c. Only thing missing is Huygens's refinement for the center of oscillation for the circular pendulum, removing an element of idealization

5. This absence makes the third option above more credible because of the emphasis Newton was always inclined to place on virtually exact agreement between experiment and theory
   a. Did not have the sort of cavalier attitude about the limits of experimental precision displayed by Galileo, Descartes, and Mersenne
   b. Hence he was always looking to achieve high quality evidence through precise measurement
6. We can thus have reason to think that Newton fully appreciated the conception of empirical evidence implicit in Huygens's work after reading the *Horologium Oscillatorium*
   a. Newton could have used this conception as a point of departure when he began developing a still more sophisticated conception while fashioning the *Principia*
   b. And this would explain his seeming expectation that Huygens would appreciate the full thrust of the evidential argument in the *Principia*
7. Nonetheless, the parallels and overlaps between Huygens and early Newton notwithstanding, it is important to see that Newton was not embarked on a project of developing a full mechanics before 1684 in the way Huygens was
   a. Newton was working on isolated problems, generally in response to Descartes and with an eye toward developing a compelling argument for Copernicanism -- to complete the work of Galileo's *Dialogue*
   b. Huygens, by contrast, showed no interest in arguing for Copernicanism at the time; he was developing a general mechanics, extending the work of Galileo's *Two New Sciences*
   c. The question, What started Newton into developing a general mechanics?, will be answered in the next two classes

V. Newton's Fragment on Hydrostatics (vs. Descartes)

A. Background: the Anti-Cartesian Introduction

1. The fragment, "De Gravitatione et Aequipondio Fluidorum," is presumably an introduction to a book on hydrostatics which stops abruptly after making just a few claims about pressure in liquids
   a. 35 pages long (in Hall and Hall, 40 handwritten), the last 4 of which deal with deforming fluids, and the first 31 of which comprise an anti-Cartesian introduction to the rest in which Newton is endeavoring "to dispose of his [Descartes'] imaginings" -- "figmenta"
   b. Date uncertain, though thought for a long time to be around the same time as the "Lawes" if only because it too is clearly a response to having read Descartes' *Principia* and much of the physics in it seems far removed from that of Newton's *Principia*
   c. But Betty Jo Dobbs put forward an argument that it dates from the early 1680's -- probably 1684 -- and as such represents Newton's final break with Descartes; from manuscript evidence Rob DiSalle and I have now concluded that it does not date from 1685

d. Howard Stein regards it as the fundamental expression of Newton's metaphysics, as underlying the *Principia*, and hence as perhaps contemporaneous to the latter, and I have emphasized that it uses the word *inertia* just as Newton first started using it (and *massa*) in late 1685
e. I am going to treat it as an amalgam, the (unusually clean) manuscript dating from 1684, but with critical thoughts about Descartes dating from late 1660s and early 1670s

2. Herivel's excerpts have dropped a good deal of further anti-Cartesian material, including philosophical discussions of God in relation to physics and discussions of substance and accident; the best full translation is in Janiak's volume, though it too misleadingly translates *moles* as "mass"
3. Herivel's excerpts have also dropped claims about the isotropy of pressure in fluids and the consequent equilibrium of fluids
   a. Claims mathematically proven in the Greek style
   b. With an apology for accommodating "these definitions not to physical things, but to mathematical reasoning, after the manner of Geometers"
4. Given the abrupt ending of the fragment, it is not especially clear what Newton was intending to do, nor what, if any, obstacles prevented him from fulfilling his aims
   a. Pressures in fluids a central concern in Descartes' vortex theory, even though Descartes himself offers no detailed account of pressure, but relies on physical intuition
   b. So perhaps Newton saw himself as providing background physics that would then have telling implications -- either for or against -- the vortex theory
   c. Or this may be an immediate forerunner of those parts of Book II of the *Principia* where Newton develops a systematic argument against the Cartesian vortex theory -- a theory he himself had held through much of the 1670's
5. Our interests in the fragment are primarily with his concepts of motion and force
   a. Want to emphasize the dominant influence of Descartes even when he is being thoroughly anti-Cartesian in his explicit remarks
   b. Spirit of undertaking, as with "Lawes of Motion," one of giving a correct account of a phenomenon Descartes called attention to, for much the reasons that Descartes called attention to it, while rejecting Descartes' account
   c. I am not going to put much weight on the "metaphysics" in it, as several philosophers commenting on Newton have, if only because the dating is too uncertain

