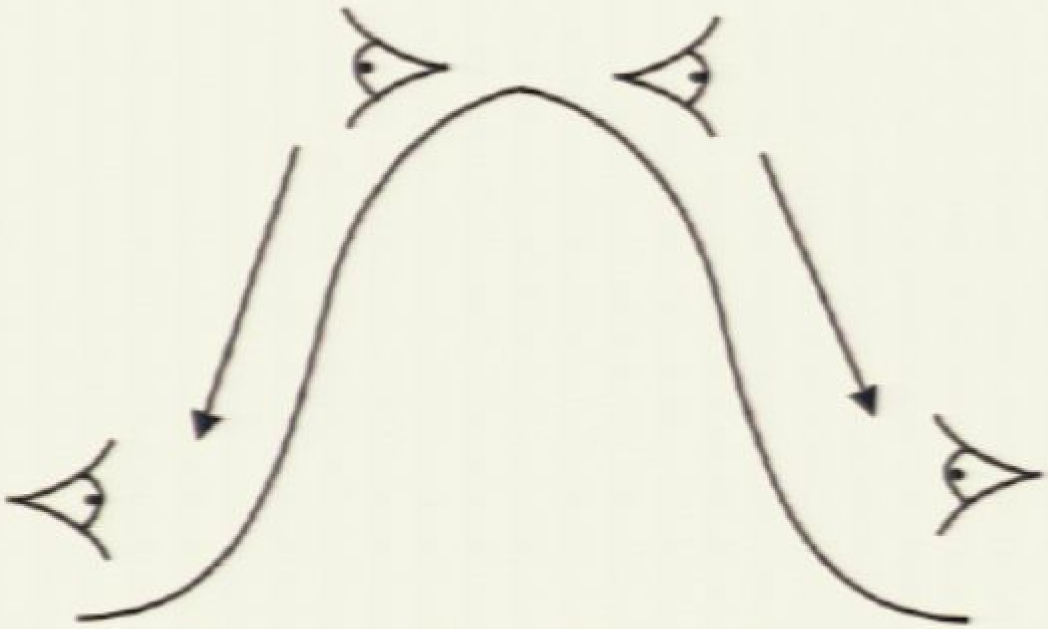
Title: Does a Computer have an Arrow of Time?

Date: Sep 30, 2008 02:00 PM

URL: http://pirsa.org/08090081

Abstract: It has sometimes - though usually informally - been suggested that the psychological arrow can be reduced to the thermodynamic arrow through information processing properties of the brain. In this talk we demonstrate that this particular suggestion cannot succeed, as, insofar as information processing (at least in the sense of a classical computer) has an arrow of time, it is not governed by the thermodynamic arrow.

Does a Computer have an Arrow of Time?



"For the universe, the two directions of time are indistinguishable, just as in space there is no up and down. However, just as at a particular place on the earth's surface we call 'down' the direction toward the center of the earth, so will a living being in a particular time interval of such a single world distinguish the direction of time toward the less probable state from the opposite direction (the former toward the past, the latter toward the future)."

Boltzmann, 1895

Minds, Memories and Computers

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".. when a computer records an item in memory, the total amount of disorder in the Universe increases. The direction of time in which a computer remembers the past is the same as that in which disorder increases"

Hawking, 1987

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"Computations are accompanied by dissipation, so much so that one of the principal issues for Intel's Itanium chip is its power consumption ... More fundamentally, Landauer ... has shown that computation requires irreversible processes and heat generation"

Schulman, 2005

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- Questions (and hopefully answers!)
  - What do I mean by an entropy increasing/decreasing universe?
  - What kind of computational process? What is the physical process?
  - What of Landauer's Principle?
  - What else might be responsible for the alignment?

Entropy Increasing
Entropy Decreasing

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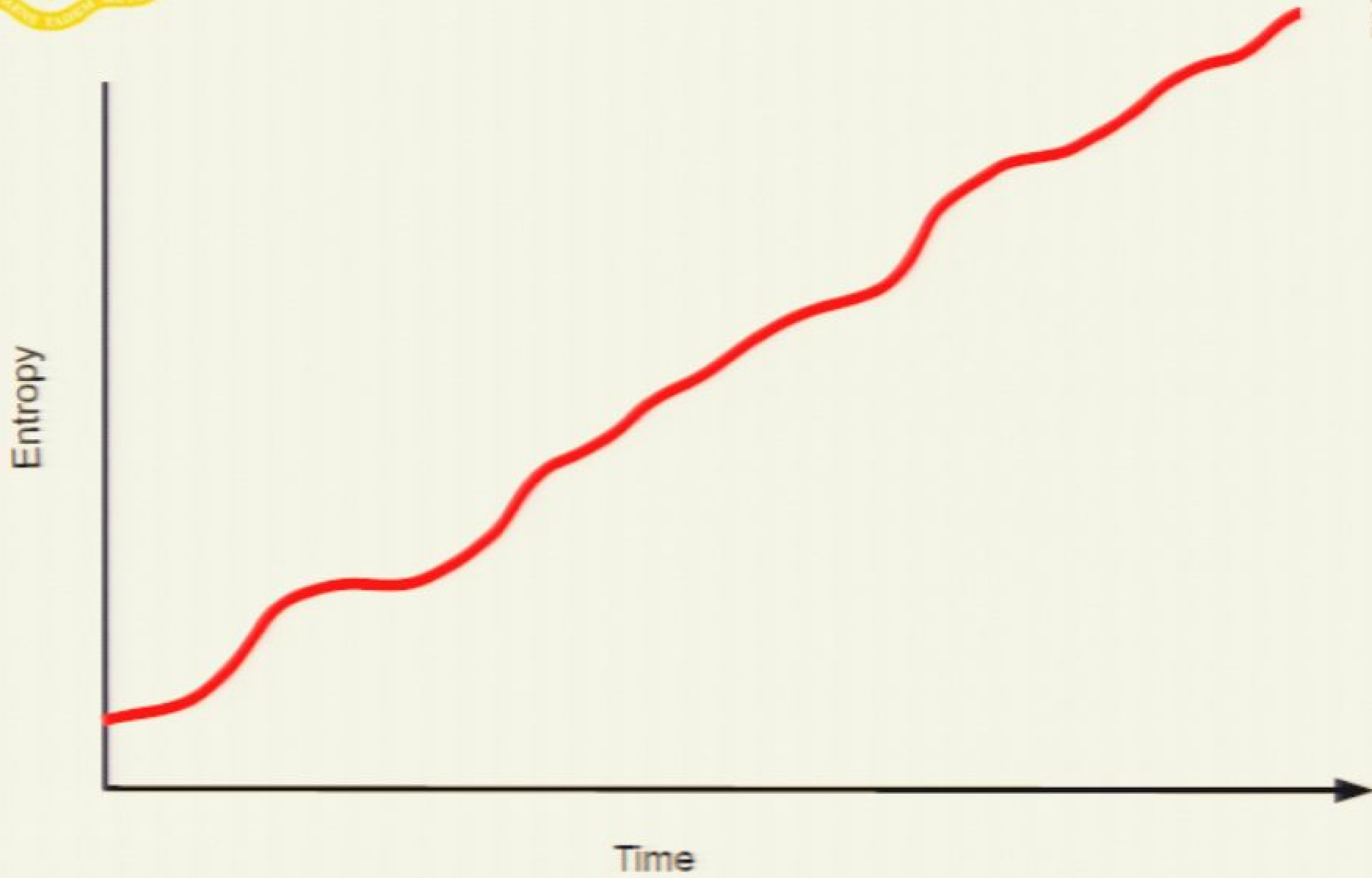
    - No equivalent conditions on *initial* statistical states.
- But *NOT* necessarily just a time reverse of our *particular* universe...

Different Arrows?



