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## SYSTEMS EXHIBITING ALTERNATIVE FUTURES

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### ABSTRACT

We construct an explicit example of a physical system having *alternative futures* (AFs). Several other such systems are also introduced and characterized, but not discussed in detail. Our major goal is to use these results to demonstrate the existence and meaning of the concept of *counterfactual histories* (CFHs). We find that any system having AFs will also exhibit the phenomenon of CFHs.

**Keywords:** Alternative futures, counterfactual histories, multiverses, realizable systems

### INTRODUCTION

The main purpose of this paper is to provide arguments for the proposition that for certain types of physical systems *alternative futures* (AFs) can exist. For a given system to have AFs, it must have open to it the possibility that at some time,  $t = t_0$ , its future evolution can manifest itself in more than one outcome. These multi-outcomes are a consequence of the system interacting with its environment. However, before giving a fuller explanation of these ideas and concepts, we illustrate their occurrence in two model systems: *coin flipping* and *in the going from location A to location B*. The next two sections are devoted to these topics. In the fourth section, we summarize the results obtained from examining the two model systems and discuss in more detail various concepts and definitions needed to follow and understand the arguments presented in this work. The final section relates our findings to the concept of counterfactual histories (CFHs) and concludes that any system possessing AFs also has CFHs.

An important, but very critical point to note is that no consideration needs to be made as to whether a given system satisfies classical or quantum physical laws.

### FLIPPING A COIN

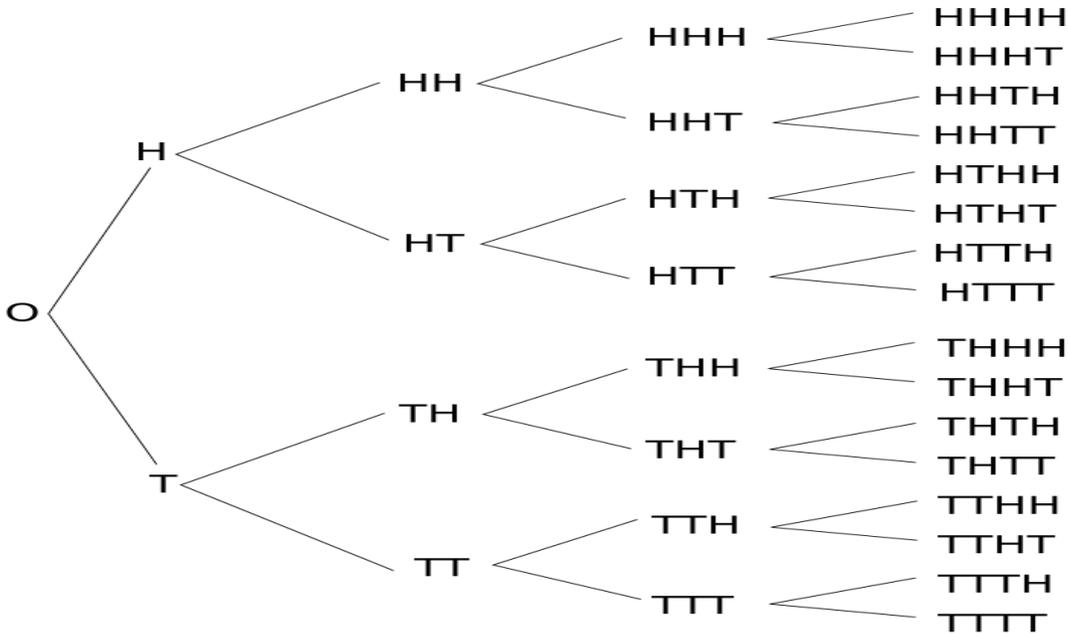
Consider a system consisting of the following components:

- a two-sided coin, with one side labeled H, the other T;
- a mechanism to flip the coin;
- a device to record the sequence of Hs and Ts after a given sequence of coin flippings.

An *outcome tree* is a diagram giving the possible sequences of Hs and Ts. Figure 1 provides the outcome tree for four coin flippings. Note that the ordering is

important, i.e., HT means the first flip was H and the second flip T, while for TH the first flip gave T, the second flip an H.

A *branch* or *trajectory* on the outcome tree gives a particular sequence of Hs and Ts. For example, Figure 1 gives all the possible branches after four (4) flips of the coin starting from the unflipped state *O*; these sixteen possibilities are indicated by the labeling on the right side of the diagram. In general, after  $N$  flips,  $2^N$  possible trajectories exist, and this follows from the fact that for each flip there are two possible outcomes, H or T.



