Time

"What, then, is time? If no one ask of me, I know; if I wish to explain to him who asks, I know not."

(Augustine, *Confessions*, Book XI, Chap. XIV.)

Puzzles about Time

1. Time seems to “flow”, or “pass”. But does it? What would this even *mean*, anyway?
2. The flow of time seems to involve “becoming”, or coming into existence. What’s that all about?
3. Are past and future events real? Or is only the present real? (Or only the past and present?)
4. In what ways is time like a spatial dimension? (In what ways is time different from space?)
5. What is the “arrow of time”?
6. Does an object have “temporal parts”? Or is the whole object always present?
7. Is time travel at least theoretically possible?

Time in physical theories

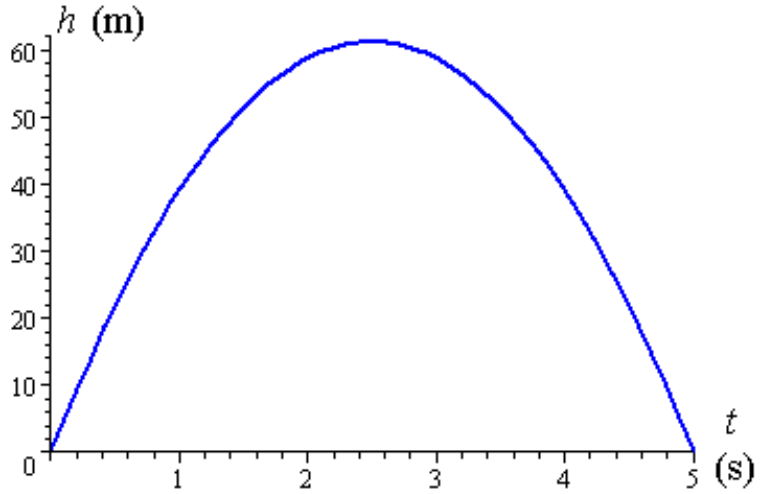
- Physicists have little or no interest in most of these questions, even though physics has a lot to say about time.
  - (With a few exceptions, e.g. Arthur Eddington)
- The current theory of time in physics is the *theory of relativity*. This theory treats time as a dimension, somewhat like the three spatial dimensions.
- Each event has a set of space-time coordinates (x, y, z, t), and a physical process (e.g. a moving particle) is seen as a spacetime 'worm'.

What physicists think

1. Time seems to “flow”, or “pass”. But does it? What would this even *mean*, anyway? Blah blah
2. The flow of time seems to involve “becoming”, or coming into existence. What’s that all about? Blah blah
3. Are past and future events real? Or is only the present real? They’re all real, just like events elsewhere
4. In what ways is time like a spatial dimension? (In what ways is time different from space?) Different in some details …
5. What is the “arrow of time”? Good question. We’re working on it.
6. Does an object have “temporal parts”? Or is the whole object always present? Of course it has temporal parts. The rest is blah blah.
7. Is time travel at least theoretically possible? Maybe

The flow of time in physics

- There is no *flow* of time in any physical theory. Physics describes a physical process as a four-dimensional object, with time being one of the three dimensions.
  - E.g. the height of an arrow, shot vertically into the air, is represented as:



How *fast* would time flow?

- As Van Inwagen notes, if time flows, then it should make sense to ask how *fast* it flows.
- But there seems to be no meaningful way to measure this.
- Rates are always measured *with respect to time*
  - 15 Gallons per minute
  - 82 Kilometres per hour
  - 25 Cigarettes per day
  - 1 second per second?

Causation in physics?

- Since there is no flow of time in the physical (mathematical) description, it's tempting to say that the flow of time isn't real.
- But remember that there's nothing in the equations of motion to show that the earlier parts of the motion cause the later parts.
- And it seems unlikely that causation is an illusion.
  - There are real 'arrow of time' phenomena that physicists struggle to explain. E.g. the 'mark transmission' time asymmetry.

