *very* long term prospects of anything *structured* in the Universe (including human beings) are not good. Although it's a bit early to start worrying about it now, we are in any case faced with annihilation when the Sun begins to expand as a red giant in about five billion years time, eventually engulfing all of its planets including planet Earth. Long before then, quite possibly, the Earth will be devastated by an asteroid strike and long before then, quite possibly, it will have been rendered uninhabitable (at least for advanced forms of life) by our own rapacious and destructive activity. The human species is widely regarded (by humans) as the *culmination* of evolutionary processes. What they may have culminated in is a species which is at once too clever and too stupid for the long-term survival not only of itself but also of other life-forms, the natural habitats of which it is busy polluting and destroying.

- Warning against "confusing biological inheritance, which is the source of evolution, with social acquisition, which is the source of progress in history", historian E. H. Carr argues: "Evolution by inheritance has to be measured in millennia or in millions of years; no measurable biological change is known to have occurred in man since the beginning of written history. Progress by acquisition can be measured in generations... The essence of man as a rational being is that he develops his potential capacities by accumulating the experience of past generations. History is progress through the transmission of acquired skills from one generation to another".[54] The problem is that such transmission has vastly increased our mastery of the environment (including our ability to split the atom) but has not been accompanied, arguably, by a commensurate improvement in our ability to master *ourselves* and, in particular, those of our biologically inherited traits which continue to provide the source of human conflict. Writing in 1961, Carr argues: " At the present time, few people would, I think, question the fact of progress in the accumulation both of material resources and of scientific knowledge, of mastery over the environment in the technological sense. What is questioned is whether there has been in the twentieth century any progress in our ordering of society, in our mastery of the social environment, national or international, whether indeed there has not been a marked regression. Has not the evolution of man as a social being lagged fatally behind the progress of technology?" [More extended quotes are provided in Annexe F).

- The so-called 'Whig interpretation of history' – i.e. that history evidences *progress* in human affairs characterised by increasing *democratisation* – has always been vulnerable to the challenge of events. Its appeal to British historians in the second half of the 19th century when Britain's industrial revolution and imperial expansion were reaping big rewards, is understandable (although from the perspective of the people subject to imperial rule and denied democratic rights, things might have looked very different). It has since been dealt a blow not only by the major conflicts (starting with the outbreak of the First World War in 1914) which have characterised the 20th century and continue in the 21st, but also by the crises now recognised of resource depletion, environmental degradation and climate change linked to a constantly rising demand for goods and services from an exponentially growing world population with aspirations shaped by the consumption habits of the minority beneficiaries of a grossly unequal distribution of spending power, both within and between communities. Disparity of *economic* power is coupled with disparity of *political* power. Democratisation has long been, and

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[54] E.H. Carr (1961) *What is History?*, Macmillan. [George Macaulay Trevelyan Lectures delivered at Cambridge University, 1961]

remains, under challenge from authoritarian and totalitarian counter-forces. In some countries deemed broadly democratic, moreover, the rise of populism/demagoguery threatens to undermine the integrity of their political processes/institutions. A facet of human nature displayed throughout history is a proclivity to trust and follow 'leaders' who may project a certain charisma (often carefully cultivated) but a disturbing number of whom peddle bigoted/divisive ideologies (targeting human tribal/territorial instincts) whilst turning out to be charlatans, crooks, incompetents, moral degenerates or plain mad. Such a proclivity raises the question as to whether the human species is as much ovine as simian in its origins i.e. that we are as closely related to *sheep* as to apes!

- What we judge as progress is essentially *subjective*, being dependent upon the values we bring to the judgement. Progress for one person may constitute *regress* for another. Apart from the issue of subjectivity, the following *time*-related issues are raised by the concept of progress:
    - the period of time (short or long) over which we judge progress to have occurred;
    - for how long we expect such progress to continue and the basis for our expectation;
    - if progress is *goal-oriented*, whether the achievement of *all* goals spells 'the end of history'.

  Carr suggests that the classical civilisations of Greece and Rome were basically unhistorical, being "on the whole as little concerned with the future as with the past". In evidence of this, he quotes Roman poet Lucretius (c. 99-55 BC): "Consider how the past ages of eternal time before our birth were no concern of ours. This is the mirror which nature holds up to us of future time after our death".[55] Viewing time as moving towards an *end* state (the so-called *teleological* view of history) emerged as a central tenet of Judeo-Christian theology associated with the coming of a Messiah to judge and govern all human souls. Its realisation in *apocalyptic* form (as portrayed in *Revelations*) dominated medieval thinking but this was to change as new ideas took root. As Carr states: "The Renaissance restored the classical view of an anthropocentric world and of the primacy of reason, but for the pessimistic classical view of the future substituted an optimistic view derived from the Jewish-Christian tradition. Time, which had once been hostile and corroding, now became friendly and creative... The rationalists of the Enlightenment, who were the founders of modern historiography, retained the Jewish-Christian teleological view, but secularized the goal; they were thus enabled to restore the rational character of the historical process itself. History became progress towards the goal of perfection of man's estate on earth".

- Regarded by Carr as the greatest of the Enlightenment historians, Edward Gibbon (1737-94) records in *The Decline and Fall of the Roman Empire* (1776) – despite its theme – his "pleasing conclusion that every age of the world has increased, and still increases, the real wealth, the happiness, the knowledge, and perhaps the virtue, of the human race". Equally optimistic about human history is the physicist and historian of science Sir William Cecil Dampier (1867-1952) who, in his contribution to the final volume of the *Cambridge Modern History* published in 1910 just four years before the outbreak of the First World War, expresses the belief that "future ages will see no limit to the growth of man's power over the resources of nature and of his intelligent use of them for the welfare of his race".[56] As already indicated, such optimism has been, and continues to be, challenged by events including two World Wars. Carr's observation back in 1961 that "We live in an epoch when – not for the first time in history – predictions of world catastrophe are in the air, and weigh heavily on all", seems as apt now as it was then. If 'history' concerns the societal activity of humans over time, the extinction of humanity spells the *end* of history. Pointing out that the inevitability of our individual deaths "does not prevent us from laying plans for our own future", Carr proceeds to discuss "the present and future of our society on the assumption that this country – or, if not this country, some major part of the world – will survive the

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[55] *De Rerum Natura* – translatable as "On the Nature of Things" or "On the Nature of the Universe".

