Class #12 - Space and Time
Newton, "Scholium to Definitions" from *Principia*, and other selections
Leibniz, from *Letters to Clarke*

0. Where are we? Really, where? More on relational space

I. Absolute and Relational Notions of Space and Time

Theories of space and time have their roots in our observations about change.
Most or all change appears due to some sort of motion, of the change of place of some objects over time.
Motion is ordinarily measured relative to some external object.
When I am traveling on the highway, I am moving, with respect to the world outside the car, and sitting with respect to the car itself.
We use terms like 'up' and 'down', relative to the Earth.
But, even the Earth itself is moving, spinning on its axis.
The axis of the Earth is shifting as well, in the annual revolution of our planet around the sun.
The solar system is moving relative to our Milky Way Galaxy, and the Milky Way is moving within our local system of galaxies.
And so on, one supposes.
I am driving 50 mph west, while the Earth is spinning at 650 miles per hour East, and the whole system is flying through space in its revolution around the sun at around 66,000 miles per hour.
Further, our solar system is moving within our galaxy, which is moving in relation to other galaxies.
Is there some fixed point, some privileged reference frame, to which all motion can be measured?
For most practical purposes, we can pick a frame of reference outside of our solar system, measuring motion with respect to distant stars.
But, is there an absolute sense in which we can be said to be moving or not?
If so, can we measure this motion relative to some special body or substance, like absolute space?
Is there space, in addition to places?

Newton and Leibniz clashed over whether space and time had absolute reality, or whether they were merely relational concepts.
Newton's view is that space is something distinct from the bodies that occupy it, and that time is something that passes uniformly without regard to events in the world.
Space is an empty container, and time marches inexorably forward.
Though we measure space and time using bodies and events, these are only indicative of relative motions.

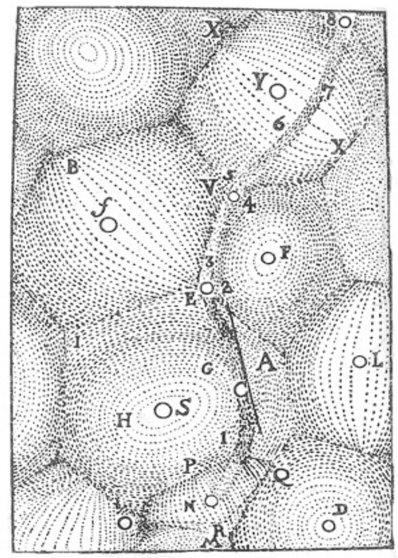
In contrast, Leibniz's relationalist view is that space and time are idealizations, abstractions from the realities of the material world.
(Here, we will put aside Leibniz's idealism, and consider bodies as real things.)

> I hold space to be something merely relative, as time is...an order of coexistences, as time is an order of successions (Leibniz, LIII.4, AW 297b).

The differences between Newton and Leibniz over the nature of space and time are tied to their different conceptions of motion, and acceleration.
If motion is change of place over time, then to define motion, we have to know if we are appealing to absolute motion, the change in the place in absolute space of an object, or relative motion, the mere rearrangement of bodies.

Newton and Leibniz were influenced by two distinct schools of thought.
On the one hand, Descartes's physics denied the possibility of a void, or vacuum.
This view was inherited from the Aristoteleans who believed that a void is nothing, and what is nothing does not exist.
Descartes incorporated the opposition to a vacuum into the new science by taking the world to be a plenum, in which space is not distinct from the bodies which fill it.

> All places are full of bodies... Each body can move only in complete circle of matter, or ring of bodies which all move together at the same time: a body entering a given place expels another, and the expelled body moves on and expels another, and so on, until the body at the end of the sequence enters the place left by the first body... (Descartes, *Principles of Philosophy*, II.33).



(Right: Descartes's depiction of the plenum, *Principles of Philosophy*, II.553)

Despite his many differences with Descartes, both in physics and metaphysics, Leibniz adopts Descartes's views on the completeness of the material world.

He argues for the saturation of the plenum from the contradiction he sees as inherent in the concept of empty space.

> Let us fancy a space wholly empty. God could have placed some matter in it without derogating, in any respect, from all other things; therefore, he has actually placed some matter in that space; therefore, there is no space wholly empty; therefore, all is full (Leibniz, LIV.PS, AW 303a).

Leibniz believes that the idea of empty space contradicts God's commitment to creating the best of all possible worlds.
His denial of a void implies that there is no space beyond the places of objects.

