

Gödel's Time-Travel Theorem

and an “insoluble problem” arising therefrom

Selmer Bringsjord

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Context ...

Gödel's Great Theorems (OUP)

by Selmer Bringsjord

- Introduction (“The Wager”)
- Brief Preliminaries (e.g. the propositional calculus & FOL)
- The Completeness Theorem
- The First Incompleteness Theorem
- The Second Incompleteness Theorem
- The Speedup Theorem
- The Continuum-Hypothesis Theorem
- The Time-Travel Theorem
- Gödel’s “God Theorem”
- Could a Finite Machine Match Gödel’s Greatness?



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Hilbert's problems

From Wikipedia, the free encyclopedia

Hilbert's problems are twenty-three problems in [mathematics](#) published by German mathematician [David Hilbert](#) in 1900. The problems were all unsolved at the time, and several of them were very influential for 20th-century mathematics. Hilbert presented ten of the problems (1, 2, 6, 7, 8, 13, 16, 19, 21, and 22) at the [Paris](#) conference of the [International Congress of Mathematicians](#), speaking on August 8 in the [Sorbonne](#). The complete list of 23 problems was published later, most notably in English translation in 1902 by [Mary Frances Winston Newson](#) in the *[Bulletin of the American Mathematical Society](#)*.^[1]

Contents [\[hide\]](#)

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David Hilbert



Earlier:

Gödel as logician/mathematician; Gödel as prophet.

Table of problems [\[edit \]](#)

Hilbert's twenty-three problems are (for details on the solutions and references, see the detailed articles that are linked to in the first column):

Problem ↕	Brief explanation	Status ↕	Year Solved ↕
1st	The continuum hypothesis (that is, there is no set whose cardinality is strictly between that of the integers and that of the real numbers)	Proven to be impossible to prove or disprove within Zermelo–Fraenkel set theory with or without the Axiom of Choice (provided Zermelo–Fraenkel set theory is consistent , i.e., it does not contain a contradiction). There is no consensus on whether this is a solution to the problem.	1940, 1963
2nd	Prove that the axioms of arithmetic are consistent .	There is no consensus on whether results of Gödel and Gentzen give a solution to the problem as stated by Hilbert. Gödel's second incompleteness theorem , proved in 1931, shows that no proof of its consistency can be carried out within arithmetic itself. Gentzen proved in 1936 that the consistency of arithmetic follows from the well-foundedness of the ordinal ϵ_0 .	1931, 1936
3rd	Given any two polyhedra of equal volume, is it always possible to cut the first into finitely many polyhedral pieces that can be reassembled to yield the second?	Resolved. Result: No, proved using Dehn invariants .	1900
4th	Construct all metrics where lines are geodesics .	Too vague to be stated resolved or not. ^[h]	—
5th	Are continuous groups automatically differential groups ?	Resolved by Andrew Gleason , assuming one interpretation of the original statement. If, however, it is understood as an equivalent of the Hilbert–Smith conjecture , it is still unsolved.	1953?
6th	Mathematical treatment of the axioms of physics (a) axiomatic treatment of probability with limit theorems for foundation of statistical physics (b) the rigorous theory of limiting processes "which lead from the atomistic view to the laws of motion of continua"	Partially resolved depending on how the original statement is interpreted. ^[9] Items (a) and (b) were two specific problems given by Hilbert in a later explanation. ^[1] Kolmogorov's axiomatics (1933) is now accepted as standard. There is some success on the way from the "atomistic view to the laws of motion of continua." ^[10]	1933– 2002?
7th	Is a^b transcendental , for algebraic $a \neq 0,1$ and irrational algebraic b ?	Resolved. Result: Yes, illustrated by Gelfond's theorem or the Gelfond–Schneider theorem .	1934

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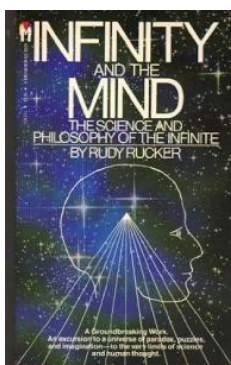
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Grandfather Paradox . . .

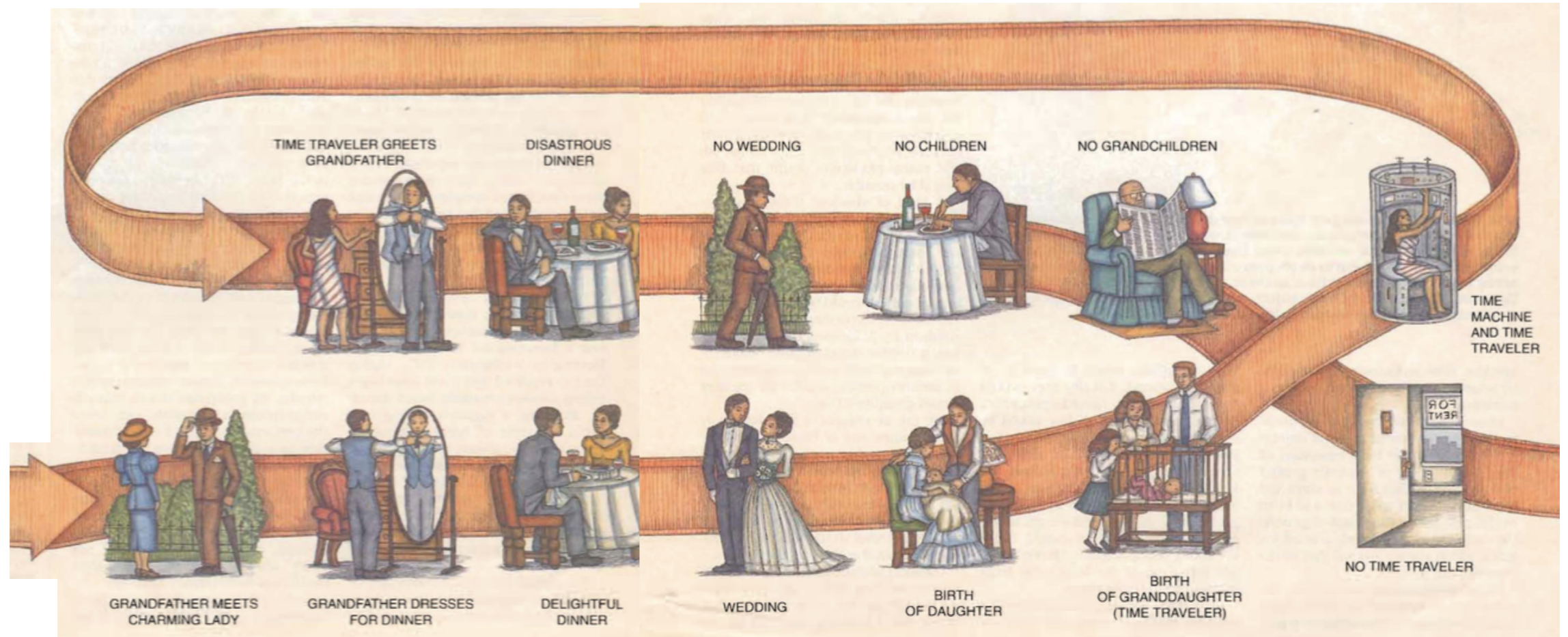
“This state of affairs seems to imply an absurdity. For it enables one e.g., to travel into the near past of those places where he has himself lived. There he would find a person who would be himself at some earlier period of his life. Now he could do something to this person which, by his memory, he knows has not happened to him.”

–Kurt Gödel

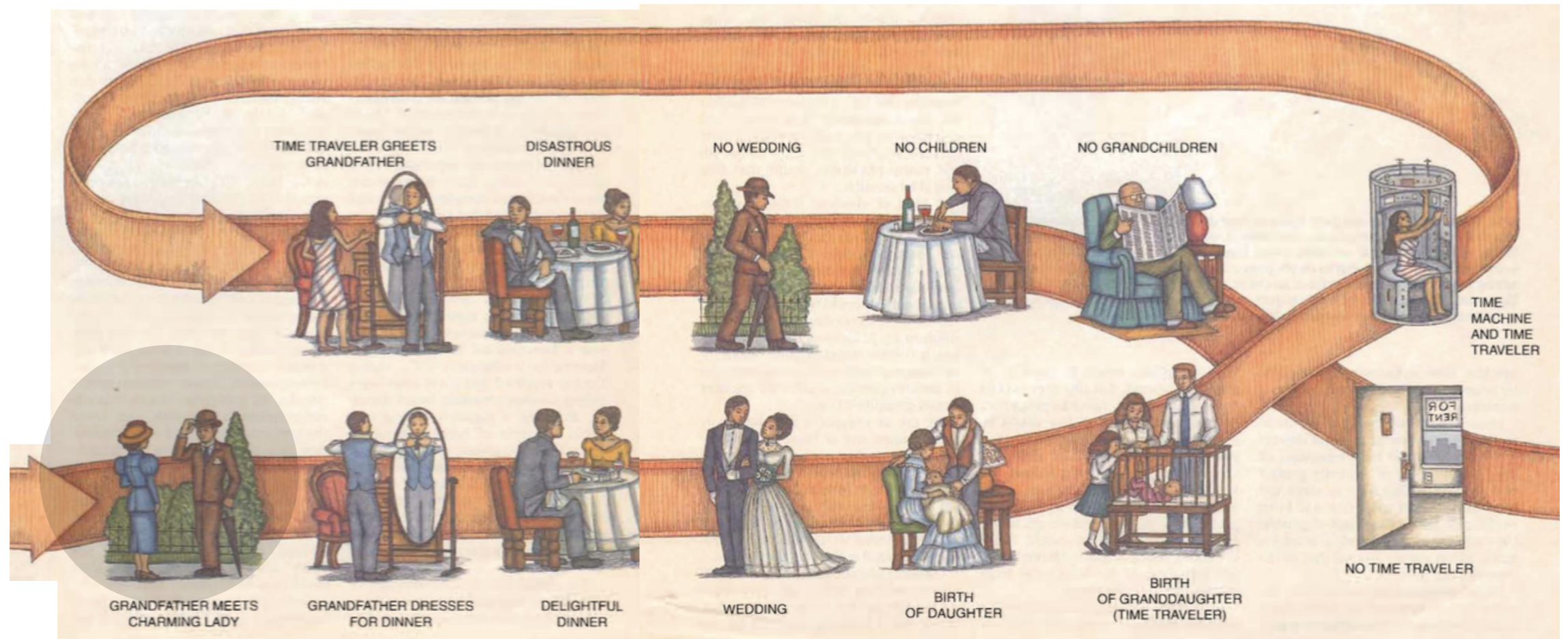


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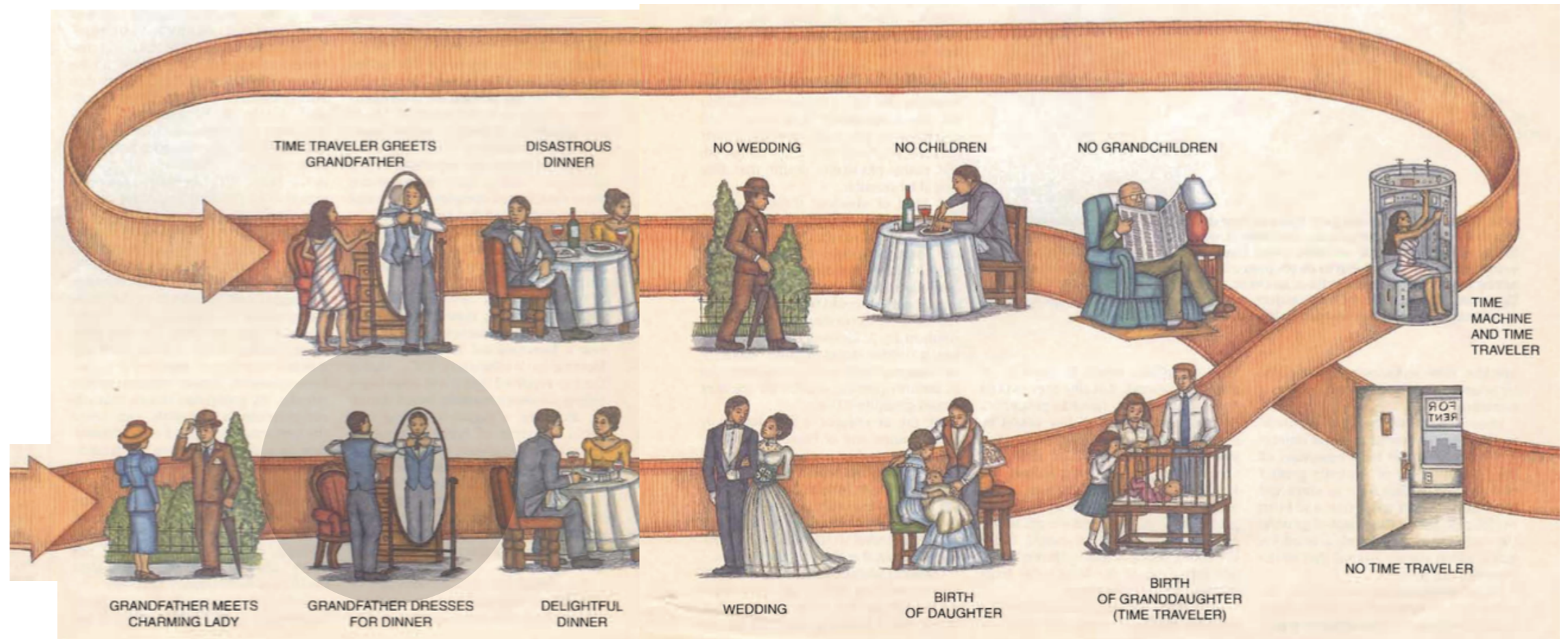
Story for The Grandfather Paradox



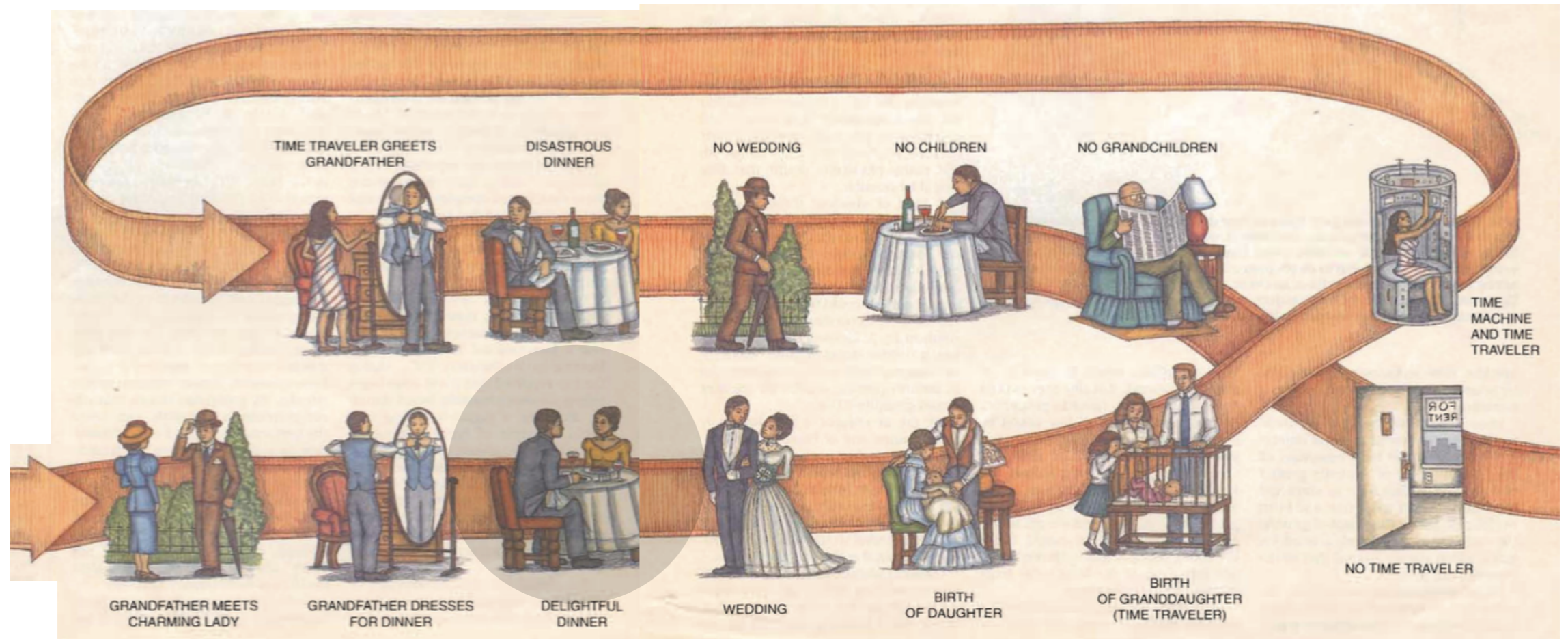
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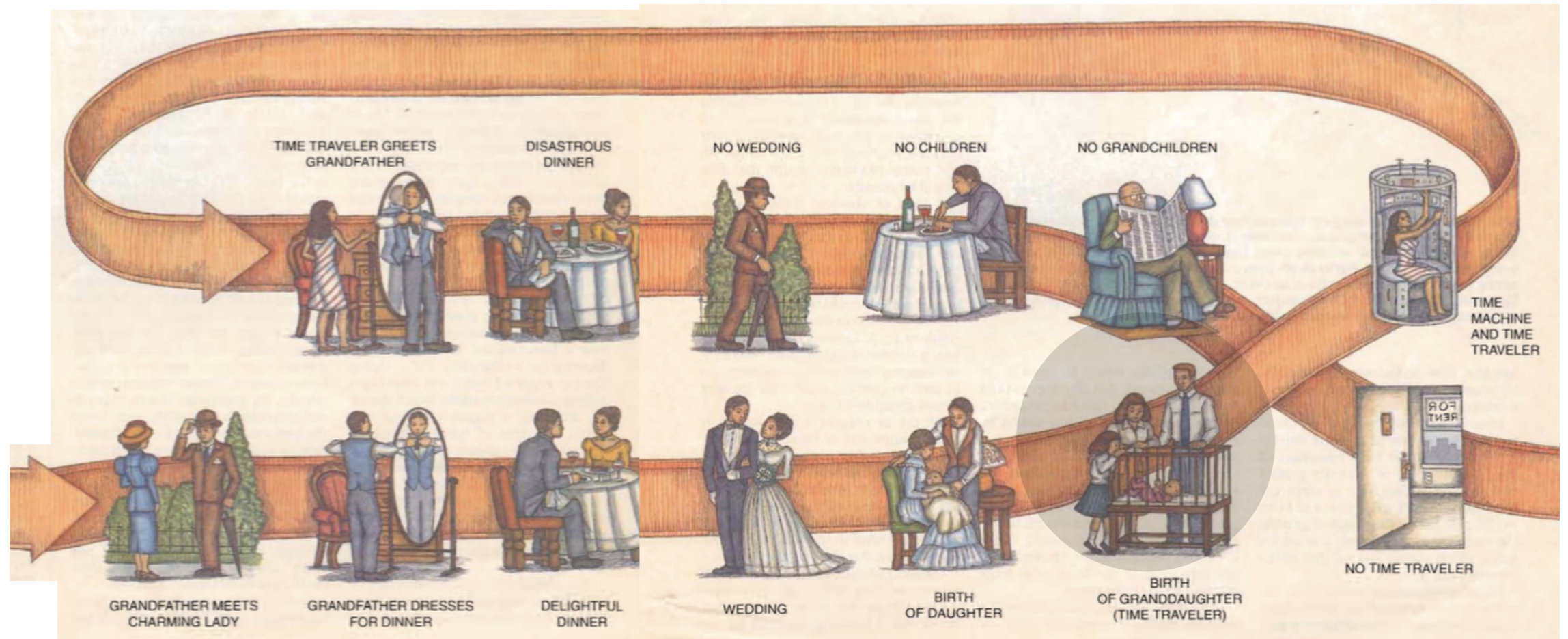
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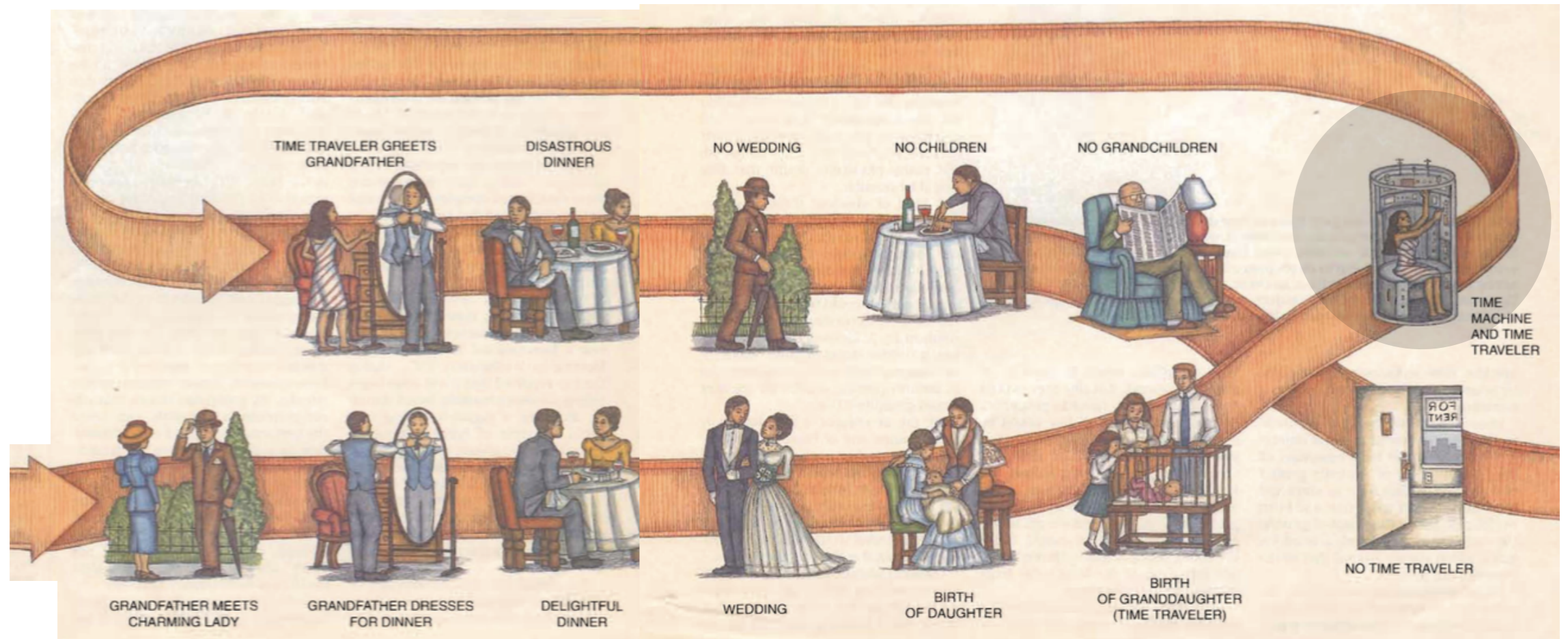
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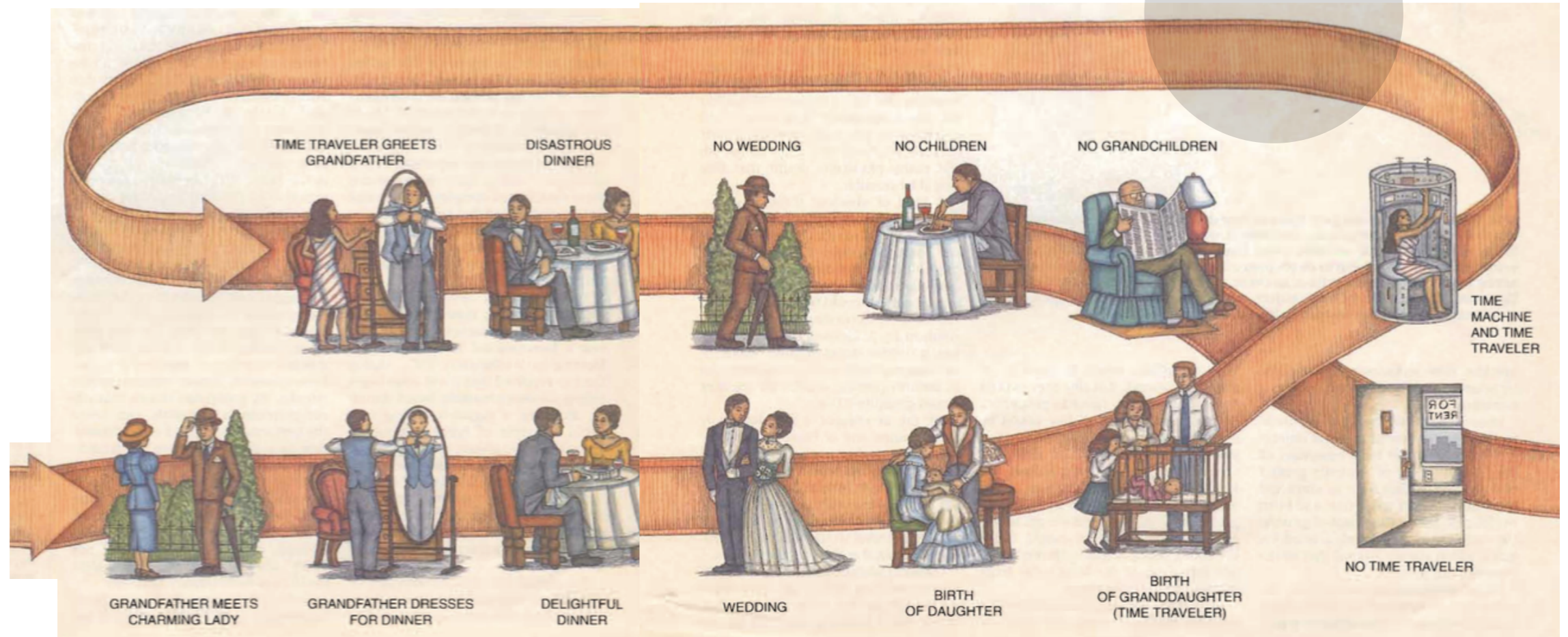
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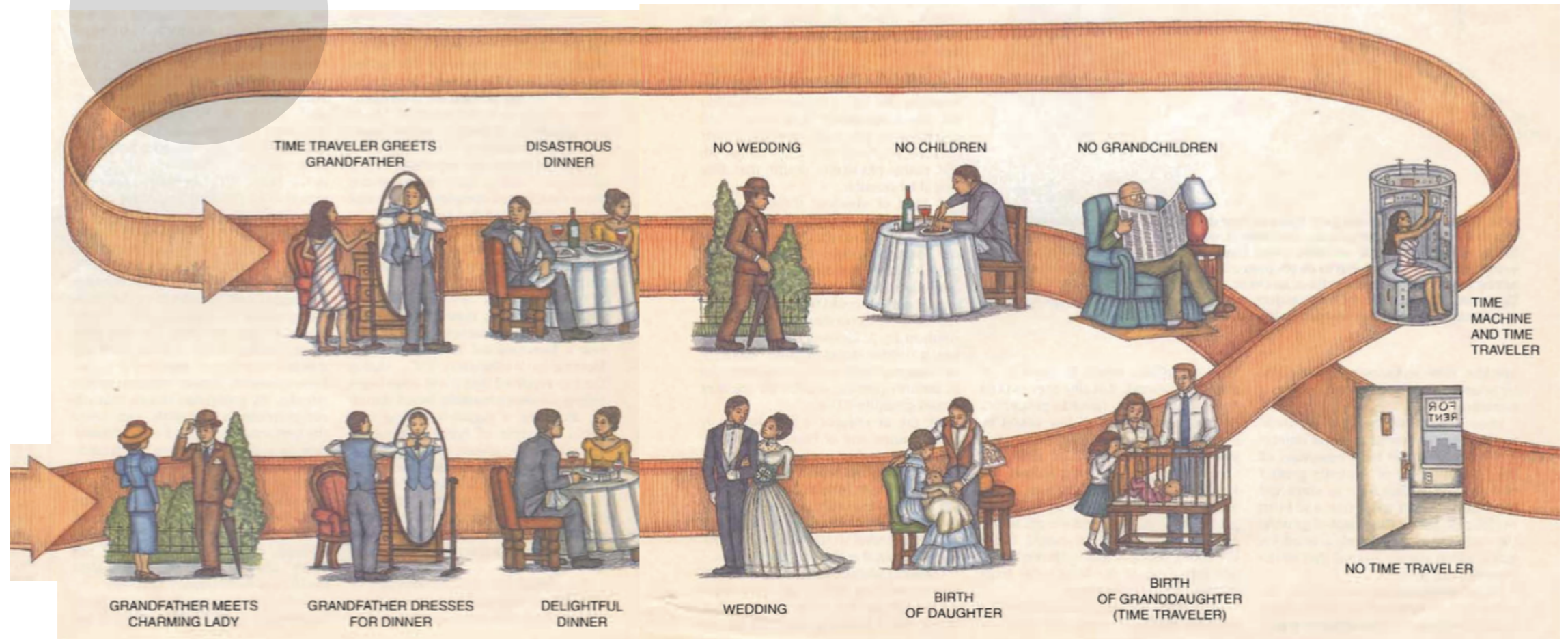
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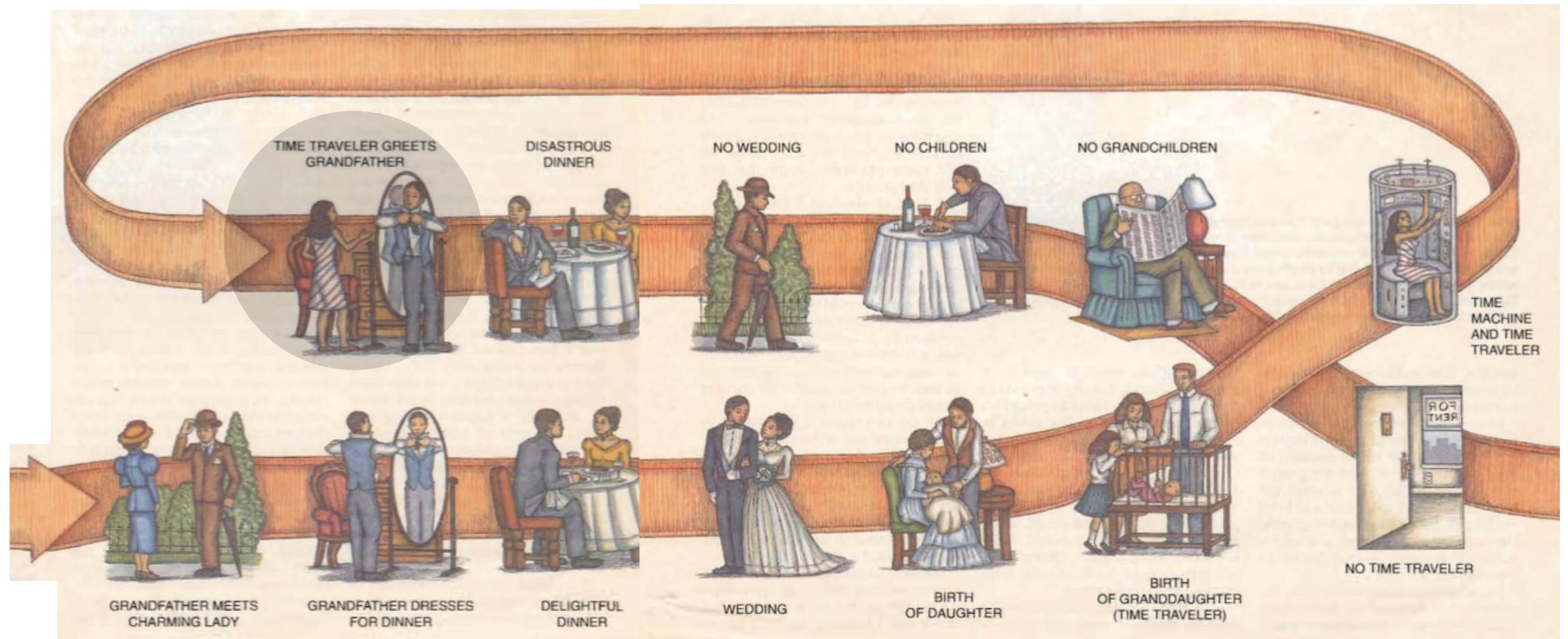
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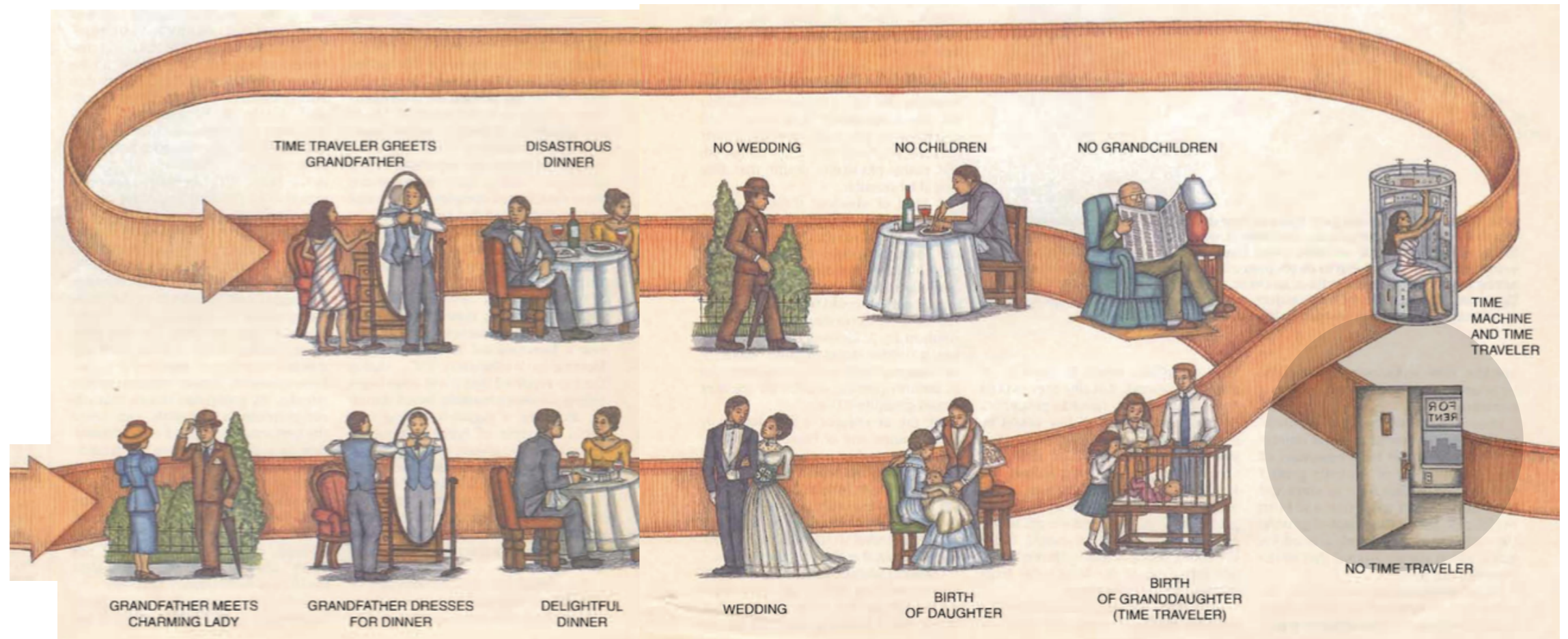
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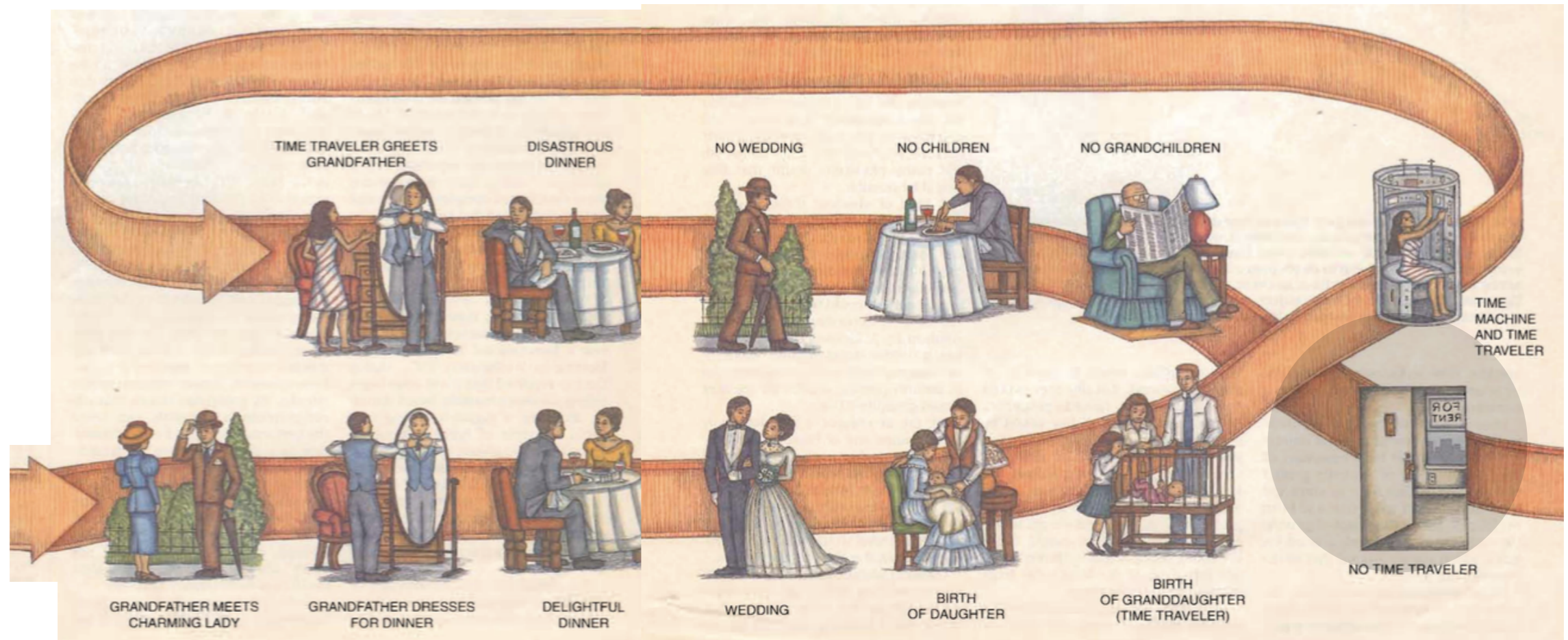
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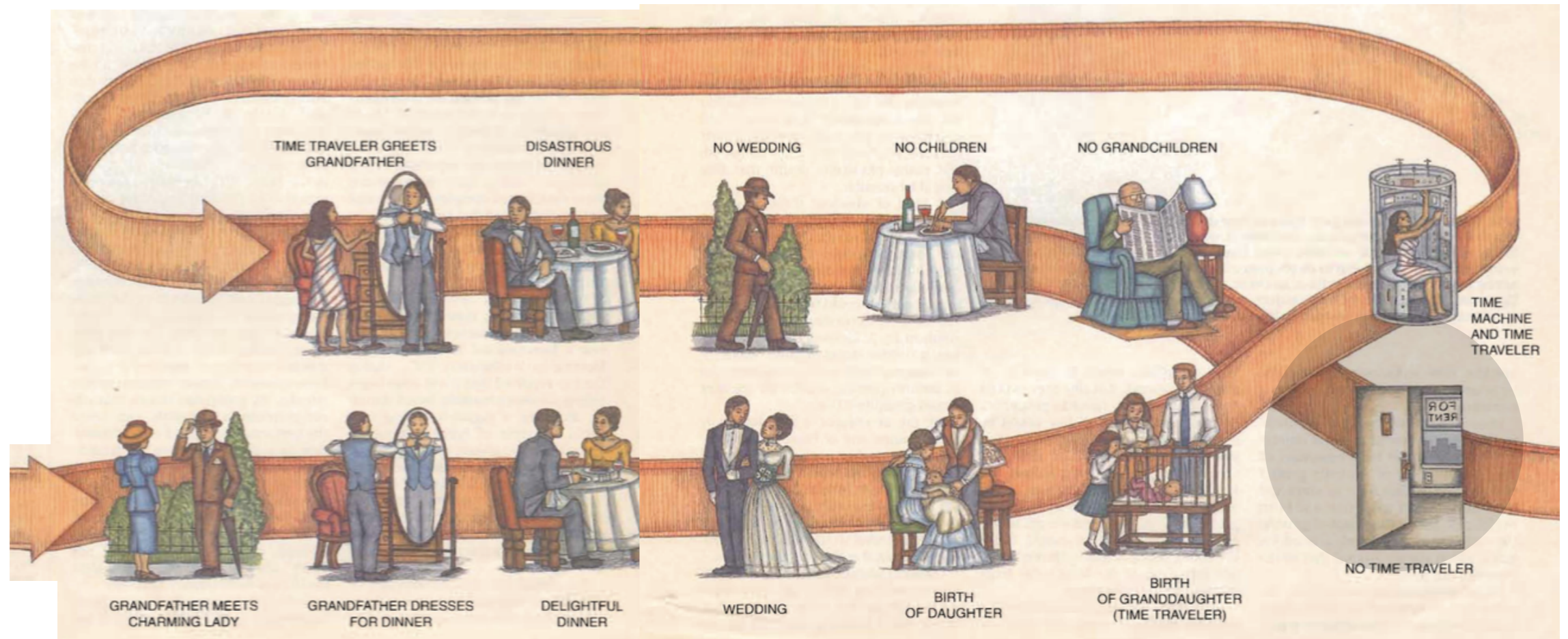
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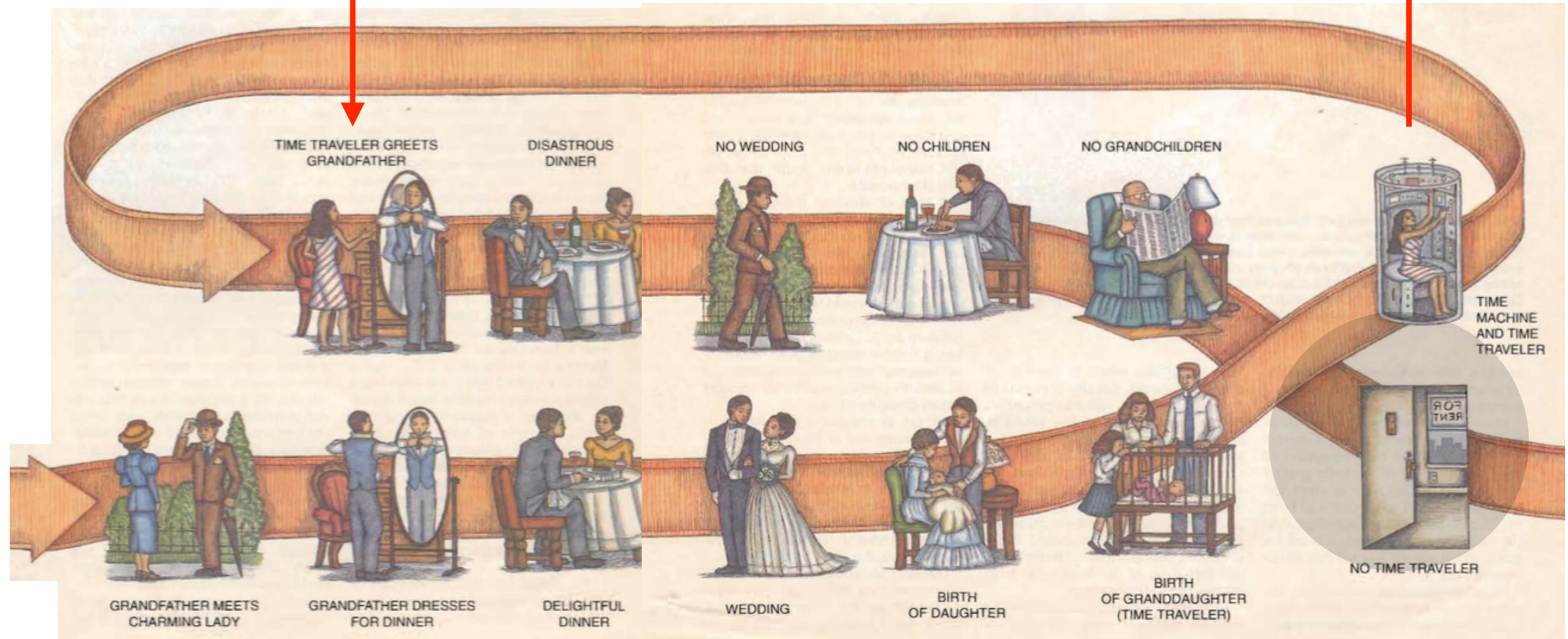
“jumping” macroscopic backwards time travel