[56] *Cambridge Modern Hist*ory [Vol. 12 - The Latest Age, Ch. 24 - The Scientific Age], 1910. Apart from many scientific papers, Dampier wrote more broadly on the subject of science and its history, his most notable work being *A History of Science, and its Relations with Philosophy and Religion* (1929).

hazards that threaten us, and that history will continue". Any who survive will be at least as keen as their forebears to improve (as they judge it and whether or not they believe in the certainty of 'progress') human society and to enhance its future prospects. Their choices will be informed by their ongoing interpretation and re-interpretation of past events. As Carr states: "Modern man is to an unprecedented degree self-conscious and therefore conscious of history. He peers eagerly back into the twilight out of which he has come, in the hope that its faint beam will illuminate the obscurity into which he is going; and, conversely, his aspirations and anxieties about the path that lies ahead quicken his insights into what lies behind. Past, present and future are linked together in an endless chain of history".

- The ending of human existence (and thus of human history) as well as that of any other intelligent beings in the universe possessing self-consciousness, intentionality and the ability to generate the mental constructs required for complex social interaction, would appear to eliminate anything capable of forming a *concept* of time. It would not, however, bring to an end the *processes of physical change*, the observation of which provides the basis for how we both conceptualise and measure time. In that sense, at least, time would go on – which is to say no more than that those processes would continue regardless of the existence or non-existence of beings capable of observing them. Where those processes might lead, of course, remains a matter of speculation. The laws of thermodynamics indicate that the universe is heading towards a state of *total entropy*. But this requires it to be in a *non*-entropic state in the first place – perhaps the product of the 'big bang' hypothesised to have generated the universe out of a putative but obscure 'singularity'. A possible scenario is a universe which yo-yos endlessly from a singularity to expansion via a big bang and then, if there is enough matter in the system, back to a singularity. Intelligent beings evolving in each phase, however, would be totally ignorant of those existing in other phases or of their creative achievements. A long-standing and seemingly profound philosophical question (which still awaits a meaningful answer) is why the universe (or multiple universes) should exist at all i.e. why there should exist *something* rather than *nothing*. Only in relation to 'something' which *exists* and *changes*, is 'time' in any way meaningful.

Roger Jennings
February 2023

Annexe A: An assortment of clocks

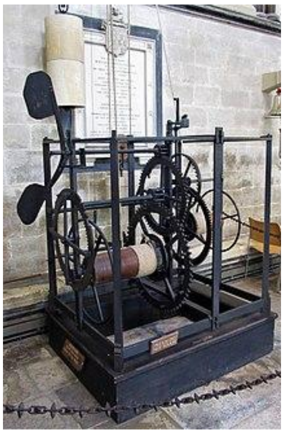
Ancient Egyptian ***clepsydra*** (c. 1400BC)
The time is indicated by the water level inside. This falls steadily as water drips from a hole at the base.

Hourglass

Candle clock

Horizontal sundial
Kew Palace /Kew Gardens

Vertical sundial
St. John the Evangelist Church,
Kingston upon Thames



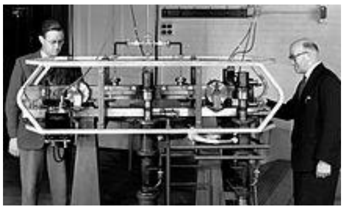
Mechanical clocks convert the continuous pull of a weight or spring into even 'ticks'. The earliest (late C13th) did this using a 'verge-and-foliot' mechanism. The mid C17th replacement of the foliot with a pendulum much improved clock accuracy (to about ±10 seconds per day). Further improvements culminated in the London-made Shortt 'free pendulum' clock (1921) which achieved the highest level of accuracy for a pendulum clock (±1 second per year).

Left: Clock in Salisbury Cathedral (c. 1386) – possibly the oldest surviving mechanical clock in the world.

Right: A 'longcase' or 'grandfather' clock – weight driven and regulated by the swing of a pendulum.

Quartz clocks/watches are now the most widely used devices for everyday timekeeping and work by applying an electric current to a quartz crystal, causing it to vibrate at a fixed frequency (32,768 times per second). Although sensitive to temperature changes, they are generally accurate to about ±15 seconds per month.

Right: Internals of the Seiko Astron – the world's first quartz watch (1969)



***Atomic* clocks** count oscillations in the energy levels of atoms (generally of Caesium-133) which resonate at extremely consistent frequencies. A second is defined as measured by 9,192,631,770 of such oscillations. *International Atomic Time* is calculated by averaging readings from 400 atomic clocks distributed worldwide.

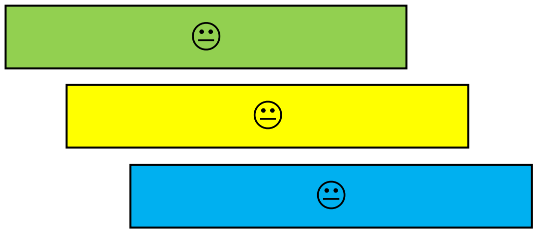
Above left: The world's first caesium-133 clock constructed in 1955 at the UK National Physical Laboratory, Teddington. *Above right:* FOCS 1 – a continuous cold caesium fountain atomic clock which became operational in Switzerland in 2004 and is estimated to be accurate to within one second in 30 million years. Quantum and optical lattice clocks promise even higher levels of accuracy, perhaps gaining/losing no more than one second in several billion years (although, without a better measure of time, how this might be confirmed is unclear).

Annexe B: Relativity of position and motion: an example.

- Three trains stop alongside one another (see A below). You are sitting in the central (yellow) train. All you can see on either side are the green and blue trains and, within each, a passenger sitting in line with yourself. You become aware of a change in the relative position of the trains (see B below) but it occurs so briefly and smoothly that you cannot be sure which trains have moved or in what direction.