**Figure 1.** Outcomes of flipping a coin.

An important point to note is that every possible sequence of flippings is physically realizable, i.e., the flipping of the coin can actually produce this sequence.

A detailed inspection of Figure 1, which corresponds to only four flips of the coin, allows the following conclusions to be reached:

(i) Every item listed in the fourth column has a unique trajectory taking it back to the initial state *O*.

To illustrate, consider HTHH. It came from the prior state HTT, which came from the prior HT, which came from the prior H, which was in turn a consequence of a coin flip at the initial state *O*.

(ii) The exact state, after say one flipping, does not allow the exact prediction of the state after two additional flippings.

An example of this can be seen by considering the state TH; after two additional flippings, the following four distinct possibilities exist: THHH, THHT, THTH, and THTT.

The above results can be easily generalized, allowing the following conclusions to be reached:

(a) Given the initial, unflipped state  $O$ , after  $N$  flips,  $2^N$  sequences are possible.

(b) All  $2^N$  sequences are realizable in the physical sense that they could be the outcome of some actual sequence of coin flippings.

(c) A given state after  $k$ -flips has a unique trajectory going backwards to the unflipped state  $O$ . Call this the *history* of the given state at the  $k$ -th level.

(d) A given state, i.e., sequence of H/T values at the  $k$ -th level of flipping, does not allow the definite prediction of its state after an additional  $M$ -flips. In fact, for a given state, achieved from  $O$  by flipping  $K$ -times, additional  $M$ -flippings permits  $2^M$  possibilities. Call these new states or possibilities, *alternative futures*.

(e) If two separate trajectories intersect, then up to the point where they intersect, they both have exactly the same history, but they will not have any overlap in their alternative futures.

A concise summary of the conclusions reached from the above analysis is this. From a given state, its past or history is exactly known, while its future has alternative possibilities.

### GOING FROM A TO B

A second example of a system having the features stated in the last paragraph of the previous section is associated with moving from a location  $A$  to another location  $B$ . This system is composed of the following elements:

- The various motions take place within the confines of a bounded space; see Figure 2.

In Figure 2, the outer rectangle is the confining boundary. The smaller, shaded rectangles are barriers to movement, with motion possible along the five pathways

$$\begin{aligned} 5 &\leftrightarrow B, & 1 &\leftrightarrow A \leftrightarrow 2, & 4 &\leftrightarrow 3 \\ 4 &\leftrightarrow 1 \leftrightarrow 5, & 3 &\leftrightarrow 2 \leftrightarrow B. \end{aligned}$$

The double arrows mean movement is possible in either direction along a given pathway.

- The task to be done by an individual is to leave position  $A$ , at time  $t_0$ , and arrive at position  $B$  at a later time.

Note that the time of arrival at  $B$  is not needed to be known since it will depend on the actual path selected by the individual.

The following is a subset of possible paths between  $A$  and  $B$

$$\begin{aligned} A &\rightarrow 2 \rightarrow B \\ A &\rightarrow 1 \rightarrow 5 \rightarrow B \\ A &\rightarrow 1 \rightarrow 4 \rightarrow 3 \rightarrow 2 \rightarrow B \\ A &\rightarrow 2 \rightarrow 3 \rightarrow 4 \rightarrow 1 \rightarrow 5 \rightarrow B. \end{aligned}$$

Observe that if doubling-back is allowed, then very long trajectories can be constructed. In any case, it is obvious that multi-paths exist to get to  $B$  from  $A$ . It is also important to be aware of the fact that once the individual selects a given path, at time  $t_0$ , they will have no knowledge or experience of the *paths not taken*. Consequently, while this system is somewhat more complex than the previous system, the flipping of a coin, the essential ideas and related concepts still hold: for