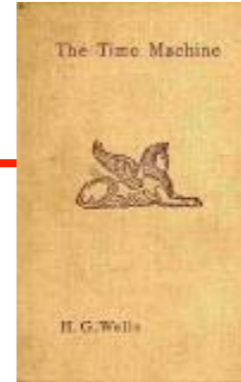
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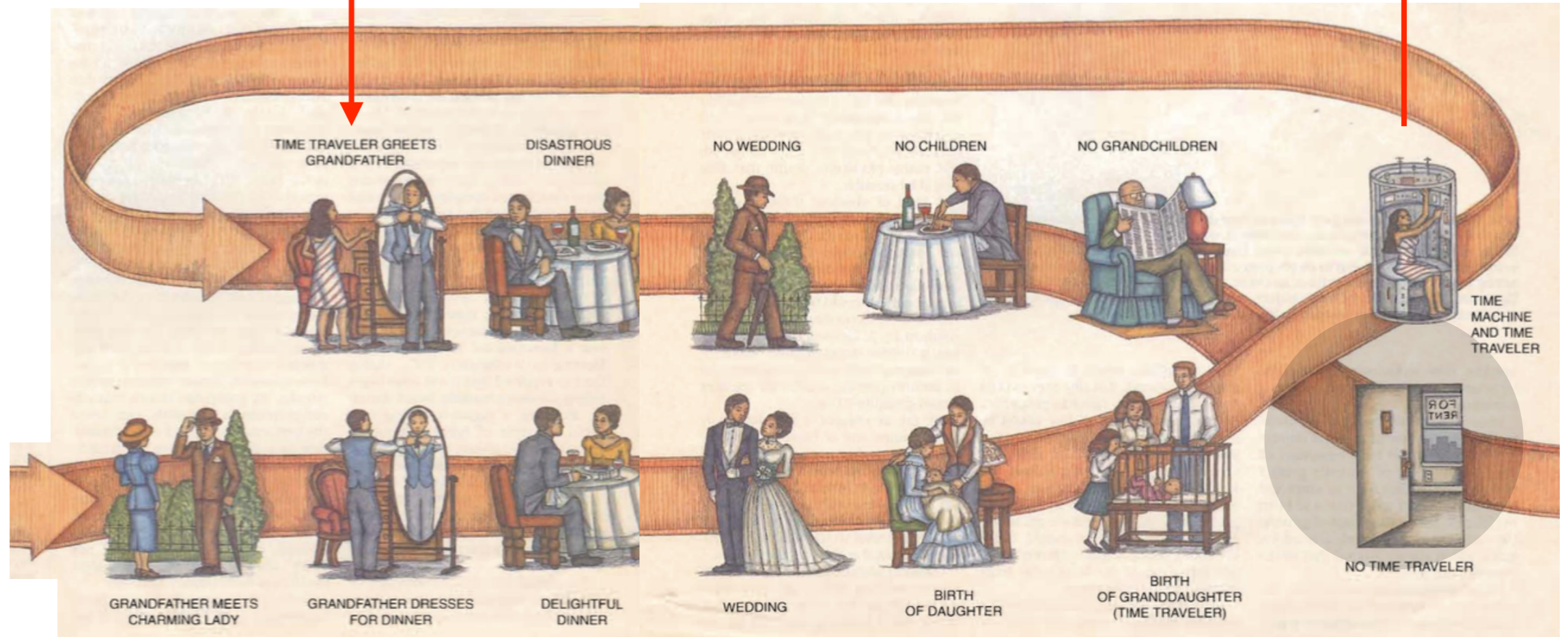
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Story for The Grandfather Paradox



“jumping” macroscopic backwards time travel



H ⊥

GP “Disproof” of Backwards Time Travel

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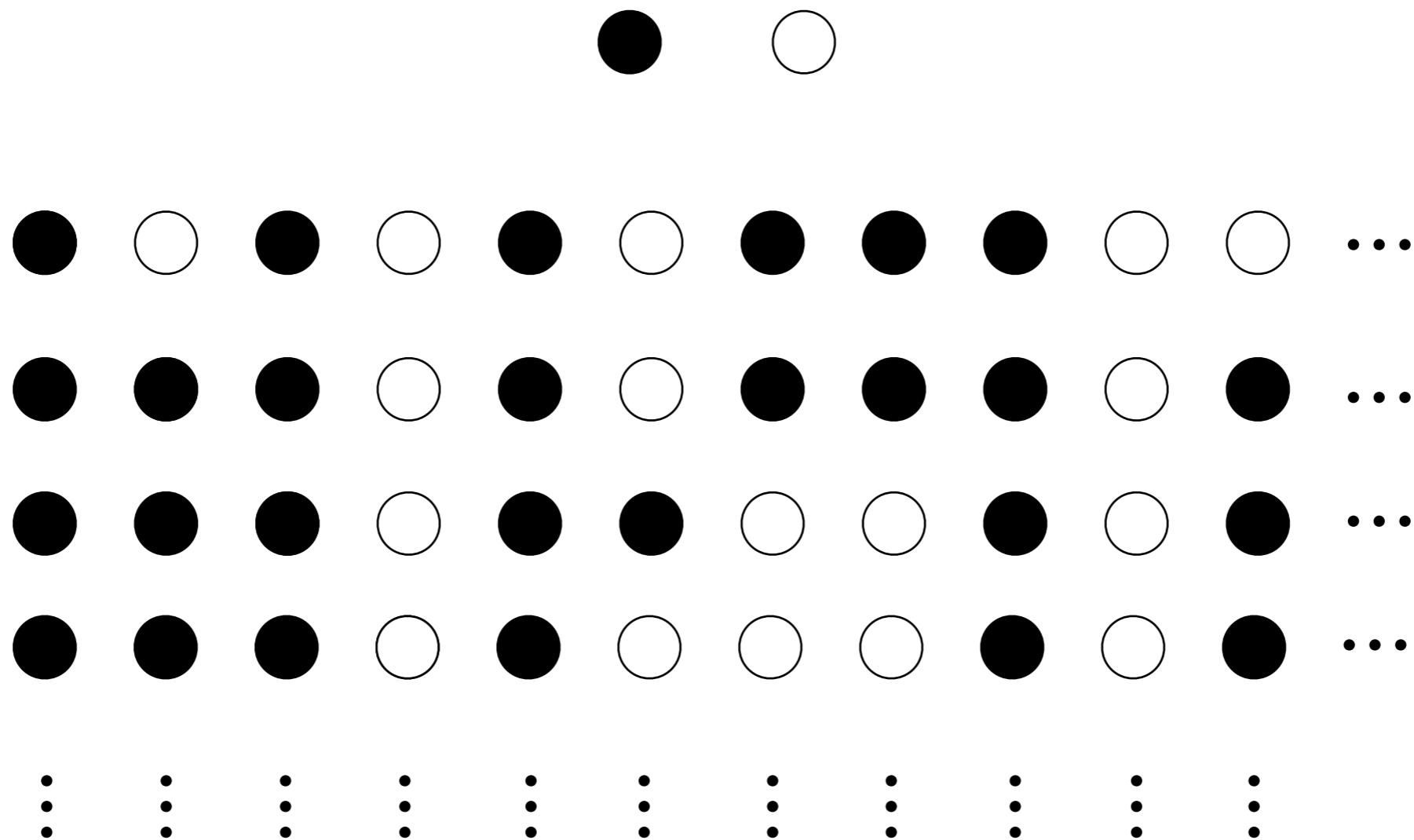
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4. It’s a contradiction and hence impossible that an existent thing x never exists, so it’s impossible that existent Sonia never exists.
5. Hence, “jumping” macroscopic backwards time travel *isn’t* possible. (*modus tollens* given that a contradiction is false)

The “Multiverse Escape”

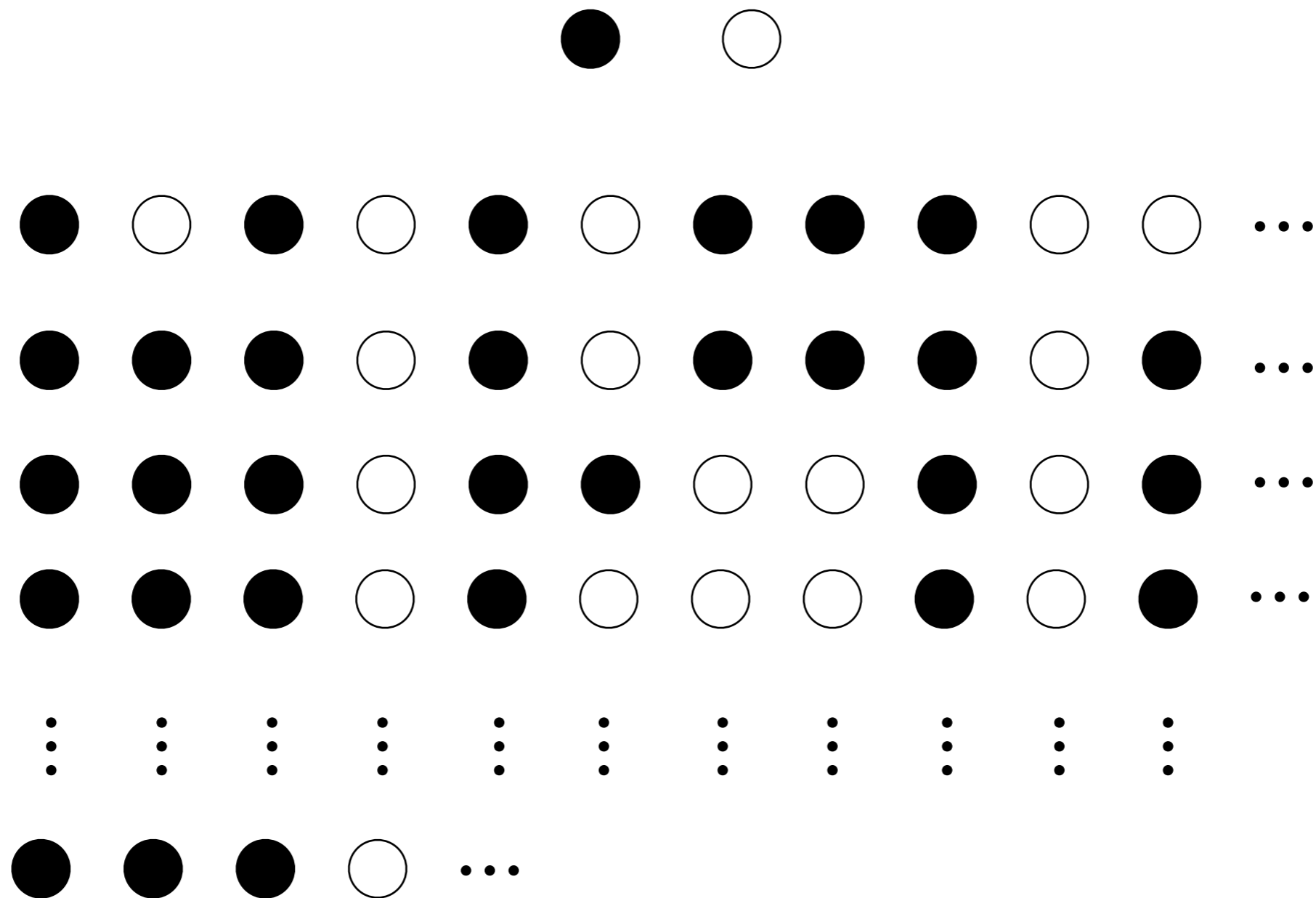
So does Sonia prevent her own birth or not? That depends on which universe one is referring to. In the universe she leaves, the one she was born in, her grandfather did marry her grandmother because, in that universe, he received no visit from Sonia. In the other universe, the one whose past Sonia travels to, her grandfather does not marry that particular woman, and Sonia is never born. (Deutsch & Lockwood 1994, p. 73)

Heterogeneous proofs
can be perfectly valid ...

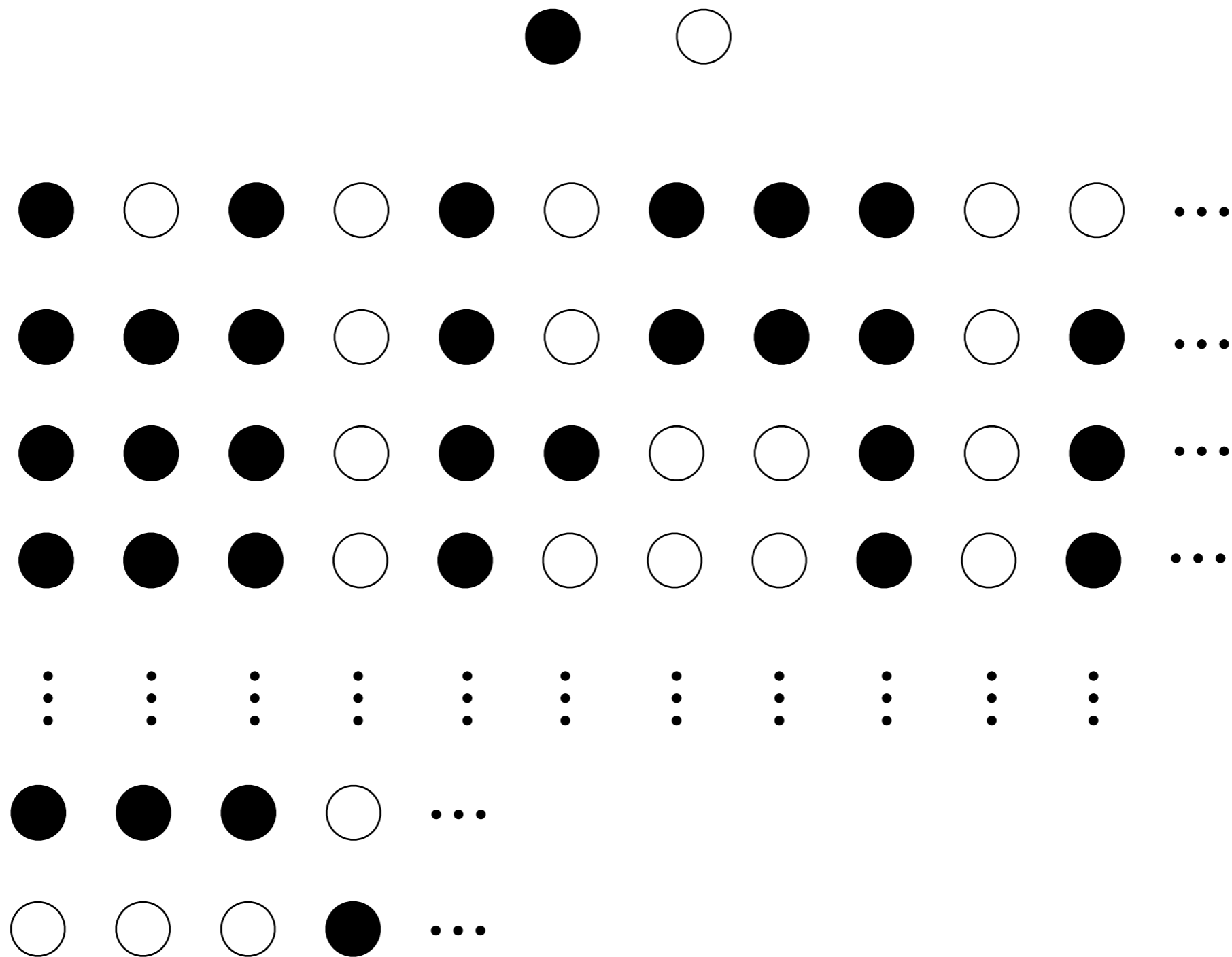
E.g.: Heterogeneous Proof of
Cantor's $\mathcal{P}(\mathbb{Z}^+) > \mathbb{Z}^+$