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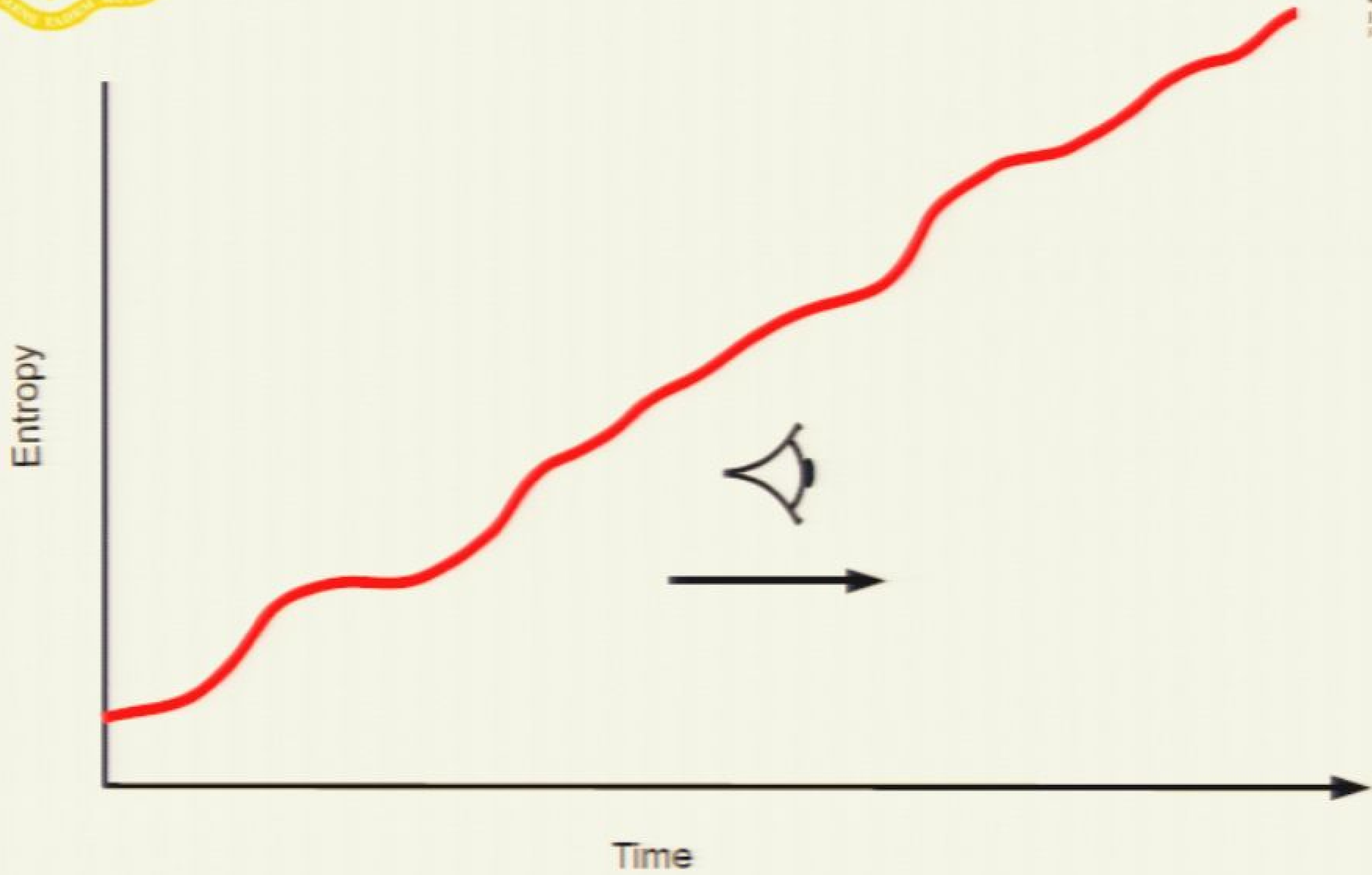

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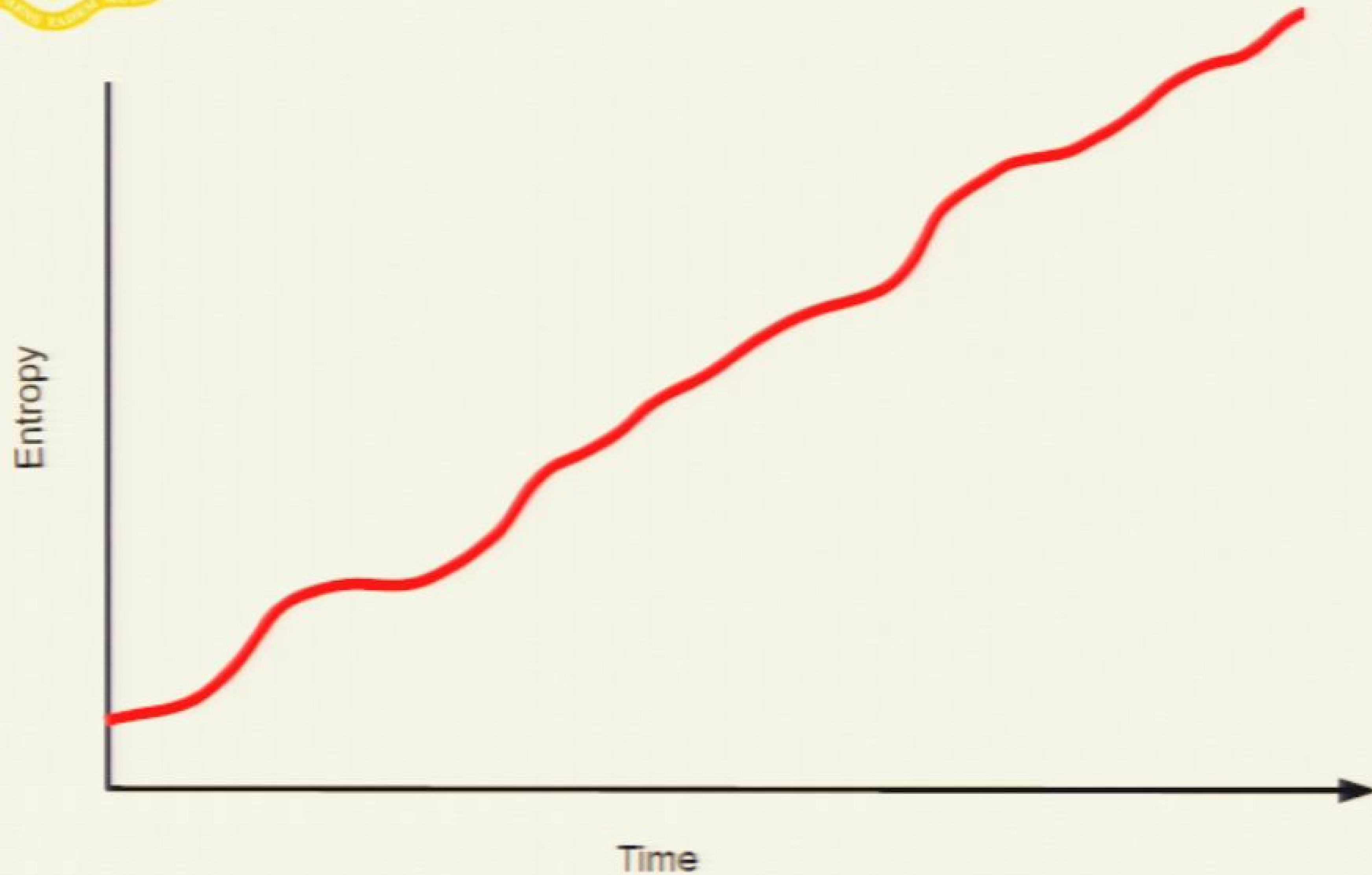