In contrast to Descartes and Leibniz, atomists like Gassendi argue that the places between objects are empty.
Objects are placed in a transcendent void.
When we move, we change our place relative to the objects around us, and, they argue, we change our location in absolute space.
Newton adopts the view of the atomists and their commitment to a vacuum.

Here is one way to see the difference between Newton's absolutist view and Leibniz's relationalism.
Consider the question, "What exists outside the universe?"
Leibniz, with the Cartesians, answers that the universe extends infinitely, so that there is no outside.
Newton, with the atomists, answers that there is an empty void.
Today, the debate between relationalism and absolutism continues between space-time relationalists, who believe that space-time is an artificial, or nominal, construct out of particular bodies, and substantivalists, who believe in the existence of space-time points or regions.

II. Newton's Bucket

Here is a summary of Newton's views on space and time.

> Absolute time passes steadily without relation to anything external, and thus without reference to any change or way of measuring of time.
> Absolute space remains without relation to anything external.
> Relative spaces are measures of absolute space defined with reference to some system of bodies; a relative space may be in motion.
> The place of a body is the space which it occupies, whether absolute or relative.
> Absolute motion is the translation of a body from one absolute place to another; relative motion is the translation from one relative place to another.

For the absolutist, space is distinct from, and exists independently of, bodies.
It is logically and metaphysically prior to bodies and events among bodies, in that bodies require space but space need not include any bodies.
There is a fact of the matter whether a given body moves and what its true quantity of motion is.
The true motion of a body does not consist of, or cannot be defined in terms of, its motion relative to other bodies.
See the Stanford Encyclopedia of Philosophy article on Newton's views of Space, Time, and Motion; also see Tlumak 167-8.
More speculatively, Newton refers to space as the sensorium of God, and as the seat of divine cognition.

Newton's view can be found in the Scholium, as well as in the other assigned selections.
In the Scholium, Newton starts with definitions of absolute and relative spaces and motions and proceeds to argue for the existence of absolute time and space.
In large part, Newton's arguments are aimed against the Cartesians who defined motion in terms of the translation of a body relative to its surrounding objects in the plenum.
Newton had many reasons to be unhappy with Cartesian physics.
For one, Descartes centered his account of physics around motion, rather than acceleration.
The arguments in paragraphs 8-11, the last of which immediately precedes the discussion of the bucket experiment, are mainly directed at Cartesian physics.
He argues that the definition of motion as translation of a body relative to its surrounding objects will not allow us to arrive at a measurement of absolute motion.

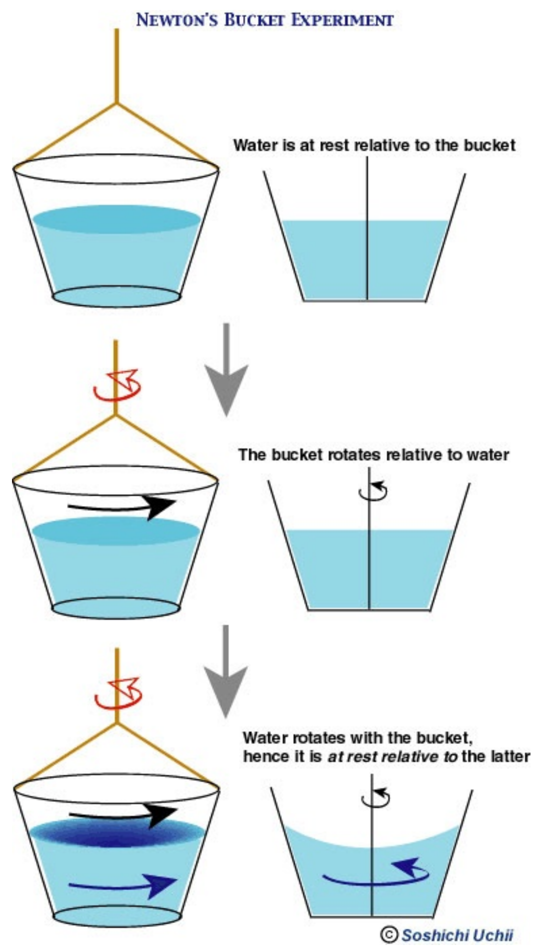
For example, let's assume that bodies that are truly at rest are at rest with respect to one another.
Imagine that there is a distant star which is absolutely at rest.
We might wonder if something in our vicinity, say this table, is at rest, too.
But, if we measure the motion of the table relative to the motions of things around it, we can not know whether it is moving or at rest relative to the distant star.
The table is at rest with respect to its surroundings, but that does not determine whether it is at rest, absolutely.
Thus, true rest cannot be defined simply in terms of position relative to bodies in the vicinity.