The idea of existence in physics

"Even if there is only one possible unified theory, it is just a set of rules and equations. **What is it that breathes fire into the equations and makes a universe for them to describe?**... Why does the universe go to all the bother of existing? Is the unified theory so compelling that it brings about its own existence? Or does it need a creator, and, if so does he have any other effect on the universe? And who created him?

(Stephen Hawking, *A Brief History of Time*, p. 192)

"Once Einstein said that the problem of the Now worried him seriously. He explained that the experience of the Now means something special for man, something essentially different from the past and the future, but that this important difference does not and cannot occur within physics. …

pp. 37-38 of Carnap, R. (1963), "Carnap's Intellectual Biography" in *The Philosophy of Rudolf Carnap,* P. A. Schilpp (ed.), pp. 3-84. La Salle, IL: Open Court.

Carnap replies

"I remarked that all that occurs objectively can be described in science; on the one hand the temporal sequence of events is described in physics; and, on the other hand, the peculiarities of man's experiences with respect to time, including his different attitude towards past, present, and future, can be described and (in principle) explained in psychology.

But Einstein thought that these scientific descriptions cannot possibly satisfy our human needs; that there is something essential about the Now which is just outside the realm of science."

The A-series and B-series

- McTaggart's paper "The Unreality of Time" is famous for introducing the terms *A-series* and *B-series*.
- After McTaggart, philosophers still talk of the 'A properties' of time, and the 'B relations'.
- Also, one important debate among philosophers studying time is between the 'A theory' and the 'B theory'.

The ‘A’ Properties

- The so-called ‘A Properties’ of events are the properties of *being past*, *being present*, and *being future*.
- E.g. the Battle of Hastings (1066) has the property of being in the *past*. Justin Trudeau’s being PM of Canada is *present*.
- Of course these A properties are always changing! The Battle of Hastings, for example, was a future event at one time. Then it became present, and now it is past.

The B relations

- The B-relations are the relations of *earlier than* and *later than* between events.
  - (Of course we need only one of these relations.)

- Unlike the A properties, the B-relations *do* appear in the physical description.
- The B-relations do not change. The Battle of Hastings is before the Battle of Trafalgar, plain and simple.

McTaggart's Argument

1. The A-properties are essential to time. (I.e. there can be no time unless it has a dynamic element.)
2. The A-properties are absurd and contradictory

$\therefore$ Time is not real

(See the *Stanford Encylopedia of Philosophy*, entry "Being and Becoming in Modern Physics", by Steven Savitt.)

- Why is the A-series contradictory?

(A_1) Every event must have many, if not all, the A-properties

(A_2) since the A-properties are mutually exclusive, no event can have more than one of them.

(See the *Stanford Encylopedia of Philosophy*, entry "Being and Becoming in Modern Physics", by Steven Savitt.)