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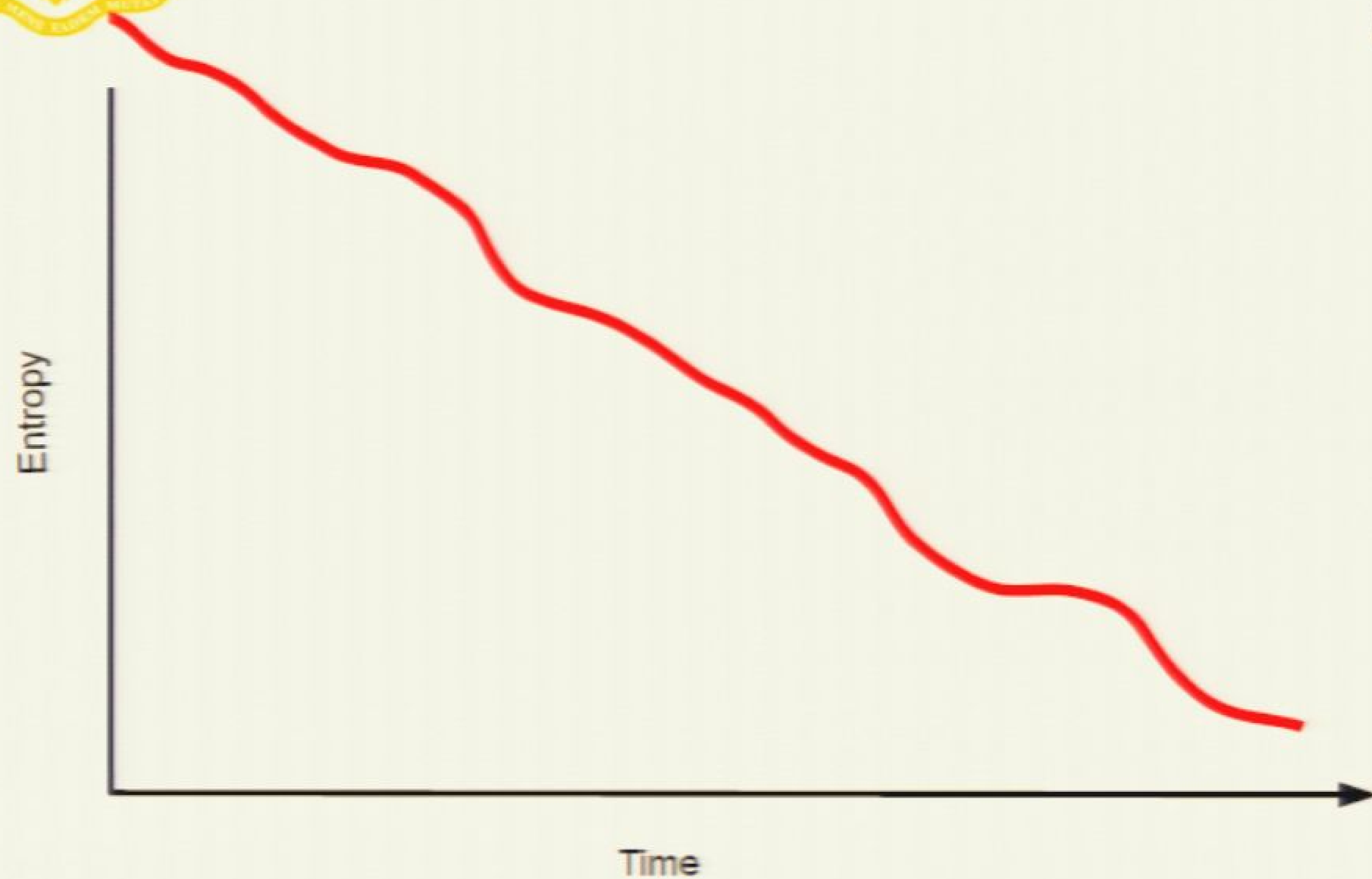

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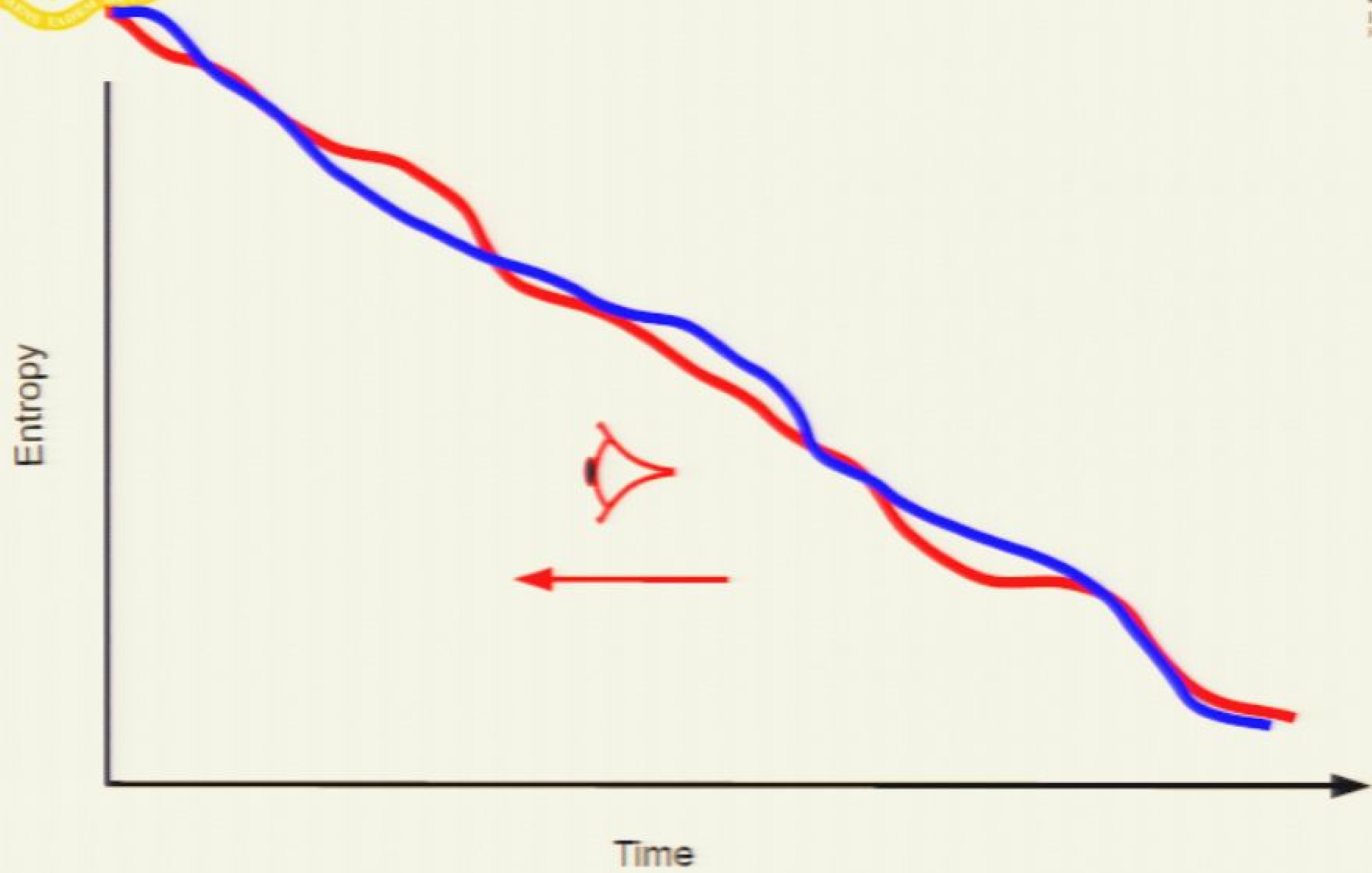