Newton discusses other properties of motion that lead to difficulties for Cartesian physics.
The property that if a part of a body maintains a fixed position with respect to the body as a whole, then it participates in the motion of the whole body entails that absolute motion cannot be defined as a translation from the immediately surrounding bodies.
Imagine that I am sleeping in the back of a car.

My femur is at rest with respect to me.
I am at rest with respect to the car.
But, my femur and I are both moving.
The property that a body participates in the motion of its place when it moves away from that place entails that the absolute motion of a body cannot be defined except by means of stationary places.
You can change the relative motion of a body by changing the motion of the bodies to which you are comparing it.
But, you can only change the true, or absolute, motion of a body by applying some force to it.

These arguments from properties and causes are important for characterizing Newton's concept of absolute space and motion.
But, the most influential argument in favor of his thesis that we must posit absolute space in order to make sense of motion is Newton's example of a rotating bucket.
Newton's bucket experiment provides a case in which there are states of a system with different motions, yet which can not be described in terms of changes of place with respect to surrounding objects.
We know that the motions are different in the two states, but we can not differentiate them in terms of local changes of place.

Consider a bucket, suspended by a rope, and filled with water.
Turn the bucket many times, so that the rope twists.
In state 1, hold the bucket still.
The surface of the water inside the bucket is flat.
Now, let go of the bucket.
In state 2, the motion of the bucket is fast, but the motion of the water is slow.
The surface of the water in the bucket remains flat.
The water is moving very rapidly with respect to the bucket, and yet there is no centrifugal force manifested.
After a while, the water begins to turn with the bucket, and centrifugal force pushes the water up the sides of the bucket.
The surface of the water becomes concave.
In state 3, the bucket and the water are at relative rest, and yet the water has a concave surface.



Now, compare state 1 to state 3.
In both states, the water and the bucket are at relative rest.
In state 1, for both the relationalist and the absolutist, there is no motion.
But state 3 is measurably different to state 1, and the relationalist seems unable to describe the difference between the two states, since the water and the bucket are at relative rest in both states.
The absolutist needs merely to point out that in state 3, the system is in absolute motion, while in state 1, the system is at absolute rest.

One problem for the doctrine of absolute motion, a problem which Newton admits, is that, in contrast to rotation, which the bucket experiment measures, it is difficult to measure absolute velocity.
The absolute speed of a body is the rate of change of its position relative to an arbitrary point of absolute space.
According to Newton's account, absolute velocity is a well-defined quantity.
But consider, as Galileo did, riding in a ship at a constant velocity.

> Shut yourself up with some friend in the main cabin below decks on some large ship, and have with you there some flies, butterflies, and other small flying animals. Have a large bowl of water with some fish in it; hang up a bottle that empties drop by drop into a wide vessel beneath it.
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> With the ship standing still, observe carefully how the little animals fly with equal speed to all sides of the cabin. The fish swim indifferently in all directions; the drops fall into the vessel beneath; and, in throwing something to your friend, you need to throw it no more strongly in one direction than another, the distances being equal; jumping with your feet together, you pass equal spaces in every direction.
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> When you have observed all of these things carefully (though there is no doubt that when the ship is standing still everything must happen this way), have the ship proceed with any speed you like, so long as the motion is uniform and not fluctuating this way and that. You will discover not the least change in all the effects named, nor could you tell from any of them whether the ship was moving or standing still. In jumping, you will pass on the floor the same spaces as before, nor will you make larger jumps toward the stern than towards the prow even though the ship is moving quite rapidly, despite the fact that during the time that you are in the air the floor under you will be going in a direction opposite to your jump. In throwing something to your companion, you will need no more force to get it to him whether he is in the direction of the bow or the stern, with yourself situated opposite.
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> The droplets will fall as before into the vessel beneath without dropping towards the stern, although while the drops are in the air the ship runs many spans. The fish in the water will swim towards the front of their bowl with no more effort than toward the back, and will go with equal ease to bait placed anywhere around the edges of the bowl. Finally the butterflies and flies will continue their flights indifferently toward every side, nor will it ever happen that they are concentrated toward the stern, as if tired out from keeping up with the course of the ship, from which they will have been separated during long intervals by keeping themselves in the air... (Galileo Galilei, *Dialogues Concerning the Two Chief World Systems*)

We cannot determine from observations inside the cabin whether the boat is at rest in harbor or sailing smoothly.
The point of the ship example, in this context, is to show that Newton's absolute velocity cannot be experimentally determined, unlike absolute rotation.