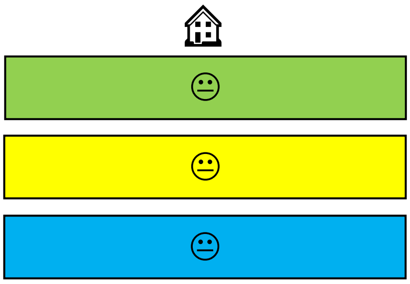
A

B

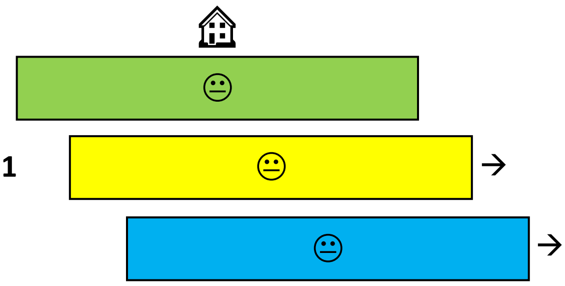


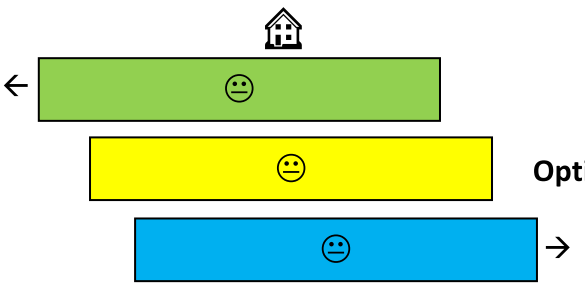
- Only by relating the position of the trains to something extraneous to all three, could you identify this. Suppose that a house is located as shown in C below and that your smartphone can pick up images from an overhead camera covering this section of track. You could then identify which of the five options accounts for the repositioning of the trains. In options 1-3, one train remains stationary (relative to the house and track) whilst the other two move either in opposite directions (option 2) or in the same direction but at different speeds (options 1 & 3). In options 4 & 5, all three trains move in the same direction but at different speeds.

C



Option 1





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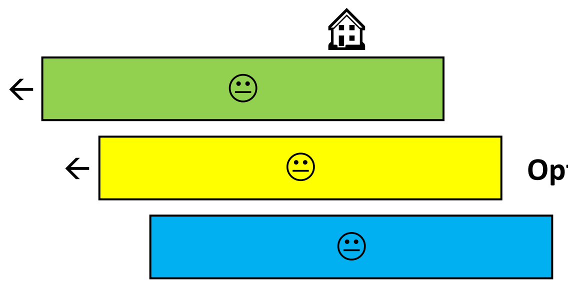
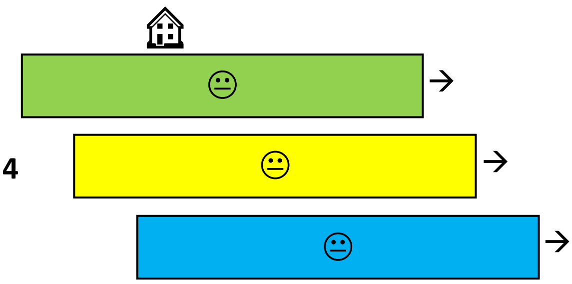
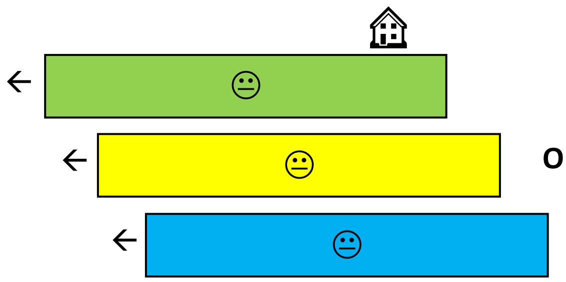


Option 3

Option 4



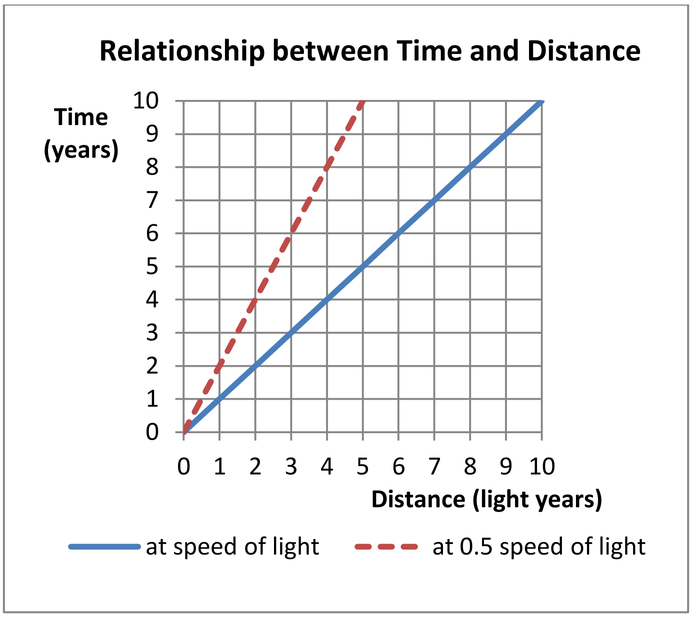


Option 5

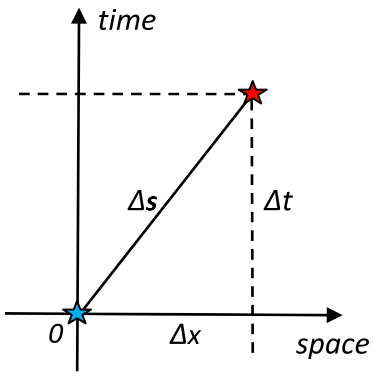
- The example illustrates that whether something is moving or at rest can be judged only in relation to something *else* deemed, for comparative purposes, to be itself motionless. In everyday life, the surface of the Earth and fixtures upon it generally serve the purpose, although we know that all are in motion relative to the Sun and to other objects within the universe. How meaningful would the five options be in a universe which comprised *nothing but* the three trains (with or without their human occupants)?

Annexe C: Measuring distances between events in spacetime.

- If we treat the three dimensions of space as a single dimension, the relationship between time and distance can be displayed in the form of a two-dimensional diagram. In the example below, time is measured (in *years*) on the vertical (y) axis and distance (in *light years*) on the horizontal (x) axis.[57] A light year (as explained in footnote 3 on page 4) is the distance (about 5.88 trillion miles) travelled by light in a vacuum in one Julian year (365.25 days). In spite of its name, therefore, a light year is a unit of *length*. The blue line indicates the trajectory of anything moving to/from the diagram's 'point of origin' (i.e. the zero point of its vertical and horizontal axes) at the speed of light (about 300,000 km or 186,000 miles per second). Thus, for example, an object moving from that point at the speed of light would take 4 years to travel 4 light years (the approximate distance between Earth and Proxima Centauri, the nearest star to our Sun). At half the speed of light it would take 8 years (following the trajectory indicated by the dotted red line). Crucially, if nothing can exceed the speed of light, a trajectory less 'steep' than that of the blue line (i.e. one crossing the spacetime zone beneath it) is impossible. If, for example, humans were to colonise a planet 10 light years from Earth, it would be impossible for any communication to pass between them and people back on Earth in less than 10 years.



