What is Time?

Throughout history, philosophers and scientists have found it difficult to understand and explain the basic meaning of time. Davies (1995) summarizes the dilemma as follows:

> Important though Einstein's time turned out to be, it still did not solve "the riddle of time." People often ask: What *is* time? Many centuries ago, St. Augustine of Hippo, one of the world's most influential thinkers on the nature of time, gave a perspective, if enigmatic, reply to this question: "If no one asks me, I know; but if any Person should require me to tell him, I cannot." … It is easy to conclude that something vital remains missing, some extra quality to time left out of the equation, or that there is more than one *sort* of time. The revolution begun by Einstein remains frustratingly unfinished.

We can begin to grasp the meaning of time, though, if we take heed of Hermann Bondi's comment, also quoted by Davies (1995), "Time must never be thought of as pre-existing in any sense; it is a manufactured quantity."

Indeed, time is not pre-existing or fundamental. When we observe nature, we find that we observe objects, and events involving those objects. We do not observe "time" directly. If we record our observations (e.g. in our minds, on paper, in a computer, etc.) then we are able to use these records to compare objects and events across a sequence of successive observations. In many of these sequences, we observe that objects *change*, either in "position", as measured in three-dimensional space, or in their internal "state" or "condition". Changes in the "state" of an object include changes in its intrinsic properties, e.g. the loss of an internal particle due to radioactive decay.

As we analyze sequences of events in our observational records, we notice that some objects change position or state in an "ordered" and "systematic" manner, which allows us to quantify and compare the different types of changes. For example, in our sequential records, we might observe that some objects change their positions in space (i.e. "move") faster or slower than other objects. That is, we observe differences in the "rates" of change of the different objects. We also observe differences in the "amounts" of change. For example, we might observe that some objects change their positions in space more or less than other objects. So, in cases of changes in positions, we observe and measure the rate of change in terms of "speed", and the amount of change in terms of "distance".

In many cases, the systematic nature of the observed changes allows us to quantify their rates of change and amounts of change, and to develop relationships between them. One of these relationships, called "time", turns out to be an extremely useful metric of change. We use this metric every day to plan for the changes that occur in our daily lives. We define the time metric as the ratio *x/r*, where *x* is an amount of change, and *r* is a rate of change. For example, the time of "30 seconds" is the amount of time for a car to travel 2640 feet at a rate (speed) of 88 feet/second. "30 seconds" is also the time for a TV to change its state from "Starting a 30-second ad" to "Ending the ad" at the standard TV broadcast rate. It is also the time for an analog clock's second hand to travel a distance from the 12 to the 6 on the clock face at the rate of motion of the hand, or the time for a digital clock to change its display state from 12:00:00 to 12:00:30 at the digital clock's rate of display change.

The time metric is useful because it provides a standard measure that we employ to compare and manage the changes occurring around us. And the usefulness is maximized, since everyone we know uses the same standard time metric in their planning, also. Indeed, the time metric is so useful in areas such as event planning, in mathematical graphs of coordinate systems, in scientific equations of motion, etc., that it takes on a mythical status as a fundamental property of nature. But it is not. Instead, it is derived property, a "manufactured quantity", as Bondi calls it. It helps to realize this if we remember that, whenever we use "time" in our planning, we need to consider both the amount and the rates of changes that are involved in our plans.

For example, if I am watching TV and a 30-second ad appears, I might want to decide whether I have the time to go to the kitchen, grab a soda, and return to the TV room before the ad ends. To judge this, I need to consider the rate of speed that I will use to move to the kitchen and back, along with the distance from the TV room to the kitchen and back. The ratio of this distance divided by my speed will determine the time I will need to get the soda. I need to compare that ratio with the time required for the TV ad. This time will be the ratio of the amount of changes in the TV screen during the commercial divided by the rate of the TV broadcast. If I am watching the TV ad at the normal broadcast rate, I will have 30 seconds to get the soda. If I am watching the ad as a video at the fast forward rate, I will have less time.

As another example, if I agree to meet someone at a designated place at a designated time, my planning for that meeting will depend on the distance I must travel to get there, and on my rate of travel. How far away is the place? Will I be walking to the meeting or driving a car?

Why is it so hard to define and describe time? The fact that "time" is the ratio of two different things (i.e. amount of change / rate of change) is what can make it difficult to understand and describe on a basic level. After all, understanding ratios is hard. (Ask any 4th grader.)