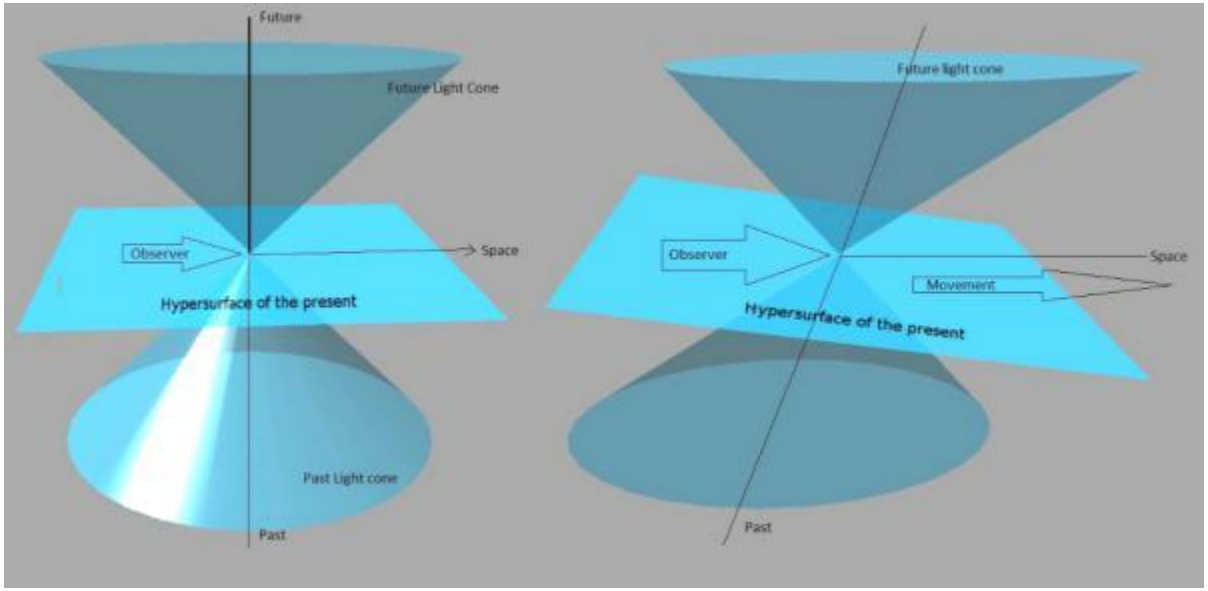
- Is the A-series idea *really* contradictory?

  "I felt from the first, and still feel, that the difficulty which arises is (a) embarrassing enough prima facie to demand the serious attention of anyone who philosophises about time, and (b) almost certainly due to some purely linguistic source (common, and perhaps peculiar, to the Indo-European verb-system), which it ought to be possible to indicate and make harmless"

  (Broad, C. D. 1959. "A Reply to My Critics", p. 765)

Special relativity and “the present”

- Special relativity doesn’t have a “present”, in the sense of a 3D space of objectively simultaneous events.



There is no objective simultaneity between events as seen by observers moving at different velocities.

The B-theory

- The “B theory” of time is the view that the B-relations (*earlier than*) provide a complete account of time.

- The A properties (*being over*, *going on right now*, *not happened yet*) are only real in so far as they can be defined in terms of (or ‘reduced to’) the B properties.

- E.g. Bertrand Russell takes this view.

The B-theory

- How could such a reduction be carried out?
- For example, how could ‘now’, or ‘the present’, be defined in a 4D block universe?

“The most popular version of this view holds that *now* is a token-reflexive or indexical term, like *here* ... Physics is not felt to be incomplete because it fails to treat *hereness*. Why should its indifference to *nowness* be of any greater concern?”

(SEP again)

- In a similar way, ‘past’ and ‘future’ are treated as relations to the speaker’s temporal location, by analogy with ‘north’ and ‘south’.

- E.g. speaking in Vancouver, one says that Whistler is “to the north”. But speaking in Smithers, one says that Whistler is “to the south”.

Part 2

"Something must be added to the geometrical conceptions comprised in Minkowski's world before it becomes a complete picture of the world as we know it."

(Arthur Eddington)

What must be added to physics?

- The arrow(s) of time
  - This is definitely real. It has clear empirical effects. But it's mysterious.
- The flow of time
  - But maybe this is psychological, i.e. part of appearance rather than reality?
- I suggest that we should tackle the arrow of time first. If can solve that, it might shed some light on the flow of time.

The ‘arrows’ of time

- The ‘arrows’ of time are temporal asymmetries in physics, i.e. physical processes that never “go backwards”. E.g.
  - The thermodynamic arrow: entropy never decreases
  - The radiation arrow: waves spread from point sources, but don’t converge to point sinks.
  - Mark transmission: paper is marked after the pen touches it (never before).
  - Memories only exist after the events concerned

The Causal Arrow and Diffusion

- Diffusion of (e.g.) gas molecules can be adequately modelled by assuming that each molecule is a Newtonian “billiard ball” with perfectly elastic collisions.
  - The dynamics of such a system are fully time symmetric. How then does diffusion only go one way?

