a. Quantity of motion: B∗speed, where B represents bulk (Lat. *moles*) or quantity of matter (ultimately, volume for Descartes) and speed is a scalar

b. Our momentum, by contrast, includes an intensive quantity, mass as a measure of quantity of matter, and more important it is a vector quantity -- i.e. it is directional

5. Rationale for the principle: everything surrounded by touching bodies so that any change of place -- i.e. motion -- of one volume requires changes of place of others

a. The only way to change the total motion is to accelerate a closed circuit

b. God would not do this

6. Given this rationale, Descartes' claim is more akin to the principle of continuity in fluid mechanics than it is to conservation of momentum

a. Volume flow rate = v ∗A, where A is normal to v (in units of volume of fluid per time)

b. Picture a continuous, incompressible fluid flow through a pipe of varying cross-sectional area: v∗A everywhere a constant

c. Now "sum" across the universe, and have Descartes' principle

d. Spinoza offers just this line of interpretation (Propositions vii-xi of his *Principles of the Philosophy of Descartes*), and hence not a Whig interpretation at all

7. Not an empirical principle, but led to a serious controversy in empirical science 40 years later about what is conserved in e.g. a closed system

a. B∗v for the Cartesians, versus B∗v^2 for Leibniz (and Huygens), both scalar quantities

b. This dispute worth looking at to see how those in Descartes' wake tried to bring empirical considerations to bear, and how they still depended on non-empirical considerations

B. The First Law of Motion (i.e. Nature)

1. "Each thing, provided that it is simple and undivided, always remains in the same state as far as is in its power, and never changes except by external causes [*causis externis*]" (37)

Le Monde: "Each individual part of matter always continues to remain in the same state unless collision with others forces it to change that state." (p. 61)

a. '*Quantum in se est* ' (translated above, "as far as is in its power") is a phrase borrowed from Lucretius's *De Rerum Natura*

b. The law is a general principle of change, in the same sense that Aristotle's four causes or principles are

c. But Descartes is ruling out final and formal "causation" for simple, undivided things

2. Descartes distinguishes two states of concern, rest and motion

"If it is at rest, we do not believe that it will ever begin to move unless driven to do so by some external cause. Nor, if it is moving, is there any significant reason to think that it will ever cease to move of its own accord and without some other thing which impedes it." (37)

a. Law says it continues to move, but says nothing about how it continues to move

b. Notice the argument for continuing to move: "no significant reason to think that"

3. As this phrase suggests, the law is really a tenet of explanation of change, akin to those put forward by Aristotle, and not as such an empirical generalization
   a. That is, it is indicating which why-questions are appropriate -- e.g. not 'why does that continue to move?'
   b. And it is indicating what sorts of answers are appropriate to these questions -- e.g. 'because that thing impeded it'
   c. Also 'why is that thing moving?' -- 'because it was already moving and nothing has impeded it'
4. This import of the law is illustrated by Descartes' immediate application of it to answer the old Aristotelian problem of why projectiles keep moving after they are thrown (38)
   a. Reason amounts to rejection of question ('why not?')

      "For there is no other reason why things which have been thrown should continue to move for some time after they have left the hand which threw them except that, having once begun to move, they continue to do so until they are slowed down by encounter with other bodies."

   b. Thus rejecting Medieval impetus, and the line of thought offered by Sagredo in the "Third Day" and then carried over into the "Fourth Day"
5. The status of this law is not entirely clear, for Descartes begins by saying that it is a consequence of God's immutability, but then offers no derivation
   a. Spinoza offers a derivation in his *Principles of the Philosophy of Descartes* (II, xiv), but I still do not see why it follows on Spinoza's account
   b. Descartes' appeal is to metaphysics, with empirical considerations to remove objections
   c. Thus the law is best viewed as a proposed way of conceptualizing motion, built off a meta-physical claim

C. The Second Law of Motion: Circular Motion

1. "Each part of matter, considered individually, tends to continue its movement only along straight lines, and never along curved ones" (39)

   Le Monde: "When a body is moving, even if its motion most often takes place along a curved line and can never take place along any line that is not in some way circular, nevertheless each of its individual parts tends always to continue its motion along a straight line. And thus their action, i.e., the inclination they have to move, is different from their motion." (p. 71)

   a. In the margin statement of the law, he says that bodies moving "in a circle always tend to move away from the center of the circle"
   b. A source of subsequent confusion: are they trying to recede from the center?
2. This law complements the first one by specifying what a state of motion is
   a. Change of direction is a change of state, warranting a why-question
   b. No mention of no change of speed, but can take this for granted from the context
3. First argument for the law appeals to the immutability and simplicity of God

a. God maintains all things, and hence maintains the direction of motion at an instant, which is rectilinear motion

b. I find this argument question-begging, for why not curvilinear directions?