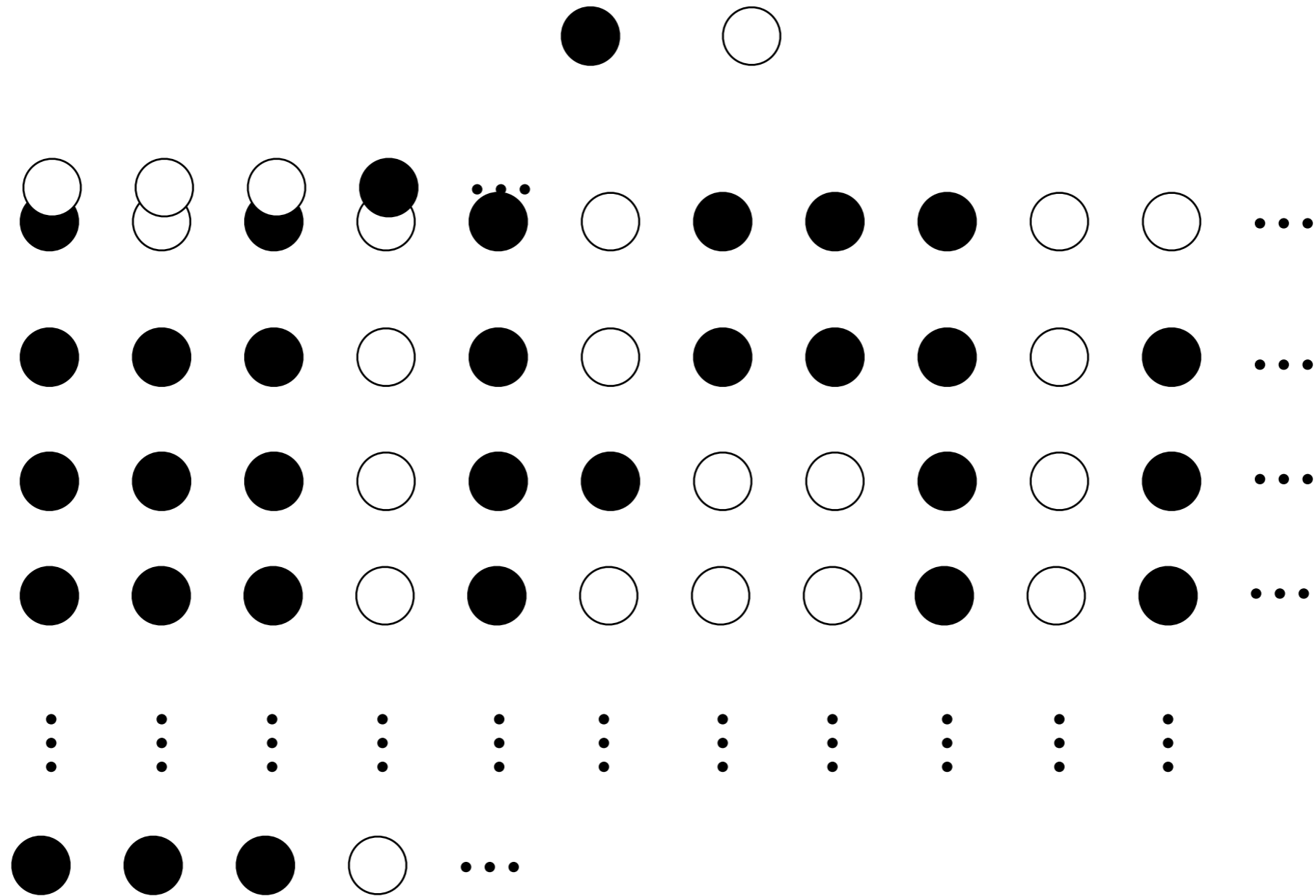
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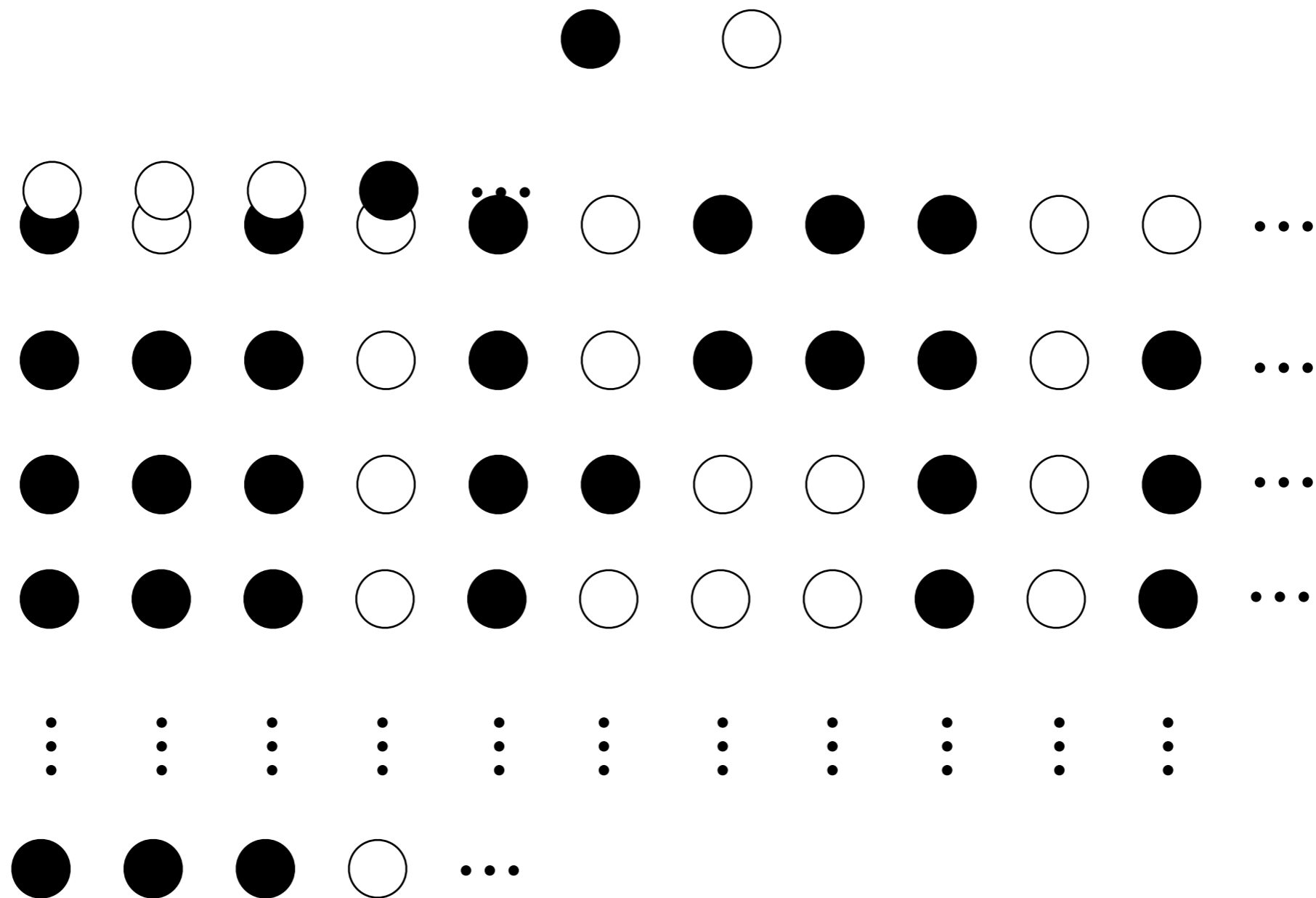
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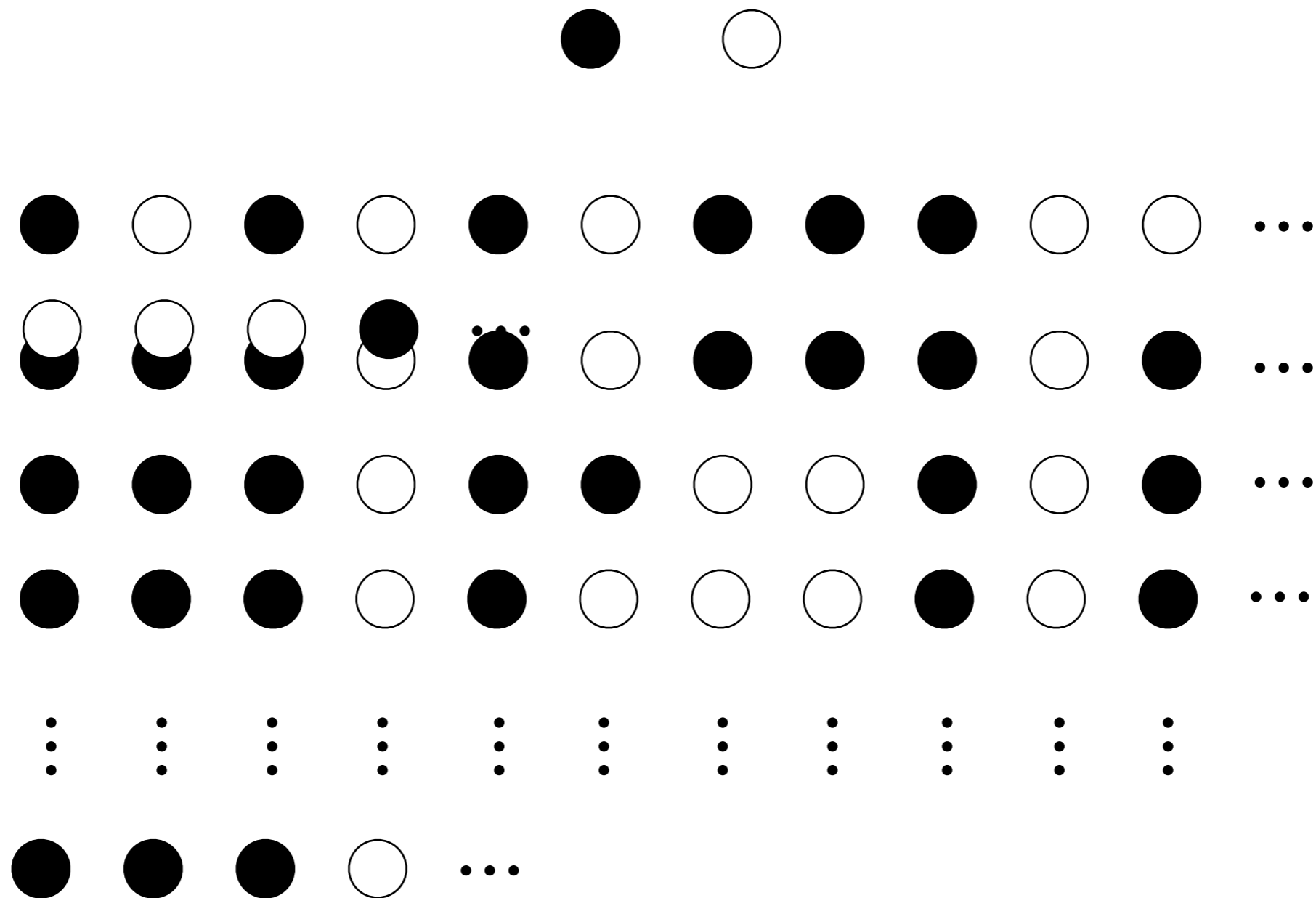
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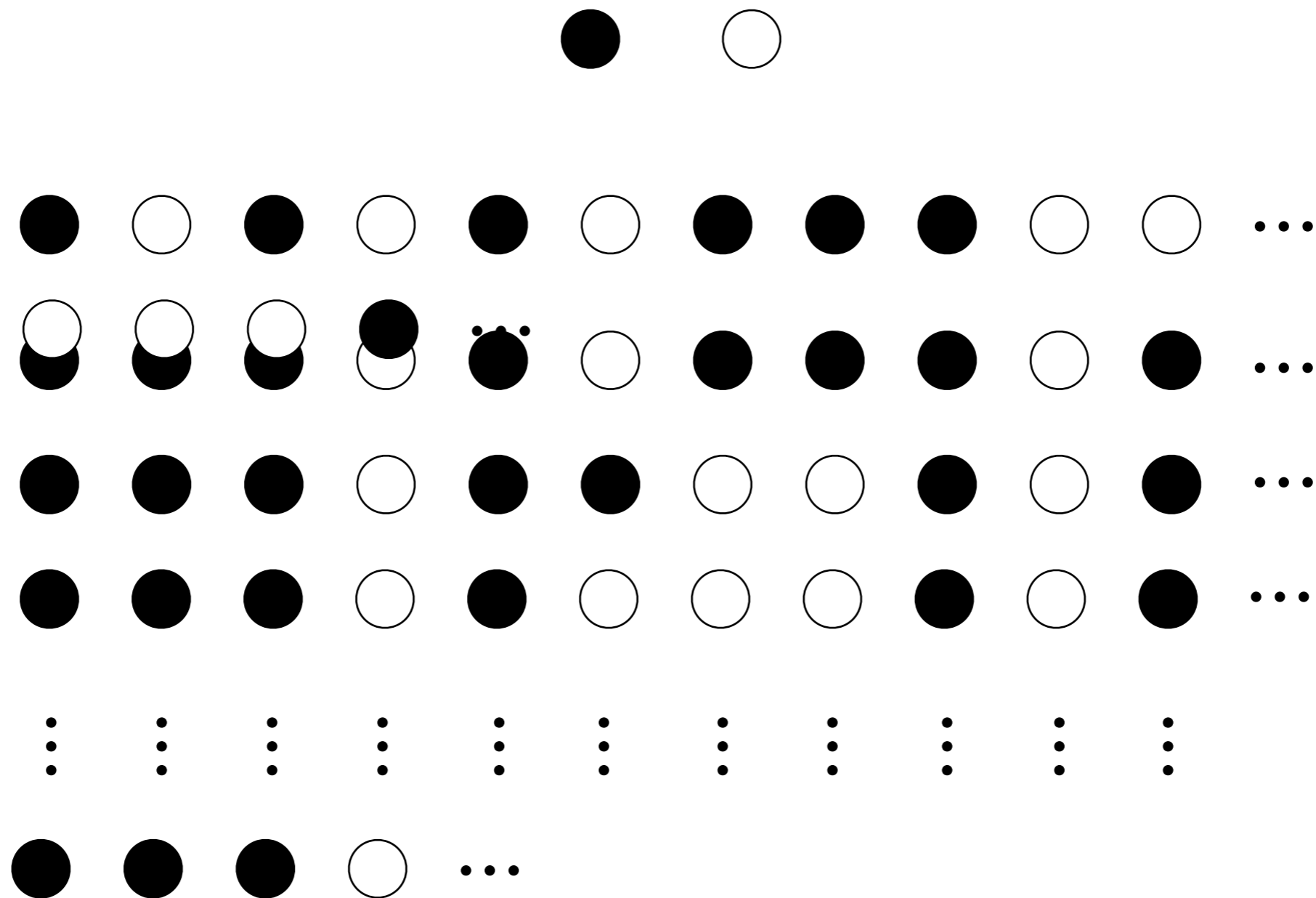
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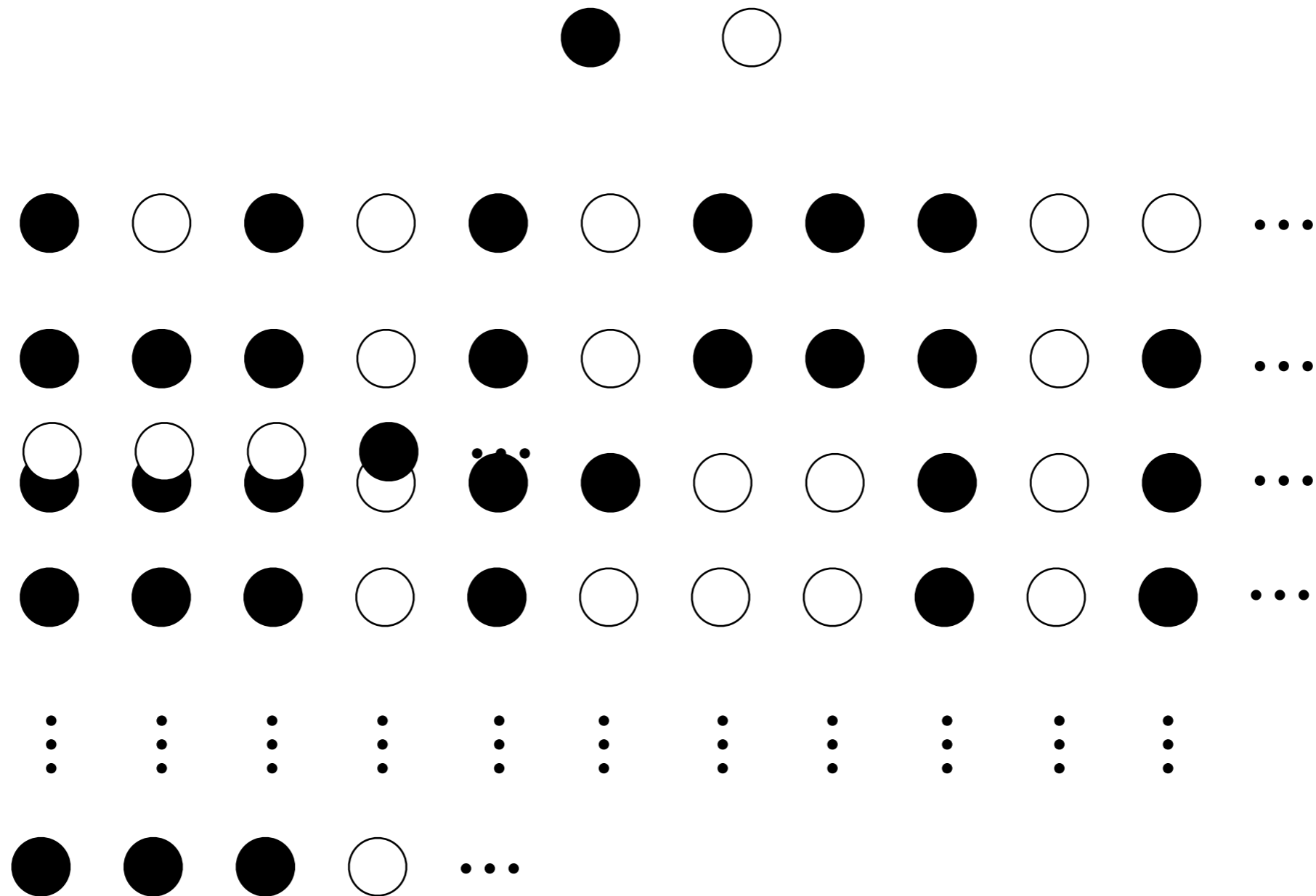
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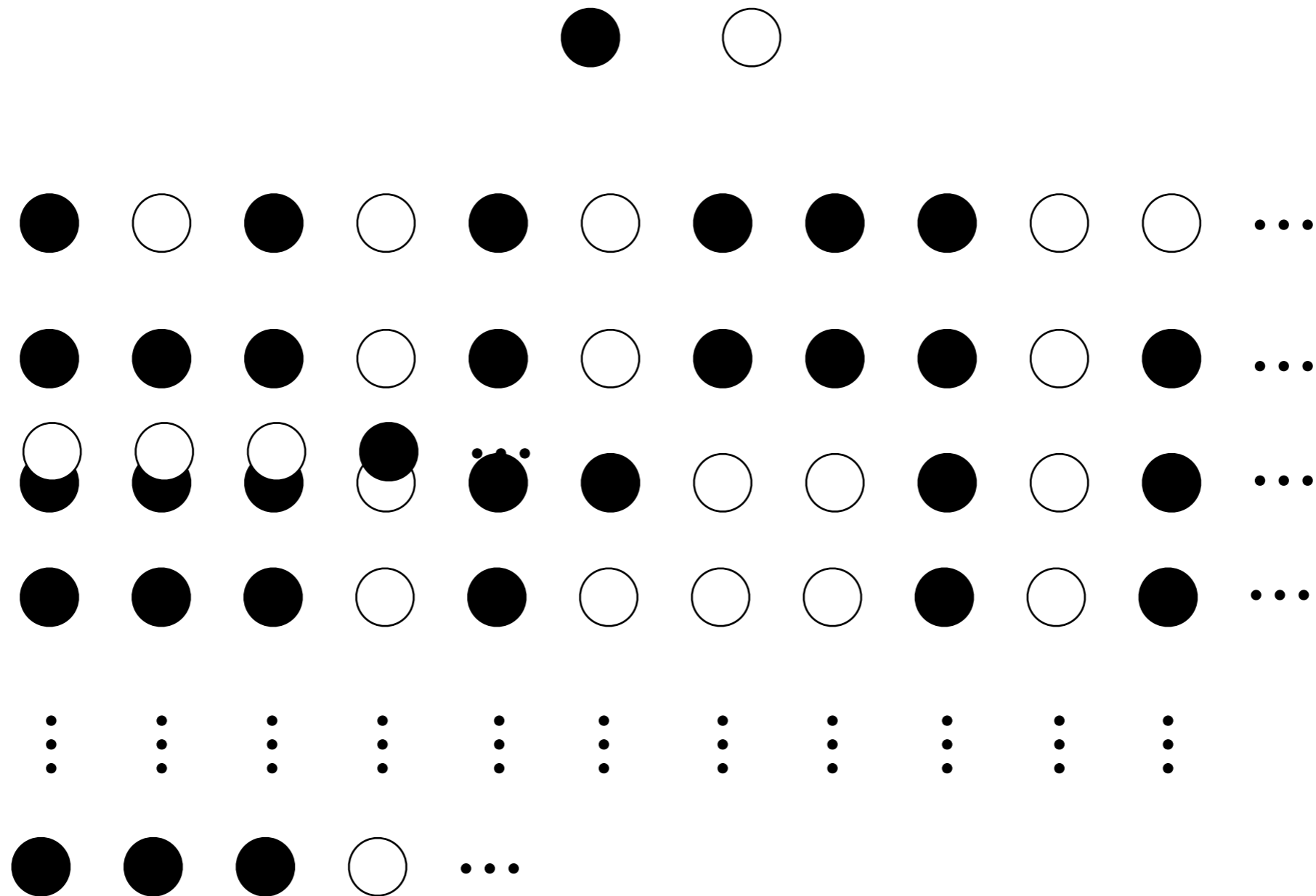
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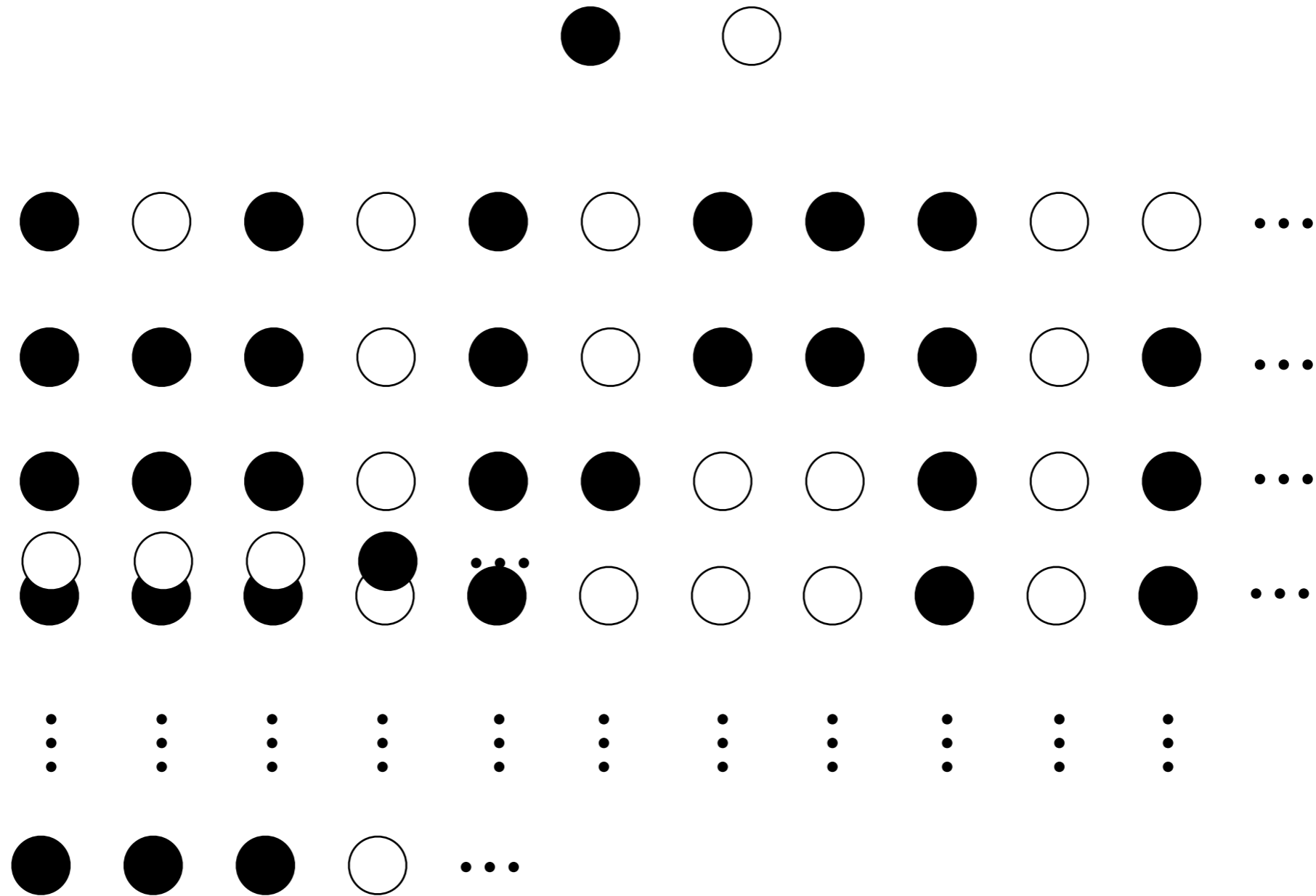
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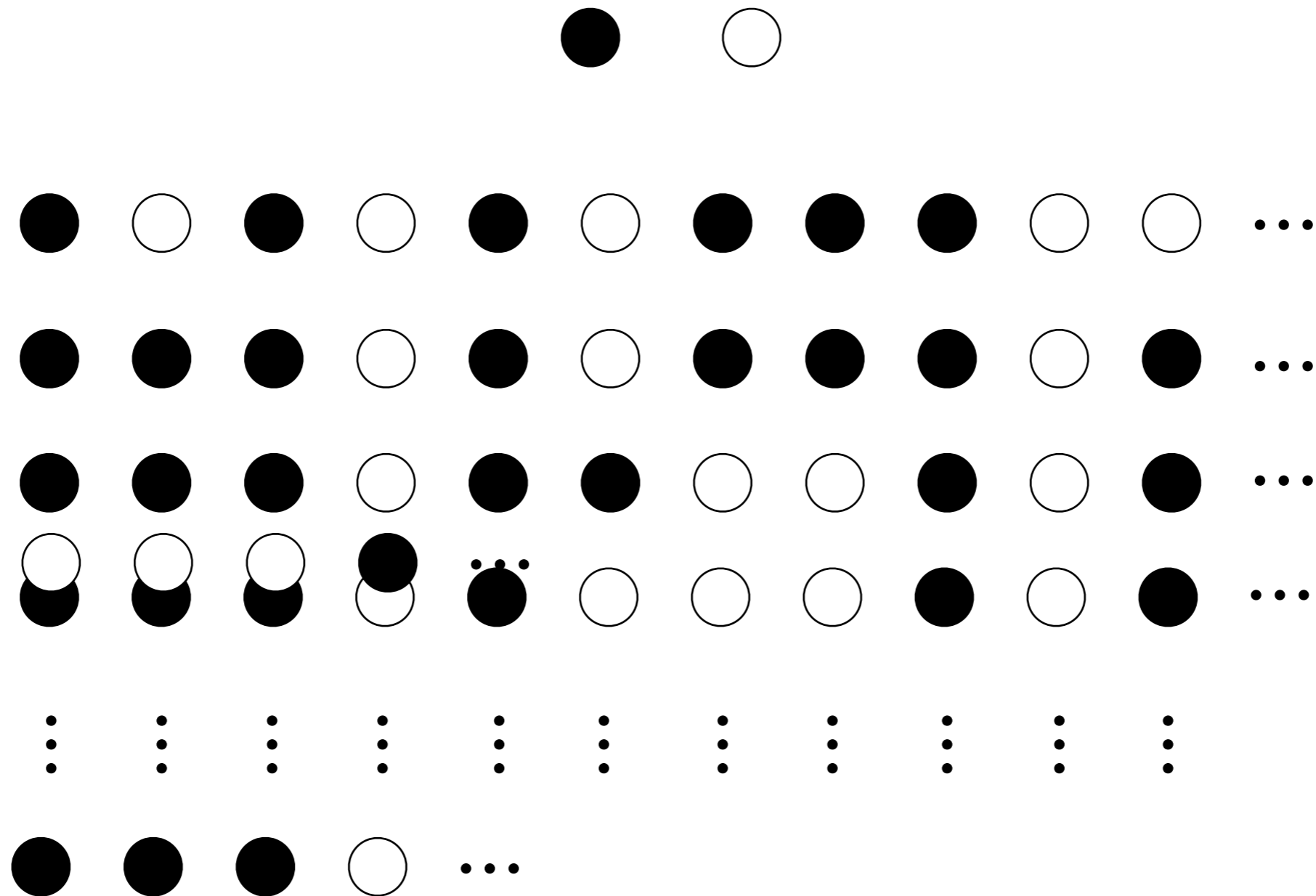
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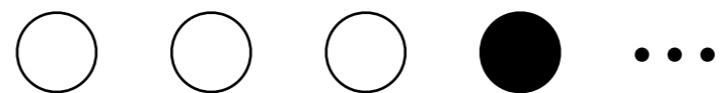
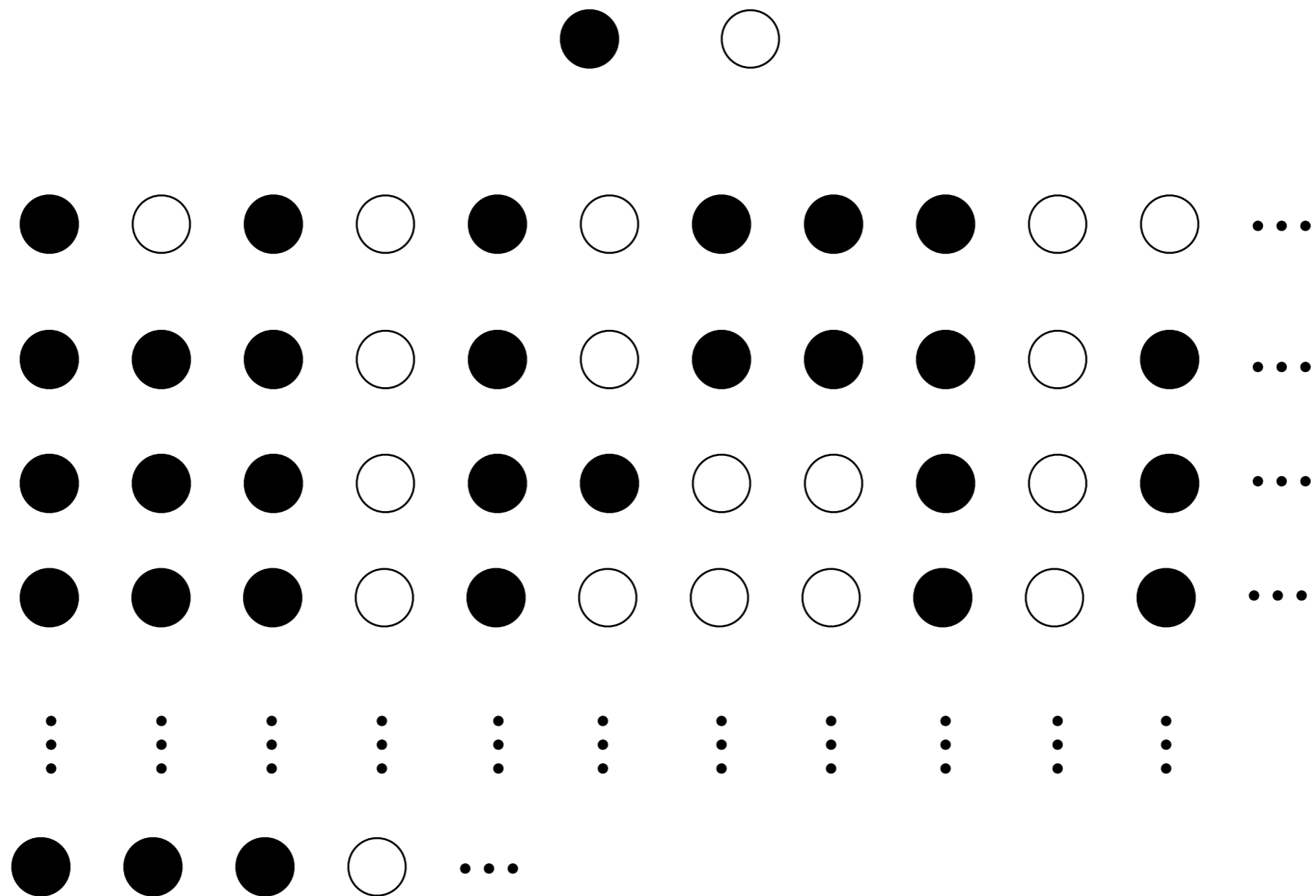
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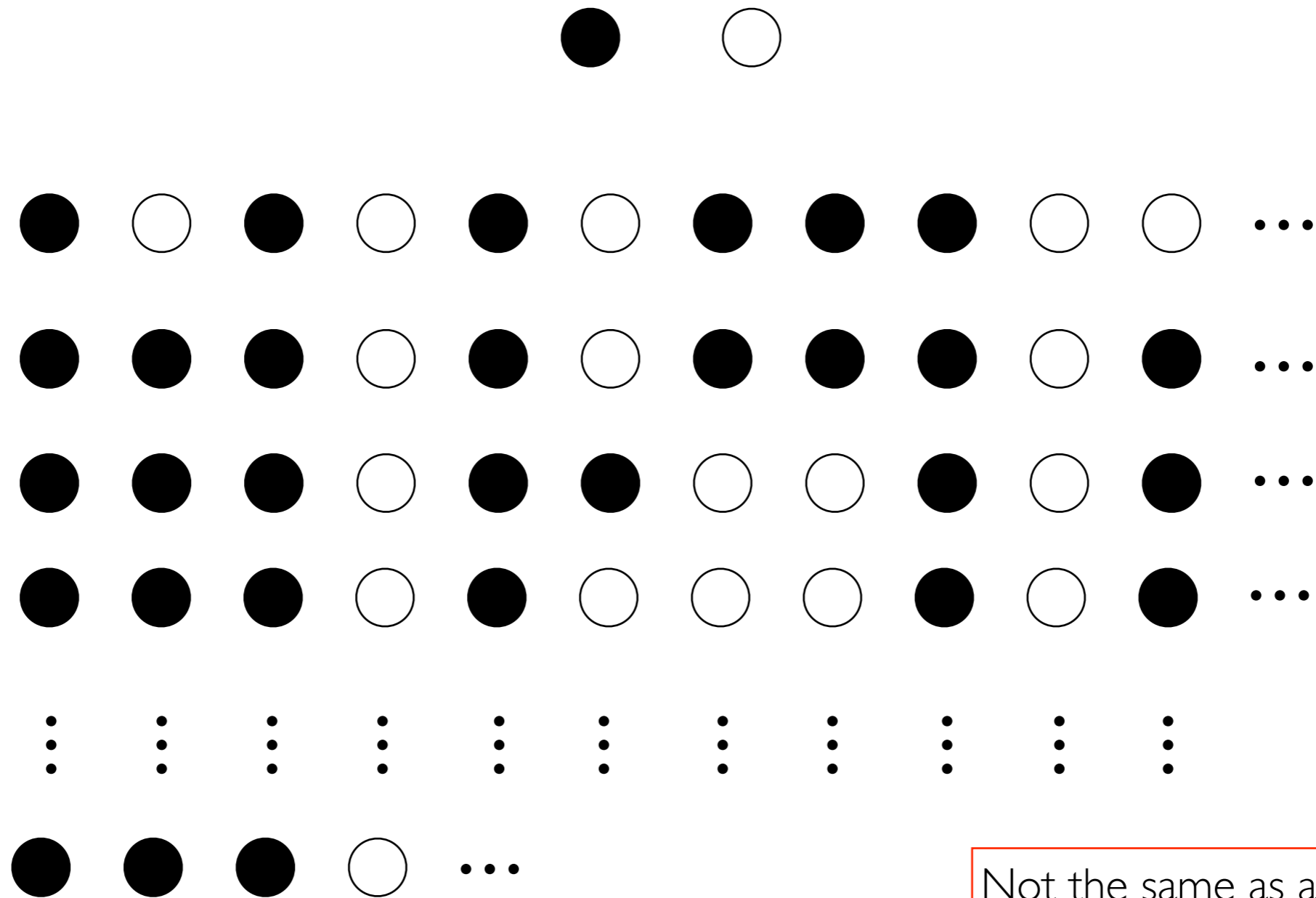
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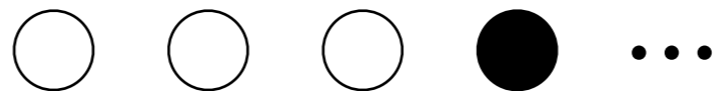
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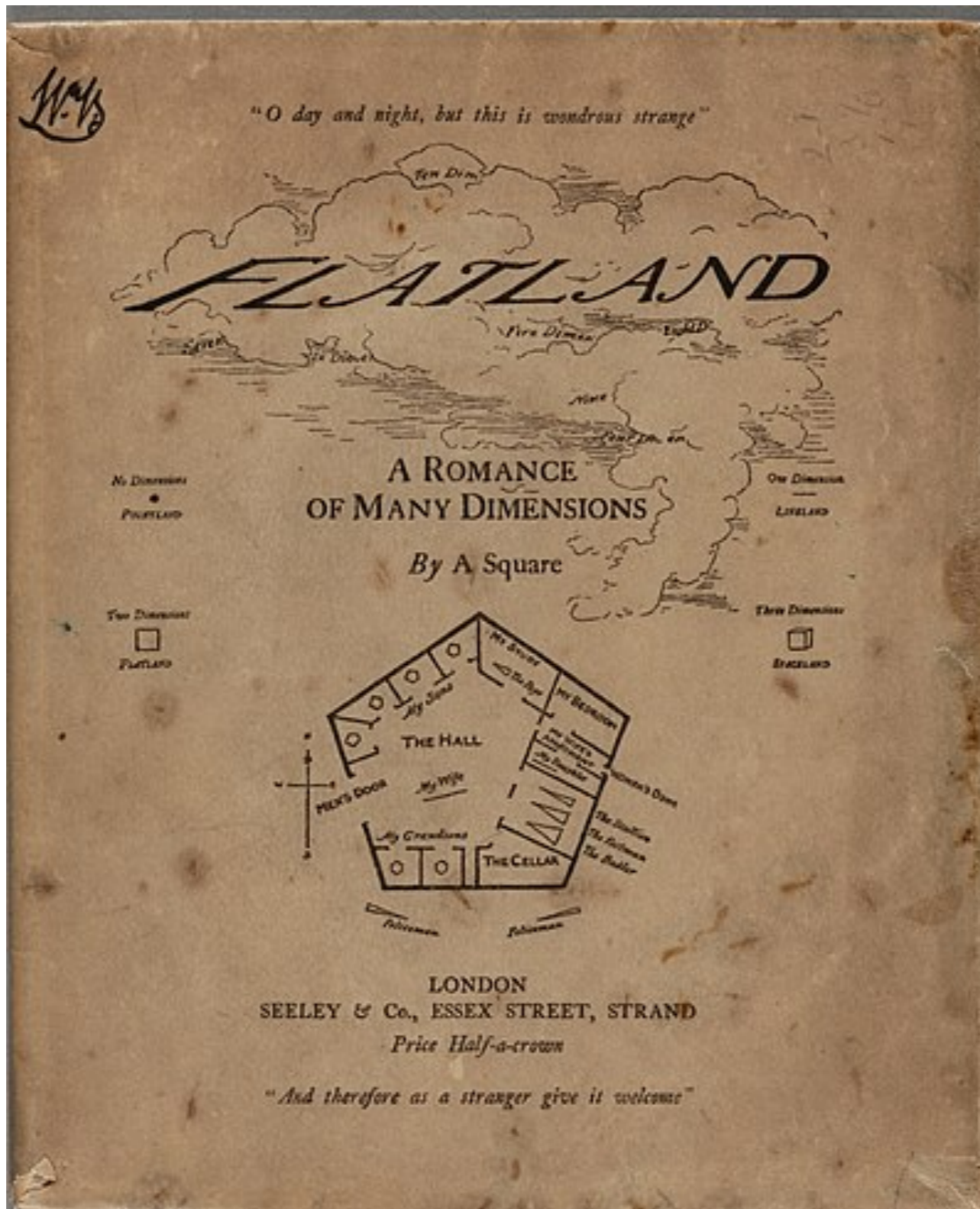
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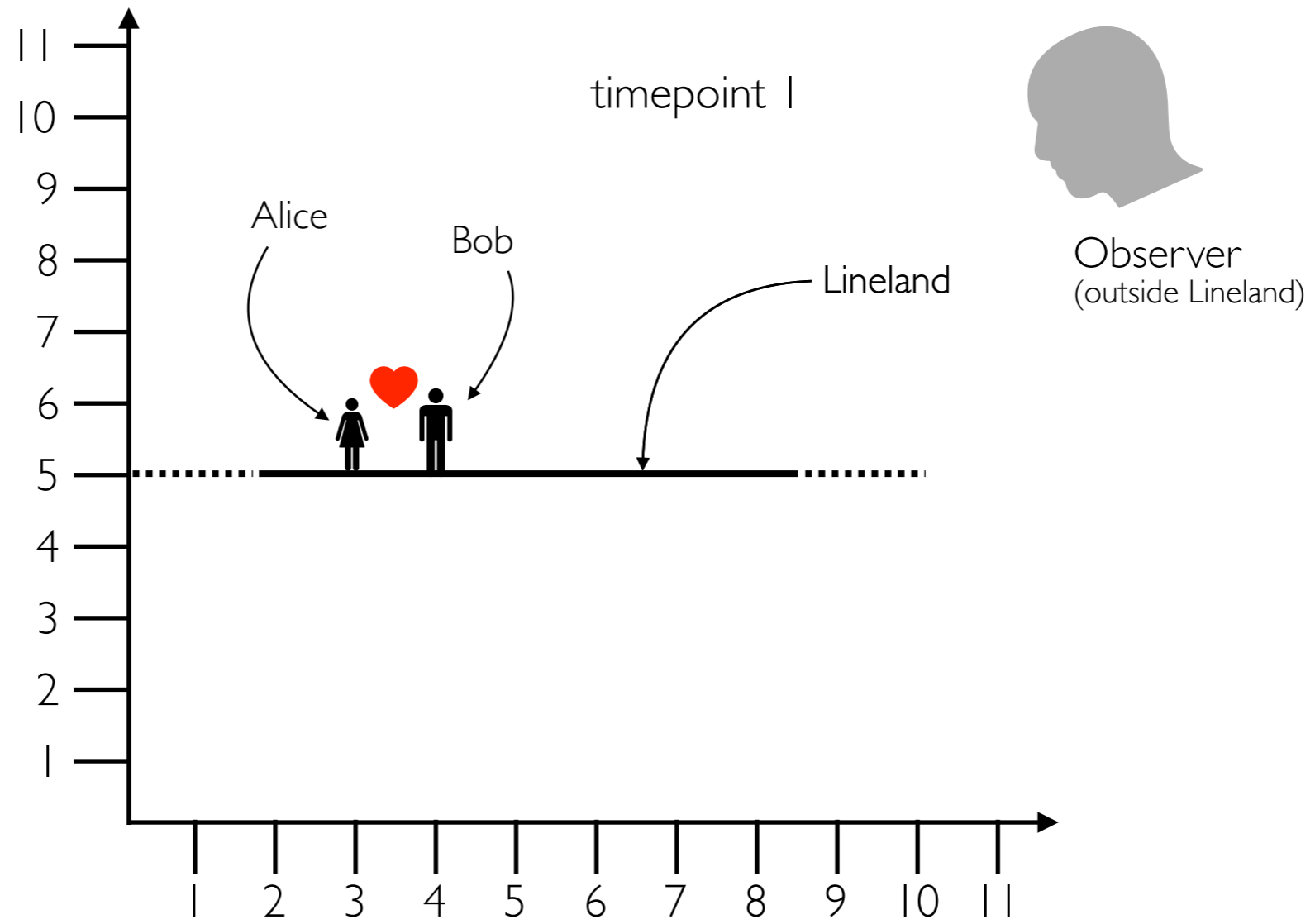
Not the same as any row! Ergo,
the set of all subsets of \mathbb{Z}^+ , i.e.
 $\mathcal{P}(\mathbb{Z}^+)$, is greater than \mathbb{Z}^+ itself!