The Second Law

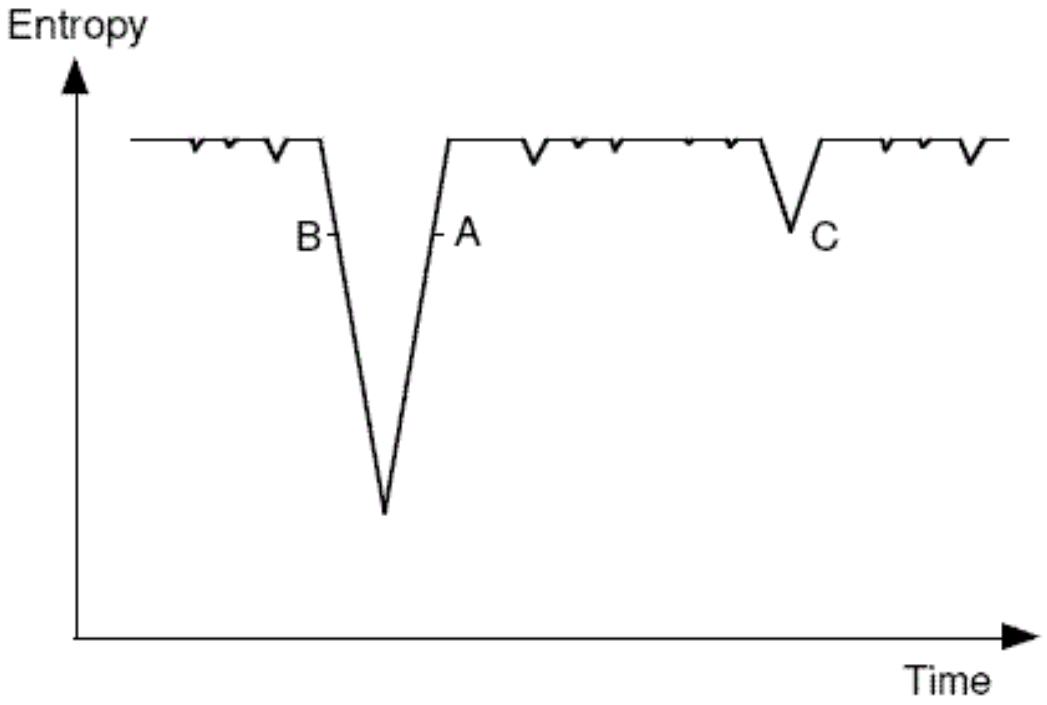
- The Second Law of Thermodynamics says, among other things, that diffusion will only go one way.
  - E.g. you can stir cream into coffee, but you can't stir it out again.

"If your theory is found to be against the second law of thermodynamics I can give you no hope; there is nothing for it but to collapse in deepest humiliation"