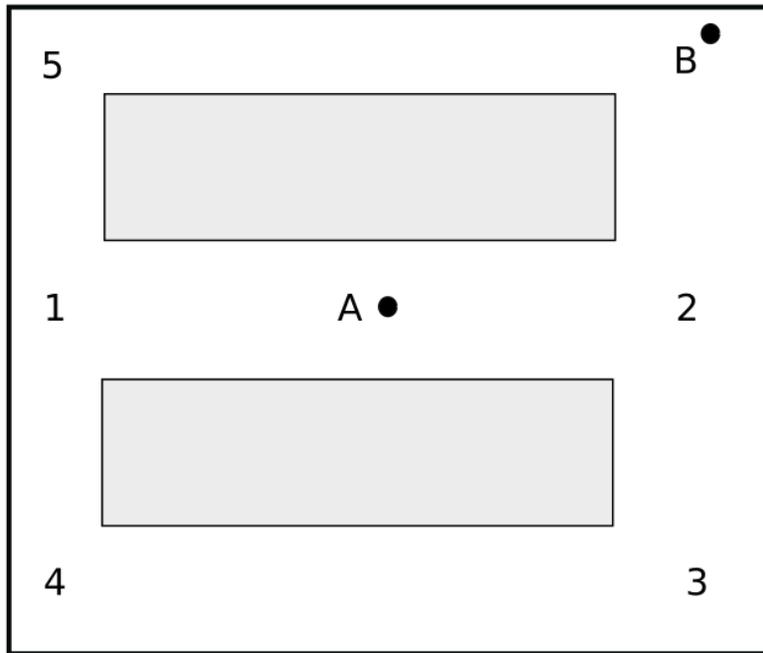
a given path, there is a unique trajectory back to  $A$  from  $B$ , and this is obtained by reversing the order of the path's segments. To illustrate this consider the path

$$A \rightarrow 1 \rightarrow 4 \rightarrow 3 \rightarrow 2 \rightarrow B.$$

An individual taking this path will *experience* or *remember* this path and not experience or remember an alternative path, such as

$$A \rightarrow 1 \rightarrow 5 \rightarrow B.$$

Finally, it is obvious from how the system is defined that starting at location  $A$ , at time  $t_0$ , multi-paths can get the individual to  $B$ . In other words, there exist a number of alternative futures, all of which are physical realizable.



**Figure 2.** How to travel from  $A$  to  $B$ ? Multi-paths are possible; see text.

### RESUME OF CONCEPTS AND DEFINITIONS

To proceed, we now introduce, discuss, and define in more detail several concepts and ideas presented earlier in the essay. This is done for purposes of clarity and usefulness, especially with regard to the issues raised in the final sections.

**System:** We take the concept of a system as a primitive notion and thus *undefined*, i.e., it “is not defined in terms of previously defined concepts, but is motivated informally, usually by appeal to intuition and everyday experience” (Haack, 1978).

In general, the nature of a particular system and its various components are readily defined and understood. For example, examine the two systems given above, the flipping of a coin and going from  $A$  to  $B$ ; in each case, it is clear what is the system.

**States of a System:** These items generally follow from how the system is defined. For the flipping of a coin situation, there are two states: head (H) and tail (T).

**Interaction:** This is a process which allows a system to change its current state or remain in this state. For the coin flipping system, if the prior state is H, then the flip will either change,  $H \rightarrow T$ , or produce no change,  $H \rightarrow H$ .

**History of a System:** This is the sequence of prior states that a system underwent to arrive at its current state.

**Trajectory of a System:** This consists of a particular history for the system, plus any one of the possible alternative future sequences.

**Realizable System:** A system is realizable if it obeys all the laws of physics and thus can actually exist in the physical universe.

**Alternative Futures:** If a system undergoes an interaction, at  $t = t_1$ , such that multi-outcomes are possible, then alternative futures are said to exist. Another way of stating this result is that at  $t = t_1$ , the original (unique) trajectory bifurcates into multi-trajectories. Consequently, for  $t > t_1$ , the system has multi-sequences of possible future states.

## DISCUSSION AND GENERALIZATIONS

A goal of this paper was to examine several realizable physical systems and demonstrate that they have alternative futures. Based on definitions given in the previous section, it is clear and (now) obvious that both of the systems studied, the flipping of a coin and going from *A* to *B*, have the property of alternative futures.

It should be noted that these systems may be characterized within the framework of classical physical theory (Simonyi 2012). However, there exists a large body of research and discussion of related issues within frameworks related to how quantum mechanics should be interpreted (see for example Carr 2007; Osnaghi et al. 2009; Tegmark 2014). Further scholarship has been done in the fields of history (Bunzi 2004; Carr 2001), historical dynamics (Turchin 2003), and the literary genre of alternative history (McKnight 1994).

The current paper extends the previous work of Mickens and Patterson on counterfactual history (see Mickens and Patterson 2016; Patterson and Mickens 2016). Here, we have shown that counterfactual histories are the same as alternative futures.