- The diagram below shows the relative positions in *time* and *space* of two events: a missile launch (blue star) and the destruction by that missile of a space satellite (red star). If the *differences* in time (Δt) and space (Δx) between the two events are known, it would appear possible to calculate the *spacetime* distance (Δs) separating them by applying Pythagoras' theorem i.e. that '*the square on the hypotenuse is equal to the sum of the squares on the other two sides*'. Thus: $\Delta s^2 = \Delta t^2 + \Delta x^2$.
If *y* is measured in units of *time* (e.g. seconds) and *x* in units of *length* (e.g. kilometres), however, the calculation is not possible. A solution is to convert the units of time into units of length by multiplying them by an appropriate speed which, in relation to spacetime, is the speed of light (*c*). An interval of, for example, 0.01 seconds, converts in this way into a distance of roughly 3,000 kilometres i.e. 0.01 sec x 300,000 km/sec (the approximate speed of light). The formula thus becomes:
$\Delta s^2 = (c\Delta t)^2 + \Delta x^2$ or, which is the same thing, $\Delta s^2 = c^2\Delta t^2 + \Delta x^2$.

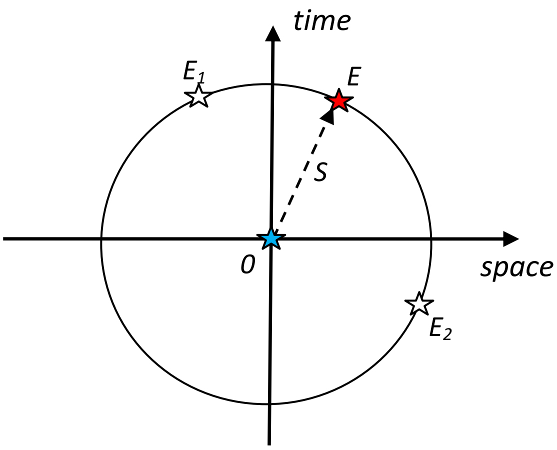


The problem with calculating the spacetime distance between events in this way, as physicists Brian Cox and Jeff Forshaw explain,[58] is that it can have paradoxical consequences.

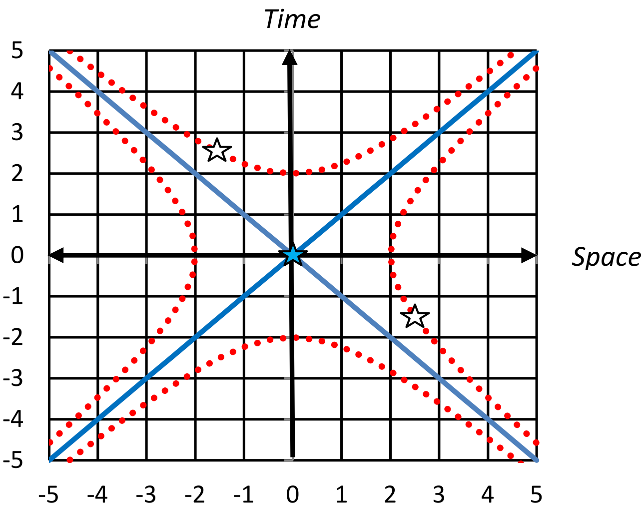
- A fundamental tenet of Einstein's relativity theory is that, whilst different observers with different inertial frames of reference may estimate differently the spatial and temporal distances between events, they must all be in agreement about the combined *spacetime* distances involved. On the basis

[57] If a different scale for the diagram were preferred, time could be measured instead in days, hours, minutes or seconds with distance being measured, correspondingly, in light days, light hours, light minutes or light seconds.
[58] Brian Cox & Jeff Forshaw (2009) *Why does E=mc²?* Da Capo Press

of the formula $\Delta s^2 = c^2\Delta t^2 + \Delta x^2$, all points at a spacetime distance *S* from the point of origin *O* (the location of the missile launch) will lie on the circle shown in the diagram below. To an observer moving at high speed relative to the Earth (e.g. a space traveller) and thus with a different inertial frame of reference, the point at which the missile's destruction of the space satellite appears to occur may not be point E but must, nevertheless, be located *somewhere* on this circle. The problem is that, whilst some points (e.g. E_1) lie in *O*'s future, others (e.g. E_2) lie in its *past*, in which case the satellite would appear to the observer to be destroyed *before* the missile causing its destruction was launched! Clearly, this contravenes Einstein's basic postulate *that the laws of physics are the same in all inertial frames of reference* (requiring that the observed order of all causally connected events are consistent with a *single* model of causality).



- Counter-intuitive though it may seem, the paradoxical consequence identified above may be avoided if we calculate the spacetime distance between events using a '*negative*' version of Pythagoras' theorem i.e. if, rather than the formula $\Delta s^2 = c^2\Delta t^2 + \Delta x^2$, we use instead the formula $\Delta s^2 = c^2\Delta t^2 - \Delta x^2$. The effect of doing this is shown in the spacetime diagram below. Points equidistant in spacetime from the zero point of the vertical and horizontal axes (the locus of the blue event) are then arrayed not as a circle but as *four parabolas*, a set of which are shown by the dotted red lines.[59] The 45° diagonals (blue lines) indicate the trajectory of anything moving at the speed of light to/from the zero point of the spacetime frame of reference represented by the diagram. From the perspective of that point, events positioned above the horizontal axis lie in the future and events below it in the past. An event occurring at the zero point can have a causal impact upon *future* events only if they are located in the *upper* 'wedge' formed by the 'speed of light' lines and can itself be causally affected by *past* events only if they are located in the corresponding *lower* wedge. If nothing can exceed the speed of light, no causal interaction is possible between an event occurring at the zero point and one located in the *left* or *right* wedges. The two white stars on the diagram are placed similarly to points E_1 and E_2 in the previous diagram i.e. they are examples of locations in spacetime which might appear to an observer moving relative to the Earth (and thus with a different inertial frame of reference) to be the point at which the missile destroys the space satellite (the particular point depending upon the observer's relative velocity). If the observed point lies anywhere on the *upper* parabola, the space satellite's destruction will always appear to happen *after* the missile's launch, making the relationship between the two events consistent with the 'laws' of physics regarding causality. Any point along the parabola, moreover, will satisfy the requirement that the spacetime distance between events should be the same for all observers regardless of differences in their frames of reference. The same satisfaction of requirements applies if an event (e.g. the missile's *installation* at the launch site) upon which the missile's launch is causally dependent and which must therefore *precede* it, is observed to occur at



[59] The particular set shown in the diagram represents the loci of points for which the formula $\Delta s^2 = c^2\Delta t^2 - \Delta x^2$ gives a value of 4.