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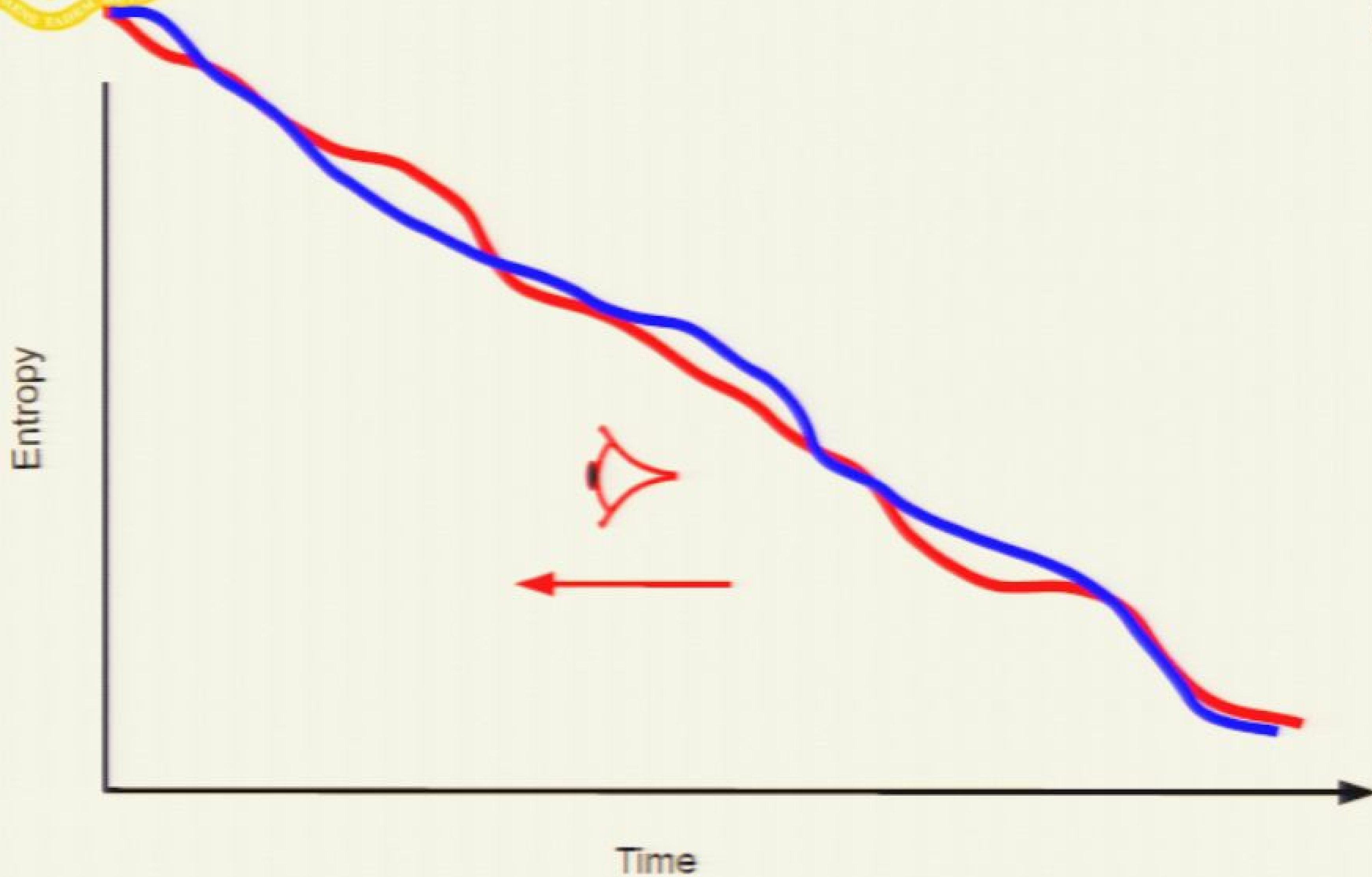

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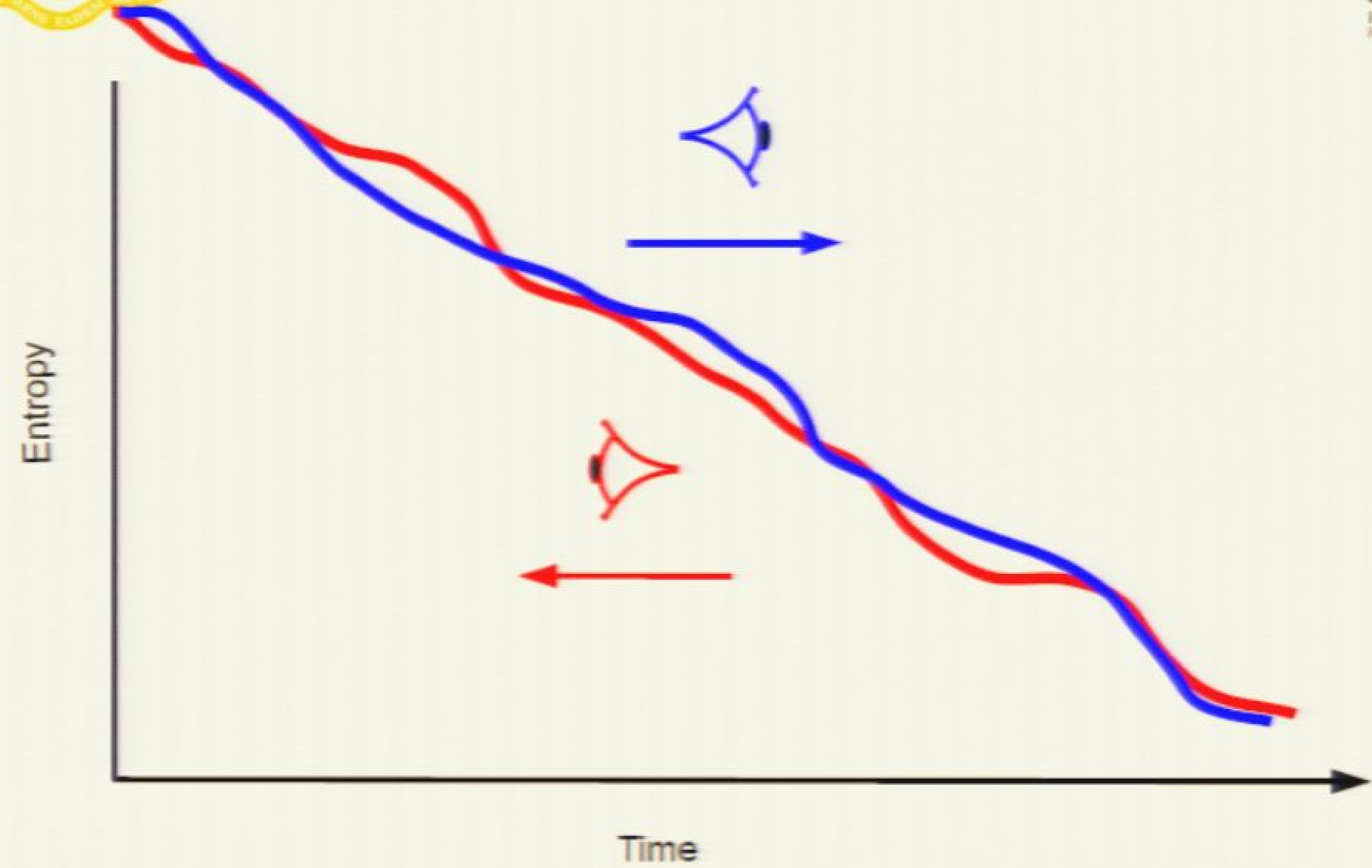

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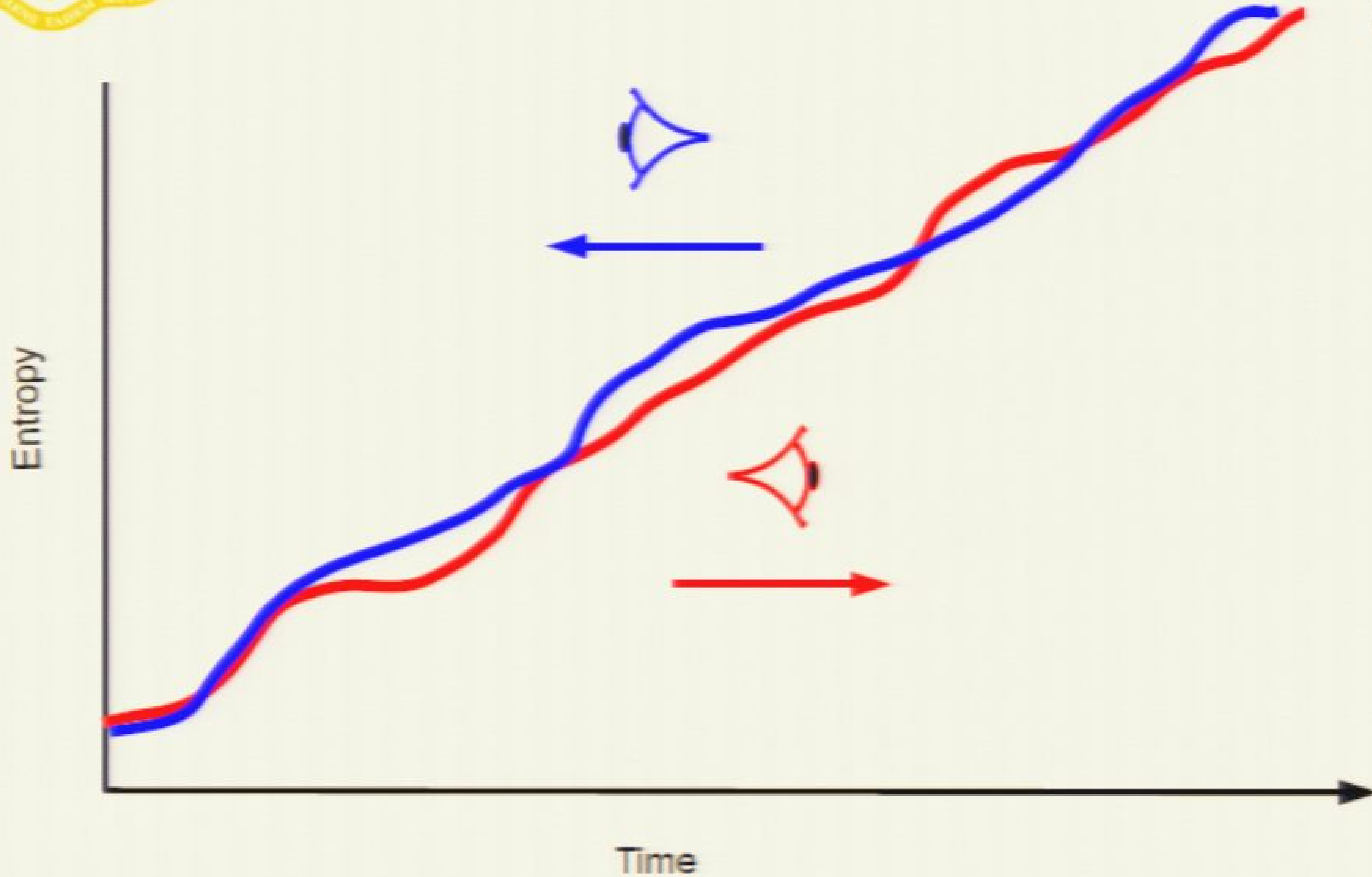

