b. Rather, for him they represent two different ways of trying to make sense of the world

c. An important dimension of this course is to stay on the lookout for any subsequent developments that provide evidence for the principle of inertia

F. The Third Law of Motion

1. The statement of the law in *Principia* expands on that in *Le Monde*

"When a body meets another, if it has less force (*vim*) to continue to move in a straight line than the other has to resist it, it is turned aside in another direction, retaining its quantity of motion and changing only the direction of that motion. If, however, it has more force; [sic] it moves the other body with it, and loses as much of its motion as it gives to that other" (40)

Le Monde: When one of these bodies pushes another, it cannot give the other any motion except by losing as much of its own at the same time; nor can it take away from the other body's motion unless its own is increased by as much" (p. 65)

2. Notice what the problem is: how is total motion maintained when local motion changes ("*ubi corpus quod movetur alteri occurrit*")

a. Answer: it depends on, and only on, the local situation

b. Case 1: perfectly elastic reflection, with no change of either B∗v; in this case the moving body never becomes one at rest (see Spinoza, for example in the Appendix)

c. Case 2: a transfer of motion, with B∗v changing in both

3. "Proof" of the first part: change in determination or direction alone does not produce a change in the motion of the body

a. Only changes in local motion have to be explained in order to explain how motion globally preserved

b. If local motion diminished, a compensating increase would have to show up somewhere else, which it doesn't

c. "Proof" here ignores question why both bodies don't change

4. "Proof" of the second part "theological": God maintains in the same way that he created motion, namely by causing "some of the parts to push others and to transfer their motion to these others" (42)

a. Hence follows from immutability of God

b. "Proof" here ignores question why some third body doesn't change, via action at a distance

5. Again notice that Descartes is offering us a way of conceptualizing change of motion, but now with an additional conceptual element, force (*vis*)

a. Either motion is preserved or transferred, with total remaining the same

b. In former, encounter shows up via change in direction, yielding answers to questions arising out of Law II

c. In latter, encounter shows up via transfer of motion from one to the other, yielding answers in response to other questions about change of state of motion

6. Empirical considerations are invoked in the discussion, but only to legitimate talk of unseen forces
    a. Law is not subject to empirical test as such, because it invokes unseen forces observable only through the consequences attributable to them by this law
    b. Hence, taken by itself, with no independent way of determining forces, a way of conceptualizing, and not any sort of empirical generalization

G. The Concept of a Law of Nature
1. Laws of nature a notion from Renaissance naturalism that makes its way into modern science primarily through Descartes' use of 'law' ('*lex*') here
    a. We did not see this term emphasized in Galileo or Kepler
    b. Newton almost certainly adopted it because of Descartes, whether directly or indirectly
    c. Then the term gained its general use in science from Newton's use
2. One feature of the Cartesian concept of a law: so-called natural necessity, supporting counterfactuals, for only God could alter
    a. I.e. "lawlike" in Goodman's sense
    b. This thread runs through all the uses of the term in modern science, and not just the narrower uses more typical of Descartes and Newton
3. Another feature of the Cartesian concept: laws hold universally of all matter, and have a certain bedrock character in the sense that all explanation of change of motion stops with them
    a. All matter conforms to these three laws at all times
    b. There is no possibility of deriving these three from more basic physical principles
    c. Contrast this with Galileo's derivation of the "law" of projectile motion, which explains this "law" by reducing it to more fundamental principles
    d. Explanation stops with these laws in the sense that the only proper sort of answer to the question why matter conforms to them is that this is the way God chose to create the world -- i.e. this is the way God legislated (the tie to Renaissance naturalism)
4. No such bedrock principles in Kepler or Galileo
    a. Galileo's basic claims -- e.g. uniform vertical acceleration near the surface of the earth -- were not put forward as applying to all matter at all times
    b. Nothing akin to these principles in Kepler at all, whose account of planetary motion does not invoke axioms of motion
    c. Descartes is the first place we have seen where the reasoning starts from such fundamental, universal principles
5. A natural question: why is this the first place we are seeing it; answer: Descartes is engaged in a different project from Kepler and Galileo
    a. Notice the title of Part II: "Of the Principles of Material Objects"
    b. Descartes laying out basic rules for all physical explanation, replacing Aristotle's four "causes,"

that is, his four different kinds of answers to “why” questions

6. The bedrock character of the laws raises a special problem that we have been noting in passing: how can one effectively test claims of this much generality
    a. Conceptualization: where explanation stops with brute descriptive fact -- i.e. with a way of describing what is happening
    b. How does one discover empirically where this is, for must describe e.g. motion before adducing any empirical considerations

V. Descartes' Rules of Perfectly Elastic Impact

A. Change of Motion and the Concept of Force

1. Descartes' rules of impact are standardly dismissed as crazy (as evidenced by the Millers' footnotes); still, however infamous they may be, they are historically important
    a. Even Descartes' defenders acknowledge how difficult the arguments for the rules are to follow, and they typically point out that the rules were added to the Latin edition at the last moment, then amplified in sometimes clumsy ways in the French
    b. I occasionally think of the criticism of Descartes here by historians and philosophers who should know better as a case of lesser minds taking comfort from others' mistakes
    c. It is not just that Descartes did not have the luxury of looking the correct answers up in a textbook, as the Millers can
    d. More, it is a matter of Descartes doing something different, which others have not elected to follow him on
2. The problem Descartes addresses is how to determine the force of resistance to motion which, once known, would allow change of motion to be determined via the rules

    In order to determine, from the preceding laws, how individual bodies increase or decrease their movements or turn aside in different directions because of encounters with other bodies; it is only necessary to calculate how much force (*virium*) to move or to resist movement there is in each body; and to accept as a certainty that the one which is stronger will always produce its effect.... This could easily be calculated if only two bodies were to come in contact, and if they were perfectly solid..." (45)

    a. The laws of motion themselves do not determine the outcome, for there are an infinity of before-to-after solutions to the equation, $(B_1*v_1 + B_2*v_2)_{before} = (B_1*v_1 + B_2*v_2)_{after}$ -- one equation in two unknowns not sufficient
    b. Worse, nothing said in laws about which force is greater, the force impressed on a body by another, or the force to resist
3. Descartes' picture is that of a contest between two forces, one impressed and the other resisting, with the greater dominating
    a. The force of rest -- to resist change from rest to motion -- is taken quite differently from the force to resist a change of motion