B. Newton's Early Views on Space and Motion

1. In contrast to Descartes' account of space in terms of the relative positions of bodies, Newton invokes absolute space, a receptacle parts of which physical bodies fill
   a. The idea of space as a receptacle dates back at least to Plato's *Timaeus*
   b. Space and extension neither substance nor accident, but having a mode of existence all to itself

2. Absolute rest and absolute motion occur within absolute space, for motion is defined to be change from one absolute place to another
    a. In principle (though not necessarily in practice) determinate whether a body is in rest or motion
    b. Motion itself also in principle determinate -- both speed and direction
    c. (Unclear whether Newton thought Descartes denied these claims, given his rules of impact, though perfectly clear that Descartes denies the existence of absolute space as a receptacle)
3. The arguments that Newton offers against Cartesian claims about space and motion being relative are of reductio form; they aim to show that Descartes himself was committed to absolute motion and hence to absolute space
    a. In particular, properties of vortices that are indispensable to Descartes' planetary theory require determinate circular motion insofar as whether an object has a certain centrifugal conatus must have a single determinate answer!
    b. More generally, all talk of motion presupposes such determinate answers to questions about direction and magnitude
4. Newton thus effecting a reform of Descartes' way of conceptualizing space and motion that will allow such things as the principle of inertia and centrifugal conatus in a vortex to remain meaningful
    a. Newton not abandoning Descartes' emphasis on the principle of inertia and its consequent implications for curvilinear motion
    b. Rather, he is doing what he thinks must be done in order to preserve the Cartesian insights he takes to be crucial
    c. (The appeal to curvilinear motion as a basis for distinguishing between absolute and relative motion will show up at the beginning of the *Principia*)
5. Newton uses his conclusions about absolute motion, however, to draw conclusions about absolute space as a receptacle that then permit him to defend the atomistic school of mechanical philosophy
    a. E.g. Descartes' principal argument against vacuums entirely undercut, for what can exist between two bodies can be empty space, even though empty space is not a substance
    b. No need then for plenism, and therefore no obstacle to adopting an atomistic view, yet still incorporating Descartes' key insights about inertia and curvilinear motion
    c. And no need to deny bodies essential properties beyond extension

C. Newton's Early Conception of Forces
1. The conceptualization of force in this fragment is closely akin to Descartes' and far removed from that of Newtonian mechanics, though not so far removed from that of Newton's *Principia*
2. Two kinds of force (*vis*): external force changing motion, and internal force conserving motion and opposing impediments to motion
    a. External, impressed force either creates or destroys motion, and hence supplies answers to questions about changes in motion

b. Internal force supplies answers to questions about why motion continues unless impeded
c. *Inertia* is expressly identified with this internal force

3. *Conatus* -- endeavor or tendency -- is an impeded force, or a force insofar as it is resisted
   a. Pressure is a conatus, for it is a force that would disappear if the fluid could pass through the boundaries on which the pressure is exerted
   b. Centrifugal conatus a real property of bodies arising from the resistance of the internal force of the body
4. Gravity is an intrinsic force imparted to a body to descend, not just to the center of the earth, but generally -- suggesting that centrifugal *conatus* imparted by curvilinear motion is somehow a species of gravity
5. Two measures of force -- intensity and extension -- with the absolute measure the product of these two; intensity a measure of power, extension in terms of quantity of space and time
   a. E.g. absolute quantity of motion (and hence force) compounded from magnitude of the body (intensity) and velocity (extension)
   b. Absolute quantity of force in the case of pressure compounded from the intensity of the pressure and the quantity of the surface pressed