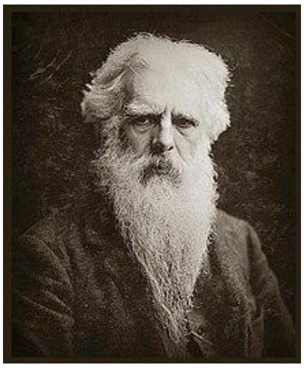
some point on the *lower* parabola. Only where an event causally related to the missile's launch appears to occur at a point on one of the *lateral* parabolas might a paradox arise – as exemplified in the diagram by the star positioned on the right parabola. This represents a situation where, to an observer in motion relative to the Earth, the missile's destruction of the space satellite appears to occur *befor*e the missile's launch. Any *causal* connection between the two events *as so observed*, however, is *ruled out* because the destruction event is identified as located in one of the spacetime zones represented in the diagram by the *lateral* wedges formed by the blue lines. If so located and if nothing originating from either event can exceed the speed of light, neither can causally affect the other, their relationship being 'spacelike' rather than 'timelike'.

- In justifying use of the formula $\Delta s^2 = c^2\Delta t^2 - \Delta x^2$ to calculate the spacetime distance between events, Cox and Forshaw invoke 'Occam's razor' – i.e. the principle that, where alternative explanations are on offer, we should choose the simplest and avoid unnecessary conceptual complexity, especially if it is unsupported by empirical evidence (e.g. invoking 'miracles' to account for what is amenable to more 'down-to-earth' explanation). Just because the formula seems to work when applied to the standard 'Minkowski' spacetime model, however, does not make it an *explanation* of the reality to which that model relates. Even if it does amount to an explanation, it would appear to be not the simplest but the *only* one on offer, use of the standard Pythagorean formula having been ruled out due to its seemingly paradoxical consequences. Within the terms of the spacetime model, moreover, use of the negative version of the formula restricts but does not *eliminate* the circumstances where the observed order of paired events might, depending upon the relative inertial frame of the observer, be inconsistent with causal requirements. Relativity theory, it is important to emphasise (see page 14), does not claim that 'everything is relative' and that all observations are equally valid. It allows for a divergence between *appearance* and *reality* and thus the possibility that appearances from some observational perspectives may present a *false* picture.

Annexe D: Time as a succession of 'stills' (with a note on a Kingston pioneer of motion pictures).

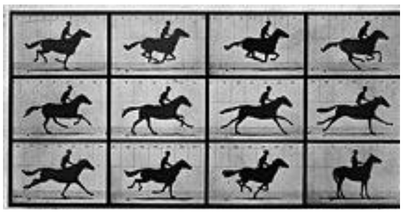
- Physicist Julian Barbour (see page 23) suggests that the impression of time as a dimension comparable to the dimensions of space arises simply from the replacement of one *static* physical configuration by another. A tempting comparison is with the impression of motion produced by the still frames of a traditional movie film. A so-called 'still' photograph, however, does not register a timeless 'instant'. It registers the light received over a period of time, the amount received being determined by a combination of *aperture* and *shutter-speed*. On non-automatic cameras, both of these are consciously chosen by the photographer taking into account lighting conditions, any movement of the subject relative to the camera and the desired effect to be achieved. Shutter speeds available on so-called 'pre-set' cameras generally range from 1/30th to 1/500th of a second, an often used speed being 1/125th of a second. Moving the camera as a picture is taken affects what is shown (e.g. 'panning' in line with a speeding object such as a racing car can keep it in focus, the background appearing blurred).

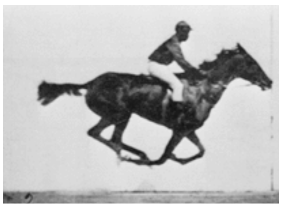
- The son of a coal and grain merchant, Eadweard Muybridge (1830-1904) was born and raised in Kingston upon Thames, adopting as an adult what he considered to be an Anglo-Saxon version of his birth name (Edward Muggeridge). At the age of 20 he emigrated to America and started a career as a bookseller and then as a photographer (focussing in particular upon architectural and landscape subjects). He became best known, however, for his pioneering work in the representation of *motion* by the rapid display of a succession of 'still' images. Experimenting with faster shutter speeds and more sensitive film emulsions, he won fame in the 1870s by identifying for the first time the exact arrangement of a horse's legs when trotting or galloping and at what point, if any, all of its legs were off the ground. He achieved this using a line of cameras triggered by wires as the horse ran along a racetrack. Muybridge's career was interrupted briefly in 1875 when he was tried for the murder of his wife's lover whom he had shot at point-blank range. A plea of insanity was entered on his behalf on the grounds that his temperament and personality had been profoundly affected by a head injury sustained in a stagecoach accident in 1860 which left him in a 9 day coma. The jury did not find him insane but instead acquitted him, deciding that the action (to which he openly confessed) constituted justifiable homicide! The trial is the subject of *The Photographer*, a 1982 opera by Philip Glass. Muybridge resumed his career, writing and lecturing extensively on the subject of his photographic studies and experiments. He returned to England in 1894 and, until his death from prostate cancer in 1904, lived at the Kingston home of a cousin where a plaque now records his contribution to motion photography. For more details of his life and work see: https://en.wikipedia.org/wiki/Eadweard_Muybridge. See also: https://www.youtube.com/watch?v=wNU7sXkZmSw



Muybridge in 1899

No. 30 High Street, Kingston upon Thames, childhood home of Eadweard Muybridge





British Film Institute plaque at Park House, 2 Liverpool Road, Kingston upon Thames where Muybridge died in 1904

Annexe E: Some literary, religious and artistic 'takes' on the subject of time

Horace (65-27BC)
Dum loquimur, fugerit invida aetas: carpe diem, quam minimum credula postero.
Invidious time flies even as we speak. Seize the day. Place your trust in the future as little as you can.
Odes 1.11