Counterfactual histories are often defined as possible histories of a system that were not in fact actualized or took place (for more details see Bunzi 2004; Carr 2001). Within the schema of this paper, counterfactual histories may be defined as follows:

(i) Consider a physical realizable system that can interact (with its environment) to produce multi-outcomes at each interaction.

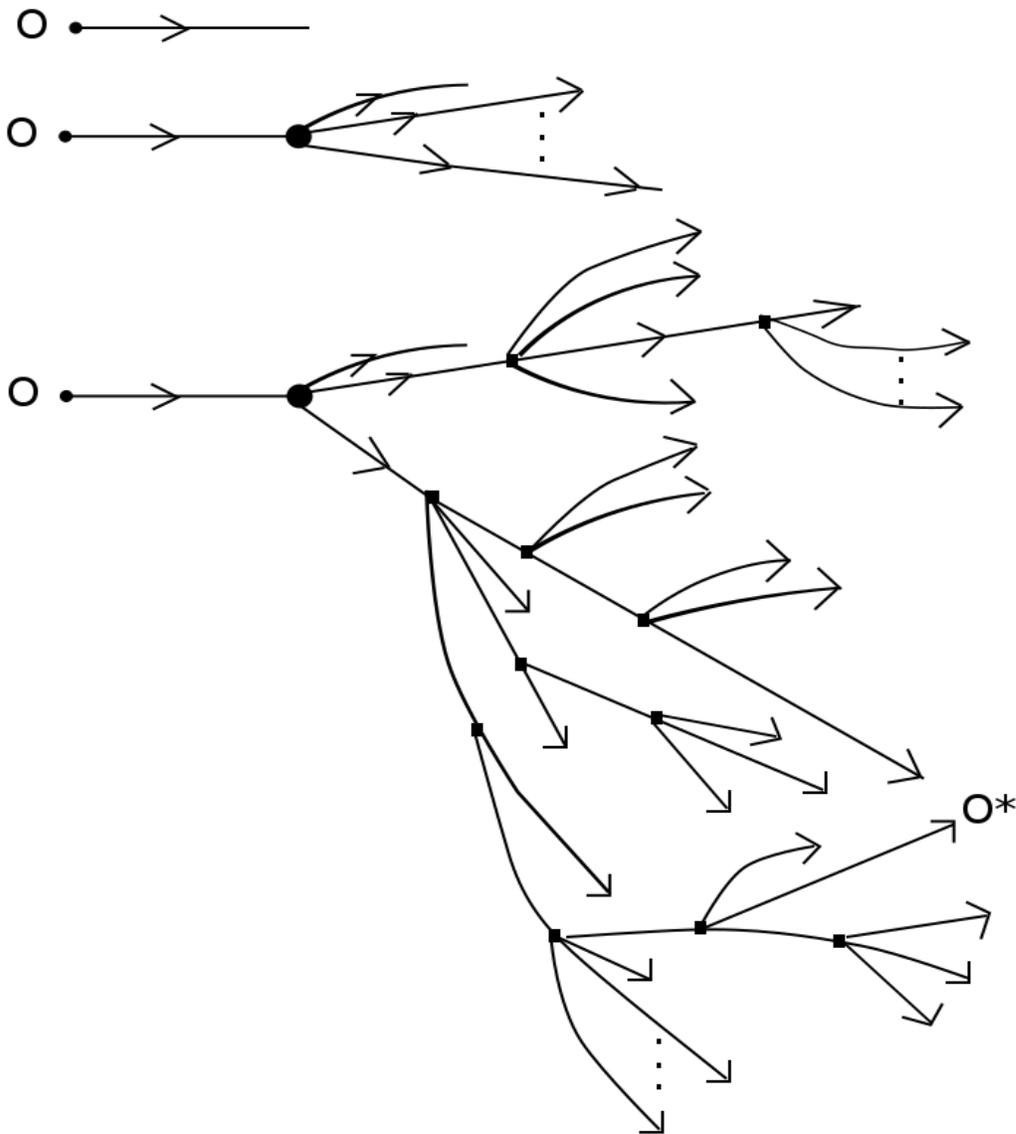
(ii) If the interaction occurs at the time  $t = t_1$ , then an “observer” of this system will see a unique history for the system, but will only experience one of the

future possibilities for the system for times after  $t_1$ . This will occur, in spite of the fact that all the multi-outcomes are in principle realizable.

(iii) The various multi-outcomes are what we have called or defined as alternative futures of the system.