D. Newton's Orientation: Copernican Concerns

1. Given the animus with which Newton attacks Descartes' solution to the problem of reconciling Copernicanism with the Church's views, reasonable to suggest that what is driving Newton here is at least in part his desire to establish Copernicanism
   a. Newton a rabid anti-Catholic (typical of Puritans)
   b. Was clearly displeased with Descartes' suggesting that the earth is not really in motion merely because it is exhibiting no relative motion with respect to matter contiguous to it
2. Newton had read the English translation of Galileo's *Dialogue* at roughly the same time as he had read Descartes' *Principia*
   a. Had formed a goal of proving Copernicus correct somewhere around this time, a goal that remained with him thereafter
   b. Saw Descartes' treatment of space an impediment to doing so, Descartes' arguments against the Ptolemaic and Tychonic systems notwithstanding
3. At the very least, Newton saw a strict relativity of motion view as an impediment to showing that Copernicus is correct and Tycho is wrong, for not clear how to distinguish between the two if no determinate answer to the question whether the earth is moving
4. Perhaps Newton saw Descartes' concept of *conatus a centro* as the key to effecting a proof that the earth is undergoing curvilinear motion
   a. Could be a reason for developing an account of pressure in vortices that would enable him to show that the Earth is moving

b. E.g. by showing that Kepler's third law must hold, and that it cannot hold for the Moon and the Sun orbiting the Earth

5. This is speculation, but it is supported by a good deal of evidence from the 1660's that Newton wanted to settle the question of the motion of the earth after reading the *Dialogue*
   a. The important thing to notice is that Newton is not fashioning the account of space and force in this fragment in order to develop a general mechanics; indeed, no mention of centripetal force
   b. His interests, which seem far narrower, fit better with the view that Galileo provoked him, and he was now looking for a better argument than Galileo had managed to supply
   c. This would fit with the selectivity Newton shows over which features of Cartesian physics he is prepared not just to retain, but to build around, and which features he is prepared to discard and to rail against
6. When Newton finally finds a way of using centrifugal conatus to argue for the Copernican system and embarks on the *Principia*, he returned to his earlier objections to Descartes, but now formulating them in a philosophically more sophisticated way tied to it
   a. If so, then this is an important tract, just as Stein suggests, for it offers a philosophic response to Descartes' philosophic arguments
   b. Keep this tract in mind as we read the *Principia*

<u>Select Sources</u>

Westfall, Richard Samuel, *Never at Rest: A Biography of Isaac Newton*, Cambridge University Press, 1983.

--------, *Force in Newton's Physics: The Science of Dynamics in the Seventeenth Century*, Macdonald, 1971.

--------, "Newton and the Acceleration of Gravity," *Archive for History of Exact Sciences*, vol. 35, 1986, pp. 255-272.

Hall, A. Rupert, *Isaac Newton: Adventurer in Thought* (Oxford: Blackwell, 1992).

-------- (ed.), *Isaac Newton:Eighteenth-Century Perspectives*, Oxford University Press, 1999. (A collection of 18th century biographical remembrances and notes)

--------, *And All Was Light: An Introduction to Newton's Opticks*, Clarendon Press, 1993.

--------, *Philosophers at War: The Quarrel between Newton and Leibniz*, Cambridge University Press, 1980.

Cohen, I. Bernard, "Newton," *Dictionary of Scientific Biography*, vol. 10, Charles Scribner's and Sons, 1974, pp. 41-103.

Keynes, John Maynard, "Newton, the Man," in *Essays in Biography*, Norton, 1951, pp. 310-323.

Hall, A. Rupert and Hall, Marie Boas (eds.), *Unpublished Scientific Papers of Isaac Newton: A Selection from the Portsmouth Papers in the University Library, Cambridge* , Cambridge University Press, 1962.

Herivel, John, *The Background to Newton's* Principia: *A Study of Newton's Dynamical Researches in the Years 1664-84*, Oxford at the Clarendon Press, 1965.