Ovid (43BC - AD18?)
Tempus edax rerum.
Time the devourer of all things.
Metamorphoses xv. 234

William Shakespeare (1564-1616)

Tomorrow, and tomorrow, and tomorrow,
Creeps in this petty pace from day to day,
To the last syllable of recorded time;
And all our yesterdays have lighted fools
The way to dusty death. Out, out, brief candle!
Life's but a walking shadow, a poor player
That struts and frets his hour upon the stage,
And then is heard no more; it is a tale
Told by an idiot, full of sound and fury,
Signifying nothing.
Macbeth, v. v. 13

When I have seen by Time's fell hand defac'd
The rich proud cost of outworn buried age;
When sometime lofty towers I see down-ras'd
And brass eternal slave to mortal rage;
When I have seen the hungry ocean gain
Advantage on the kingdom of the shore,
And the firm soil win of the wat'ry main,
Increasing store with loss and loss with store;
When I have seen such interchange of state,
Or state itself confounded to decay;
Ruin hath taught me thus to ruminate,
That Time will come and take my love away.
This thought is as a death, which cannot choose
But weep to have that which it fears to lose.
Sonnet 64

Andrew Marvell (1621-78)
Had we but world enough, and time,
This coyness, Lady, were no crime...
But at my back I always hear
Time's wingèd chariot hurrying near,
And yonder all before us lie
Deserts of vast eternity...
The grave's a fine and private place,
But none I think do there embrace.
To His Coy Mistress

Isaac Watts (1674-1748)
Time, like an ever-rolling stream,
 Bears all its sons away;
They fly forgotten, as a dream
 Dies at the opening day.
Hymn: Our God, our help in ages past...

Alfred Edward Housman (1859-1936)

Loveliest of trees, the cherry now
Is hung with bloom along the bough,
And stands about the woodland ride
Wearing white for Eastertide.

Now, of my threescore years and ten,
Twenty will not come again,
And take from seventy springs a score,
It only leaves me fifty more.

And since to look at things in bloom
Fifty springs are little room,
About the woodlands I will go
To see the cherry hung with snow.
A Shropshire Lad: Poem 2

How clear, how lovely bright,
How beautiful to sight
Those beams of morning play;
How heaven laughs out with glee
Where, like a bird set free,
Up from the eastern sea
Soars the delightful day.

To-day I shall be strong,
No more shall yield to wrong,
 Shall squander life no more;
Days lost, I know not how,
I shall retrieve them now;
Now I shall keep the vow
I never kept before.

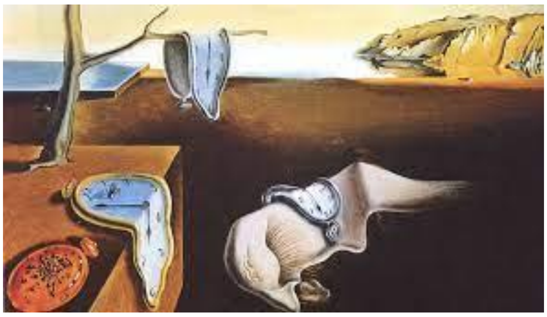
Ensanguining the skies
How heavily it dies
Into the west away;
Past touch and sight and sound
Not further to be found,
How hopeless under ground
Falls the remorseful day.
More Poems: XVI How clear, how lovely bright...

The title of Colin Dexter's final Inspector Morse novel, *The Remorseful Day* (1999), is taken from Housman's poem. In ITV's dramatisation of the novel, Morse (played by John Thaw) recites the poem's last verse as he views the setting sun from an Oxford pub garden whilst contemplating his impending retirement enforced by illness (soon to prove terminal) brought on by excessive alcohol consumption.

Kurt Weil (music); Maxwell Anderson (lyrics)
But it's a long, long while from May to December
And the days grow short when you reach September
And the autumn weather turns the leaves to flame
And I haven't got time for the waiting game...
September Song
from Broadway show *Knickerbocker Holiday* (1938)

Holy Bible: Ecclesiastes 3 *(King James Version)*
1 To every thing there is a season, and a time to every
purpose under the heaven:
2 a time to be born, and a time to die; a time to plant,
and a time to pluck up that which is planted;
3 a time to kill, and a time to heal; a time to break
down, and a time to build up;
4 a time to weep, and a time to laugh; a time to
mourn, and a time to dance;
5 a time to cast away stones, and a time to gather
stones together; a time to embrace, and a time to
refrain from embracing;
6 a time to get, and a time to lose; a time to keep, and
a time to cast away;
7 a time to rend, and a time to sew; a time to keep
silence, and a time to speak;
8 a time to love, and a time to hate; a time of war, and
a time of peace.

T. S. Eliot (1888 - 1965)
Time present and time past
Are both perhaps present in time future,
And time future contained in time past.
If all time is eternally present
All time is unredeemable.
Opening lines of *Burnt Norton* (1936)
(the first of Eliot's *Four Quartets*)



The Persistence of Memory (1931)
by Salvador Dali (1904-89)
(Museum of Modern Art, New York)

The Three Ages of Man (c. 1513) by Titian (c. 1489-1576)
(National Gallery of Scotland, Edinburgh)

Allegory of Prudence (c. 1550-65)
by Titian (c. 1489-1576)
(National Gallery, London)

A barely legible inscription above the heads reads: "EX PRÆTERITO PRÆSENS PRUDENTER AGIT, NI FUTURUM ACTIONE DETURPIT" – "From [experience of] the past, the present acts prudently, lest it spoil future action".

A Dance to the Music of Time (c. 1635)
by Nicolas Poussin (1594-1665)
(Wallace Collection, London)

Annexe F: Progress in nature and in history.

Extracts from E.H. Carr (1961) *What is History?* (The George Macaulay Trevelyan Lectures delivered in the University of Cambridge January-March 1961).

"The thinkers of the Enlightenment adopted two apparently incompatible views. They sought to vindicate man's place in the world of nature: the laws of history were equated with the laws of nature. On the other hand, they believed in progress. But what ground was there for treating nature as progressive, as constantly advancing towards a goal? Hegel met the difficulty by sharply distinguishing history, which was progressive, from nature, which was not. The Darwinian revolution appeared to remove all embarrassments by equating evolution and progress; nature, like history, turned out after all to be progressive. But this opened the way to a much graver misunderstanding, by confusing biological inheritance, which is the source of evolution, with social acquisition, which is the source of progress in history. The distinction is familiar and obvious... Evolution by inheritance has to be measured in millennia or in millions of years; no measurable biological change is known to have occurred in man since the beginning of written history. Progress by acquisition can be measured in generations. The essence of man as a rational being is that he develops his potential capacities by accumulating the experience of past generations. Modern man is said to have no larger a brain and no greater innate capacity of thought, than his ancestor 5,000 years ago. But the effectiveness of his thinking has been multiplied many times by learning and incorporating in his experience the experience of intervening generations. The transmission of acquired characteristics, which is rejected by biologists, is the very foundation of social progress. History is progress through the transmission of acquired skills from one generation to another.

