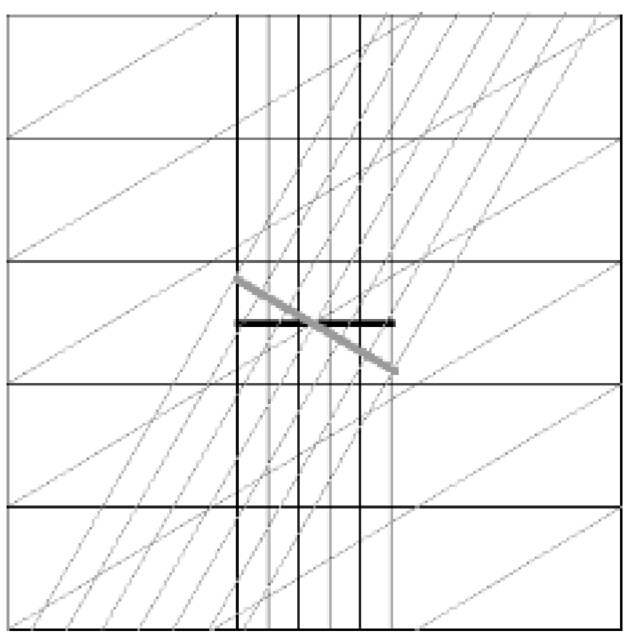
Phil 124 — Philosophy of Space and Time — Final Forrest Cameranesi

1) Clarke argued that God could move the material universe, a view which Leibniz disputed. The fundamental difference of conception underlying this debate is whether space exists as something ontologically separate from objects (as Clarke held), rather than just being a relation between those objects (as Leibniz held). In the latter view, relationalism, it makes no sense to speak of the entire universe moving with no relative motion within itself, for there is nothing else for it to move relative to (as the universe is, by definition, everything), and so this "motion" would be indistinguishable from stillness, and thus (by the Principle of Sufficient Reason) identical with stillness. In Clarke's absolutist view, space is something against which the objects of the universe are set, and so motion relative to space alone is certainly possible. A problem arises from this view, however, in that in so moving the universe, God would presumably apply a universal force to all objects in the universe, since pushing or pulling one part could not transmit that force across space to all the other distant objects in the universe, the way pushing one part of a ball moves the other parts of it. Because of this universal force, we would notice no acceleration, as there would be no relative motion of anything, and as the space that Clarke envisions is flat and featureless, we could not tell that we were moving to a different part of space by somehow watching the space go by. So again, even in Clarke's vision, it seems that universal motion relative only to space would be indistinguishable from a universe "at rest", and so again by the Principle of Sufficient Reason, such a state ought to be considered identical to a state of rest.

2) Galilean Relativity is the principle that there is no special or privileged reference frame of motion; that is to say, that any reference to one state of motion as "still" or "at rest" is arbitrarily chosen. All frames of reference are equally valid, inasmuch as from any frame of reference the laws of physics will appear constant. This principle came up in the debate between Clarke and Leibniz over the absolute or relational nature of space with the imaginary scenario of a sailor in his cabin in a large and steady ship at sea, plowing very quickly across the ocean. This ship is in uniform motion and experiencing no acceleration, but relative to the Earth and the waters around it, it is moving very fast. Nevertheless, events occurring inside the sailor's cabin — say him tossing a ball in the air and catching it — occur precisely as though the sailor, his ball, and the cabin were all at rest. The ball goes straight up and comes straight down, relative to the sailor; it does not fly toward the back of the ship as though it was trying to stay still relative to the Earth. This demonstrates the principle of Galilean Relativity, that these things are only thought to be "in motion" from the reference from of the Earth or the sea, but that to the sailor in his cabin, he may equally say that he is at rest, and the sea is moving past his ship. Leibniz felt that this lent credence to his notion that there is no absolute space, and thus no absolute motion; all motion is relative, so too all space is relative. Einstein used this in his theory of Special Relativity to show that space and time must be measured differently to observers in relative motion, in order for the laws of physics which dictate the speed of light to be constant to remain themselves constant. Without such spatiotemporal transformations dependent on relative motion, certain laws of physics (and the experimental observation that light always travels at the same speed to any observer) would be rendered different depending on motion, thus violating Galilean Relativity.

3) From the perspective of someone on a 100-meter space station, it is possible for spaceship which, when at rest relative to the space station, measures 120 meters, to fit entirely within the space station if it is moving at 60% the speed of light relative to the space station. (We imagine this space station being tube-like, such that spacecraft could fly straight through it). This is possible because according to Special Relativity, observers in different states of motion will measure space differently, such that objects moving more rapidly (relative to the observer) will appear contracted along the direction of their motion. Thus to an observer on the space station, the supposedly 120-meter spaceship will actually measure just less than 100 meters, and so momentarily fit entirely within the space station as it passes through. Conversely, to the spaceship the space station will appear contracted to well less than 100 meters, and thus at no time will the ship seem entirely enclosed by the space station. Nevertheless, despite this the two apparently different states of reality can still be reconciled as one if we take a four-dimensional view of the universe, accounting for the fact that not only do the two observers measure distance differently, but time also. Thus, while to the space station crew the tail end of the spaceship enters the space station a moment before the nose end of the spaceship leaves, to those on the spaceship the two events occur in vastly different sequence, with the nose of the ship leaving the space station well before the tail ever enters. Because of this, if the two frames or reference were to become unified — say because the space station closed doors at its end, with which the ship collided — then the two would agree that the same events had occurred, but in different order. Those on the space station would say that they closed both doors simultaneously. But those on the spaceship would say that they closed the far door first, which their ship then ran into, and after the ship had crumpled against the one door and its tail thus gone inside, the other door closed. Either way the result is the same — a crashed spaceship between two doors — but precisely how that happened depends on your frame of reference. To illustrate with a diagram:



The spaceship (thick gray line) appears 120 meters (six grid marks) long in its own frame of references (gray diagonal lines), while from the frame of reference of the space station (black orthogonal lines), it measures only around 100 meters (five grid marks), as does the space station itself (thick black line). Representing the space station's frame of reference as orthogonal lines here indicates that we are taking that reference frame to be "at rest". Another diagram would be necessary to show the station's size from the perspective of the spaceship.

4) To make any sense of changing the past, we must understand what we mean by both "change" and "past". First, change in general is the difference of some given continuous thing between one point and another. These points can be across space or across time. A stationary cone's diameter changes between its base and its tip, despite the fact that there is no motion of it; likewise, a growing circle's diameter changes between earlier times and later times. Secondly, the past is simply all those events which, from our frame of reference, lie in the direction of time which we consider to be "earlier". (Why time is so asymmetric is another question entirely). An event, in this case, being something existing at a certain place at a certain time, a sort of four-dimensional chunk of the universe. Thus, to make any sense of changing an event, would require that we postulate some other dimension beyond the four in which the event is defined, across which some qualities of the event differ; i.e. a "hyper-time", or some dimension of alternate "universes". Likewise with events in the future: either we cannot change events in the future, and all future facts are true right now (which is not to say that future events are not caused by us), or there is some other dimension besides the four of space-time, across which future events may change.

5) Aristotle's "Sea Battle Tomorrow" is a hypothetical situation where two warring nations are attempting to negotiate a peace, while their respective navies face off in the sea nearby, awaiting the results of these negotiations to either begin hostilities or not. If the negotiations fail that evening, then there will be a battle at sea the next day. If they succeed, there will be no battle. A four-dimensional view of the universe, which holds that the past, present, and future all exist equally, would conclude that it is true now, on the day of the negotiations, that there either will or will not be a battle at sea tomorrow. Though we don't yet know which, one of those options must be true, and its negation false. Aristotle believed that this conception contradicted the self-evident truth that we have free will, it being the case (so he thought) that if statements about the future were true now, then nothing that we could do would change those facts. So he came to the conclusion that statements about the future are neither true nor false yet, though they will become true or false later, depending on the outcome of the future. Thus Aristotle in effect denied that the future exists, in the same tenseless sense that we say the past exists. This is a position that scientific people such as Prof. Humphrey and myself are rather disinclined to assume. The obvious "out" or solution to this problem, as Prof. Humphrey mentioned in lecture, is that even if statements about the future are true now, they are only true because of the events which will occur between now and then, events which include our own decisions and actions. Thus we still have free will in the sense that, whatever the causes or determination of our actions and decisions, if we make different decisions, there will be different outcomes. Whether (to use metaphorical language) God already knows what decisions we will make and what events will occur has no bearing on the fact that we make certain decisions which impact the events which follow them.

6) The anisotropy or asymmetry of time is the apparent fact time "flows" only in one direction, and we never experience anything which seems to "move" backward in time. That is to say that systems which evolve and change in any complex way over time (thus excepting simple motions of single particles in space) appear to never reverse their evolution and go back to an earlier state. The second law of classical thermodynamics provides one explanation for this in that it claims as a law that all thermodynamic systems (which encompasses nearly all evolving systems that experience temporal asymmetry) will increase in entropy over time, irreversibly. That is to say that all closed thermodynamic systems (ones with no energy input) will necessarily tend toward a general state of disorder and thermal equilibrium, with energy being distributed equally across the available space. Thus all systems must continue evolving "forward" in time, since to evolve "backward" would be to violate this supposedly inviolable natural law.