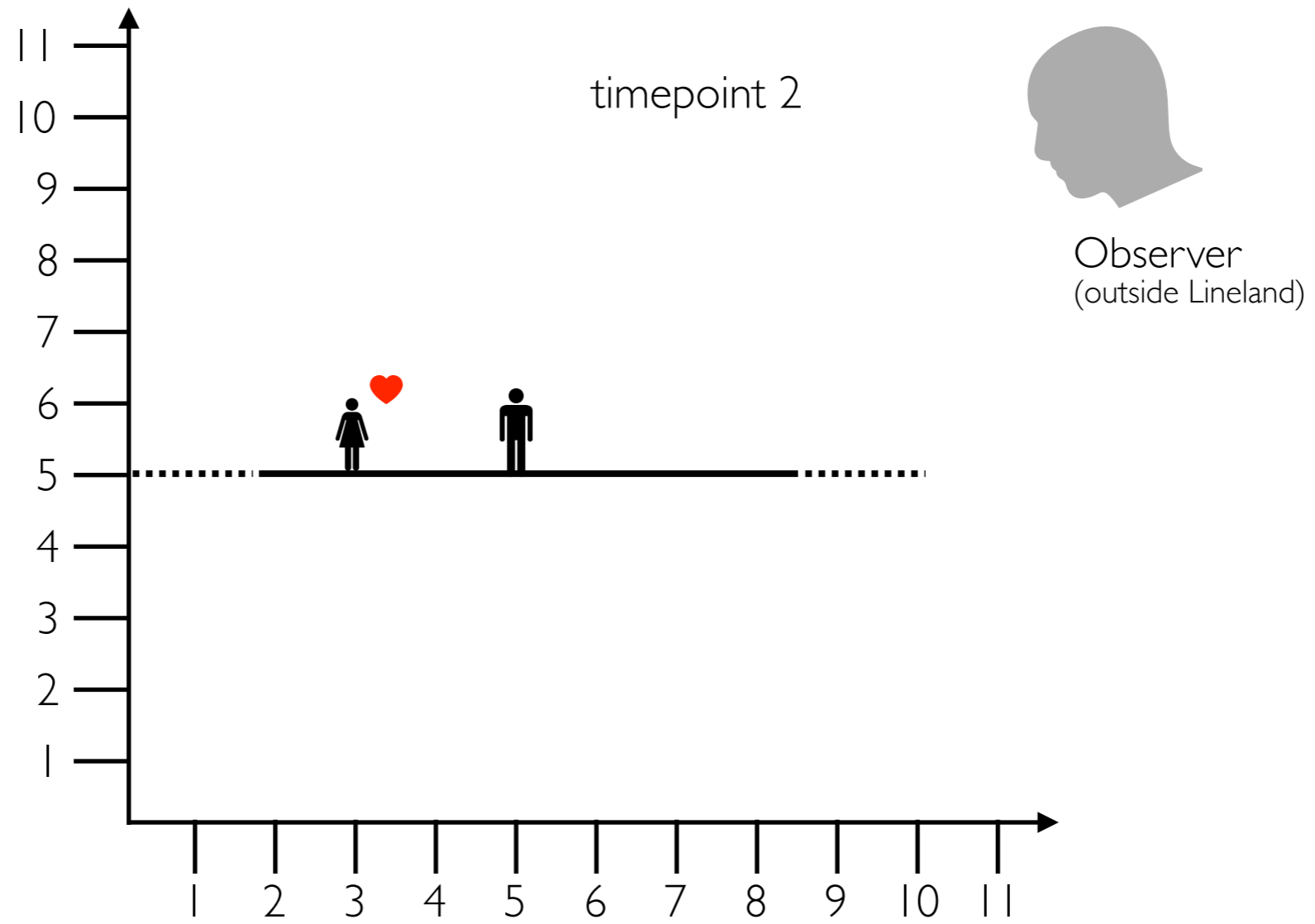


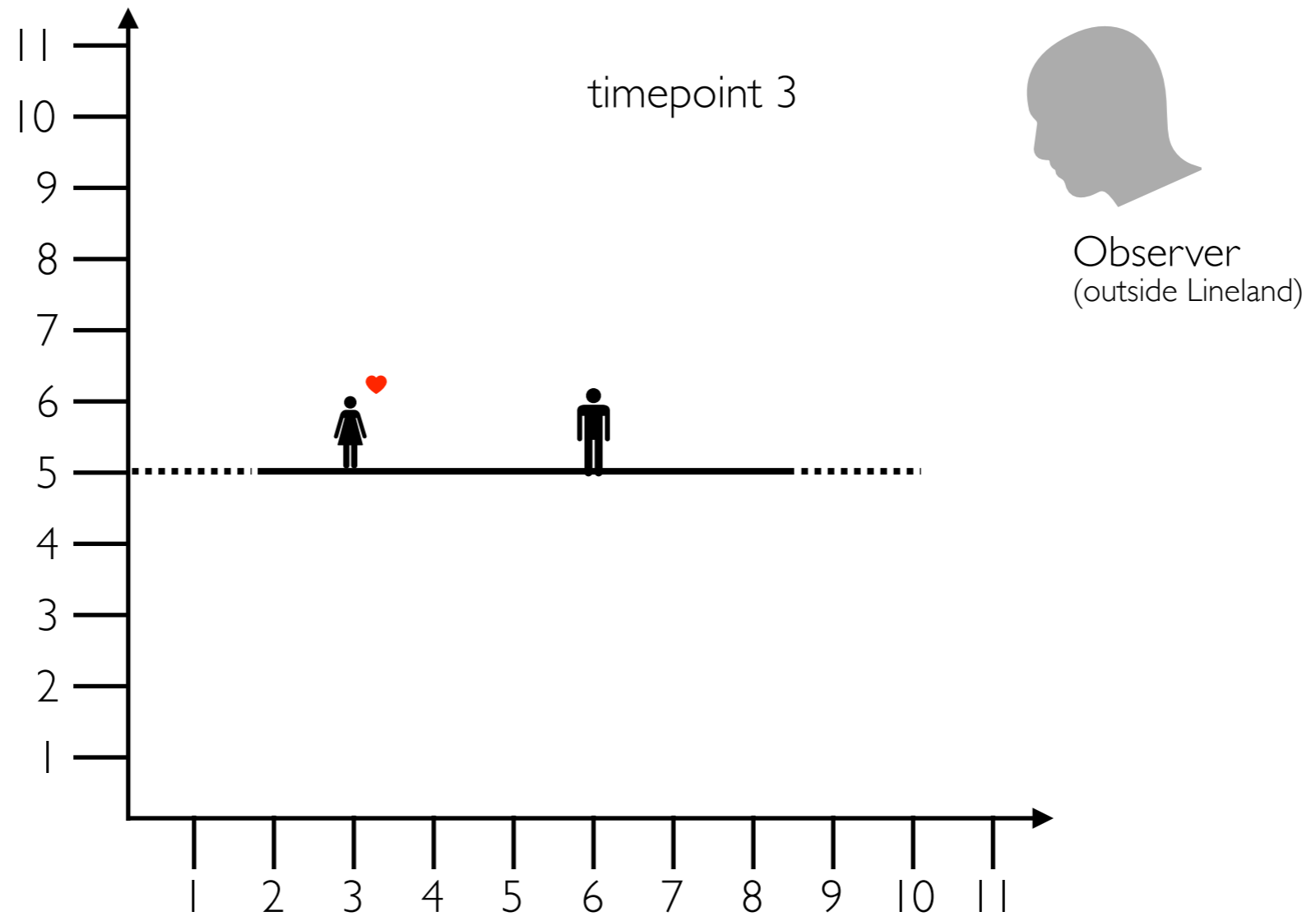
Heterogeneous Proof of
Possibility of Time Travel in
Lineland ...

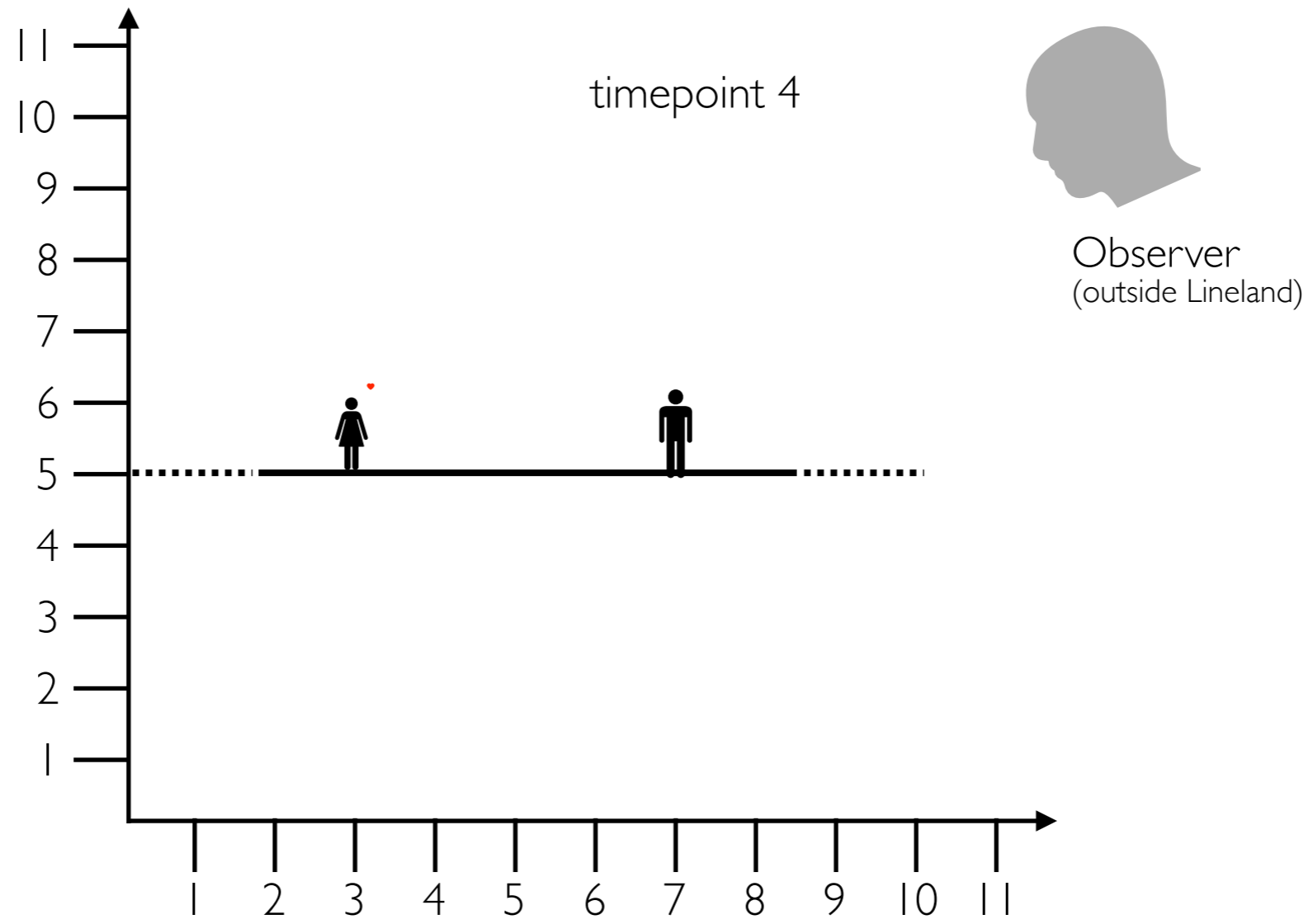


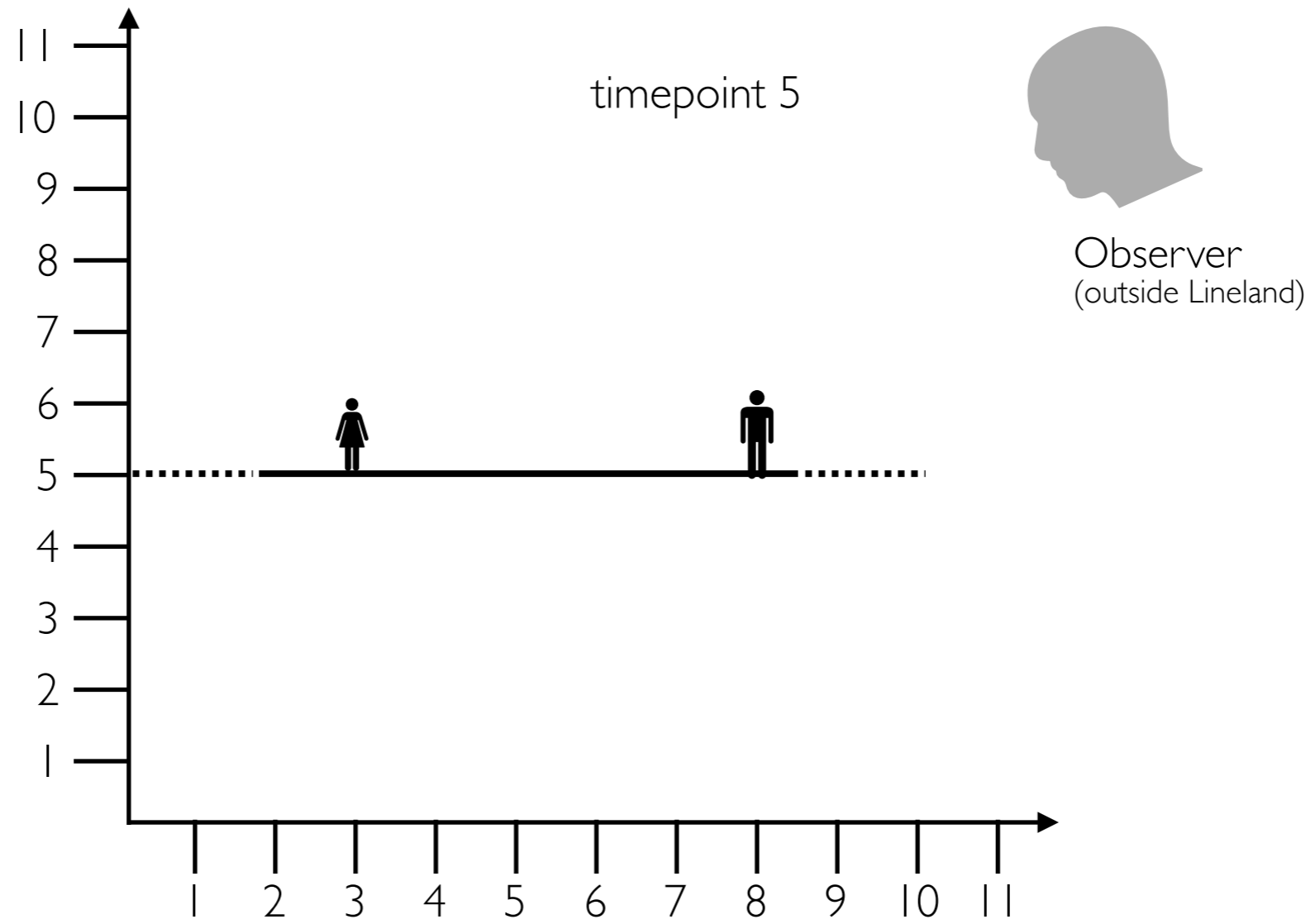
First Edition, 1884

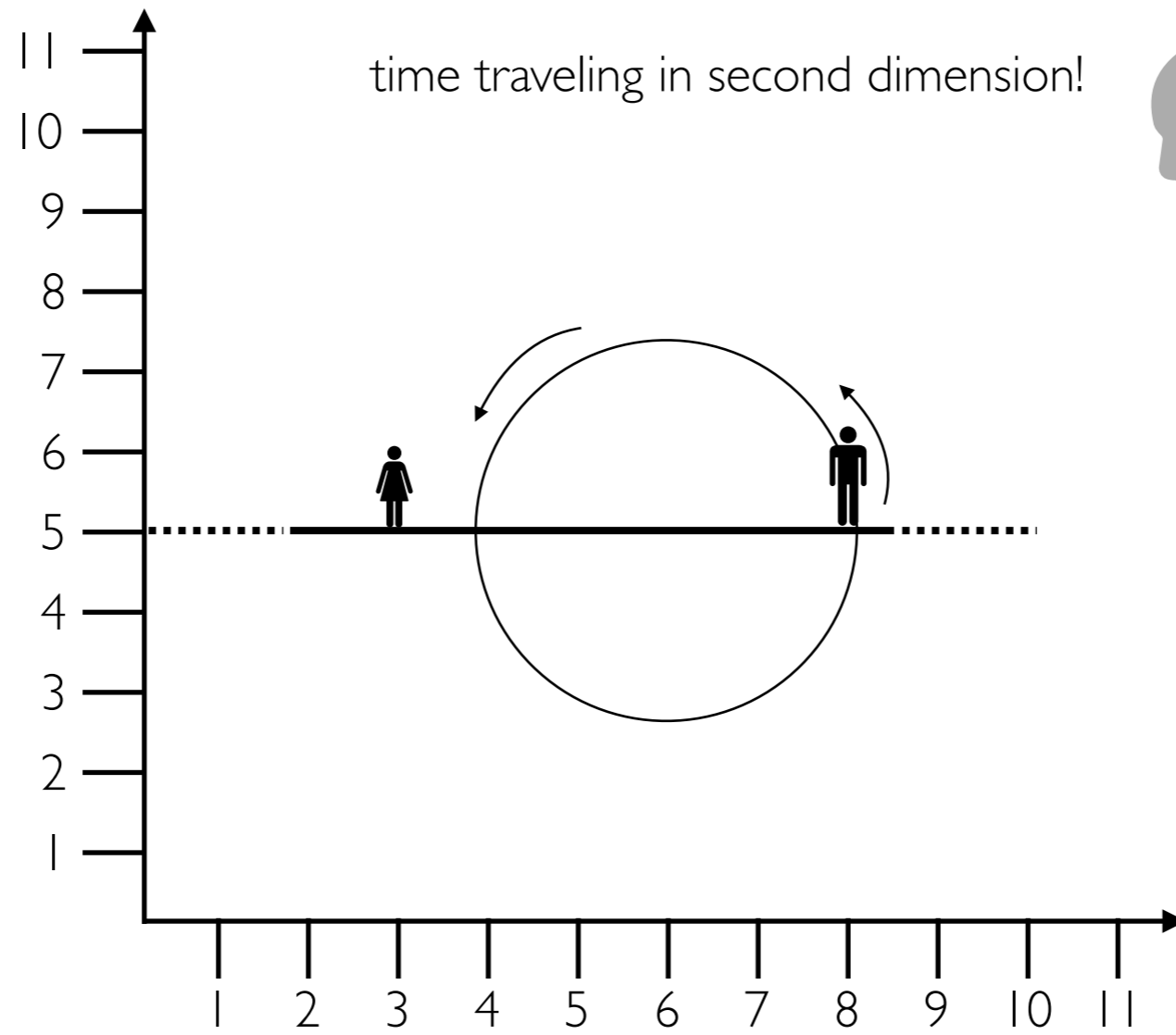




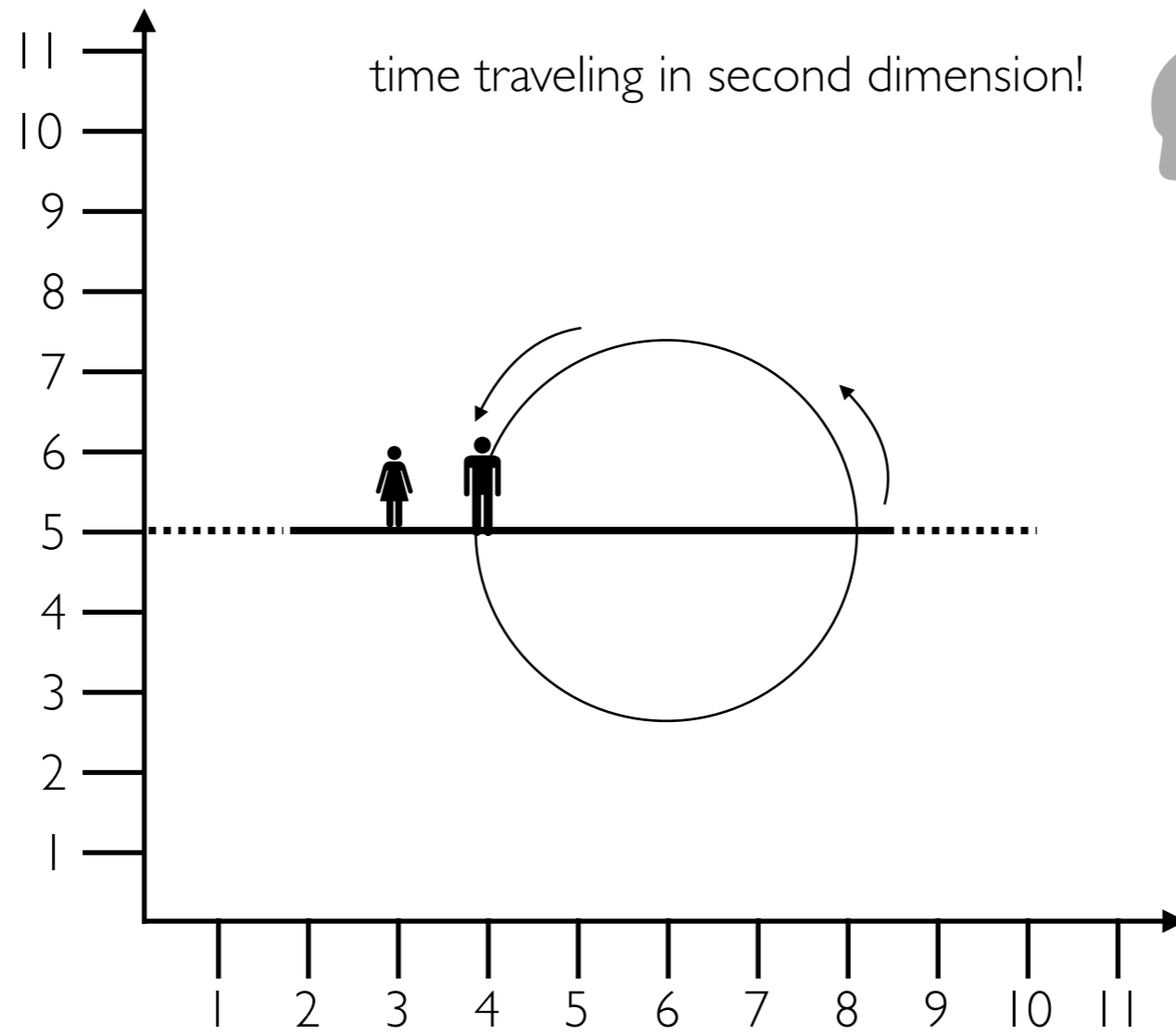




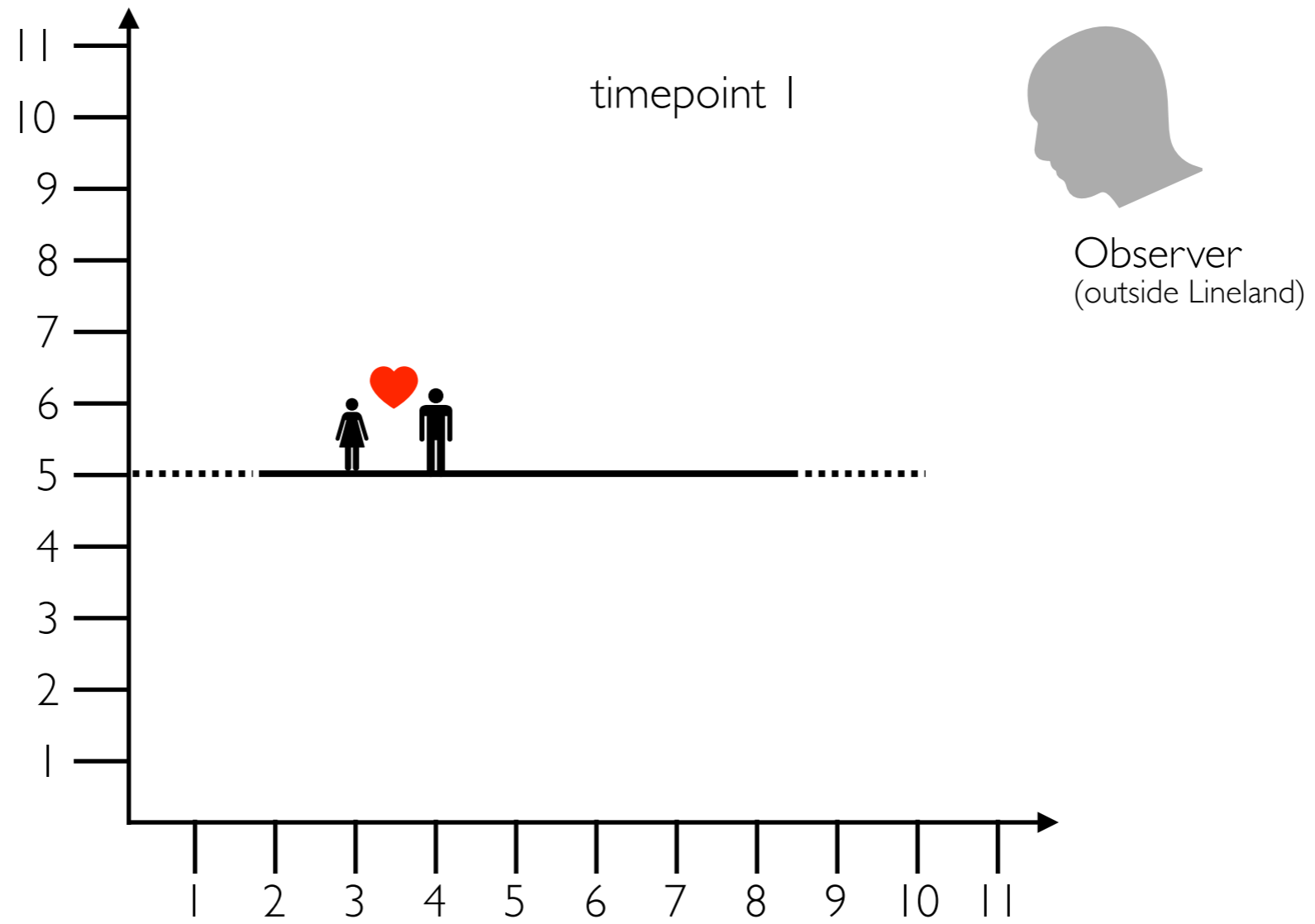


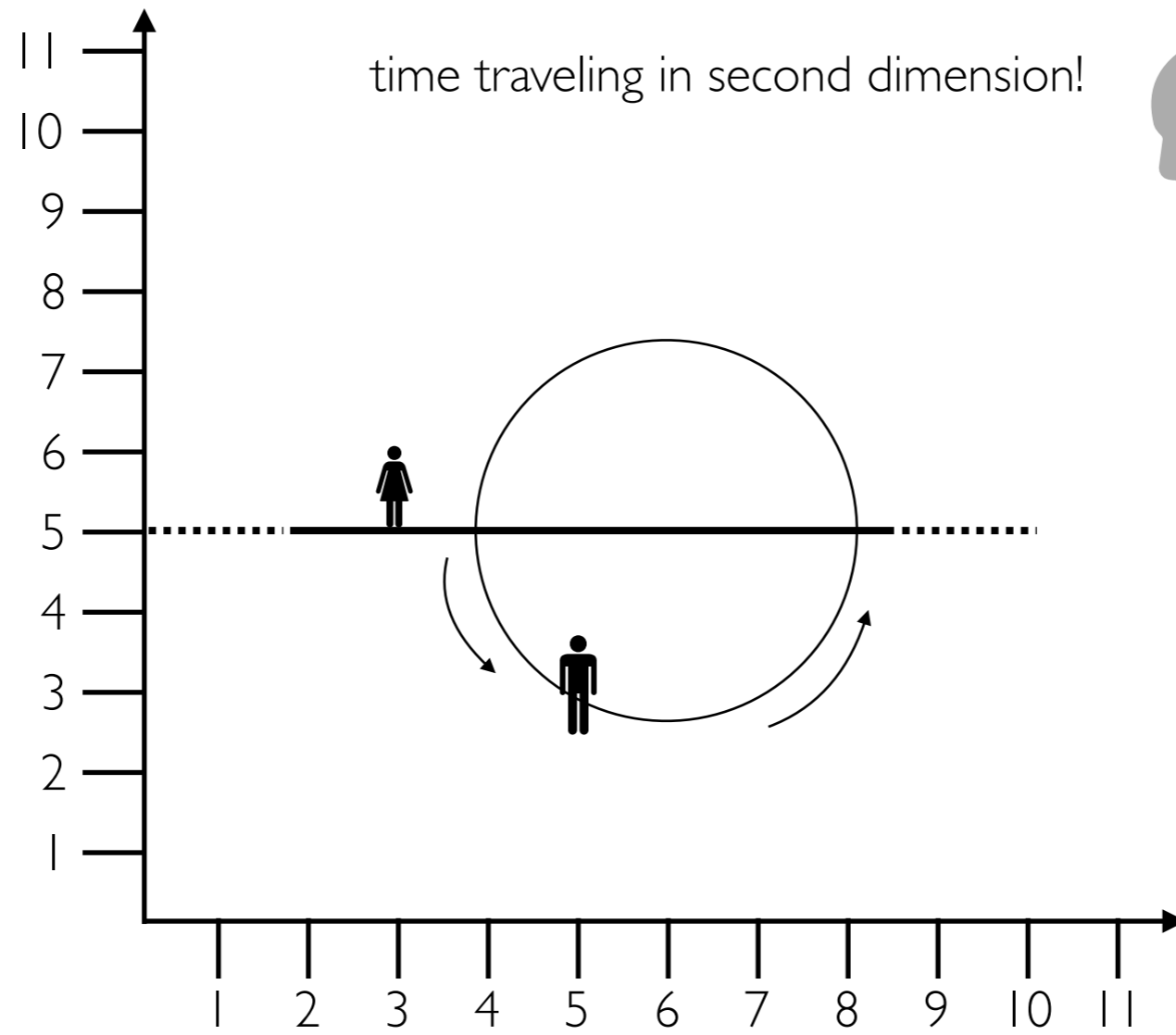


Observer
(outside Lineland)