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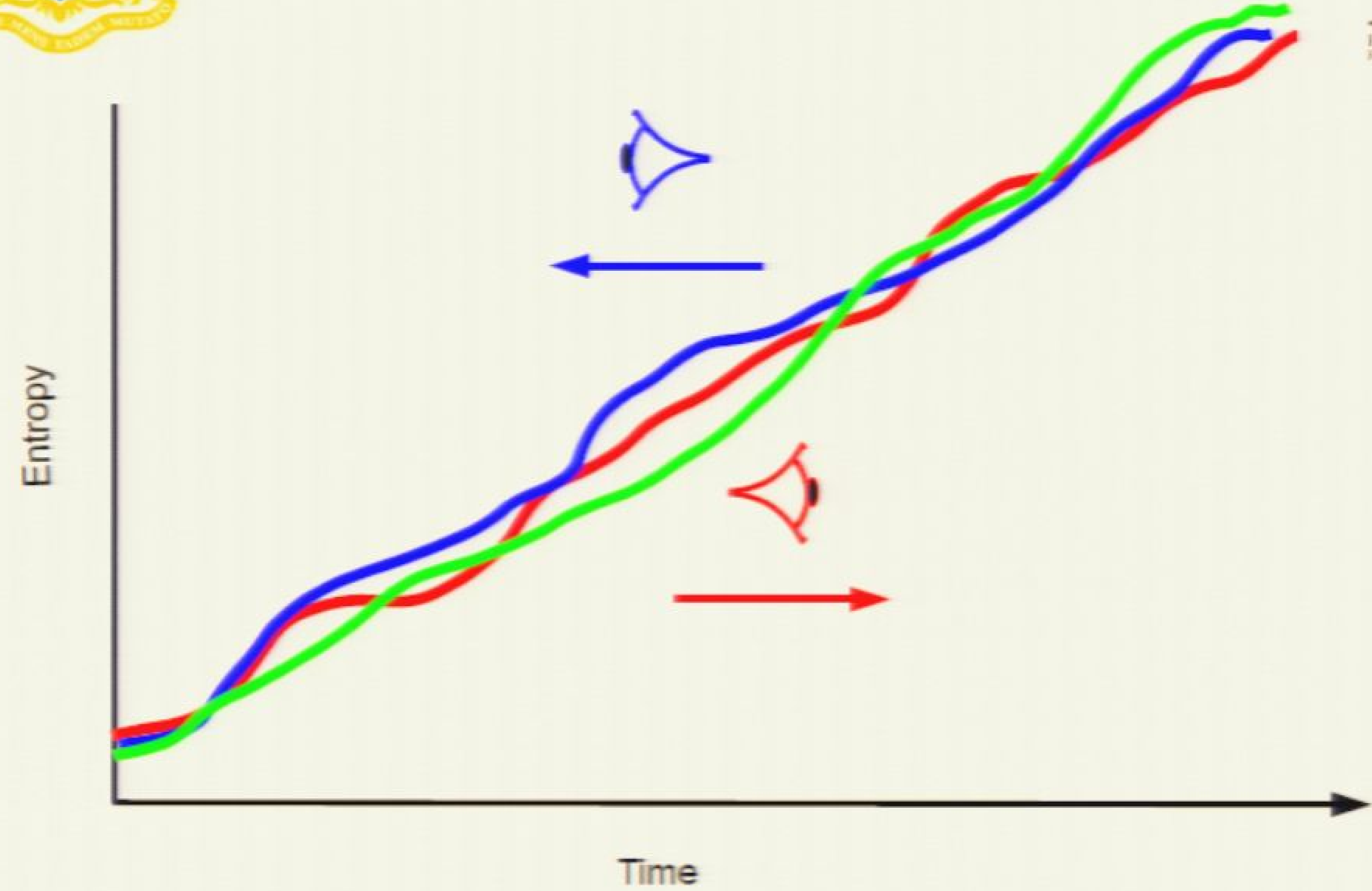

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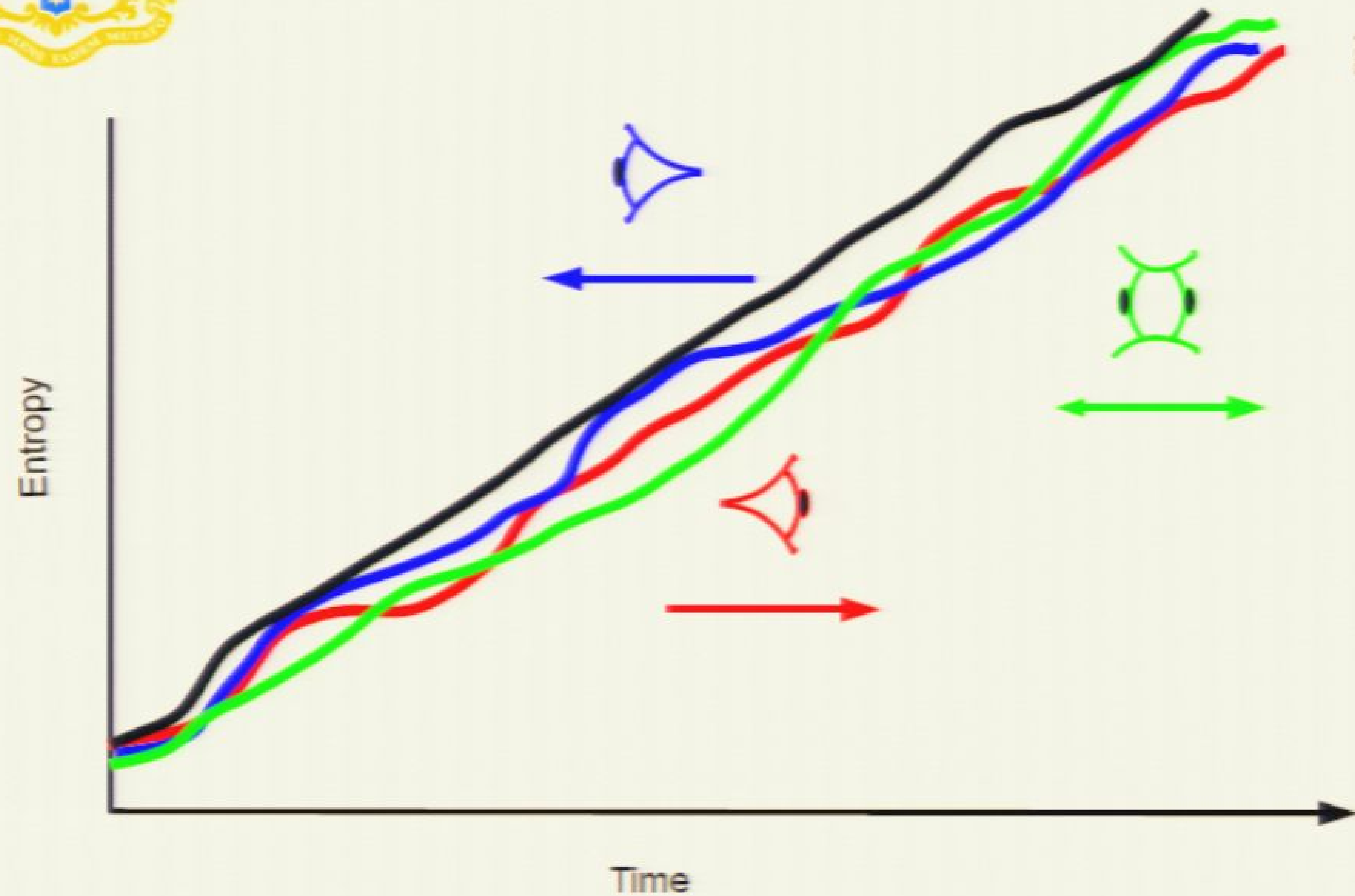