7) Boltzmann's reduction of the second law of thermodynamics to statistical mechanics is as follows: The complete, fine-grained state of any thermodynamic system (say for example a cloud of gas) can be described using a "phase space", that is, an N-dimensional diagram in which N is the number of possible different variables in the system. (In the case of thermodynamic systems, this is usually six — for the individual X, Y, and Z positions and momenta of each particle — times the number of particles in question). Any fine-grained description of a state of the system can be thus given in its entirety by naming a point in this phase space diagram, which will have values along each dimension of the diagram corresponding to all the possible variables of the system. To say that such a description is "fine grained" is to say that it discriminates between states which may seem, to an outside observer, indistinguishable. For an extreme example, two different fine-grained states may be identical in every way except that two identical particles in the system have swapped positions and momenta with each other, so that instead of particle A being at place B and moving along vector C, A is at Y moving along Z, and the identical particle X, which was at Y moving along Z, is now at B moving along C. To any observer, as these particles are absolutely indiscernible from one another, these two states are also indiscernible, and so would have the same coarse-grained description; but nevertheless, they are physically different, and thus represented by different fine-grained descriptions. A coarse-grained description is represented on a phase space diagram as an N-dimensional figure of such a shape and volume that it encompasses all the fine-grained descriptions (points in the phase space) which have that same coarse-grained description. But coarse grained descriptions do not need to involve so extremely similar groups of fine grained descriptions as the one described above, and this is the root of Boltzmann's reduction. To a human observer, any state of a system in thermal equilibrium (high entropy) is indistinguishable from another, and thus has the same coarse-grained description. But the vast majority of possible fine-grained descriptions fall under this coarse-grained description, and only a vanishingly small number of fine-grained descriptions fall outside of it. That is just to say that of all possible states a system of (for example) gas molecules could have, most of them we would describe as being "high entropy". Thus, statistically, as a system evolves, even according to deterministic and time-reversible laws such as Newtonian mechanics, the odds of it happening to come into a state of extremely low entropy — of the point in the phase space describing it "wandering into a region of low entropy" — are vanishingly unlikely, such that we never, ever witness such a thing occurring. Thus the second law of thermodynamics is *de facto* true, simply in that we never witness its violation, despite the fact that it is theoretically possible and, given sufficiently insane amounts of time, would eventually be witnessed.

8) Two closely related possible objections to to Boltzmann's theory above are: (A) That given sufficiently long periods of time, we would eventually witness entropy decreasing again by mere statistical probability, and (B) That given a system that starts in a state of low entropy, it is just as valid to deduce that the system was previously in a state of higher entropy as it is to deduce that it will later be in a state of higher entropy, again implying a reversal of the second law at some point. To retain our notion that entropy must never decrease in spite of these apparent truths, we may introduce the notion of "branch systems". A branch system is simply a closed system which was not always, and will not always be, a closed system isolated from everything else. That is to say that a branch system is a *created* closed system, one with a beginning and an end, rather than an eternal one. A cup of hot water with an ice cube melting in it is a closed system for the duration of our watching of the ice cube melting in the water. But that system did not spontaneously come into its initial state of low entropy, it was created out of another low-entropy system (including humans, stoves and freezers) and then closed off; and it will be destroyed (or more properly, absorbed back into the larger system) long before it has a chance to spontaneously experience a reversal of entropy. Thus we see that any experimental closed system is such a "branch system", and we will never observe a decrease of entropy therein.

9) Another objection to Boltzmann's statistical conception of entropy is that coarse-grained description of a thermodynamic system are entirely a product of our ignorance. That is to say, if we could really discern between possible fine-grained microstates of a system, and did not give any special significance to one kind of arrangement or another, we would see that all possible states are equally likely, and we would never say anything about entropy increasing. Rather, we would if anything just describe the different changing arrangements of particles and such. An illustrative analogy for this is a deck of cards. The odds of drawing any possible hand of five cards are exactly the same. However, the odds of drawing a Royal Flush are much lower than the odds of drawing a random crappy hand, because we put special significance on Royal Flushes, and lump all possible crappy hands together into one description. Thus there will be many more crappy hands dealt than Royal Flushes, simply because there are many, many possible hands which we are prone to call "crappy", and very few hands that we call a Royal Flush. I personally don't see how this is a really valid objection, because by saying that a state is "high entropy", like saying that a hand is "crappy", we are simply saying that it does not fall into a specially ordered state, but is rather random and disordered. As special, ordered states are by their nature unique and rare, the vast majority of possible states are going to be chaotic, disordered, and high in entropy, and so Boltzmann's statistics accurately describe why a system will tend toward a state of higher entropy: because of all possible states it could tend toward, most of them are high entropy.

10) Yet another major objection to Boltzmann's theory is that that our universe as a whole appears to be winding down from a state of low entropy. As we are hesitant to call the universe a branch system (as “the universe” should, by definition, encompass everything and thus exclude the possibility of there being anything beyond it), this raises the problem of how our universe got to this state of low entropy to begin with. This is particularly problematic in that the initial state of the universe at the Big Bang was extremely high entropy, being a homogenous cloud of super hot plasma, and so how it got from there to its present state of relatively low entropy is a big question. We say that our universe is in a state of low entropy now because there is quite obviously a lot of order to the energy distribution, with bright stars against a dark background space, and complex systems such as life developing and even increasing in order and complexity here on Earth, requiring an even lower-entropy state (the concentration of energy in the sun, as opposed to being spread all about the solar system) to explain. One explanation for this given in class is that the inflationary period of the universe, when space expanded incredibly fast soon after the big bang, raised the “ceiling” of maximum entropy faster than entropy itself increased. In effect, the increase in space between energetic things like stars makes that energy concentration comparatively greater, as the energy has to spread further, and thus do more work, to reach thermal equilibrium. Thus, compared to how much entropy there could be, we have comparatively little of it in the universe as we know it today.