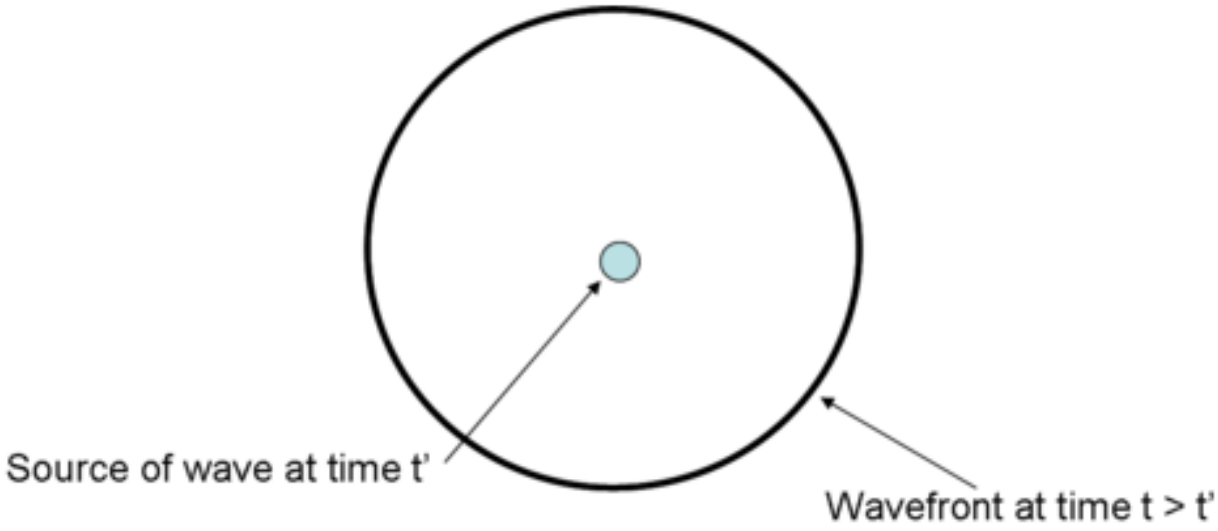
(Physicist Arthur Eddington)

Fluctuations from equilibrium

- In the short term, diffusion will occur until the system reaches equilibrium (maximum entropy). Then the system *stays* at equilibrium.
- But in the (very) long term, there will be small and even large fluctuations from equilibrium. (The Second Law isn't *strictly* true.)



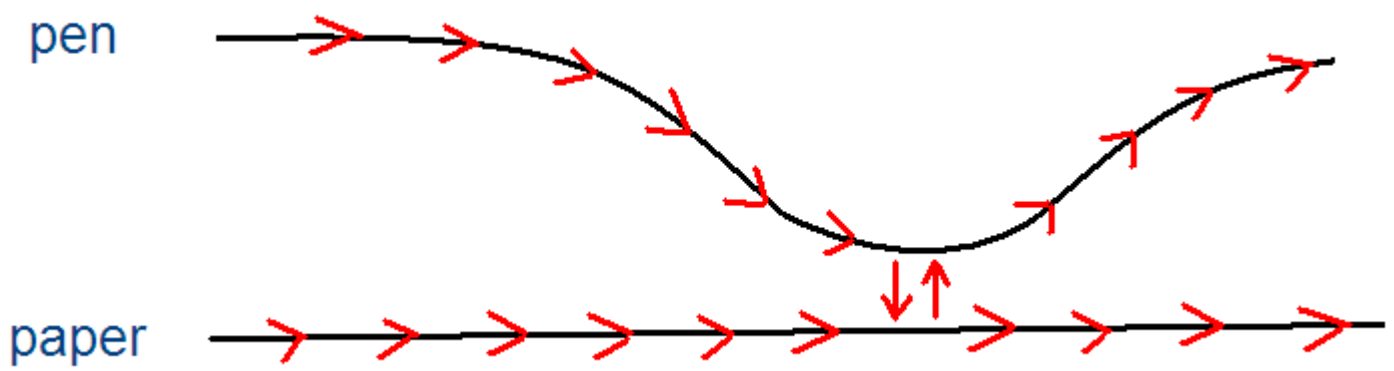
The Radiation Arrow



Why do ‘advanced’ solutions to Maxwell’s electromagnetic wave equation never exist in reality?

Mark Transmission

- If you touch your pen tip to a sheet of paper, then the paper is marked only *after* the pen is in contact with it. Why is that?



Standard Explanation: The "Past Hypothesis"

"The observed macroscopic irreversibility is not a consequence of the fundamental laws of physics, it's a consequence of the particular *configuration* in which the universe **finds itself**. In particular, **the unusual low-entropy conditions in the very early universe, near the Big Bang**. Understanding the arrow of time is a matter of understanding the origin of the universe."

