3. The obvious difficulty with adopting this sort of approach at the outset is that it tends to undercut the very possibility of developing evidence for the theory through comparing precise measurements with precise predictions
    a. Of course, in Galileo's case could not easily make precise measurements at the time anyway, because of the time scale of the phenomena
    b. But even if he could, discrepancies between prediction and experiment would not as such have been grounds for falsification or revision
4. Kepler's situation, by contrast, is that he first develops an account, then finds small residual discrepancies, putting him into position to argue that various higher-order mechanisms are at work
    a. For Kepler the question of discrepancies between observation and theory is central to the entire evidence process!
    b. For Galileo, it cannot be once he stipulates that exact agreement with observation not the goal
5. The challenge of developing an idealized science of the sort Galileo is proposing, then, is to find other ways of bringing evidence to bear on the theory
    a. Ways that will allow distinctions to be drawn between errors in the theory and confounding effects from other mechanisms -- this is the key concern
    b. Challenge doubly difficult in Galileo's case since the observations themselves were often so difficult to make
6. And, of course, the danger lurking in the wings is a science that is immune not just to falsification, but to progressive refinement on the basis of empirical evidence
    a. A non-empirical, philosophical theory all over again, though mathematically motivated
    b. Ultimately justified on grounds of elegance etc.
7. The move to such an idealized theory made here by Galileo will not be the last time in the history of science that such a move is made; indeed Truesdell claimed it has been dominant in mechanics
    a. Whenever it is made, the evidence problem becomes complicated in special ways
    b. Want to look carefully this week and next at how Galileo and his contemporaries tried to deal with it and problems related to it

II. "The Third Day": Some Conceptual Obstacles

A. Galileo's Conceptualization of Motion

1. Galileo faced another difficulty that anyone must face at the beginning of a new science: no reason at all to think that the concepts and distinctions with which you initially describe the phenomena are effective, and not systematically misleading
    a. By 'concepts' here, I primarily mean sets of distinctions and the basis for making them -- e.g. his weight versus heaviness (see Drake glossary)
    b. He was acutely aware that Aristotle's concepts had proved an impediment -- e.g. lightness as a correlative property of heaviness -- and hence he had profound reason for concern

c. But on top of this, his situation one in which hard to bring empirical considerations to bear, and empirical considerations are the preferred basis for revising and refining concepts
d. I.e. prefer distinctions empirical world forces on us

2. The concepts and distinctions Galileo starts with are quite remote from ours; we might even say that he was thoroughly confused
   a. One of Kuhn's key points is the need to read works in history of science from the perspective of the conceptual schemes of the time rather than ours -- prerequisite for understanding
   b. This is the main problem in reading Galileo -- the way in which he conceptualizes motion is foreign to us
   c. We need to understand him first, so that we can later see how empirical considerations helped shape our way of conceptualizing motion out of his
3. Some of the conceptual differences are owing to his use of classical Euclidean and Eudoxean mathematics, where quantities are geometric magnitudes, not numbers
   a. Everything stated as proportions within the theory of ratios, with no fractions, divisions of unlike quantities, etc., so that cannot even talk of velocity as distance per unit time
   b. Galileo chose not to use the rapidly growing body of algebraic methods, and of course had no calculus to use; stayed mostly within Euclidean strictures
   c. Geometric quantities do offer one advantage over numerical ones: exact in spite of "incommensurabilities," as illustrated by mean and third proportions (see Appendix)
4. But, over and above this, some of his key physical concepts -- most notably that of speed or velocity (*velocitas*) -- are very different from ours
   a. Speed a scalar "intensive" property of bodies in motion, akin to heaviness -- something that a moving body possesses to greater and lesser degrees
   b. In other words, speed and direction are two separate, independent quantities
   c. Uniform motion defined not in terms of speed, but in terms of equal distances being traversed in equal times [191]
   d. Axioms III and IV, which (like Axioms I and II) express qualitative comparative relations, relate speed to spaces traversed in equal times, leading to Propositions I-VI spelling out the specific quantitative relations among speed, distance, and time
   e. No quantity like our acceleration, with its units of length per unit time per unit time
5. Other physical concepts that are radically different from ours include his impetus and momenta, the coincidence of the words and some resemblance to our concepts notwithstanding
   a. E.g. impetus or momentum (*momenta*) for him an intensive property of a moveable that correlates with its effects on impact, but also a property that correlates with the effects of a downward weight on a lever arm, as in already well-developed "mechanics" of equilibrium and devices that overcome it

b. See Drake's Glossary, but always be cautious in taking Galilean concepts to be ours, for more often than you would think, they are not – especially so with '*momenta*'

c. For thorough analysis, see Galluzzi's *Momento, Studi galileiani*

B. Abrupt Versus Continuous Change in Speed

1. With some concepts -- e.g. uniform acceleration -- Galileo shows concern over their appropriateness for describing nature

   ...so I may, without offence, doubt whether this definition, conceived and assumed in the abstract, is adapted to, suitable for, and verified in the kind of accelerated motion that heavy bodies in fact employ in falling naturally." [198]

   a. Definitions are arbitrary, but something more is demanded here

   b. In other words, Galileo was aware of role of empirical considerations in shaping concepts and distinctions

2. One concern: continuous increase in speed, passing through intermediate degrees, versus abrupt change to e.g. full speed

   a. Abrupt change in speed what we seem to see at moment when moveable impacts the ground, and have trouble seeing any gradual development of speed with naked eye

   b. So, why is concept of continuous change of speed apropos at all

3. Answer: compare the effects of impact -- e.g. the depth of impressions in soft soil -- from dropping the same object from different heights

   a. Greater effects from greater heights, but this because of greater speeds (since effects from speed when weight the same)

   b. But continuous gradation of effects of impact, depending on height from which object dropped

   c. Hence continuous range of speeds, from very small to great, related to distance of fall

4. Galileo here adopting "percussive force" -- i.e. "quality and quantity of impact" -- as an indicator of speed [199]

   a. In fact the percussive effects on impact are a function of speed squared, not speed, as he might have realized from their correlation with height of fall

   b. But his argument still goes through for concluding that speeds in fall seem to admit of continuous degrees

5. Note also, in passing, how Galileo dispenses with Zeno-like arguments against having to pass through an infinity of different degrees of speed to reach given speed [200f]

   "This would be so, Simplicio, if the moveable were to hold itself for any time in each degree; but it merely passes there, without remaining beyond an instant"

6. Key point though is that he invokes empirical phenomena to show that concept of continuously increasing speed is "suitable" to the task at hand