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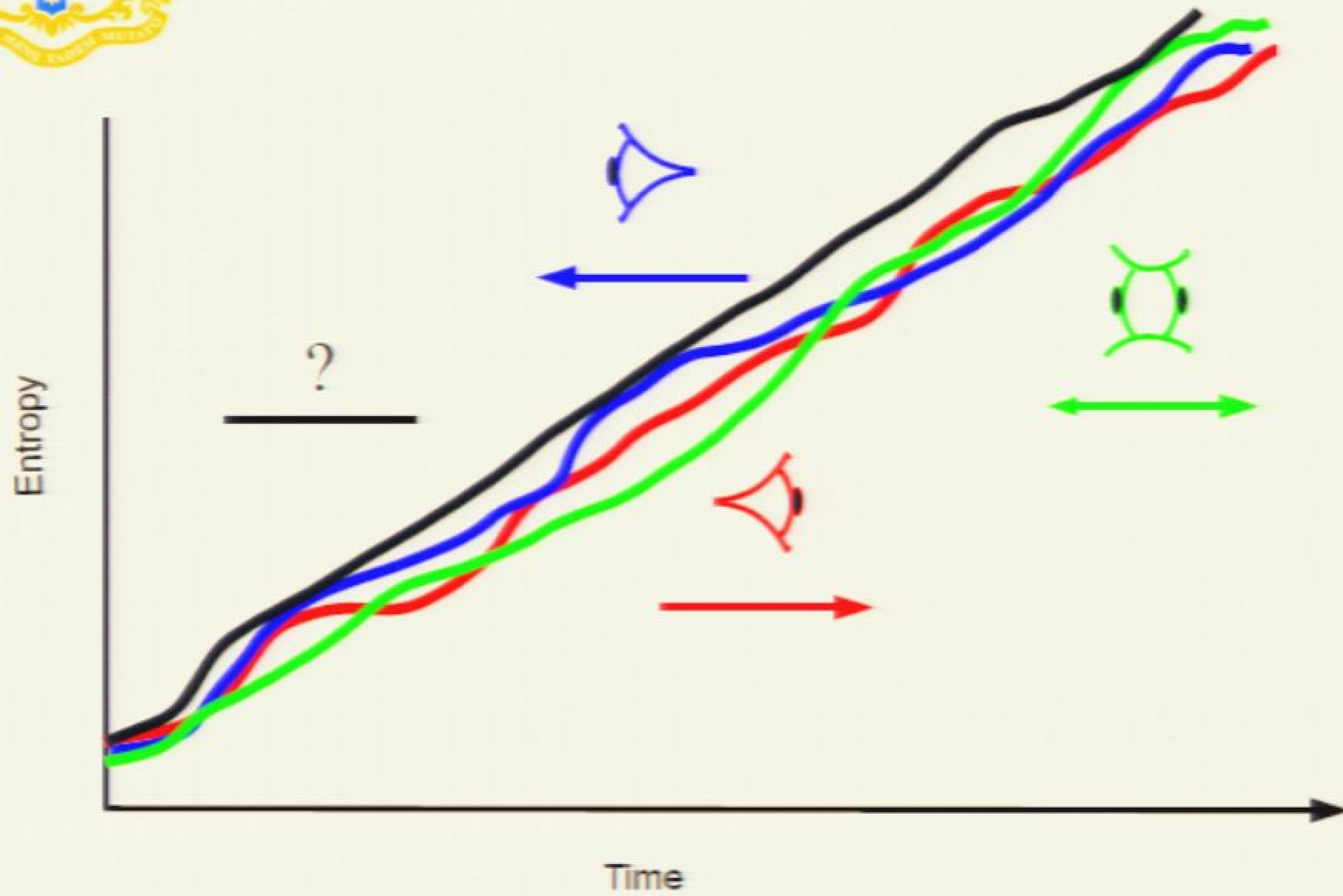

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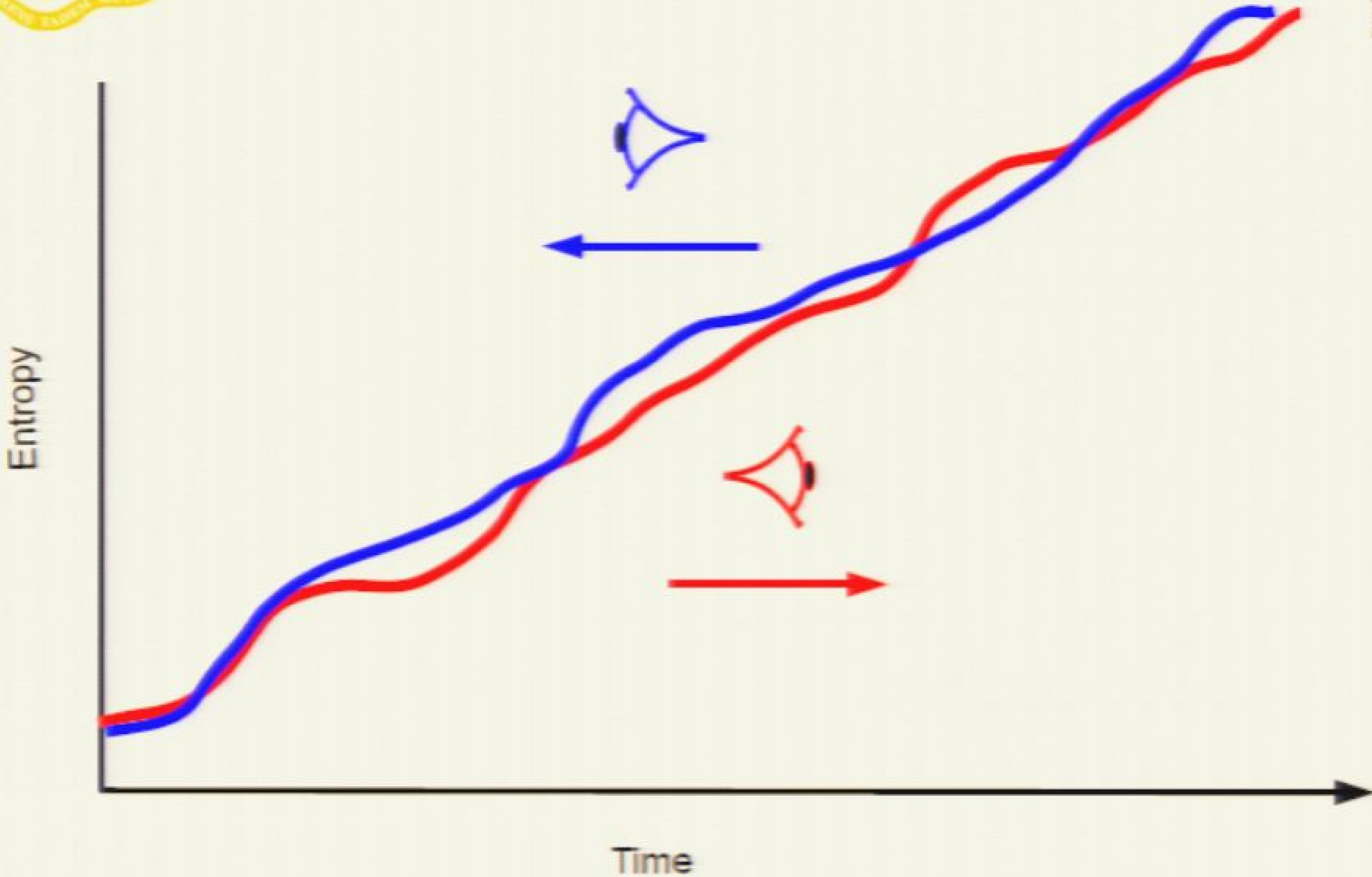