- Sean M. Carroll, cosmologist at Cal Tech, http://preposterousuniverse.com/eternitytohere/faq.html

- While matters are by no means universally agreed upon, the most plausible view at the present time seems to be that in order to get a reasonable picture of the entropic increase accompanying expansion of our current phase of (at least the 'local') universe, **we must impose a low entropy initial condition on the big-bang singularity**.
  - Sklar (1986) "The elusive object of desire: In pursuit of the kinetic equations and the second law." *PSA Proceedings 2,* 209-55.

- [W]e are led more or less inevitably to cosmological considerations of an initial 'state of the universe' having a very small Boltzmann entropy. That is, **the universe is pictured to be born in an initial macrostate M_0 for which [the phase space volume] is a very small fraction of the 'total available' phase space volume.**
  - Lebowitz (1993) "Boltzmann's entropy and time's arrow." *Physics Today,* September, p. 36

The “Past Hypothesis”

Questions:

- *Why* does the initial state of the universe have very low entropy?
  - Did it get there *by itself*, or as the result of an *external constraint*?
- With this explanation of the Second Law, are we *assuming* a causal arrow as well, or trying to *reduce* the causal arrow?
- Will this explain the other arrows of time, e.g. mark transmission?

Why does the initial state of the universe have very low entropy?

- N.B. Carroll says that the early universe *"finds itself"* in a low-entropy state.
- Sklar says that "*we* must *impose*" a low entropy initial condition on the big-bang singularity.
- Lebowitz says that the universe is pictured *"to be born"* in a low-entropy state.

Why does the initial state of the universe have very low entropy?

- To calculate what a physical system actually does, you always need:
  - the equations of motion
  - The state at one instant of time

- For a deterministic system, e.g. the solar system, *any instant of time will do*.
  - In general, such an 'initial condition' is one that the system evolved to by itself.

Why does the initial state of the universe have very low entropy?

- Suppose that the laws of physics *cause* a system to behave as it does.
  - They seem to be only part of cause, as they allow many different histories (even for determininstic laws).

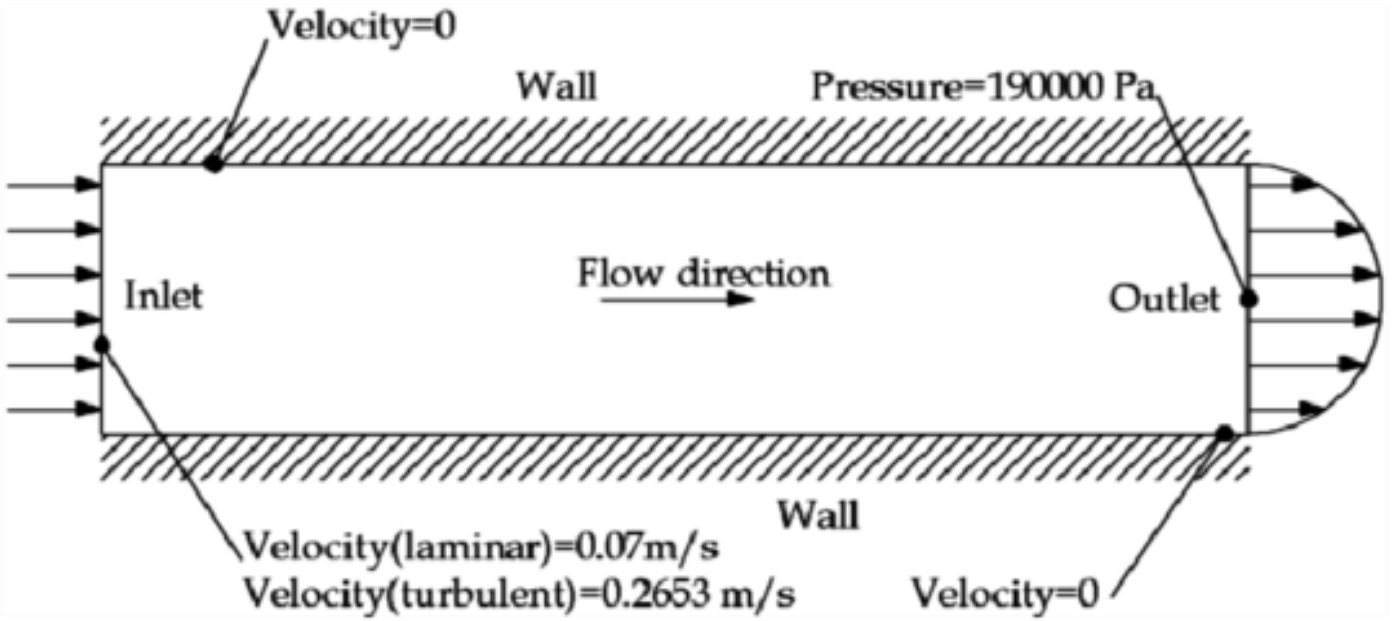
- What else helps to cause the actual history?
  - A random selection?
  - A *real* boundary condition?