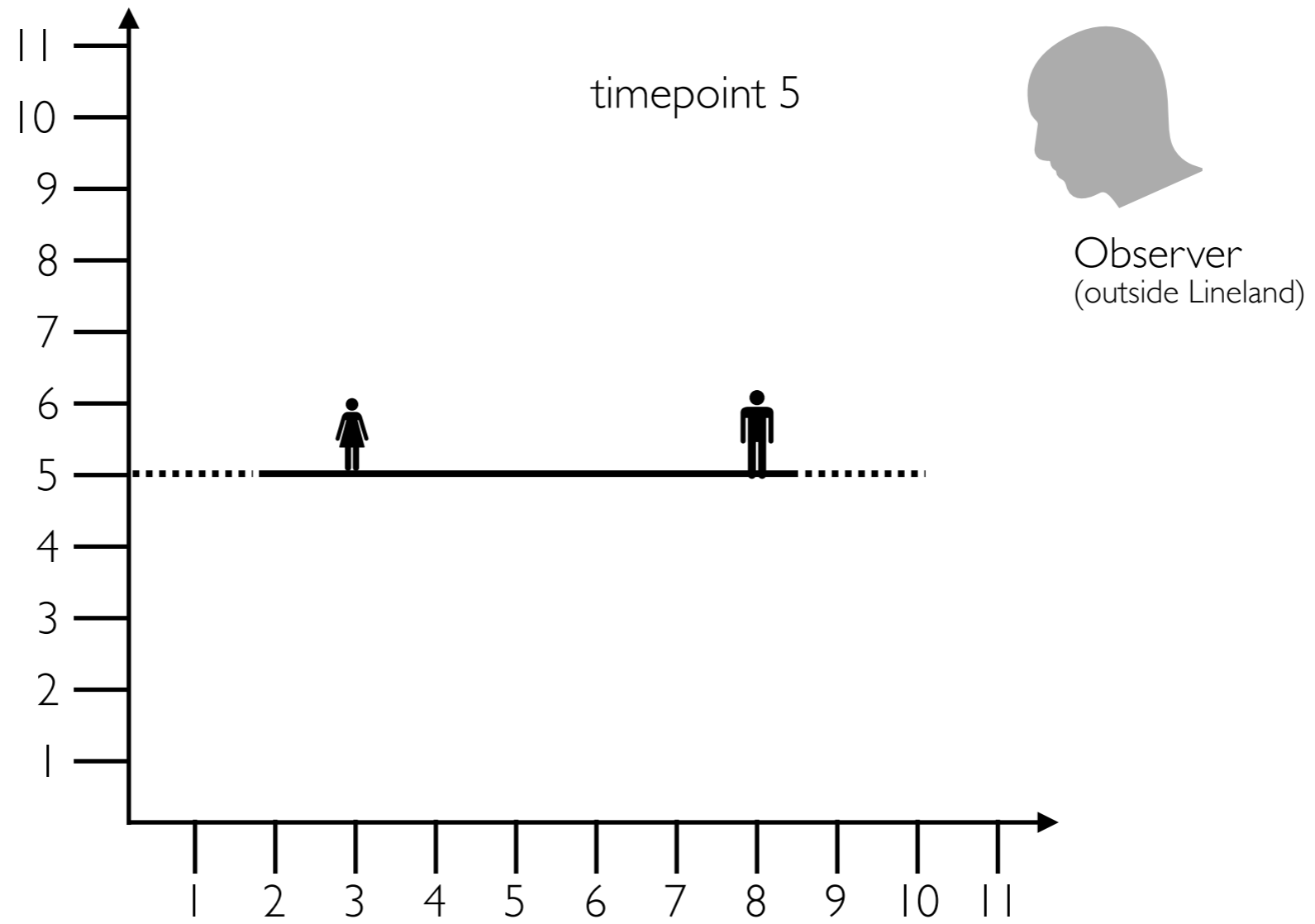


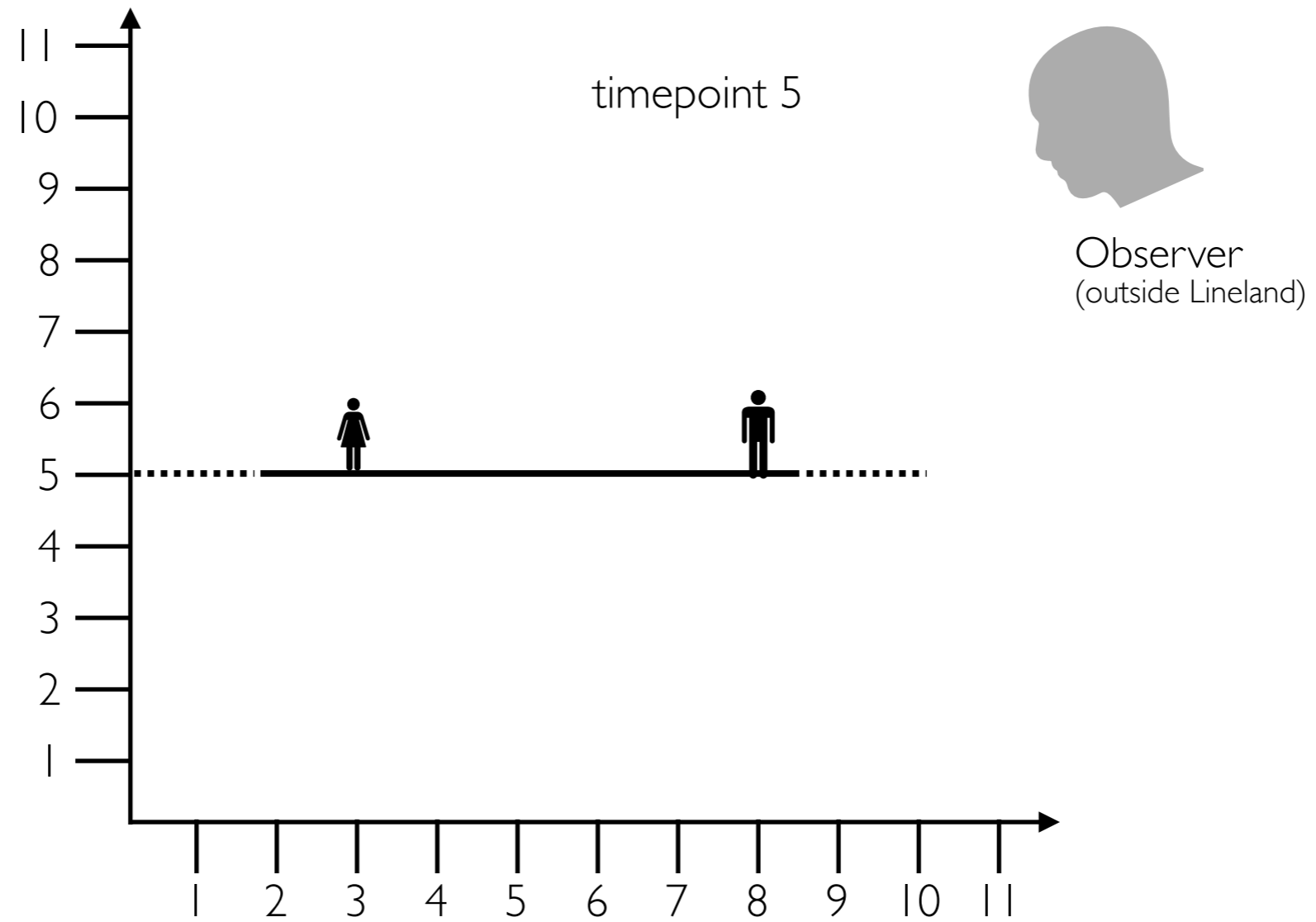
Observer
(outside Lineland)





Observer
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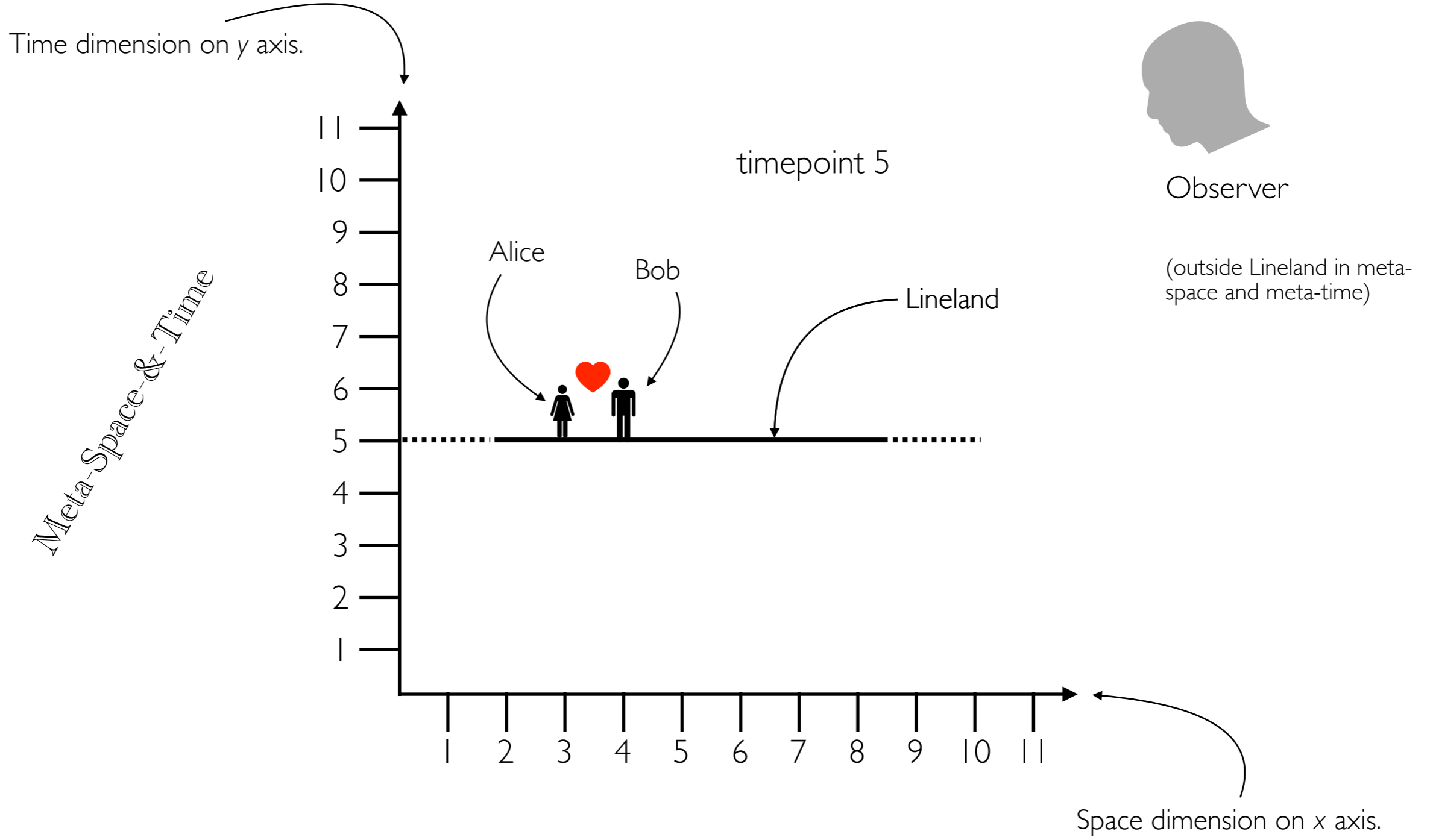


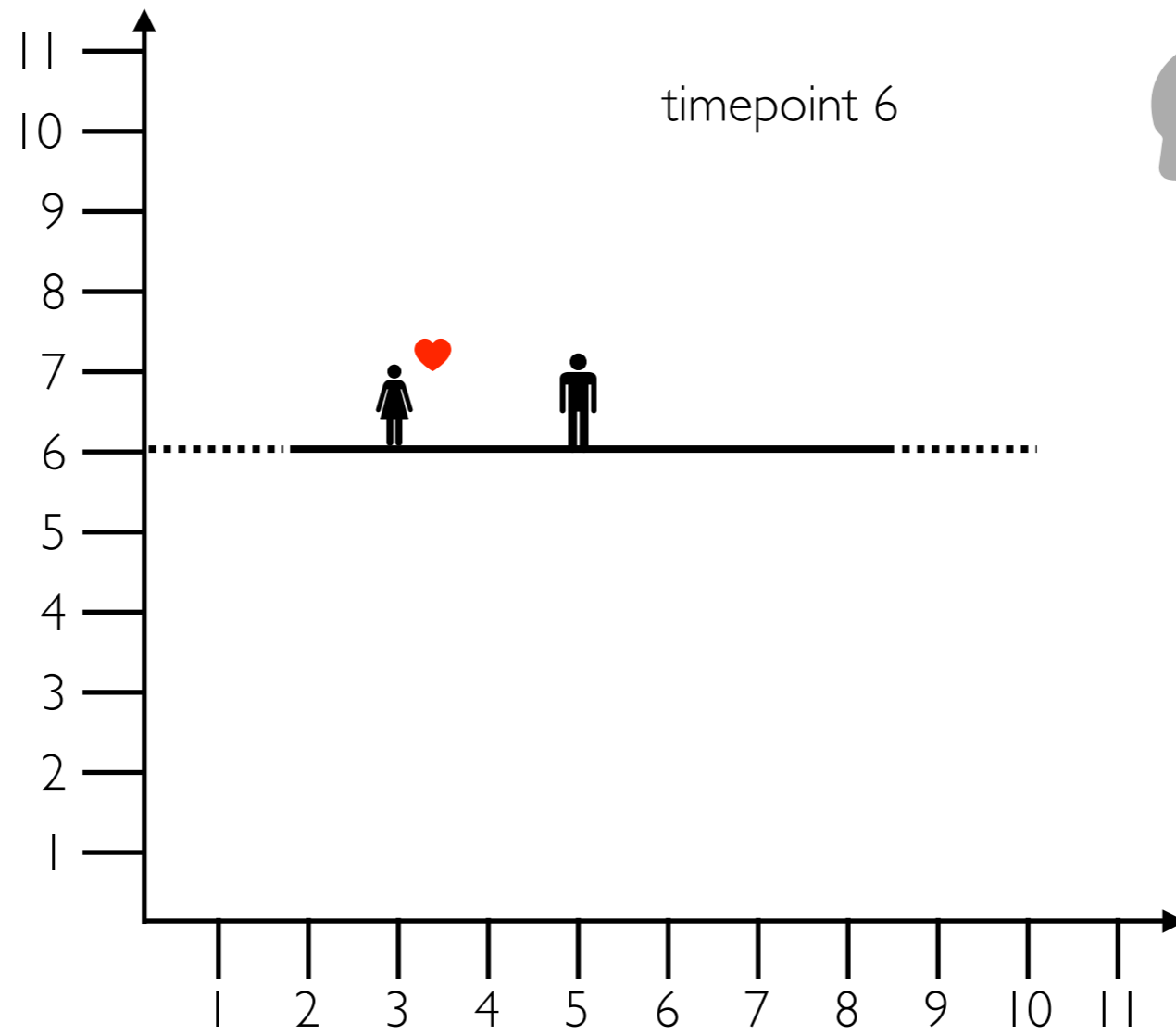


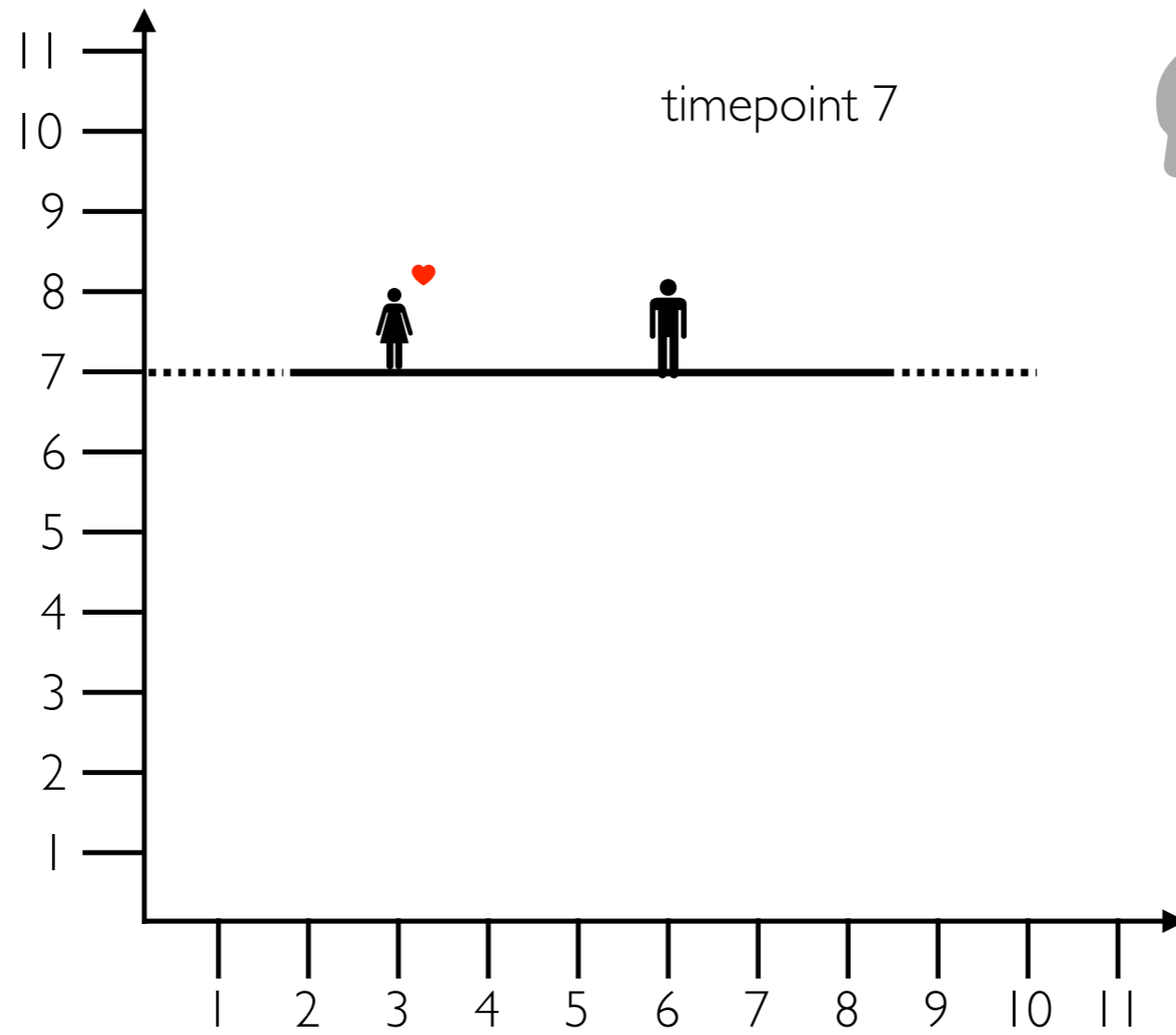
∴ Backwards time travel possible!

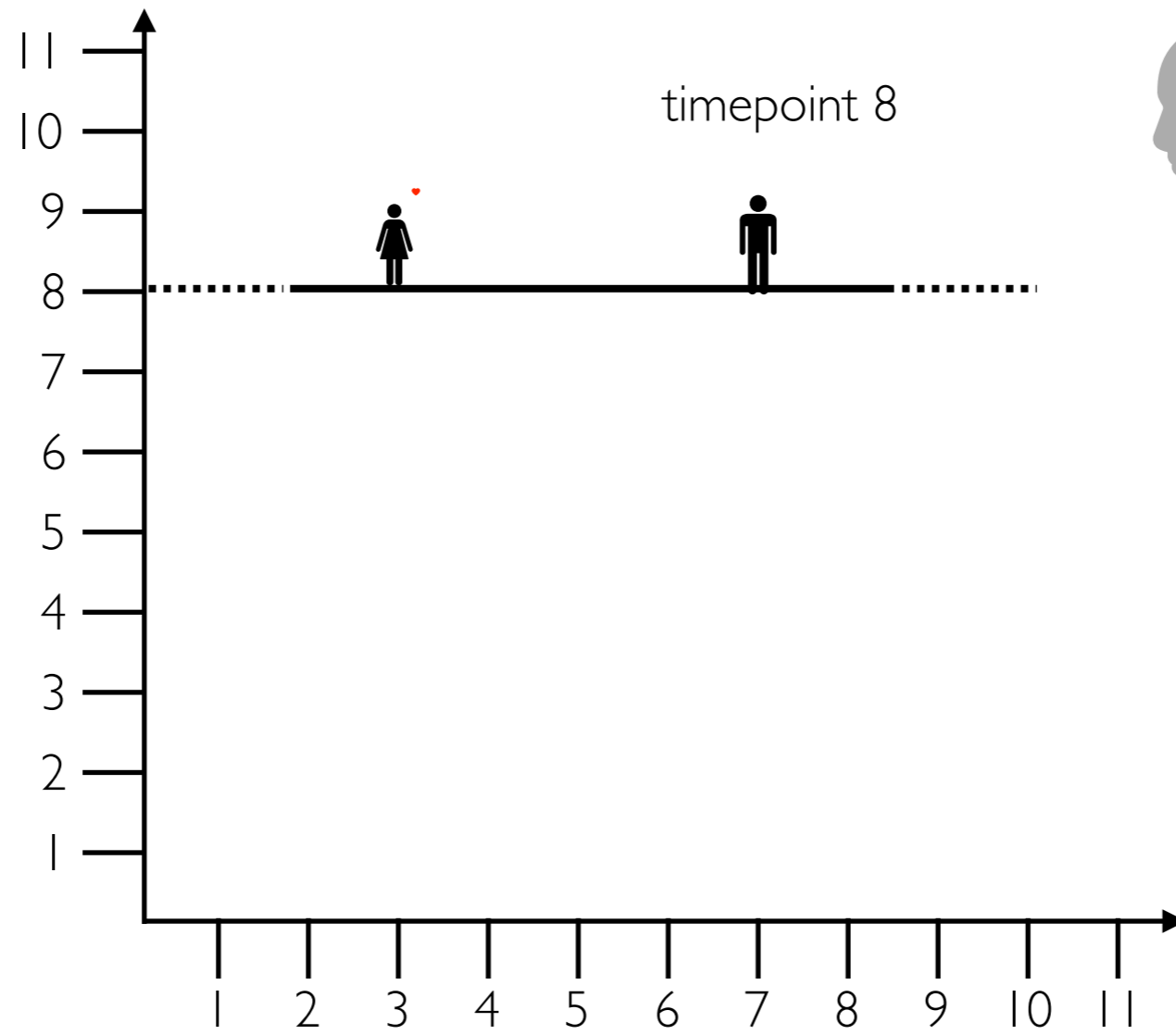
*Video Proof of Possibility of
Time Travel in Lineland ...*

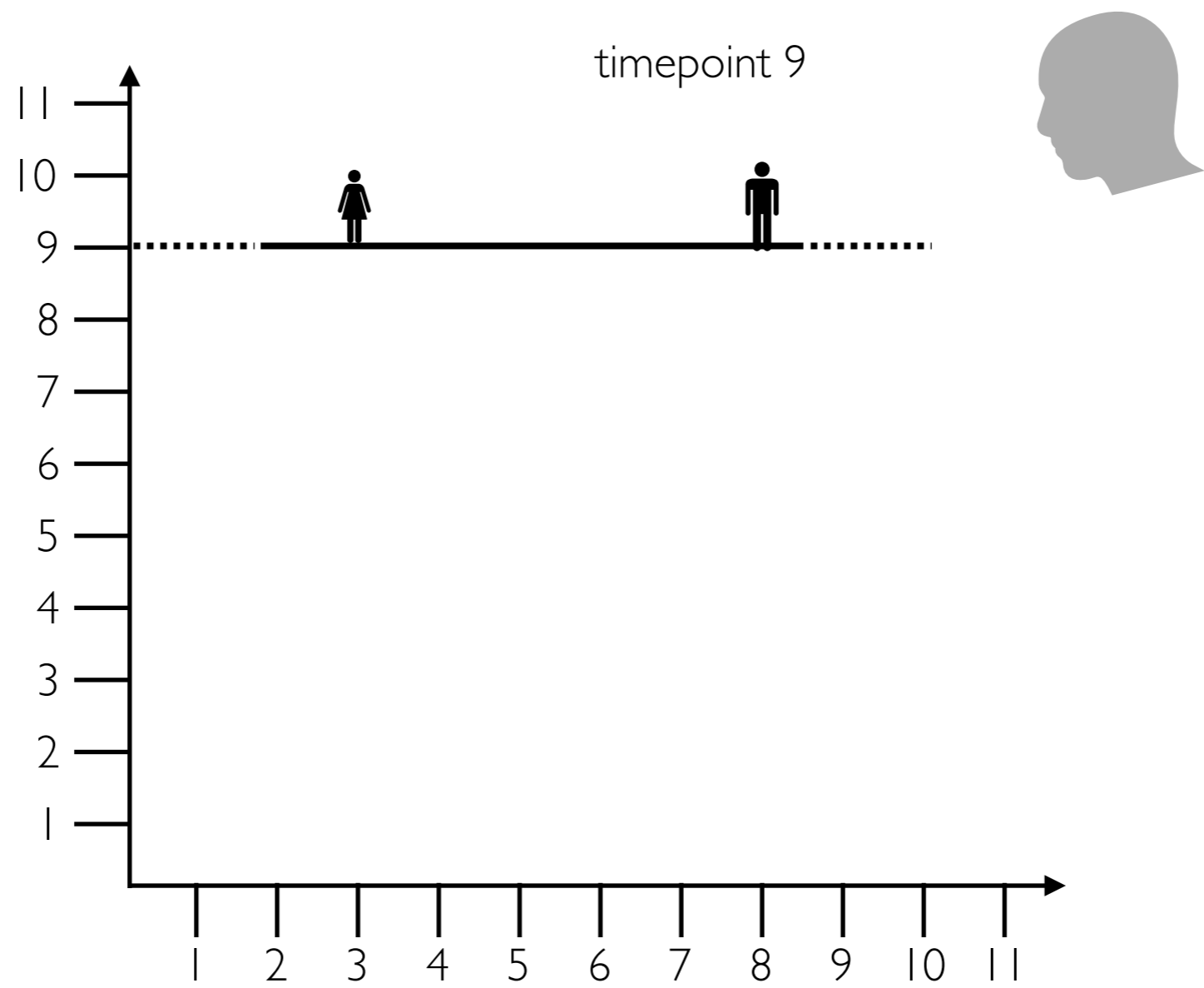
Meta-Space-&-Time



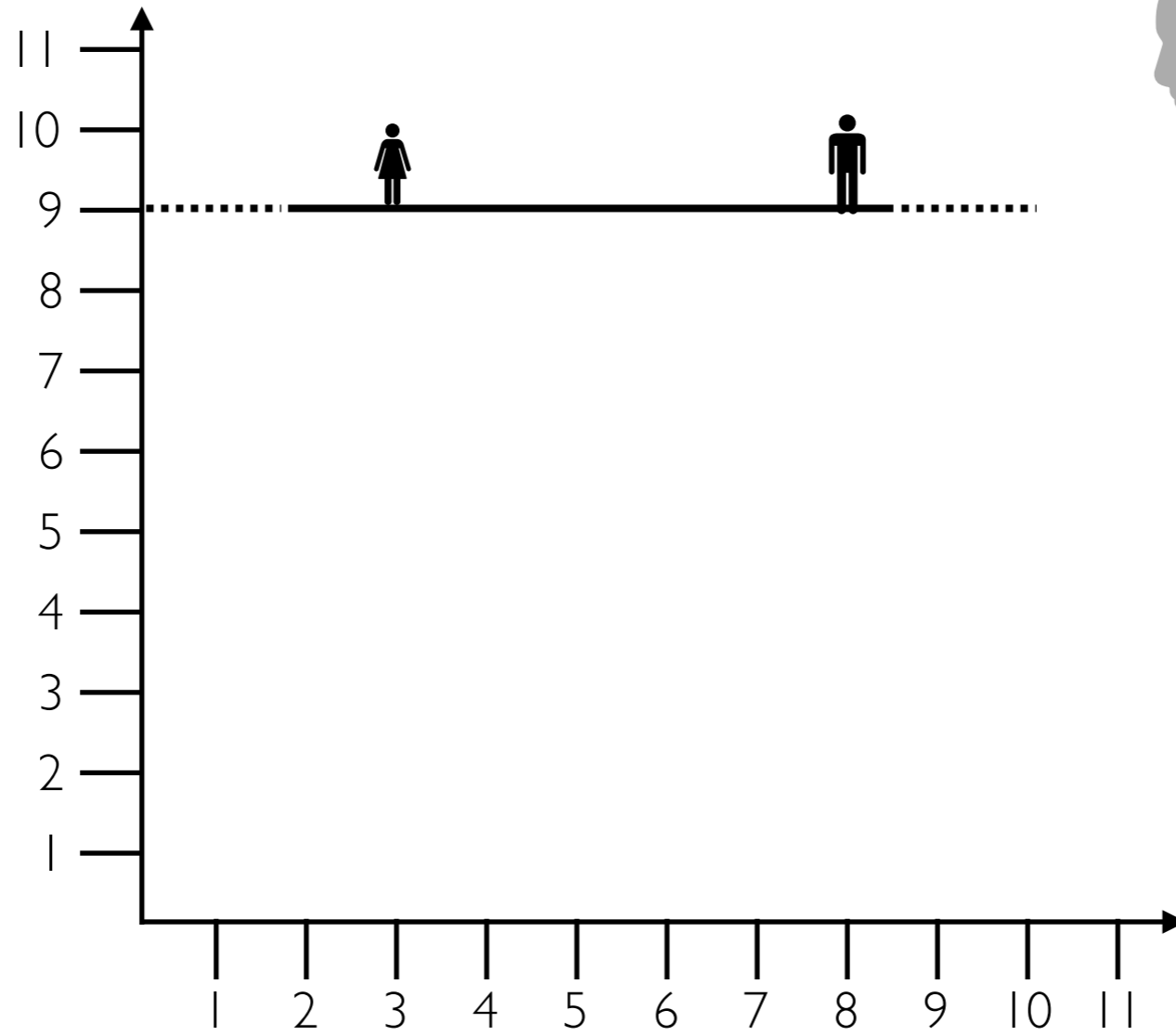




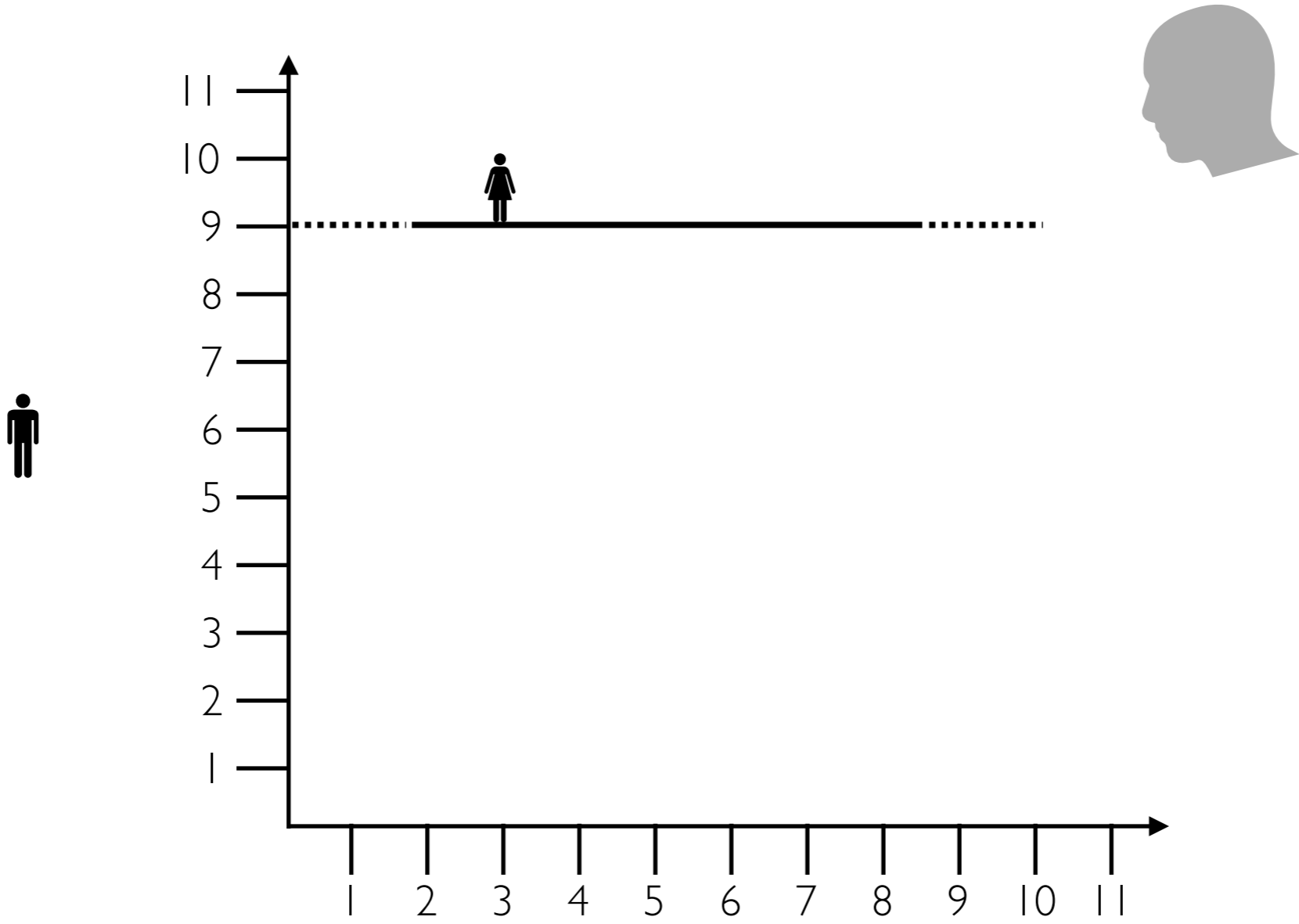


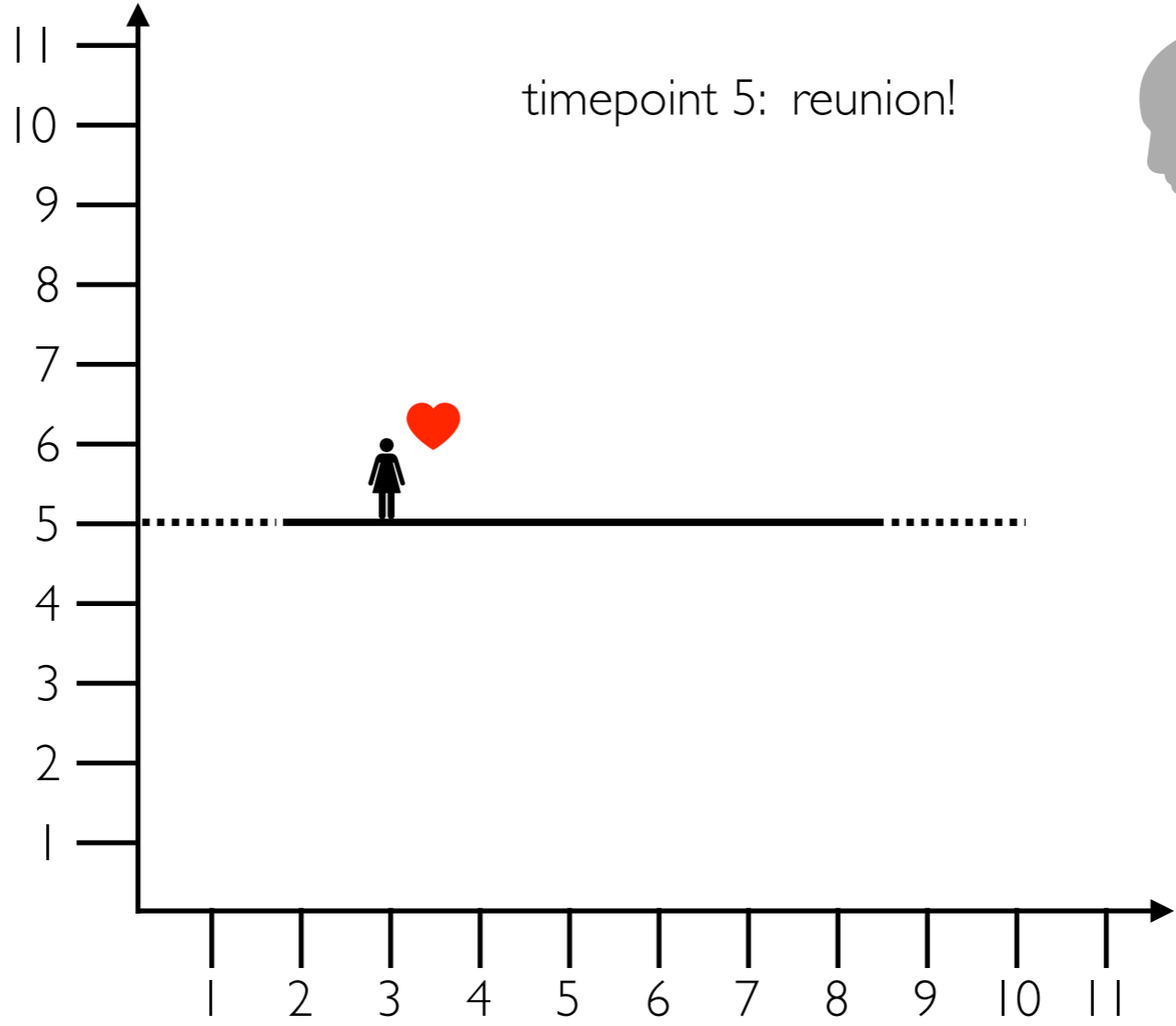


time traveling begins, watched by Observer!