Computation and Logic

Computation and Logic

Logical Operations

AND

A	B	A.B
0	0	0
0	1	0
1	0	0
1	1	1

Computation and Logic

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AND

A	B	A.B
0	0	0
0	1	0
1	0	0
1	1	1

NOT

A	$\bar{A}$
0	1
1	0

Computation and Logic

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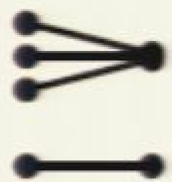
A	B	A.B
0	0	
0	1	0
1	0	
1	1	1



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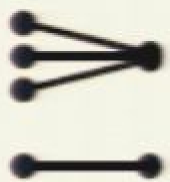

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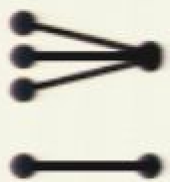

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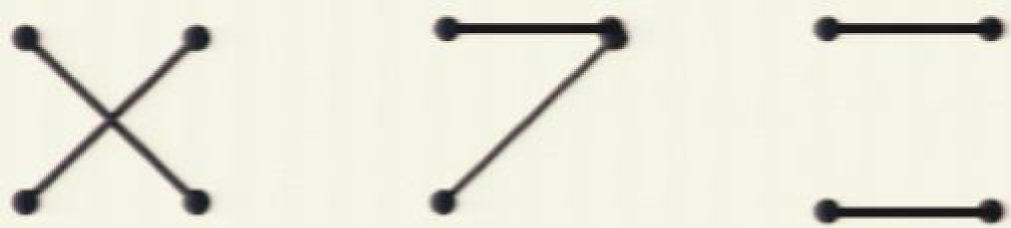

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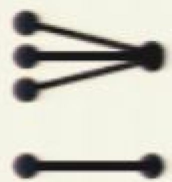

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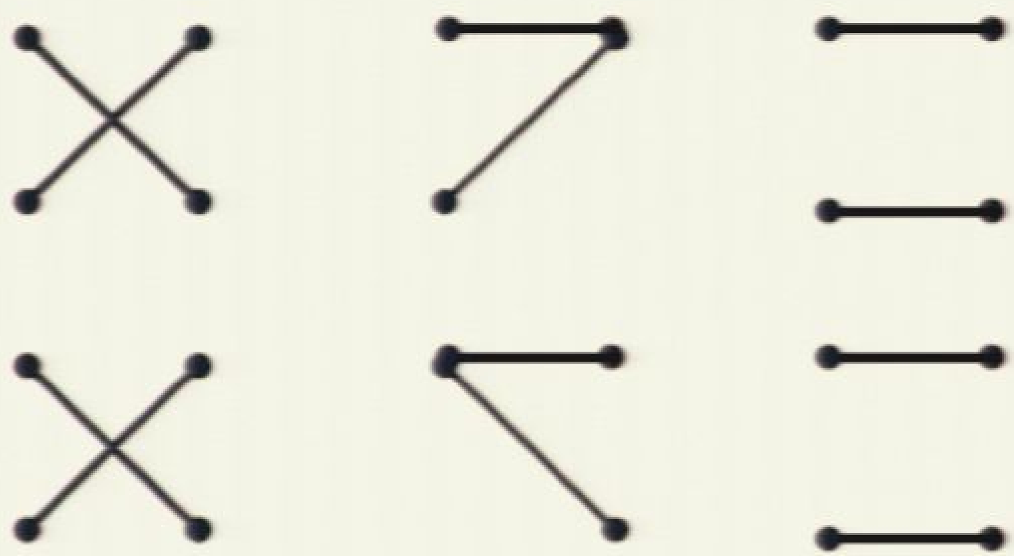

Computation and Logic

Reversible Logical Operations

CCNOT

A	B	C	D	E	F
0	0	0	0	0	0
0	0	1	0	0	1
0	1	0	0	1	0
0	1	1	0	1	1
1	0	0	1	0	0
1	0	1	1	0	1
1	1	0	1	1	1
1	1	1	1	1	0

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Computation and Logic

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0	0	1	0	0	1
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0	1	1	0	1	1
1	0	0	1	0	0
1	0	1	1	0	1
1	1	0	1	1	1
1	1	1	1	1	0

input

Computation and Logic

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CCNOT

A	B	C	D	E	F
0	0	0	0	0	0
0	0	1	0	0	1
0	1	0	0	1	0
0	1	1	0	1	1
1	0	0	1	0	0
1	0	1	1	0	1
1	1	0	1	1	1
1	1	1	1	1	0

input —*compute*→

Computation and Logic

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A	B	C	D	E	F
0	0	0	0	0	0
0	0	1	0	0	1
0	1	0	0	1	0
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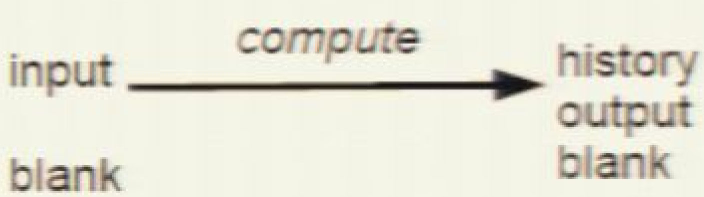

Computation and Logic

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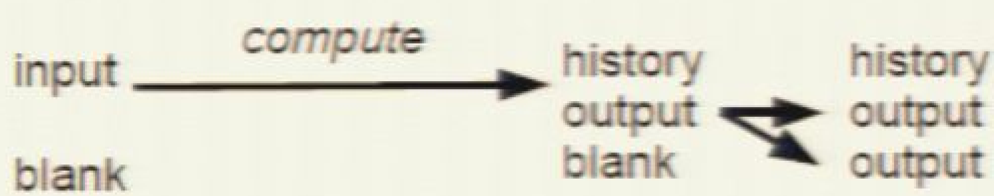

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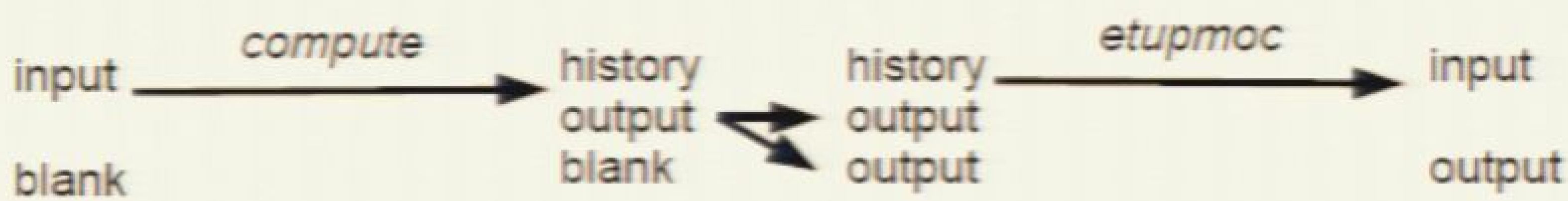
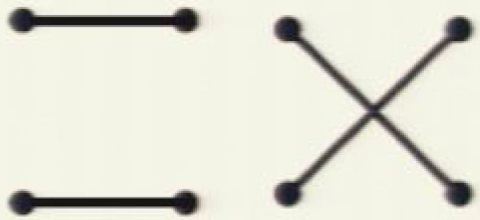