4. Second, empirical, argument is tantamount to a response to this complaint: as a matter of empirical fact, rectilinear

a. Sling argument, with two claims: stone does not stay on circle, but tends (more) in direction of tangent; and can feel the endeavor of the rock to pull away from our hand

b. This argument is also a little question-begging, though less so, for why can't the effects be attributed to encounters with other objects?

c. In short, law again a proposed way of conceptualizing motion

5. Descartes' analysis of circular motion, as in the sling, is of critical importance since it undercuts the "naturalness" of circular motion proposed by Copernicus, Galileo, and even Kepler

a. The tendency is to go off along a tangent

b. Insertion in the French edition speaks of an "attempt to pull" that anticipates Huygens' centri-fugal force

6. Descartes himself calls attention to the importance of the analysis of curvilinear motion

"This consideration is of such importance, and will be so frequently used in what follows, that it must be very carefully noticed here"

a. It sets the question for planetary astronomy: why curvilinear at all

b. In contrast to, why some curvilinear path other than a circle

D. Comments on the Principle of “Inertia”

1. The first two laws together are often said to be the first statement of the principle of inertia -- i.e. of Newton's first law

a. An anachronistic claim in some ways, for Descartes expressly rejected Kepler's concept of inertia (tendency to laziness), and Newton doesn't use the term in his statement of the law

b. The proper claim, then, is more along the lines that Descartes is here capturing the essence of what became known as “the principle of inertia” in the 18th century

2. This essence consists of two distinct parts, one concerning no need for action to continue motion, and the other concerning the specific form of motion that will continue

a. I.e. contrary to Aristotle, there is no need to invoke a cause to explain why motion continues, but only to explain why motion changes, for motion a state, and only have to explain changes of state; and uniform circular motion requires external cause and hence is not in and of itself eternal

b. Thus, for example, Kepler's appeal to the Sun's driving the planets in continued motion is being rejected here

c. I.e. a state of motion consists of a rectilinear direction and a speed

3. Where this principle was first enunciated is a subject of some controversy and confusion

a. *Le Monde*, except that it was not published, and Descartes appears not to have circulated it even within Mersenne's narrow circle

b. Galileo intimates the principle in some of his replies to arguments against the earth's motion in the *Dialogue*, and he offers what seems in retrospect to be an explicit version of it for horizontal motion in *Two New Sciences*; but he also seems to commit himself to a principle of continuing circular motion in the *Dialogue*

c. Gassendi announces the principle in published letter in 1641 (*De Motu impresso a motore translato*), in which he offers various experimental results bearing on Galilean claims (including objects falling from masts and circular arc versus inclined plane times)

> "All that has no other aim than to make us understand that motion impressed [on a body] through void space where nothing either attracts or resists will be uniform, and perpetual; ... so that in whatever direction you throw a stone, if you suppose that, at the moment in which it leaves the hand, by divine power, everything besides this stone is reduced to nothing, it would result that the stone will continue its motion perpetually and in the same direction in which the hand has directed it" (translation from Franklin)

(1) A generalization of Galileo: uniform straight-line motion everywhere, not just on the horizontal

(2) Underlying rationale: nothing would disturb the motion of Gassendi's corpuscles (i.e. atoms) unless they were to contact some other corpuscles, and his corpuscles were moving in all directions

d. But elsewhere in the same work (see Appendix) Gassendi speaks of the perpetual continuation of uniform circular motion, seemingly missing the implication of inertia that Descartes stresses

e. *Principia Philosophiae*: the most influential statement of the principle prior to Huygens's *Horologium Oscillatorium* (1673), if not to Newton's *Principia*

4. Gassendi's *De Motu impresso a motore translato* was important for other reasons as well

a. The principle we call Galileo's principle of relativity -- the motion of objects within the hull of a boat is the same whether the boat is stationary or moving forward uniformly -- was put forward in replying to anti-Copernican arguments in the *Dialogue*

b. Gassendi announced in the letter that he had carried out experiments confirming it, such as dropping an object from the top of a mast with a boat moving and not moving

5. This is a ninth Galilean principle to be added to the eight from *Two New Sciences* of the last class

6. Gassendi, it should be noted, was far more skeptical than Descartes about our capacity to establish conclusions about unseen processes, mechanisms, and entities

a. He viewed his corpuscularеanism as forever merely a hypothesis that could never achieve the same status as an observed matter of fact

b. That view carried over in Locke's writings through Charlton and Boyle, both of whom were very much followers of Gassendi, though Boyle was no less influenced by Bacon