It is a presupposition of history that man is capable of profiting (not that he necessarily profits) by the experience of his predecessors, and that progress in history, unlike evolution in nature, rests on the transmission of acquired assets. These assets include both material possessions and the capacity to master, transform, and utilise one's environment. Indeed, the two factors are closely inter-connected, and react on one another. Marx treats human labour as the foundation of the whole edifice; and this formula seems acceptable if a sufficiently broad sense is attached to 'labour'. But the mere accumulation of resources will not avail unless it brings with it not only increased technical and social knowledge and experience, but increased mastery of man's environment in a broader sense. At the present time, few people would, I think, question the fact of progress in the accumulation both of material resources and of scientific knowledge, of mastery over the environment in the technological sense. What is questioned is whether there has been in the twentieth century any progress in our ordering of society, in our mastery of the social environment, national or international, whether indeed there has not been a marked regression. Has not the evolution of man as a social being lagged fatally behind the progress of technology?

History begins when men begin to think of the passage of time in terms not of natural processes – the cycle of seasons, the human life-span – but of a series of specific events in which men are consciously involved and which they can consciously influence... History is the long struggle of man, by the exercise of his reason, to understand his environment and to act upon it. But the modern period has broadened the struggle in a revolutionary way. Man now seeks to understand, and to act on, not only his environment but himself; and this has added, so to speak, a new dimension to reason, and a new dimension to history. The present age is the most historically-minded of all ages. Modern man is to an unprecedented degree self-conscious and therefore conscious of history. He peers eagerly back into the twilight out of which he has come, in the hope that its faint beam will illuminate the obscurity into which he is going; and, conversely, his aspirations and anxieties about the path that lies ahead quicken his insights into what lies behind. Past, present and future are linked together in an endless chain of history".

Annexe G: New Year thoughts (circulated to KPC members in January 2021)

- Now and again we are intrigued by occurrences which are wholly *random* but which appear, at first sight, to be unusual and even significant. An obvious example is when a supermarket bill comes to an exact number of pounds. The reality, of course, is that there is no more reason to be surprised at a total of, say, £60.00 than one of, say, £60.43. One is neither more nor less probable than the other.

- We may be spuriously impressed not only by purely random occurrences but also by features of our own mental constructs. An example is the standard 'positional' number system we learn from infancy and which is based upon counting in *tens*. If humans had a thumb and *three* fingers on each hand, we would probably employ an *octal* (base 8) rather than a decimal (base 10) system. If we had a thumb and *five* fingers on each hand, we would probably employ a *duodecimal* (base 12) system.[60] Completed *decades* of life appear significant only because, in a decimal system, they end in 'noughts'. In an octal system, for example, no special significance would be attached to them. Reaching a *decimal* age of 60 is the same as reaching an *octal* age of 74. A seemingly unremarkable *decimal* 64, on the other hand, would appear an 'impressive' *octal* 100. With an octal system, we would doubtless attach particular significance to completing successive *eight* years of life, perhaps calling them '*octades*', with eight octades making an '*octury*'. Whatever the system, of course, any impression that certain numbers have special significance just because of how they appear when we notate them, is entirely illusory. Particular significance *does* attach to some numbers (such as *prime* numbers) but this has nothing to do with how they might appear when notated.

- The Millennium celebrations back in 2000 evidenced the semi-mystical quality which humans are capable of attaching to arbitrary round numbers produced by particular positional number systems. How much fuss would have been made if our standard number system at the time were octal, duodecimal or binary and the year was, respectively, *octal* 3720, *duodecimal* 11A8 (see footnote[60]) or *binary* 11111010000? An issue at the time was when to start celebrating. In the AD (Anno Domini) year numbering system (devised in 525 but not widely used until after 800)[61], the year starting with the supposed date of Christ's birth is designated year 1, not year zero. Some argued, therefore, that to start celebrating on 1 January 2020 would be premature as not until the *end* of that year would a span of 2000 years be *completed*.

- In the recording of our ages, unlike the numbering of years, we *do* have a year zero. We are age 0 from the date of our birth until we complete our first orbit of the Sun. Only *then*, on our first birthday, do we become one year old. Thus, although currently on my 75th orbit of the Sun, I will remain 74 until I complete it. If and when I do, I will have travelled (if my arithmetic is correct) about 44 billion space miles – in spite of having never flown in a plane. Apart from travelling around the Sun, of course, we are moving relative to other parts of the Milky Way galaxy and, with *it*, relative to other galaxies. As an aside, it seems that an increasing proportion of the world's scarce resources are likely to be devoted in the future to enabling a rich and privileged minority to engage in space tourism. The thought occurs that all of us are *already* space tourists. We may not notice that we are moving or be able to choose where we are going, but at least the ride is free and non-polluting!

[60] In terms of mathematical manipulation, twelve has more to offer than ten. It is divisible without remainder by 2, 3, 4 and 6 whereas ten is divisible only by 2 and 5 (*all* numbers, of course, are divisible by 1 and themselves). A duodecimal system obviously needs symbols for ten and eleven. X and Ɛ are widely used, as are the letters A and B (handy because easily accessed on standard keyboards). For example, if A is used to denote ten and B eleven, the *decimal* numbers 70 and 1,000 are notated, respectively, as *duodecimal* 5A [i.e. in *decimal*: (5 x 12) + 10] and *duodecimal* 6B4 [i.e. in *decimal*: (6 x 144) + (11 x 12) + 4].

[61] Other calendars are, as they say, available. In the *luna*r Hijri (Arabic) and *solar* Hijri (Persian) calendars (year 1 for both starting during 622AD and the former having 354/355 days in a year), the nearest equivalent to 2000AD (start months being different) are respectively 1420 and 1379.