Computation and Logic



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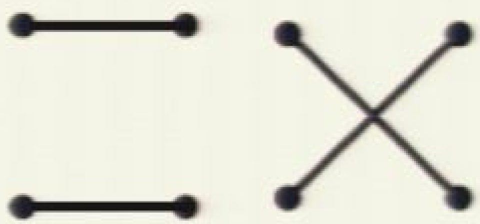
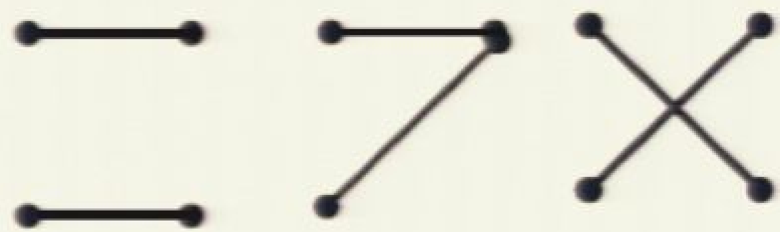
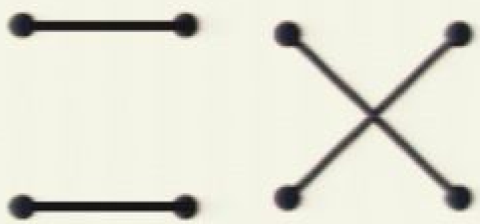


efficiently simulates



Computation and Logic

 efficiently simulates 

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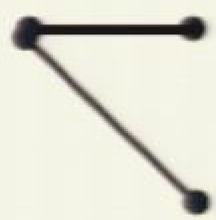

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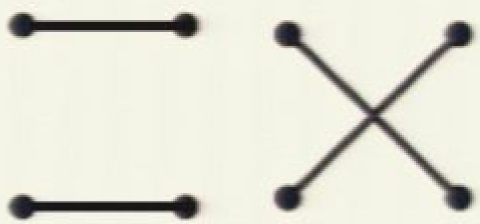

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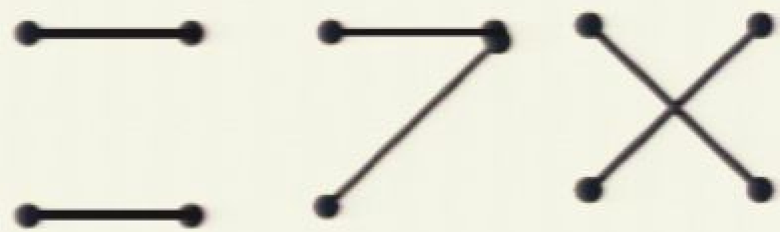

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BPP Complexity Class
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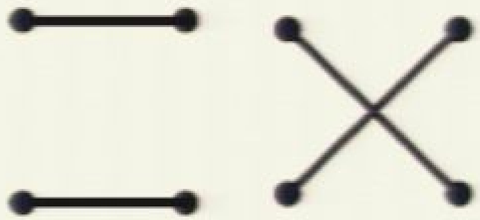

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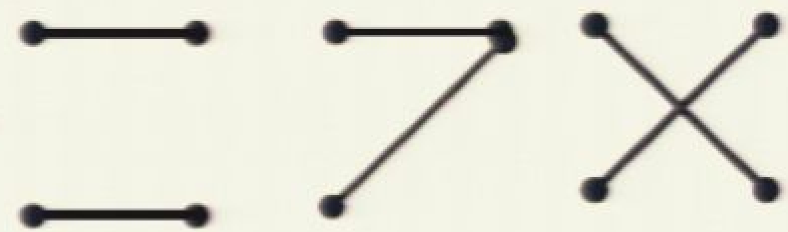

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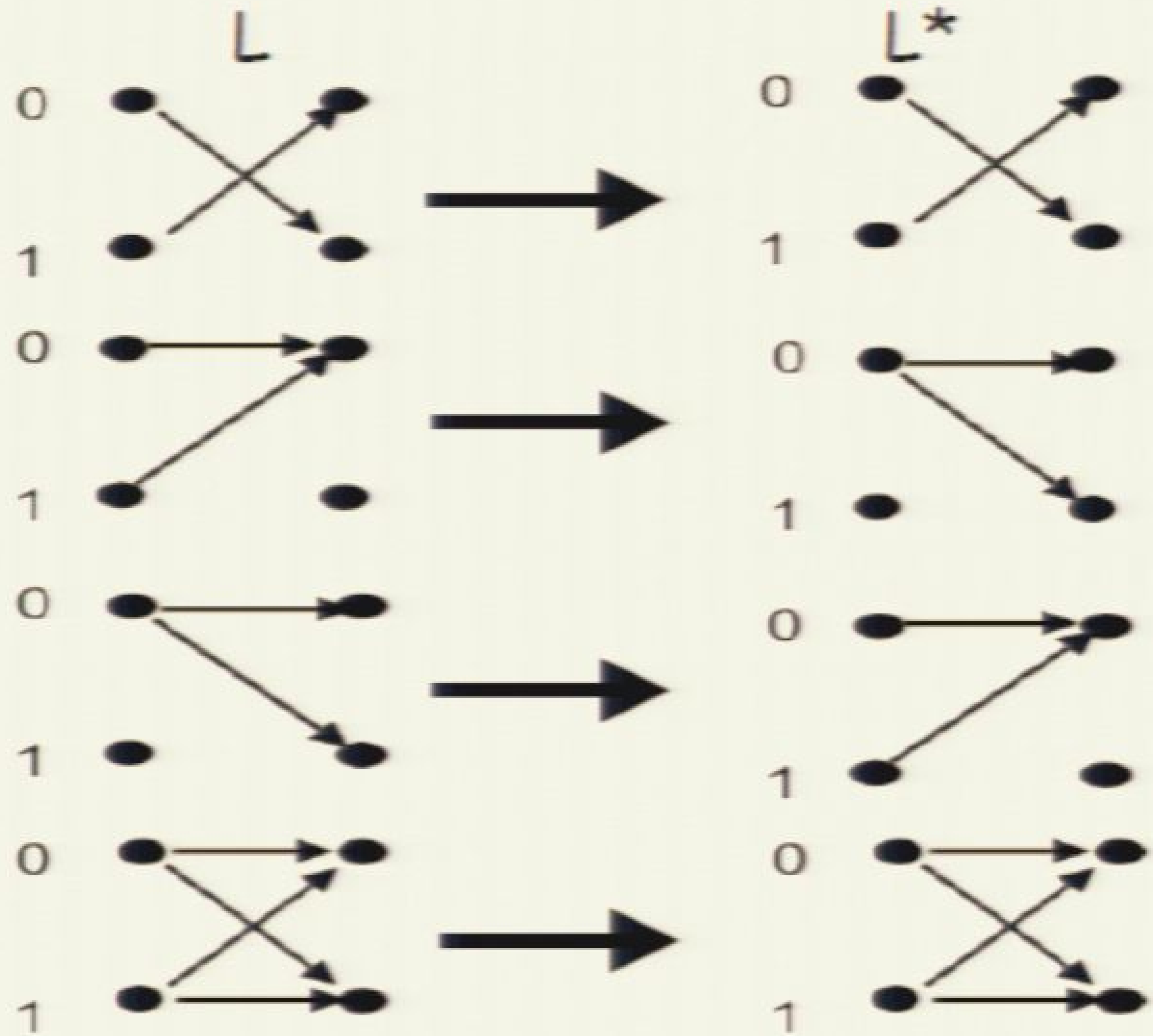

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$(H_L)^T$ is a physical implementation of L^*

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S4 is the same as *S1*, but is in an entropy decreasing universe.

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How does this relate to the conclusion of the previous slides?

Landauer in an entropy increasing universe

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Correlations with the world

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Coarse grained entropy increase. $B_i \cap B_j = A_i \cap A_j = \emptyset \, (i \neq j)$

But now consider system {A}, initially possessing information about {B}, and "anti-gathering" it:

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Still a coarse grained entropy increase.

(De-)Correlations with the world

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How does the entropy increase appear?

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- An additional condition
  - Perhaps the psychological arrow is simply independent of the thermodynamic arrow? Causal agents must agree on the direction of the causal arrow (for self consistency) but the fact that it is entropy increasing, not decreasing, may be just a contingent fact about this universe, and it could have been otherwise.

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  - Just that if it is a consequence, it cannot be via computational properties of the brain.

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