(iv) Continuing this line of argument leads to the conclusion that any system having alternative futures also has the feature of alternative histories.

To illustrate these ideas, see Figure 3. For this situation, after each interaction, the system can have multi-outcomes, the number of which need not be a priori specified; it is only required that it be at least two, and its value may change from one splitting to another. The precise details do not influence or change the final conclusions.



**Figure 3.** The general evolution of a system  $O$ . The dots indicate events where a system interacts with its environment and creates the possibility for multi-outcomes.

Consider Figure 3; it shows a system starting at  $O$  and then undergoing splitting at various future times. (The horizontal direction, left to right, indicates increasing time.) The top illustration shows the evolution of the system with no change taking place. The middle illustration shows the system after one splitting, while the bottom illustration is a resume of some of the possible future splittings. Observe that from  $O$  many possible future branches exist. However, given a location on a future branch, there is only one reversed path back to  $O$ . To get a “feel” for the last statement, consider a future state  $O^*$ , and verify that there is only one backward traveling trajectory to  $O$ . The same result holds for any other future state of the system. In summary:

(a) Every initial system has a multitude of possible future states, i.e., they have the property of having alternative futures.

(b) From any given future state,  $O^*$ , there is a unique backward path to  $O$ , i.e., each state  $O^*$  has a unique history.

(c) An additional consequence is that the number of future states increases at least exponentially. For the case of flipping a coin, after  $N$  flippings, the number of possible states is  $2^N$ .

Translating these results into the realm of human experiences, (a) and (b) are consistent with the facts that each person has a unique history, but an unknown future.

(d) The existence of multi-alternative futures for a system implies the existence of counterfactual histories.

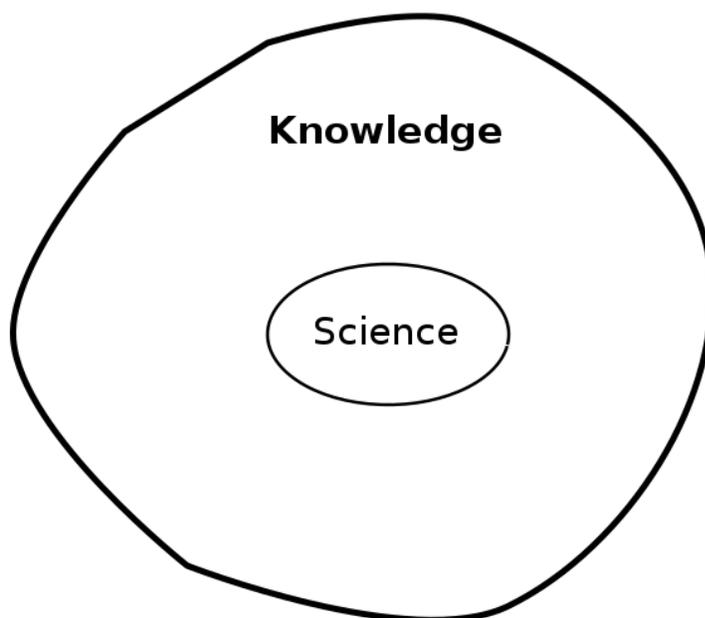
The restrictions of valid physical theories, whether classical or quantum, cannot be used to show that counterfactual histories do not exist. But the existence of a phenomenon, within the framework of a physical theory, is not the same as being able to experience all manifestations of that phenomenon. A simple illustration is provided by the flipping of a coin. After seven flips each of the following sequences are possible

HHTHTTT, HTTHTTH, THTHHTH, etc.

however, only one will actually occur and be within the experience of the flipper. At the end of the seven flips, the flipper will know exactly the outcome of the flips, but will be uncertain as to the outcomes of future flips.

The argument of the last paragraph implies that the concept of alternative futures, which implies the existence of alternative futures, which then implies the existence of counterfactual histories, is not scientific in the sense of being directly verifiable (Simonyi 2012; Tegmark 2014). However, not all knowledge and the understandings which come with it, is or has to be scientific (Boghossian 2007); see Figure 4. Nonscientific (nonverifiable) knowledge can give insights into the nature of knowledge in general, while also providing constraints on what is or is not scientific knowledge. The only requirement is that the analyses must be logically consistent.

Finally, it should be noted that for the discipline of history, the concept of alternative futures, which then produces counterfactual histories, permits the following conclusion to be reached. Accurate predictions for the future course of human based events is not possible.



**Figure 4.** Relationship of scientific knowledge to all of knowledge.

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