- Time is meaningful and measurable only in terms of the (assumed) regular and unchanging occurrence of something observable. The orbit of the Earth around the Sun provides an obvious (although not perfect) basis for dividing up the 'passage of time'.[62] Less obvious, is the point in the orbit at which the units involved (i.e. years) should be deemed to start. Given the tilt of the Earth's axis, four physically meaningful points suggest themselves i.e. the winter/summer solstices and the spring/autumn equinoxes. The first day of our modern calendar (1 January), is *near*, but does not *coincide* with, the day (usually 21 or 22 December) which has the *shortest* period of daylight in the northern hemisphere (its *winter* solstice) and the *longest* period of daylight in the southern hemisphere (its *summer* solstice). Arguably, however, it does not matter if the chosen date is arbitrary as long as it is *fixed* and *clear*. Given the arbitrariness involved, it is strange that so many people should attribute to the date a semi-mystical quality making it worthy of celebration. That they continue to do so in spite, year after year, of waking up on New Year's Day only to find everything much the same as before, evidences the triumph of hope over experience and the capacity of humans to be seduced by superstitious nonsense. The seductive power of something as run-of-the-mill as a change in year number is less understandable than that of physically observable events such as the summer and winter solstices – and yet those who gather at Stonehenge each year to observe them, or who take note of them at all, can be numbered in their thousands compared to the millions who celebrate the New Year with almost religious zeal.

- During one orbit of the Sun (i.e. a solar year), the Earth spins, with respect to the Sun, about 365.2422 times. If the calendar year is not to get out of step with the solar year, therefore, standard years of 365 days have to be interspersed periodically with leap years of 366 days. In the Julian Calendar (traceable back to a decree by Julius Caesar, hence its name) the rule observed was that three standard years should be followed by a leap year, giving an *average* year length of 365.25 days. This was insufficiently accurate to prevent significant long-term drift of calendar years against true solar years. To remedy this, the Gregorian Calendar (decreed by Pope Gregory XIII, hence its name) was adopted in 1582 by Catholic countries such France, Spain, Portugal and Italy. Under it, every year exactly divisible by four is a leap year unless it is also exactly divisible by 100, an exception being that centurial years exactly divisible by 400 *are* leap years (thus, for example, 1600 and 2000 are leap years but 1700, 1800 and 1900 are not). The result is an average year length of 365.2425 days. To eliminate the drift which had already occurred by 1582, the start date of the new calendar was designated as Friday 15 October, following on immediately from Thursday 4 October of the old calendar.

- Protestant countries were slow to adopt the Gregorian Calendar. England eventually did so in 1752 with Thursday 14 September of the new calendar following on immediately from Wednesday 2 September of the old – sparking riots and the cry of "Give us back our 11 days!" Also, the start of England's civil/legal year was changed to 1 January, having (since 1155) been 25 March (Lady Day), making 1752 a 'short' year. The countries which adopted the Gregorian Calendar in 1582 already counted 1 January as the start of the year. From 1582 to 1752, therefore, England differed from them not only with respect to the *day of the month* but also, for some dates, the *year*. Thus, for example, the date of the execution of Charles I was recorded in England as *30 January 1648* but in continental Europe as *9 February 1649*. Where such differences arise, the practice amongst historians is to give the

[62] Traditionally, so-called Universal Time (UT) was measured by the period of the earth's rotation on its axis. Recognition that this is subject to short-term variation and long-term slowing down led to the adoption in 1952 of the 'ephemeris' second based on the period of earth's orbit around the sun. Since 1968 this has been replaced in the International System of Units (SI) by a second defined as a duration of 9,192,631,770 cycles of radiation corresponding to the transition between two energy levels of the caesium-133 atom (the number of cycles being chosen so that the 'new' second, when introduced, had the same duration as that of the ephemeris second). Non-caesium atomic clocks (e.g. so-called 'quantum logic' and 'optical lattice' clocks) are now being developed that promise even higher levels of accuracy (the holy grail being some measure of *assumed unchanging regularity* that is wholly unaffected by extraneous forces such as gravity).

day/month as recorded in the country where the relevant event occurred but the *year* as recorded in the *Gregorian* Calendar. One historian, for example, describes the trial[63] and execution of Charles I as follows: "When the trial opened in Westminster Hall on 20 January 1649, King Charles refused to plead as he would not recognise the jurisdiction of the Court... On 27 January he was sentenced to die... On Tuesday 30 January, with the winter sun gleaming on him, King Charles I stepped out through a middle window of the Whitehall Banqueting Hall on to the scaffold and... laid his head on the low block. At four minutes past two the blow was struck."[64] The difference until 1752 between the calendars of England and continental Europe explains how William of Orange – without being a time-traveller – was able to set sail from the Netherlands on *11* November 1688 and arrive in England on *5* November in order, with his wife Mary, to depose his father-in-law James II in England's 'Glorious Revolution'.

- The mental brackets we put around, and the labels we attach to, the objects of our fleeting cognitive experiences are aspects of our *intentionality* i.e. the '*aboutness*' of our mental states/processes.[65] Crucially, many of such objects comprise *our own mental constructs*. We inhabit a social/institutional world featuring things such as governments, laws, ownership, marriage, money and organised religions – sometimes attributing semi-mystical qualities to individuals associated with them (e.g. to monarchs and to popes). The maintenance of such features within any human group requires significant commonality in the mental outlook of its members. Such commonality, however, is only partial and battles of ideas/interests may lead to the alteration/replacement of our social/institutional constructs in ways which may be peaceful or violent, evolutionary or revolutionary – examples of the latter being the English Civil War or Great Rebellion of 1642-51 and the Glorious Revolution of 1688. We now have the spectacle of a US President both inciting and condoning a violent attack upon the very democratic institutions he was elected to protect. It remains to be seen whether/how he and his co-conspirators will be sanctioned for an act of treason not too different, in principle at least, from that for which Charles I lost his head back in Gregorian 1649.

Roger Jennings
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[63] The king was accused of *treason* against England by using his powers in pursuit of his own personal interests rather than the good of the country.
[64] Maurice Ashley, *England in the Seventeenth Century* (Book 6 of Pelican History of England), 1967 (4th edition), Penguin Books.
[65] Only by drawing spatial/temporal/quantitative/qualitative 'boundaries' do we achieve the individuation/unitisation required if we are to *count* anything – whether it be electrons, atoms, stars, galaxies, hills, mountains, streams, rivers, towns, cities, pints of beer, pairs of socks, words, syllables, bars of music, votes, money, runs in cricket matches, years, days, hours, or whatever.