> Yet the thing is not altogether desperate; for we have some arguments to guide us, partly from the apparent motions, which are the differences of the true motions, partly from the forces, which are the causes and effects of the true motions (Newton, Scholium to Definitions in *Principia*, AW 288a).

I will not pursue the details of Newton's solutions, which are really the elements of his mechanics.

III. Leibniz's Relationalism

Leibniz discusses many conflicts in his correspondence with Newton's secretary, Samuel Clarke.
Newton, it seems, participated in constructing some of the correspondence, though some of it appears to be written by Clarke alone.

> Our dispute consists in many other things. The question is whether God does not act in the most regular and most perfect manner; whether his machine is liable to disorder, which he is obliged to mend by extraordinary means; whether the will of God can act without reason; whether space is an absolute being; also concerning the nature of miracles; and many such things, which make a wide difference between us (Leibniz, LIII.16, AW 299a).

We are focusing only on the question of whether space is relational or absolute.

One problem with Newton's claim is that space seems difficult to classify as a substance or an attribute.
Newton does not take space to be a substance, for it lacks causal powers.
But, it is also not an attribute, since its existence transcends the existence of any things.
Unlike, say, redness, it doesn't need a thing to be predicated of.

> If space is a property or attribute, it must be the property of some substance. But of what substance will that bounded empty space be an affection or property, which the persons I am arguing with suppose to be between two bodies? (Leibniz, LIV.8, AW 300a).

So, space is real, but hovers in between substance and attribute.
We could, for Newton, call it a pseudo-substance.
Leibniz seems to think that this argument is important.
He derives consequences from it that seem to impugn the perfections of God.
But, it is not clear that the argument has the ramifications that Leibniz takes it to have.
Perhaps the classification of all objects into substances and attributes is incomplete.

Leibniz's more influential arguments derive from his general principles which he claims rescue science from nonsense.

> Those great principles of sufficient reason and of the identity of indiscernibles change the state of metaphysics. That science becomes real and demonstrative by means of these principles, whereas before it did generally consist in empty words (Leibniz, LIV.5, AW 299b).

Leibniz says that the doctrine of absolute space and time lead to absurdities.
Could the universe, for example, have been created at a different time?
Could it be moved three inches to the left?
There would be no way to distinguish two universes that were identical in all their relations among objects, but put into a different space, or reoriented.

> Those two states, the one such as it is now, the other supposed to be the quite contrary way, would not at all differ from one another. Their difference therefore is only to be found in our chimerical supposition of the reality of space in itself. But in truth, the one would exactly be the same thing as the other, they being absolutely indiscernible, and consequently there is no room to inquire after a reason for the preference of the one to the other (Leibniz, LIII.5, AW 297b-298a; see also LIV.13, AW 300a-b).

Instead, Leibniz argues, space is a set of relations among bodies.
Time is an abstract relation among events (or perceptions).
Those systems of relations might be thought of as abstract, but they should not be reified.
Elsewhere, in the Fifth Letter, Leibniz refers to the structure of space time as analogous to a family tree, which is just set of organizing relations, and not a thing in itself.
The infinite divisibility of space and time are further arguments against their reality; no really existing thing could be infinitely divisible.
We must take space and time to be ideal, or imaginary constructs derived from the appearances of bodies.

The status of space and time are further impugned when we remember that even bodies, for Leibniz, are just appearances.
Space and time turn out to be abstractions on what is already only a mere appearance.
The only reality is monadic.
Monads have temporal properties, but not spatial properties, except in a thin, derivational sense.

IV. End Continental Rationalism (Until Kant)

We have come to the end of the sometimes-trippy, often-speculative, and always-difficult-to-comprehend-and-interpret continental rationalists portion of the course.
Ahead of us lie the British Empiricists: Locke, Berkeley, and Hume.
Those three writers will rein in the speculation, both by restricting the use of intuitive principles in their philosophy and by paying close attention to the limits of human cognition.
From Descartes, Leibniz, and Spinoza, we were given grand systems of knowledge: of God, and Nature, and mathematical principles which grounded deterministic physical laws, governed by divine goodness.
Never mind that our ordinary beliefs had to be re-calibrated: to deny the veridicality of sense perception, to see the thin universe both packed with matter and infinitely divisible, to deny the very existence of a material world, and to prefer a universe in which bodily existence was reduced to a mere appearance.
We were introduced to ‘compossibilities’, and ‘necessitarianism’, and ‘the plenum’.

At the end of this course, Kant will return to pick up the rationalist’s thread of argument, and attempt to unite it with what we are now going to see from the British Empiricists.
For now, we will examine attacks on the fundamental presuppositions of the grand systems-builders.
We return to our senses.