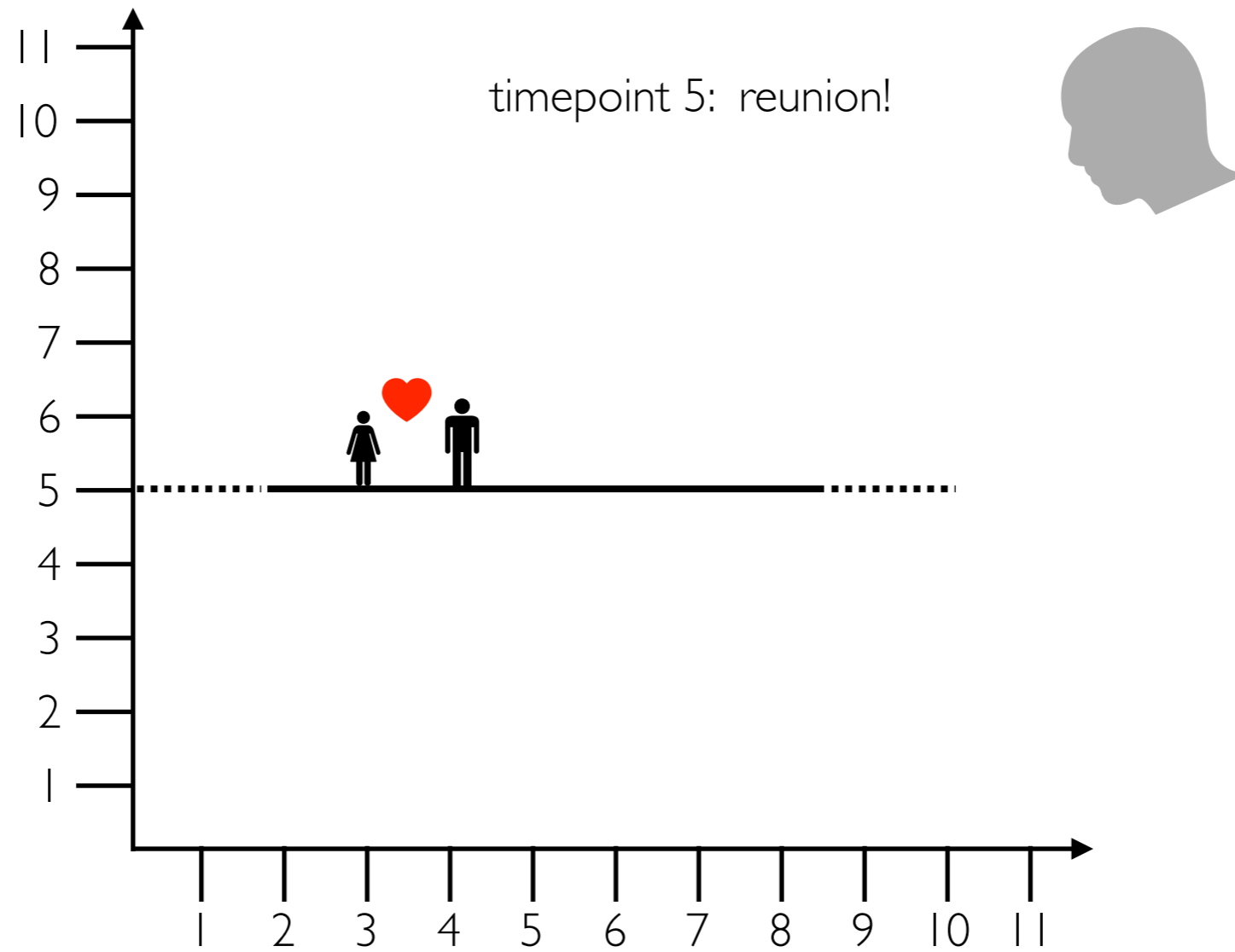
time traveling begins, watched by Observer!





timepoint 5: reunion!





∴ Backwards time travel mathematically possible!

Heterogeneous Proof of
Possibility of Time Travel in
Flatland ...

Meta-Space-&-Time

Time dimension on z axis.

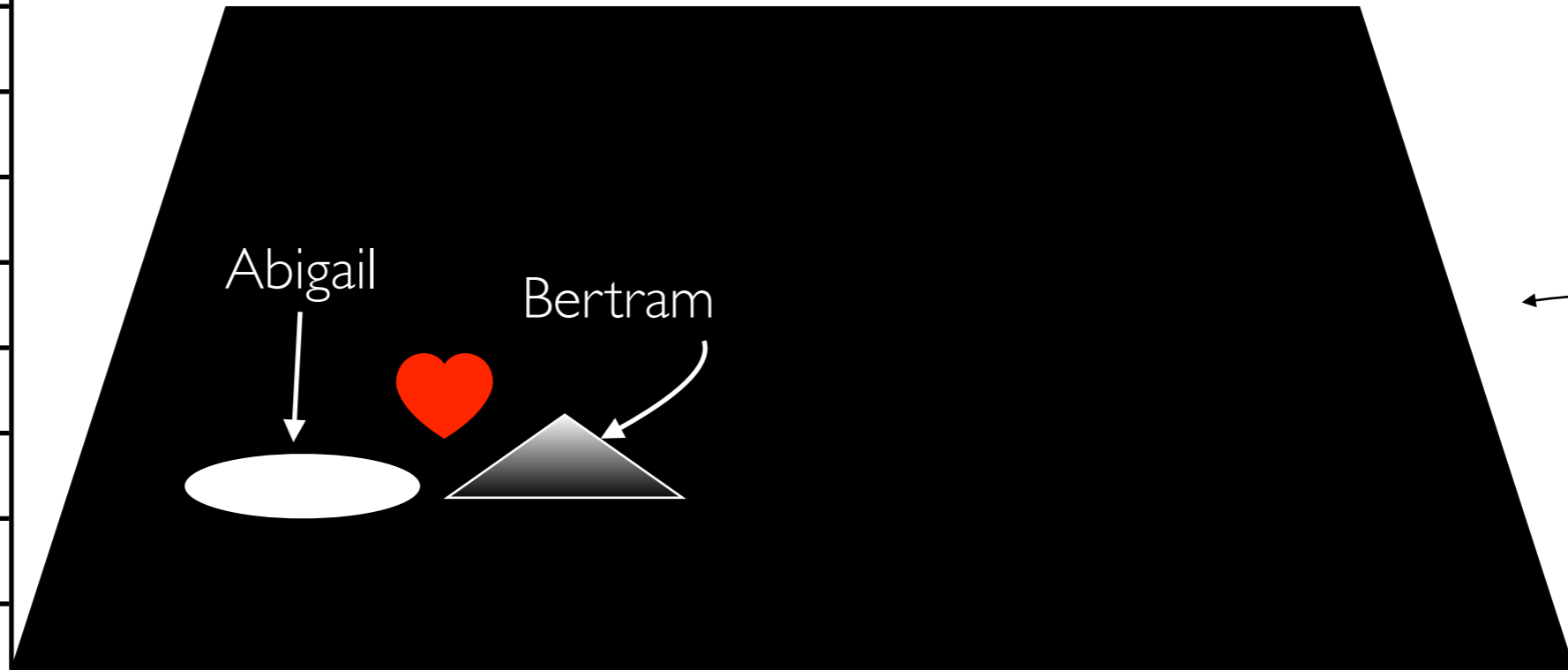
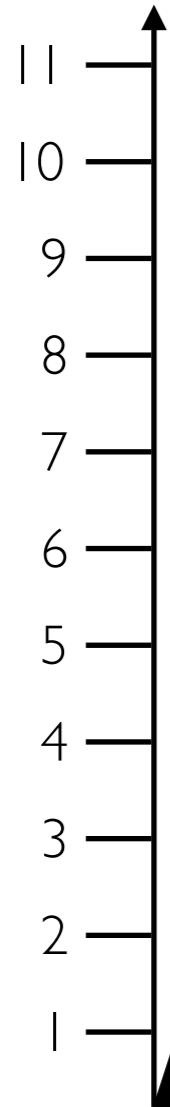


Observer (meta space-
and-time outside Flatland)

timepoint I

Flatland

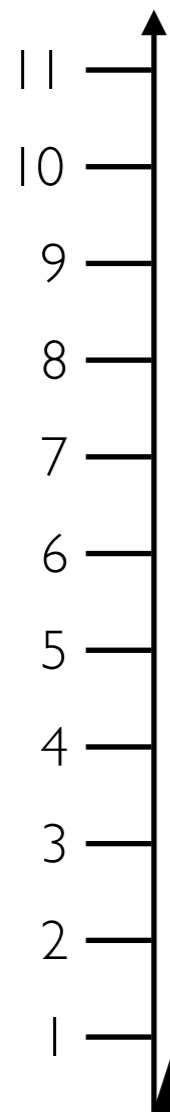
Meta-Space-&-Time



Abigail

Bertram

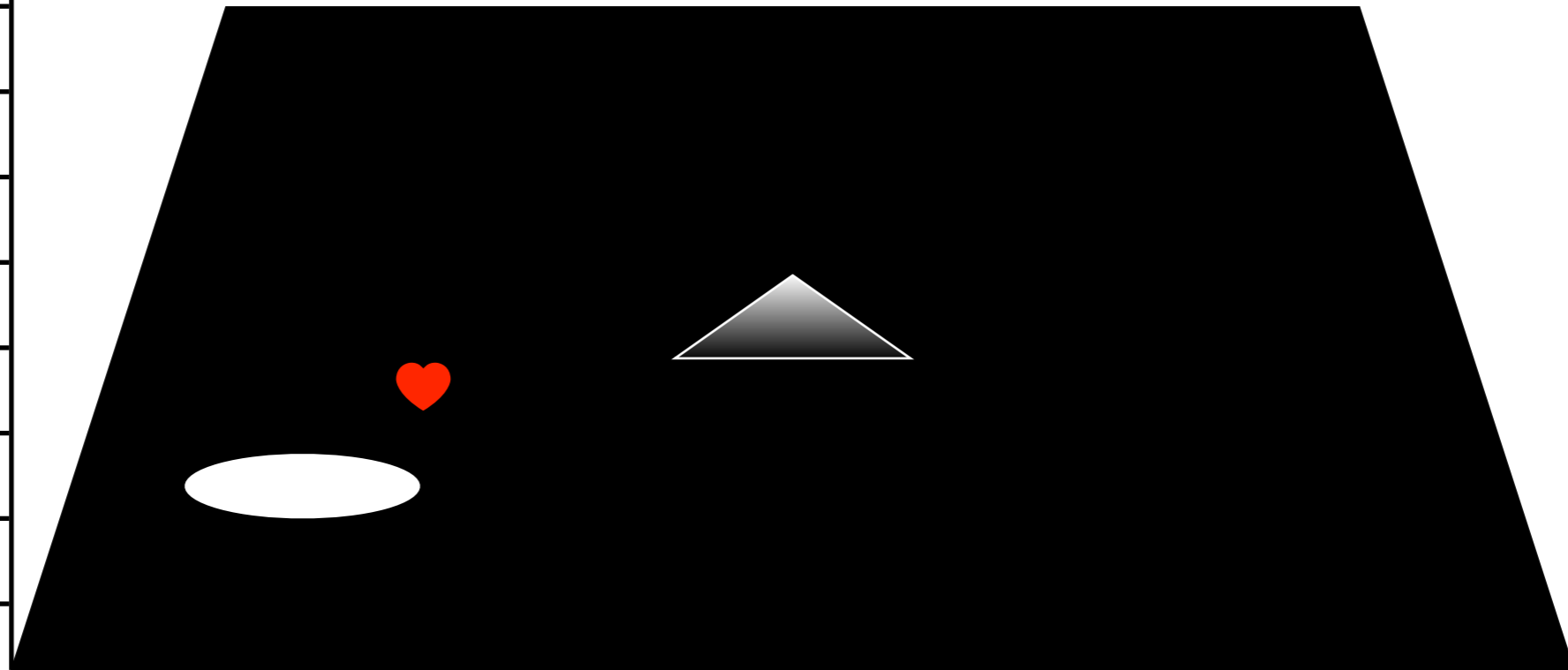
Space dimensions on x-and-y axes..

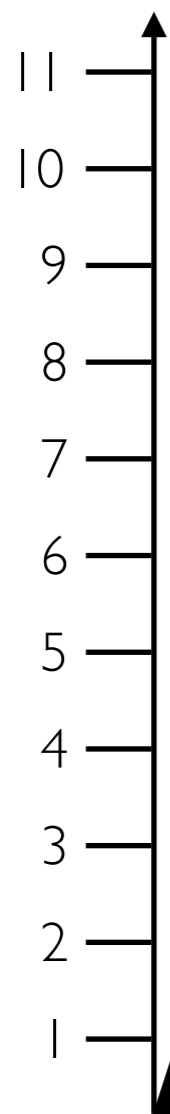


timepoint 2



Observer
(outside Flatland)

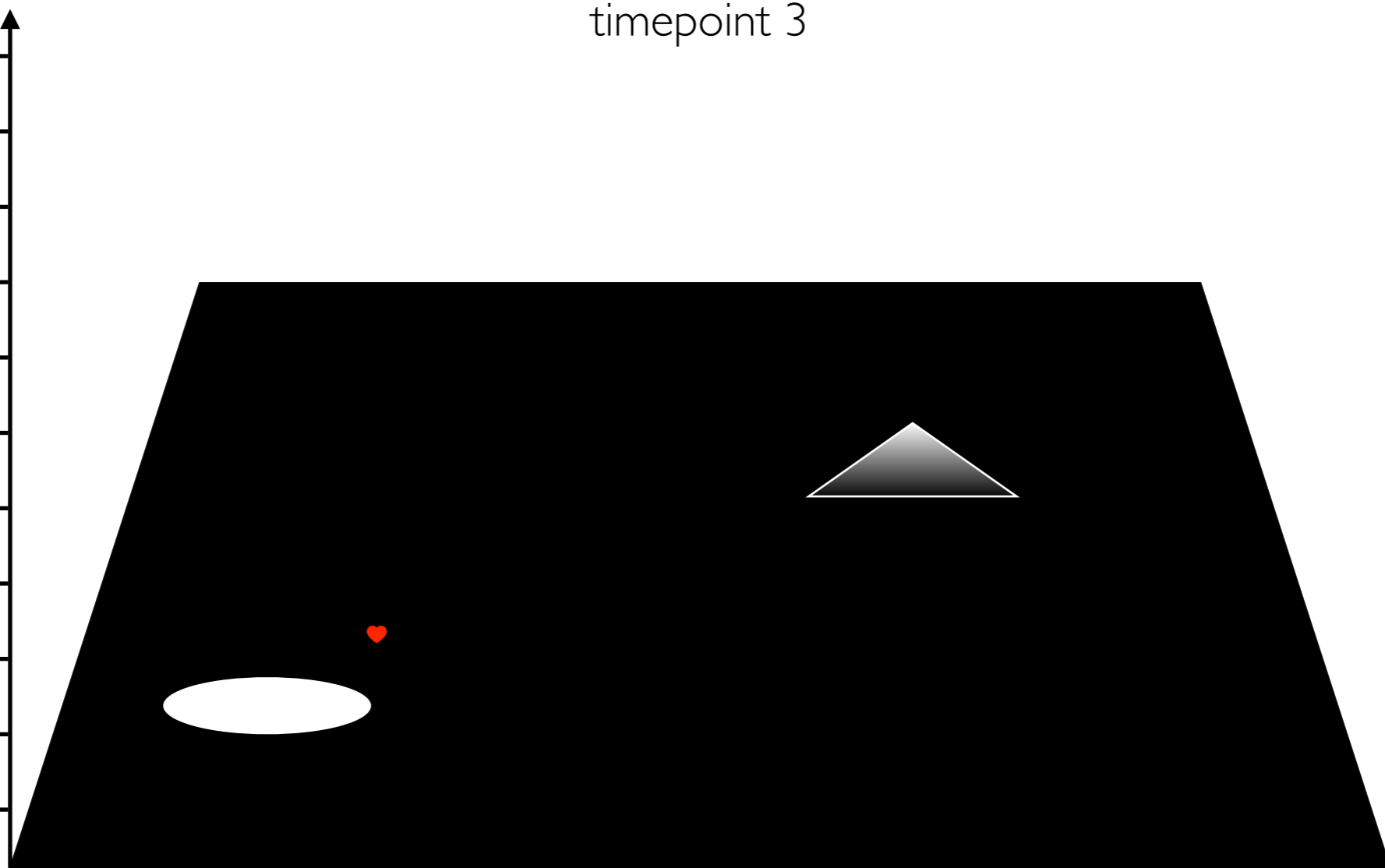


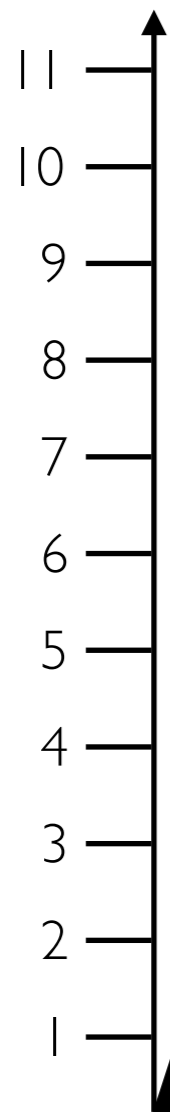


timepoint 3



Observer
(outside Flatland)

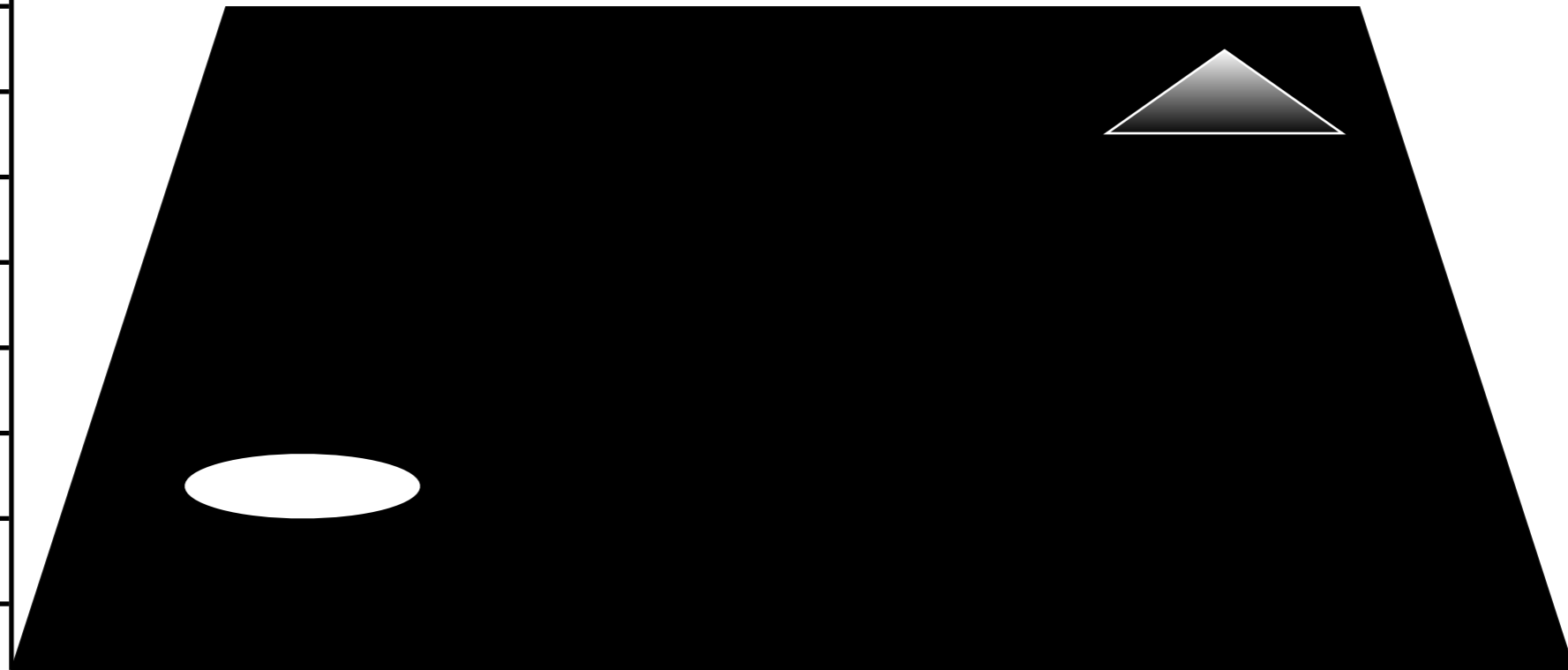




timepoint 4



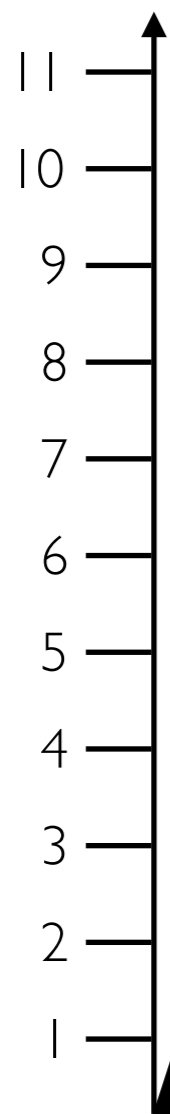
Observer
(outside Flatland)





Observer
(outside Flatland)

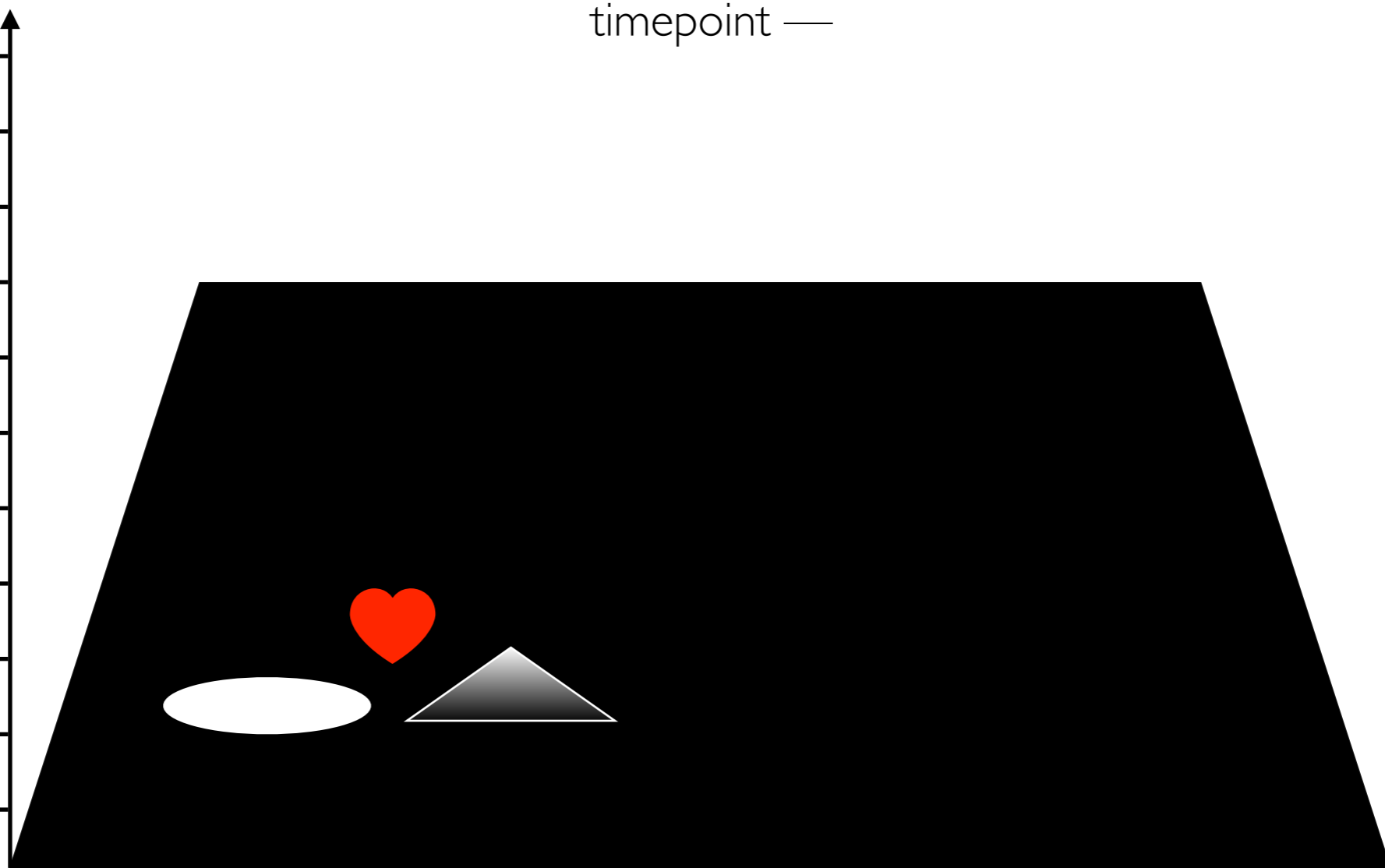


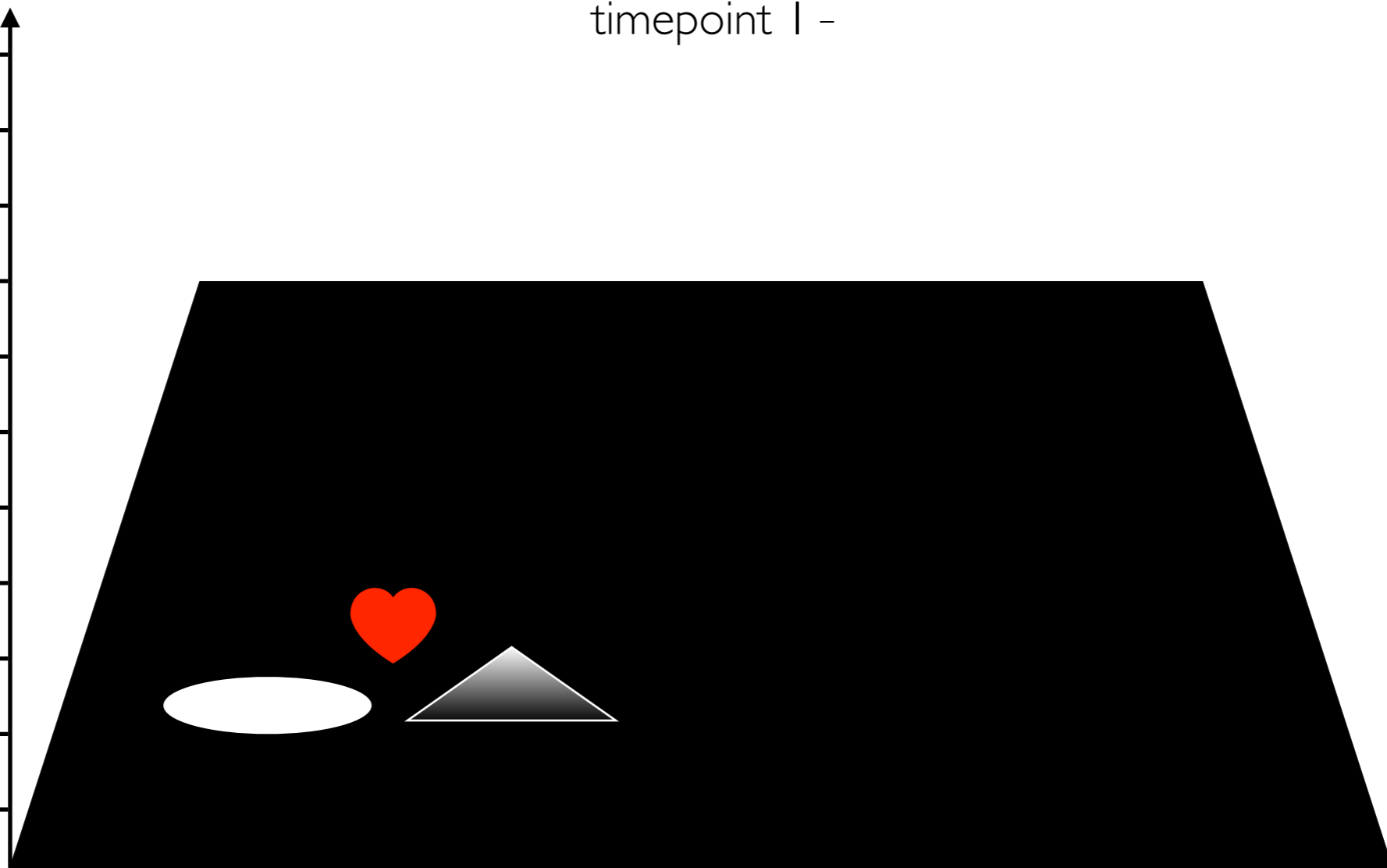
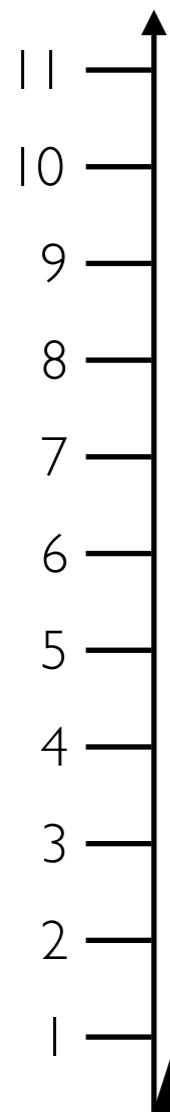


timepoint —



Observer
(outside Flatland)





timepoint I -

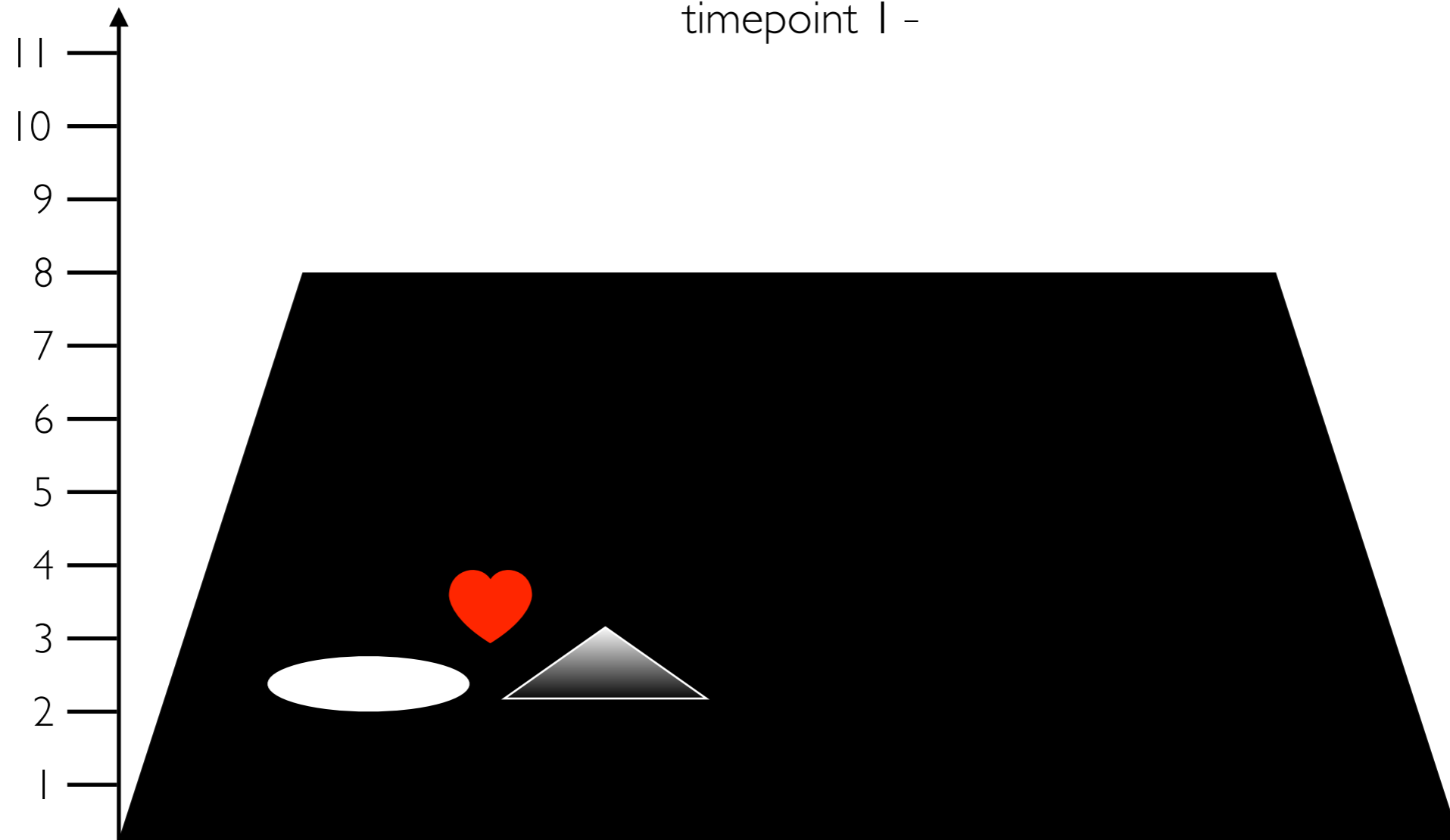


Observer
(outside Flatland)



Observer
(outside Flatland)

timepoint I -



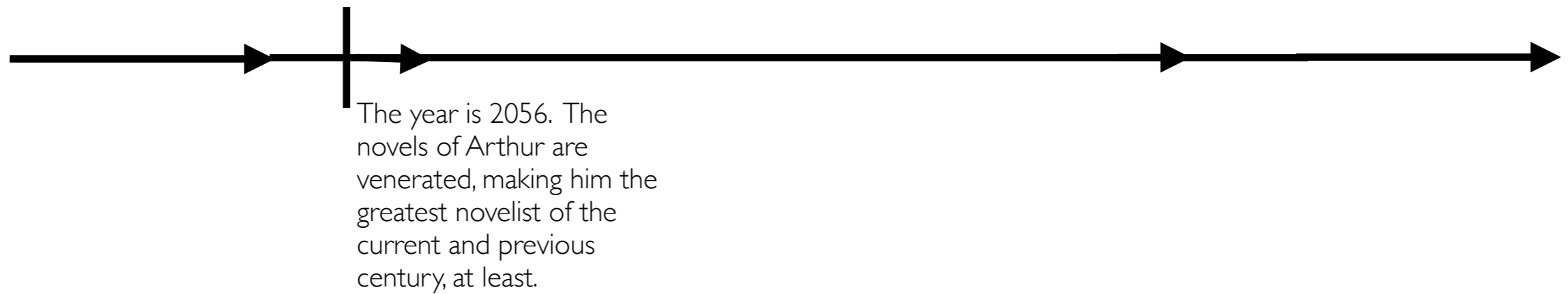
∴ Backwards time travel possible!