A *real* boundary condition?

- What could a ‘real’ boundary condition be?
- How could it help to cause the actual history?

- N.B. If a boundary condition is just *knowledge*, i.e. something “we impose” on the equations, it surely cannot *explain* any physical behaviour (other than human behaviour).
- So a ‘real’ boundary condition, that helped to cause the actual history would have to be some kind of physical constraint imposed from outside the system.

E.g. in fluid flow



God picking out the low-entropy initial conditions of our universe.

From Roger Penrose, *The Emperor's New Mind* (1989)

Random history, or real boundary condition?

- In the “Arrows of Time” reading, I explained that a real boundary condition on a deterministic system doesn’t create an arrow of time
  - So let’s focus on indeterministic systems

- Let’s compare what happens with a randomly-selected history, vs. a real boundary condition.
  - If the history is selected at random, then no arrow of time is created.
  - A real boundary condition creates an arrow pointing away from the time it’s imposed.

Causation = the spread of being?

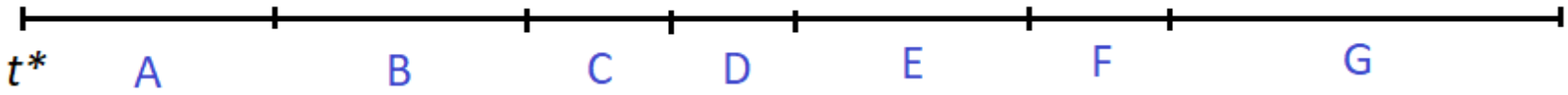
- I mentioned this idea in last week's lecture.
- Let's explore this idea, to see if such a causal arrow (invisible to physics) can explain the arrows of time.

- How fast does concretising happen?
  - It's not a process *in* time, so it doesn't have a speed.
  - It's more like a stack of books, in which each book supports the next one above it.
  - If God has his own timeline, then *he* might see concreteness spreading through spacetime.

Causation = the spread of being?

- As argued in the "Arrows of Time" reading, a real boundary condition, at the Big Bang, would explain *all* the arrows of time.
- The basic idea is that we can divide the whole time interval (in which the cosmos exists) into chunks, or "time slices".
- The chunks don't interact with each other at all, unless they overlap in time.

Causation = the spread of being?



- Starting at the boundary condition, each time slice gives existence to its neighbour.

The Causal Arrow and Consciousness

- What would it be like to live, as a conscious being, in a world with a causal arrow?
  - A conscious thought is a concrete (real) event, so each thought would occur at a moment of the real history.
  - Memories are marks, so we could only remember past (causally deeper) events.
  - Each thought would seem, from its own perspective, to be at the point where abstract possibilities become concretely real?
  - Would there seem to be a “flow” of time?

The Causal Arrow and Time Travel

- In the world we've been exploring, with a primitive causal arrow, would time travel (and backward causation) be possible?

No.

The history at earlier times is independent of what happens later.