Looping “Proust” ...

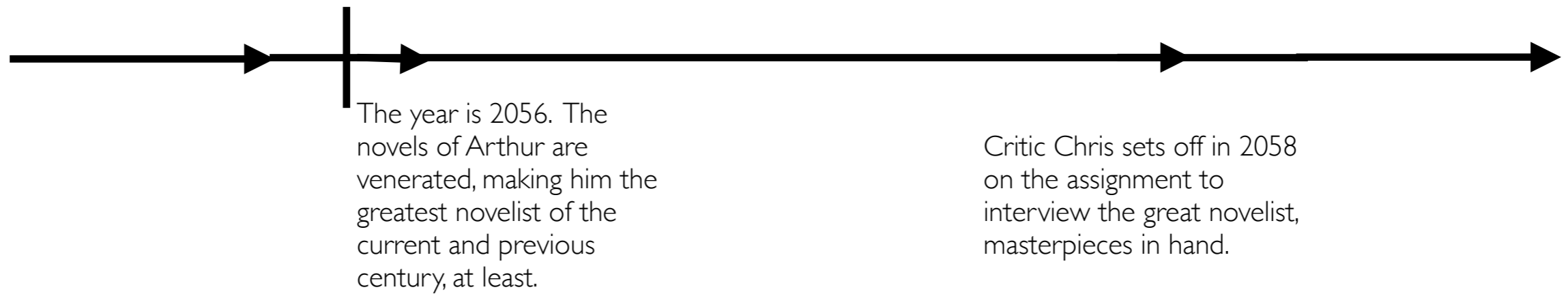
“The Discovery of Morniel Mathaway”

<https://www.you-books.com/book/W-Tenn/The-Discovery-of-Morniel-Mathaway>

The Paradox of Proust



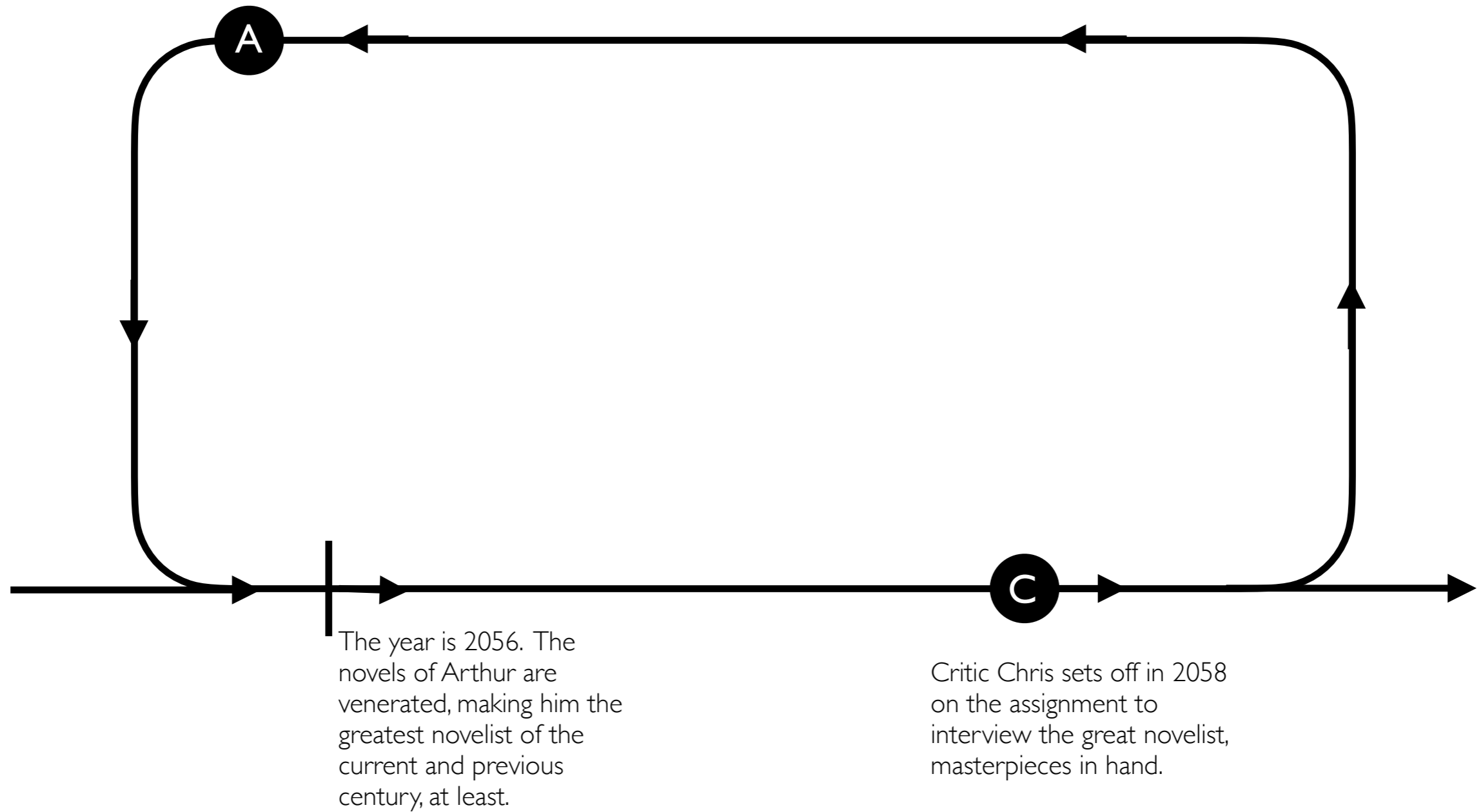
The Paradox of Proust



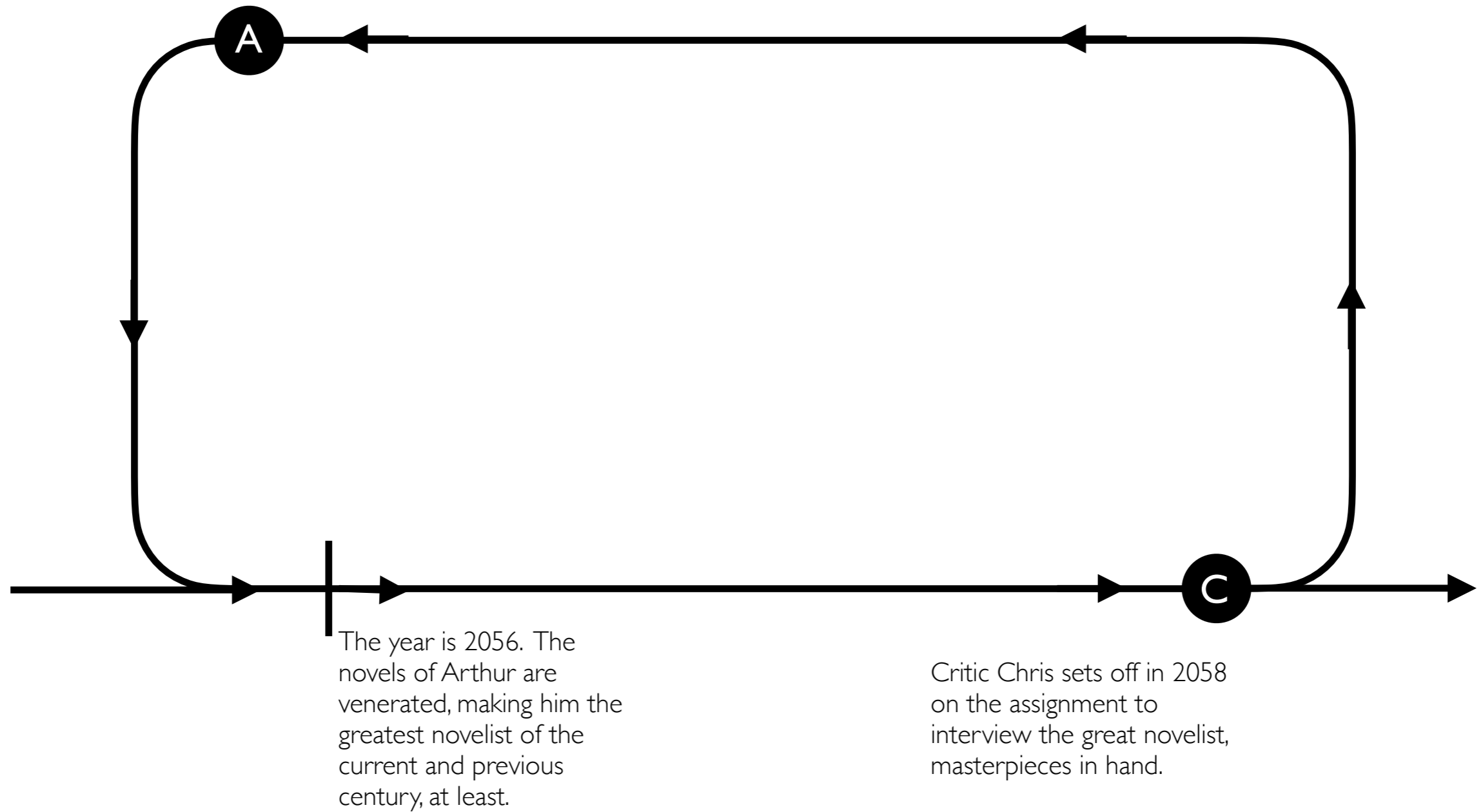
The Paradox of Proust



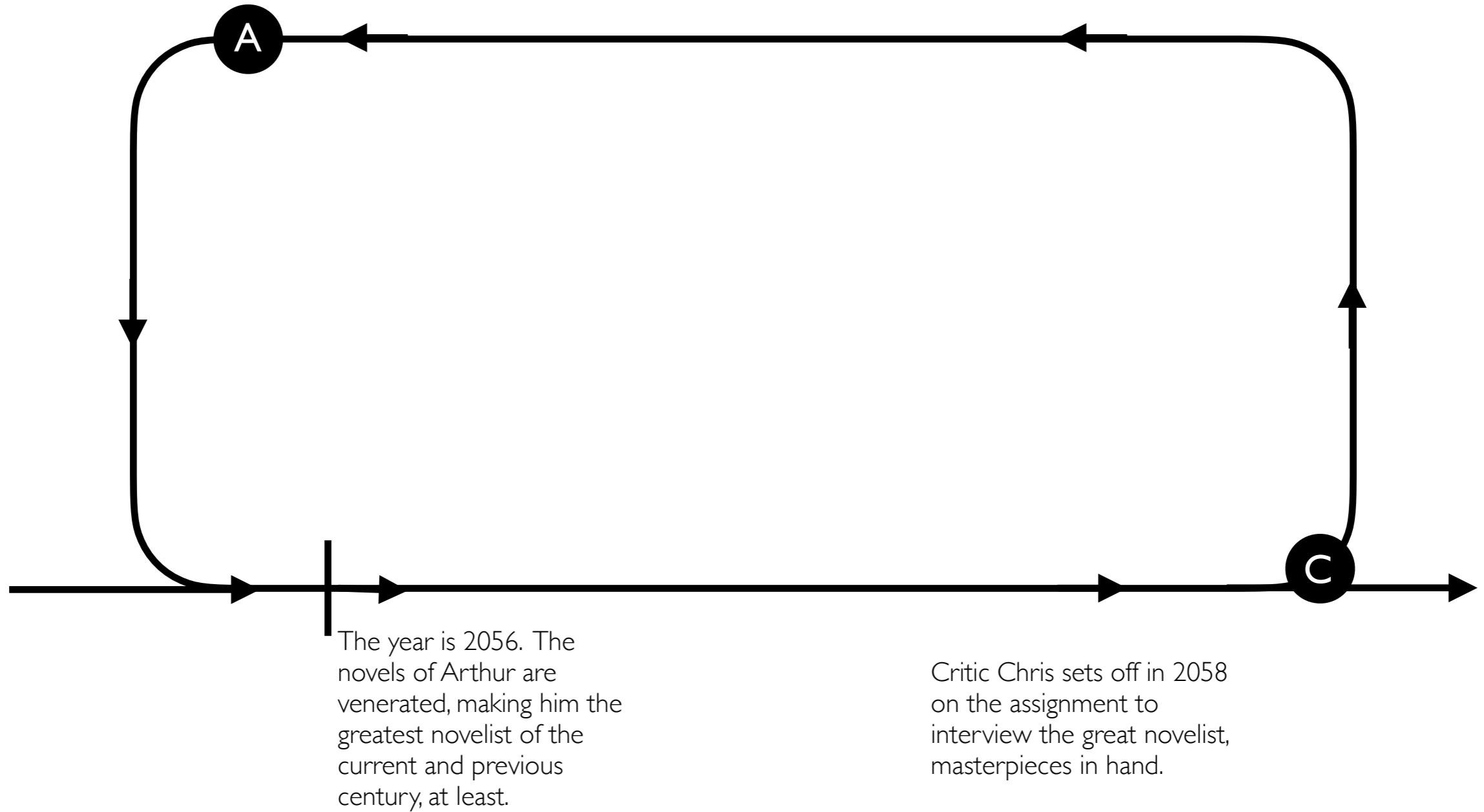
The Paradox of Proust



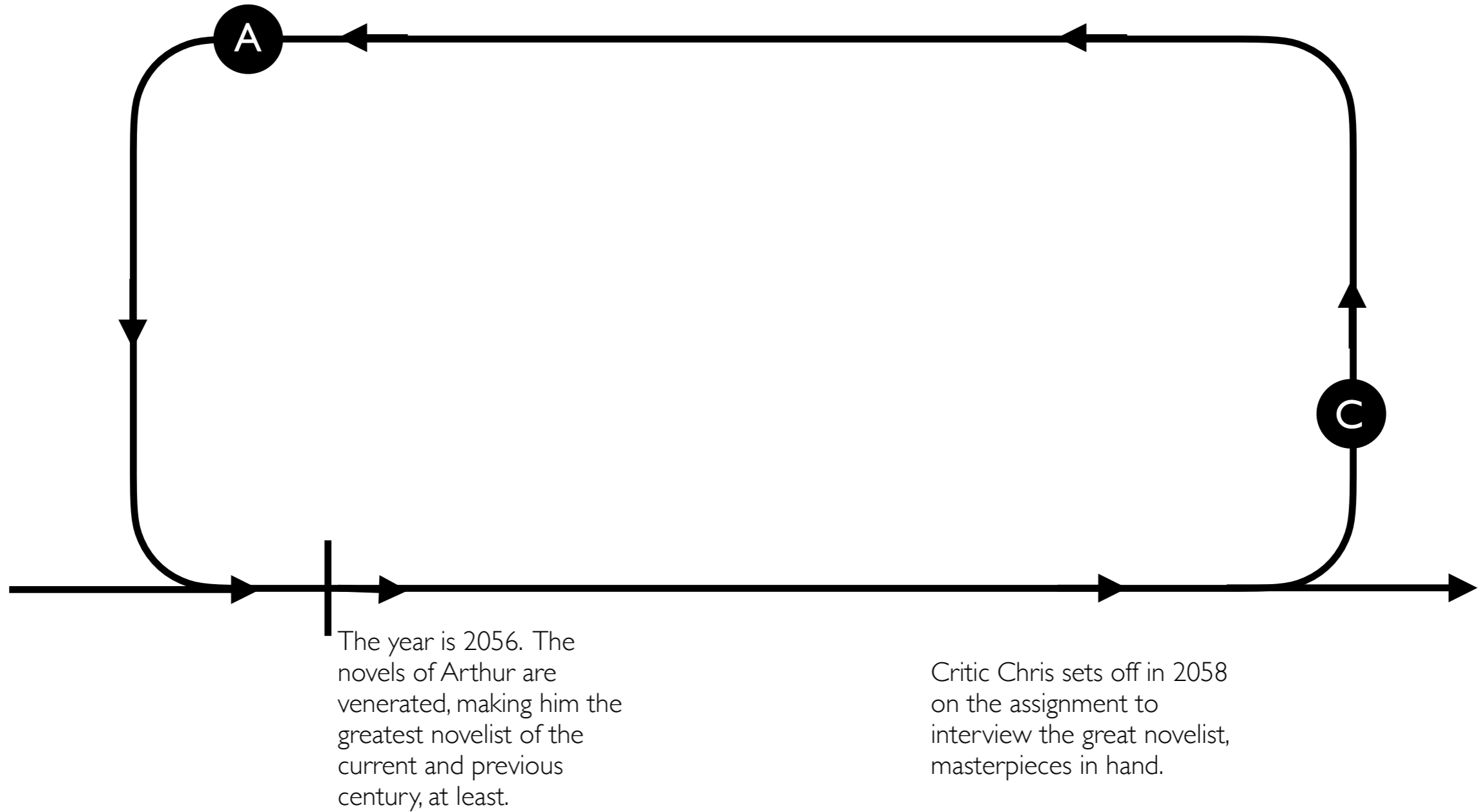
The Paradox of Proust



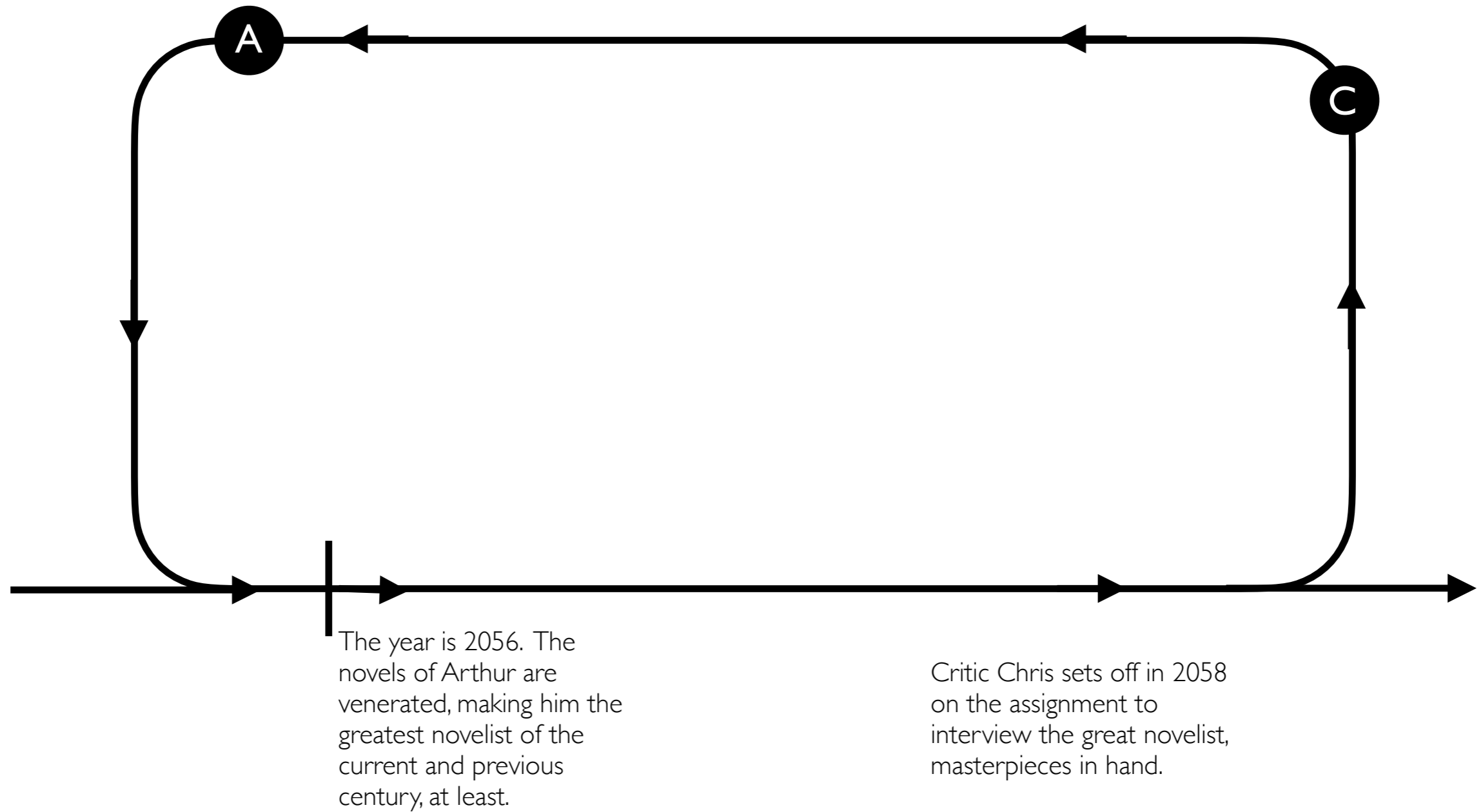
The Paradox of Proust



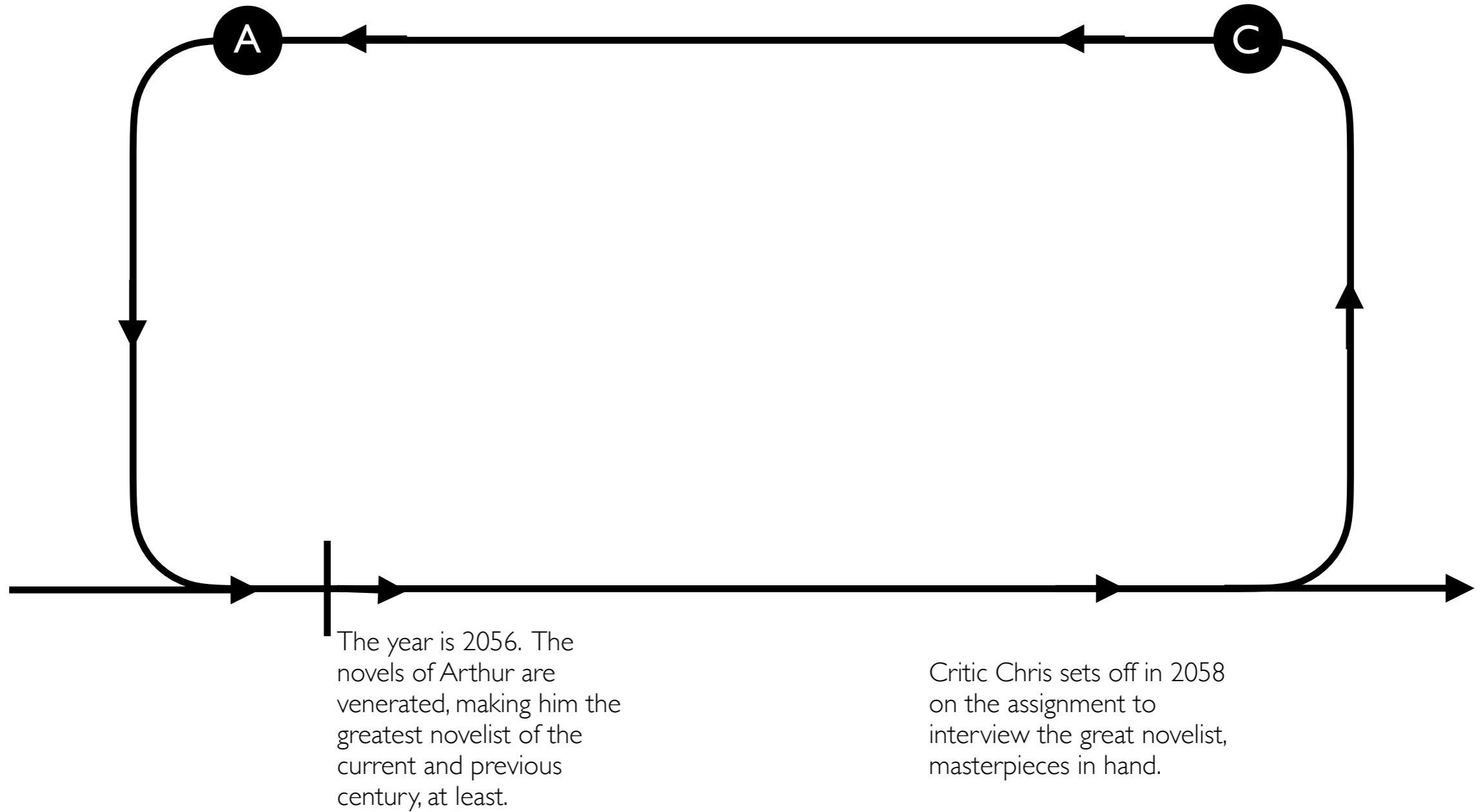
The Paradox of Proust



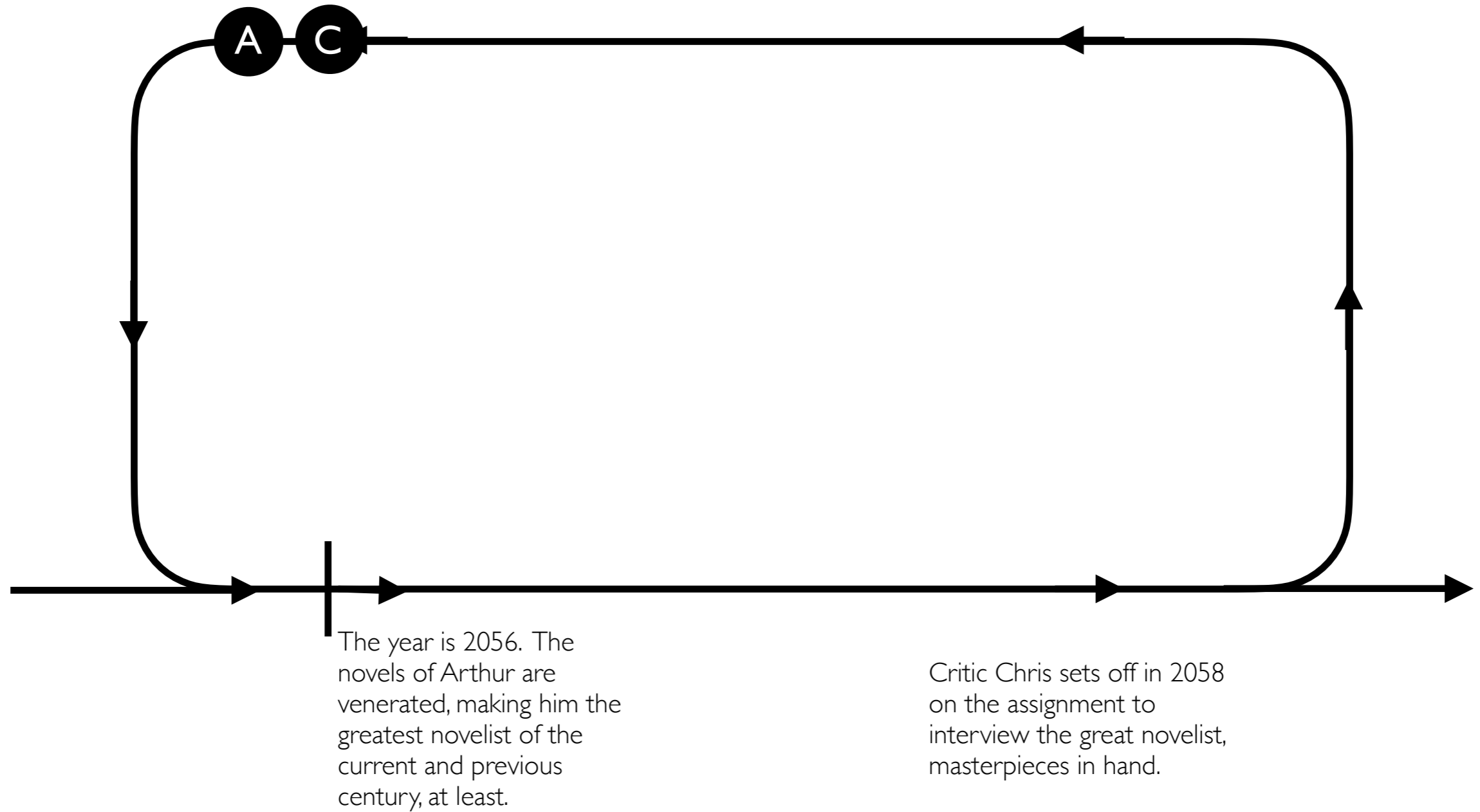
The Paradox of Proust



The Paradox of Proust

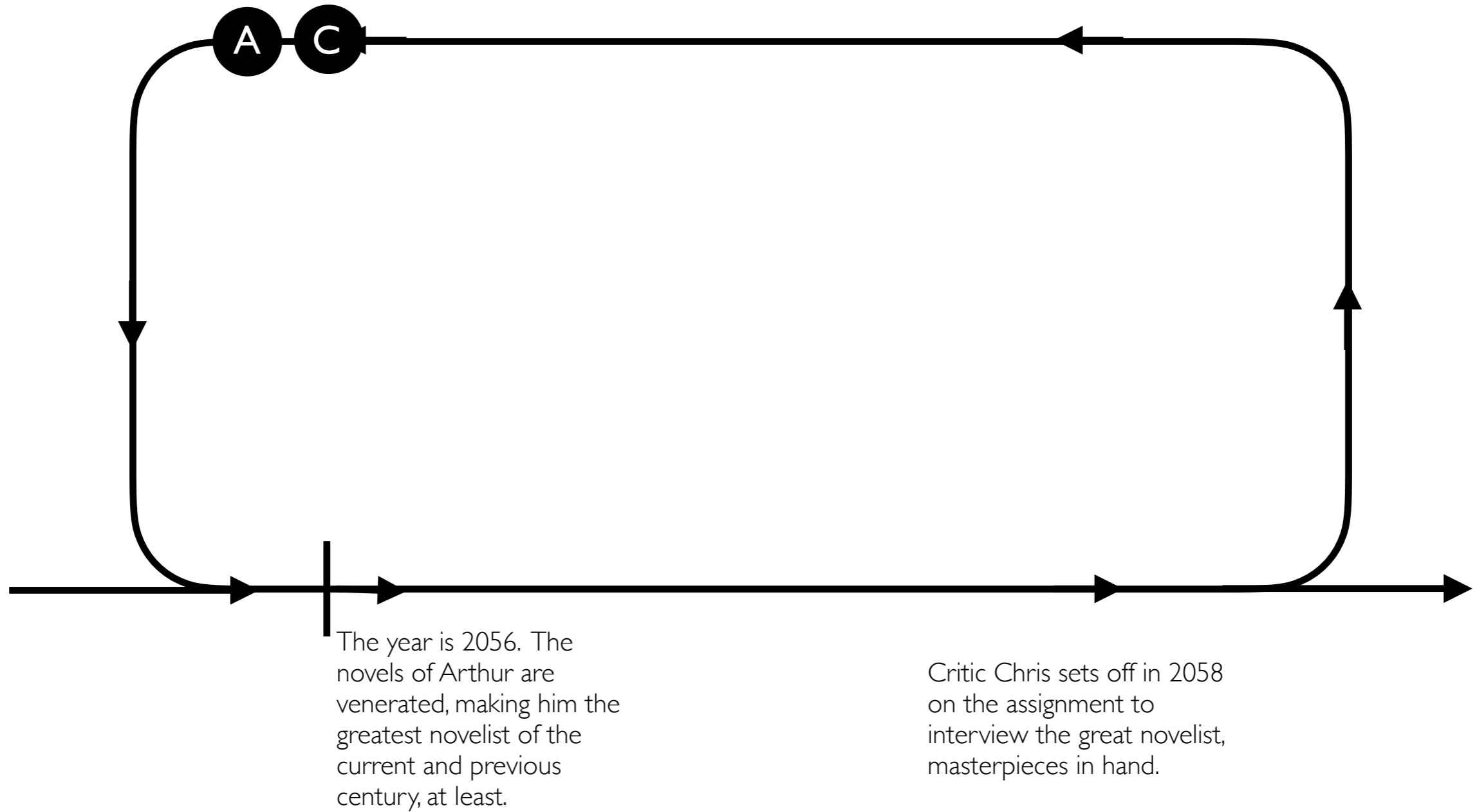


The Paradox of Proust



The Paradox of Proust

Chris interviews the fifth-rate, conceited novelist Arthur in 1958



The Paradox of Proust

Chris interviews the fifth-rate, conceited novelist Arthur in 1958

A **C**

Chris is stunned to see the logorrhea — and must quickly return to his present. He leaves the masterpieces.

The year is 2056. The novels of Arthur are venerated, making him the greatest novelist of the current and previous century, at least.

Critic Chris sets off in 2058 on the assignment to interview the great novelist, masterpieces in hand.

The Paradox of Proust

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nf1 U ? † ⊥



E.g., (599 w)

But I had seen first one and then another of the rooms in which I had slept during my life, and in the end I would revisit them all in the long course of my waking dream: rooms in winter, where on going to bed I would at once bury my head in a nest, built up out of the most diverse materials, the corner of my pillow, the top of my blankets, a piece of a shawl, the edge of my bed, and a copy of an evening paper; all of which things I would contrive, with the infinite patience of birds building their nests, to cement into one whole; rooms where, in a keen frost, I would feel the satisfaction of being shut in from the outer world (like the sea-swallow which builds at the end of a dark tunnel and is kept warm by the surrounding earth), and where, the fire keeping in all night, I would sleep wrapped up, as it were, in a great cloak of snug and savoury air, shot with the glow of the logs which would break out again in flame: in a sort of alcove without walls, a cave of warmth dug out of the heart of the room itself, a zone of heat whose boundaries were constantly shifting and altering in temperature as gusts of air ran across them to strike freshly upon my face, from the corners of the room, or from parts near the window or far from the fireplace which had therefore remained cold — or rooms in summer, where I would delight to feel myself a part of the warm evening, where the moonlight striking upon the half-opened shutters would throw down to the foot of my bed its enchanted ladder; where I would fall asleep, as it might be in the open air, like a titmouse which the breeze keeps poised in the focus of a sunbeam — or sometimes the Louis XVI room, so cheerful that I could never feel really unhappy, even on my first night in it: that room where the slender columns which lightly supported its ceiling would part, ever so gracefully, to indicate where the bed was and to keep it separate; sometimes again that little room with the high ceiling, hollowed in the form of a pyramid out of two separate storeys, and partly walled with mahogany, in which from the first moment my mind was drugged by the unfamiliar scent of flowering grasses, convinced of the hostility of the violet curtains and of the insolent indifference of a clock that chattered on at the top of its voice as though I were not there; while a strange and pitiless mirror with square feet, which stood across one corner of the room, cleared for itself a site I had not looked to find tenanted in the quiet surroundings of my normal field of vision: that room in which my mind, forcing itself for hours on end to leave its moorings, to elongate itself upwards so as to take on the exact shape of the room, and to reach to the summit of that monstrous funnel, had passed so many anxious nights while my body lay stretched out in bed, my eyes staring upwards, my ears straining, my nostrils sniffing uneasily, and my heart beating; until custom had changed the colour of the curtains, made the clock keep quiet, brought an expression of pity to the cruel, slanting face of the glass, disguised or even completely dispelled the scent of flowering grasses, and distinctly reduced the apparent loftiness of the ceiling.

PP “Disproof” of Backwards Time Travel

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- I. If (backwards time travel in the form of) closed timelike curves (CTCs) are possible, it's possible for this loop (see prior slides) to happen.

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3. It's *not* possible for Proustian prose to come into existence in the absence of a creative process (sub-argument from nfl principle).

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4. Contradiction!
5. Hence, backwards time travel in the form of CTCs *isn't* possible.

The “Multiverse Escape” Again?

In the art critic, story quantum mechanics allows events, from the participants' perspective, to occur much as Dummett describes. The universe that the critic comes from must have been one in which the artist did, eventually, learn to paint well. In that universe, the pictures were produced by creative effort, and the reproductions were later taken to the past of another universe. There the paintings were indeed plagiarized—if one can be said to plagiarize the work of another version of oneself—and the painter did get “something for nothing.” But there is no paradox, because now the existence of the pictures were caused by genuine creative effort, albeit in another universe. (Deutsch & Lockwood 1994, p. 74)

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An Insoluble Problem

In a paper published in 1986, Michael Dummett envisages the following situation.¹ A fifth-rate but conceited artist living the 20th century is visited by a time traveler from the 21st century, an art critic who is impressed by those of the artist's works that have survived and have given him the reputation of being one of the greatest painters of his time. When the critic sees the works, he is disappointed by their quality, and realizes that the artist has yet to create the magnificent paintings that subsequently made him famous. The critic produces a portfolio of reproductions of the later works, but shortly after has to depart at short notice, being permitted for some reason to remain only for a limited time in the past. The artist manages to conceal the portfolio, and spends the rest of his life meticulously copying on canvas the reproductions left behind. These copies form the basis of his subsequent artistic renown.

Is there a problem here? Yes. The whole subject of time travel is rife with problems. As Kurt Gödel showed in 1949, there exist solutions to Einstein's equations of general relativity that permit the existence of closed timelike loops, along which time travelers could, in theory, travel.² It goes without saying that such travel cannot, without contradiction, permit the occurrence of events that would negate the very possibility of the voyage itself. For instance, a traveler who visits the past could not kill his or her own grandmother. On this see Lewis (1976). However, barring such limitations, time travel is physically possible. The critic does not *change* the past in any way, though he may be said to *influence* it (Horwich, p. 116). Nothing prevents the art critic from visiting the artist, nor the artist from copying the works that make him famous. The puzzle lies not in this, but in finding where artistic creativity enters the equation.

¹ See Dummett (1986), p. 155. I am indebted to Friedel Weinert for drawing my attention to



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2. Gödel *proved* that CTCs are possible. What did he prove, exactly?
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As we left aside transfinite numbers in the case of the independence of the Continuum Hypothesis from ZFC, so we here (of course) leave aside relativity. But ...

Axiomatization: The General Theory of Relativity

$$GenRel := \{AxSelf^-, AxLine^-, AxThEx^-, AxPh^-, ExEvent^-, AxSim^-\} \cup \{AxField\} \cup CONT \cup COM.$$

<i>AxSelf-</i>	An observer m in his own coördinate system is motionless at the origin
<i>AxLine-</i>	In each inertial observer's worldview, the world-lines of inertial observers and photons are geodesics
<i>AxThEx-</i>	An inertial observer m at the origin, where he stands, sees inertial observers move in each direction with speeds < 1 , and sees at least one inertial observer in each event
<i>AxPh-</i>	An inertial observer m at the origin, where he stands, sees photons move in each direction with speed 1, and each photon meeting m moves with speed 1
<i>AxEvent-</i>	If m observes k participate in an event, then k himself "sees" this event. Further, if k sees an event that m sees, then k sees all events which occur "near" this event in m 's worldview
<i>AxSim-</i>	Any two inertial observers see each other's wristwatches run slow with the same ratio when they meet
<i>AxField</i>	The real numbers are a linearly ordered field in which every positive member has a square root
<i>CONT</i>	Arbitrary fields are continuous
<i>COM</i>	In each inertial observer's worldview, the parametrically definable time-faithful curves are world-curves of (not necessarily inertial) observers; and the photon-like curves are world-lines of bodies

Andréka, Hajnal, Judit X. Madarász, and István Németi. "Logic of Space-Time and Relativity Theory." *Handbook of Spatial Logics*. Springer Netherlands, 2007. 607–711.

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$AxSelf^-$	$(\forall m \in B)[wline_m(m) = \bar{t} \cap Cd(m) \wedge (\forall p, q \in wline_m(m))[p, q] \subseteq wline_m(m)].$	ss at the origin
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Con[**GenRel** U CTCs]

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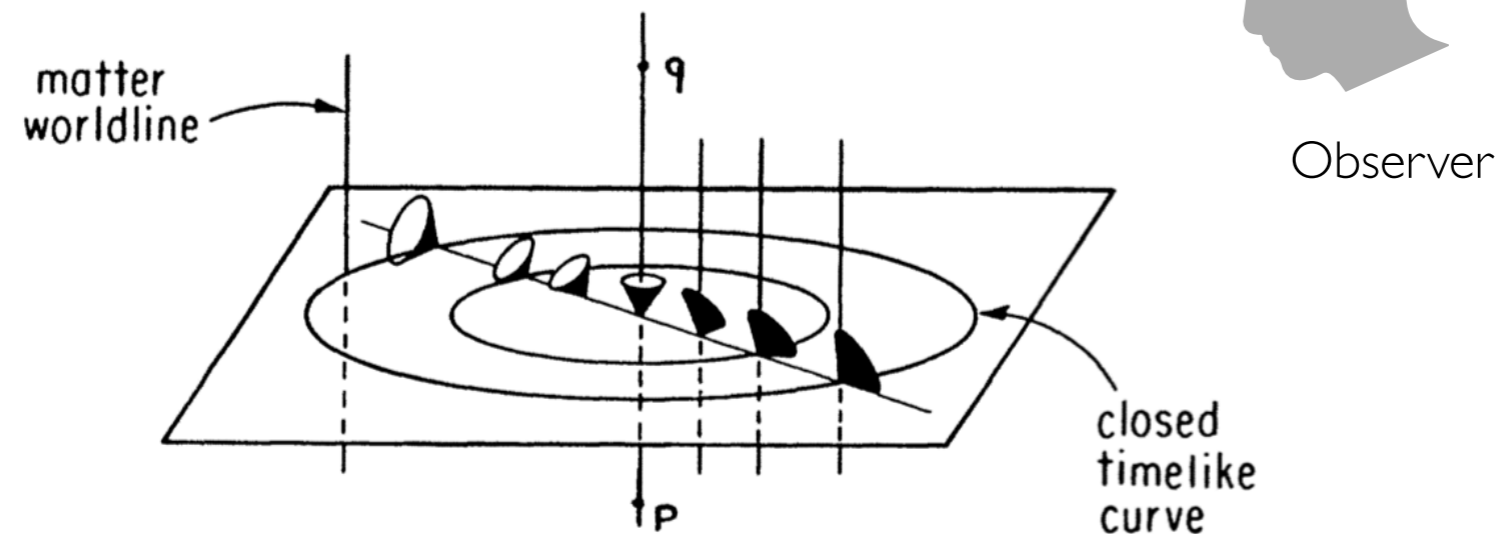
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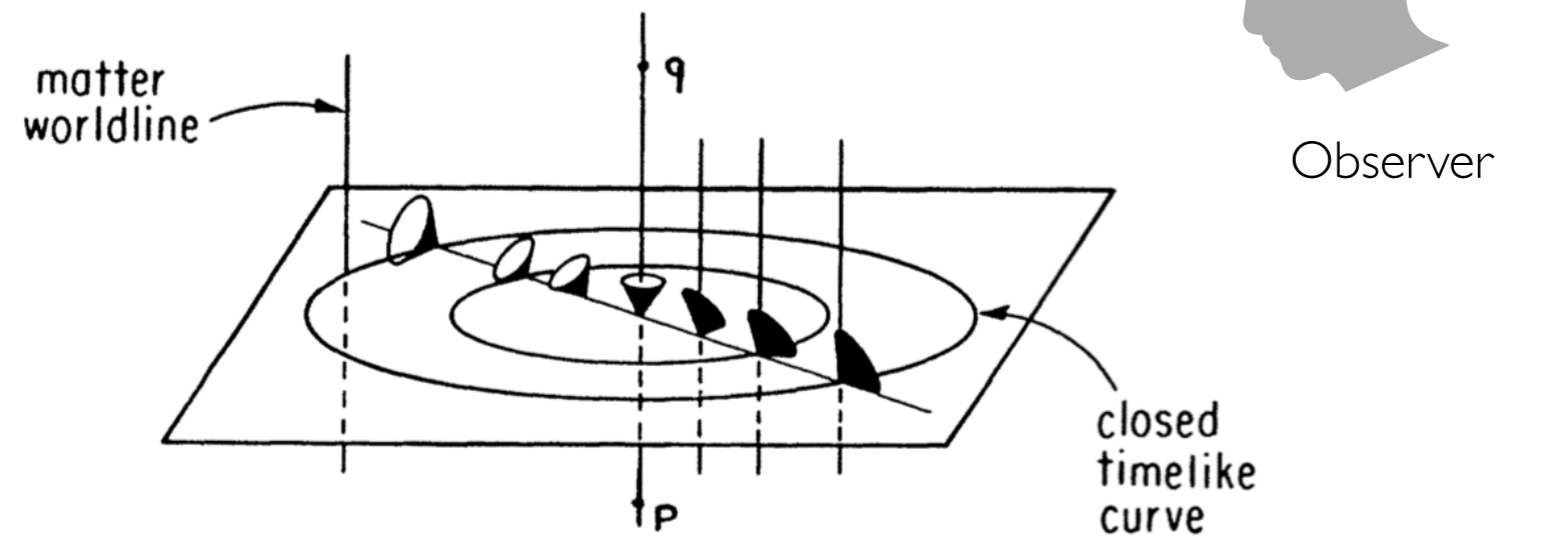
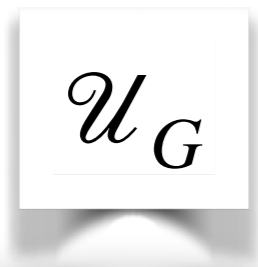
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Gödel Spacetime (with one dimension suppressed)

Malament, D. (1985) "Time Travel' in the Gödel Universe"
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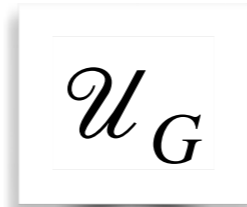
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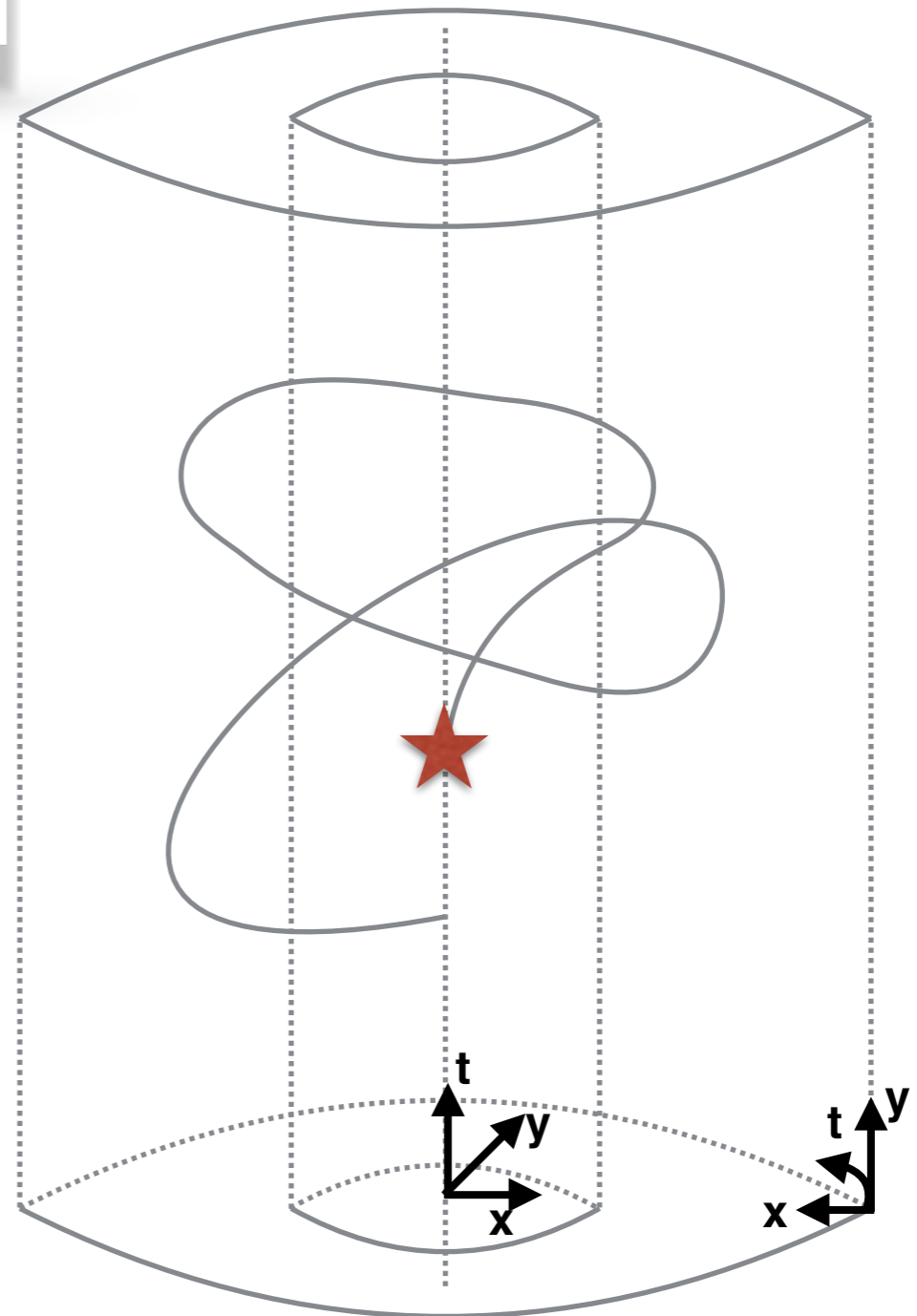
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Gödelian *Backwards* Time Travel



Observer

- Inner cylinder: vertical time axis
- Outer cylinder: circular time axis; wraps around the inner cylinder
- In Gödel's best-known actual solution, the transition between the two cylinders is gradual.
 - But I don't care, b/c jump-based scenarios show possibility to Observer.
- At every instant, the world-line of the particle (red star) is oriented toward the future (remains within local light-cones). (This crucial fact is depicted in the prior slide, and in the subsequent one.)

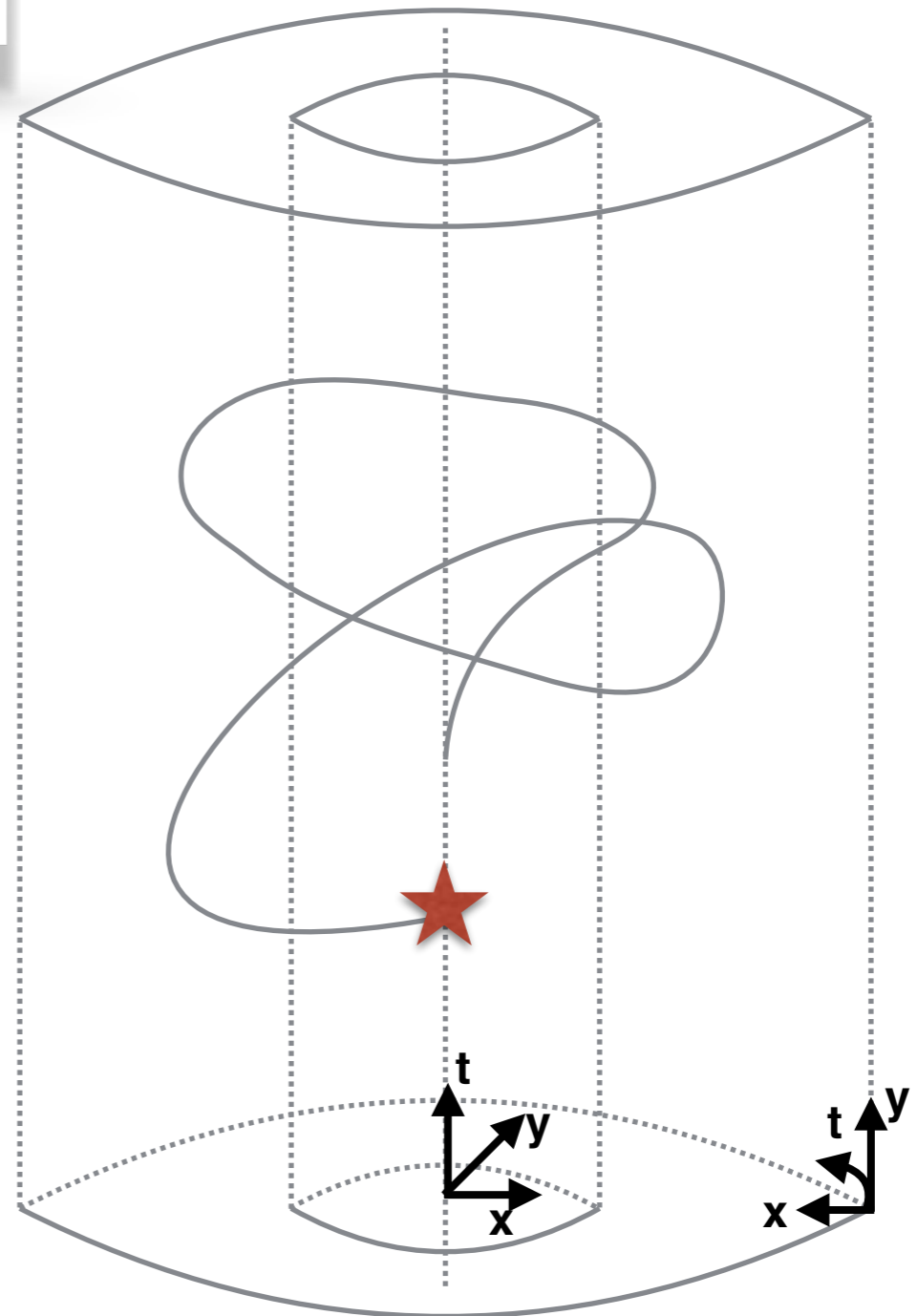


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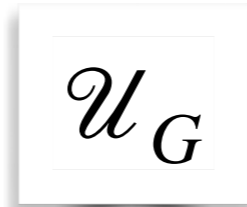
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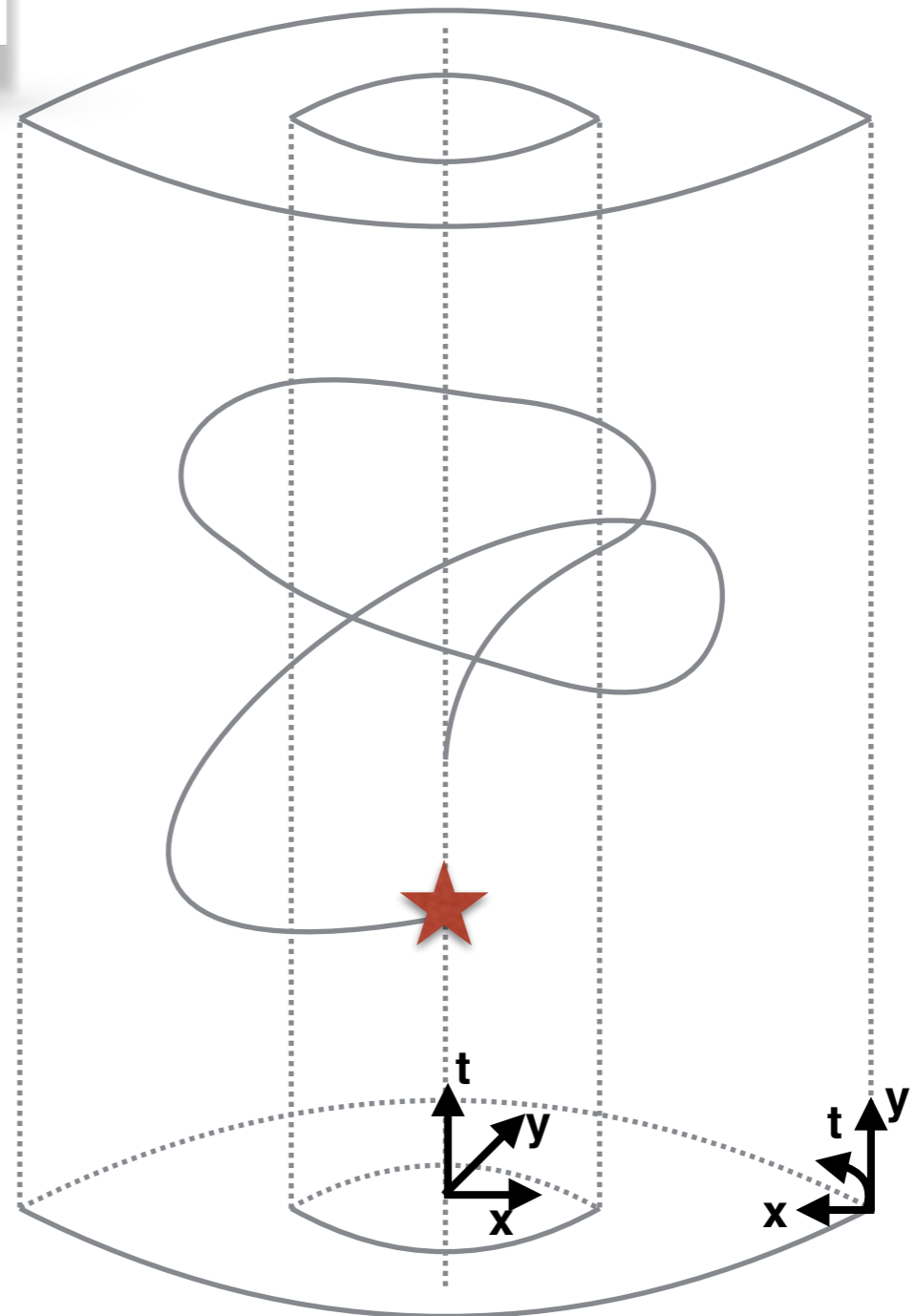
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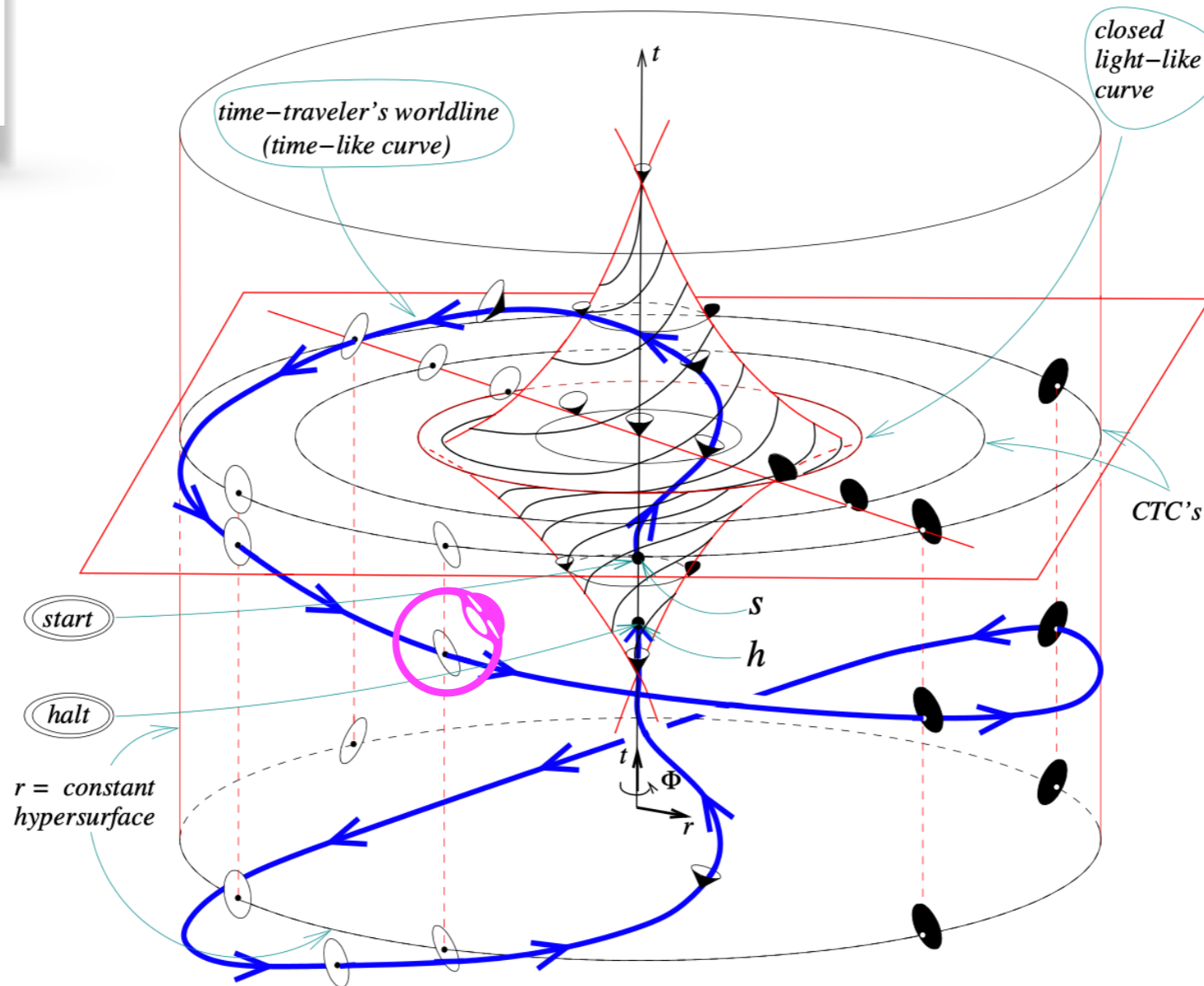


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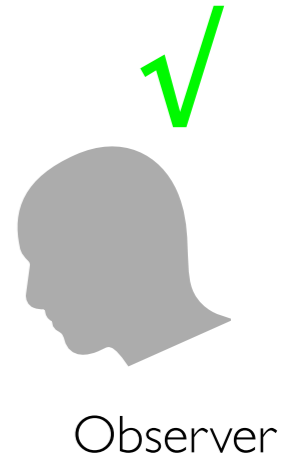
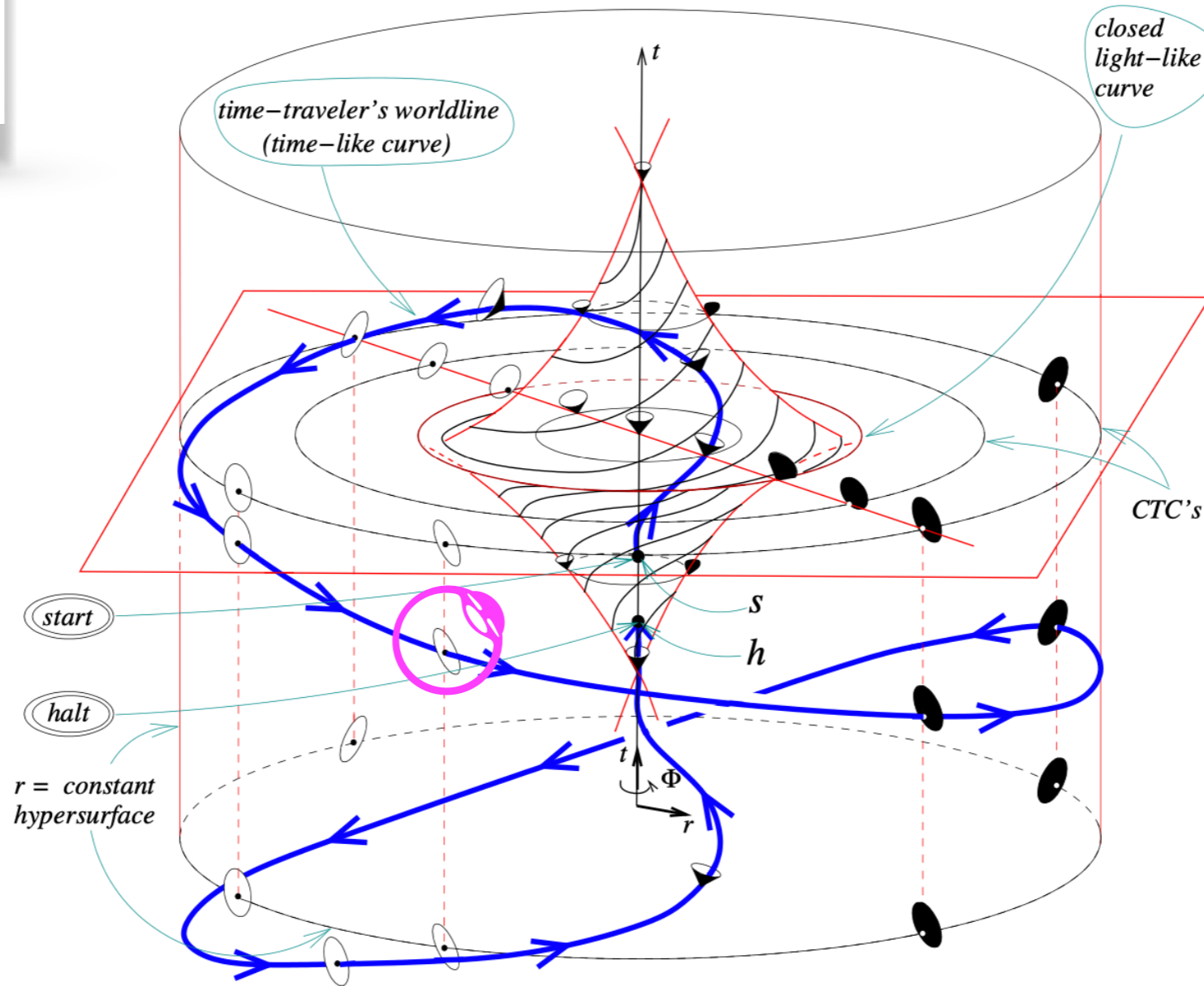
\mathcal{U}_G



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Gödelian *Backwards* Time Travel

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*Så flinke som vikingene var på reise, var
tidsreiser som dette hinsides dem.*