Remote Learning Module for 22 April 2020

Lecture Notes for Fernando Espinoza's *The Nature of Science,* Chapter 7

— Galileo Galilei & Thomas Hobbes —

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Last time we continued our examination of what the Early Moderns called the "New Science" (*Scientia Nuova*) of Nature, first by a consideration of advances in Methodology, and then by a quick tour of how these advances played out in the history of astronomy. Today we'll look more deeply into the contributions of Galileo and Hobbes.

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— Galileo —

(1) Galileo Galilei was born in 1564, as was, according to tradition, William Shakespeare. He died, under house arrest (by the Roman Inquisition) in 1642—the same year Isaac Newton was born. Galileo was, perhaps, the single most powerful intellect driving the advent of modern science; his discoveries, as we noted last time, paved the way for the major advances in physics and philosophy that would bring Newton to view him as one of the Giants on whose shoulders Sir Isaac was able to stand. Galileo lived through one of the most tumultuous times in Western history. In order better to appreciate his contributions, let's take a quick tour of the events leading up to his formulation of the law of free fall that would become the centerpiece of Newton's vindication of Kepler's laws in his *Mathematical Principles of Natural Philosophy.*

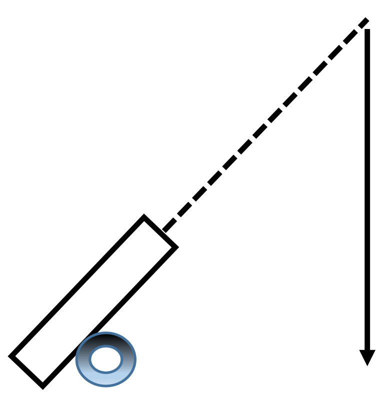
(2) In 1545, the year before Copernicus died (reading, we're told, on his deathbed, the galley proofs of his great work, *On the Revolution of the Heavenly Bodies*), Pope Paul III finally managed to bring together the Council of Trent, where the then leaders of the Roman Catholic Church gathered to formulate their response to Martin Luther's Protestant Reformation. You'll recall from our earlier discussions this semester that it took years for this Council to convene on account of the difficulties involved with calculating the coming of Easter (the first Sunday after the first Full Moon, after the Vernal Equinox), which difficulties were what brought the Pope to ask Copernicus to reform the Church liturgical calendar. It was this very effort at calendar reform that brought Copernicus to devise his new geometrical model of the Solar System (see yesterday's lecture material).

(3) Although it is often said that Luther's *Ninety-Five Theses* (against the practice of granting indulgences) spawned the Reformation, it's more likely that it was his translation of the Bible from Latin into German that actually fueled the progress of Protestant thought in the mid-16th century. It took him a long time: he began the translation in 1521; he did not complete it until 1534, after which over 100,000 copies were printed.

(4) One of the more significant products of the Council of Trent was the formation of the Jesuit Order (founded by Ignatius Loyola, and answering directly to the Pope), whose expressed purpose at this time was to effect what came to be called the Counter-Reformation. In pursuit of this goal, the Jesuits revised and standardized the curriculum of Roman Catholic higher education. Hitherto, a university education would have been a series of courses in the Liberal Arts (that is, the arts of free men, as over against the Servile Arts, or the arts of slaves). The Liberal Arts were broken down into two broad categories: the Trivium (logic, grammar, and rhetoric—what amounted to what we call General Education today), on the one hand, and, on the other hand, the Quadrivium (arithmetic, geometry, music and astronomy—the sciences of number). The Jesuits replaced all this with a curriculum of Classical Literature, Algebra, Cosmology, Geography, Scripture, and, if you can believe it, Manners. This curriculum was designed to produce a highly educated and fanatically faithful elite, dedicated to the project of returning all Christendom to the Catholic Church. Among the many elements of this project was the institution of the Holy Office of the Inquisition (the very Cardinals and Prelates who would one day condemn Galileo and sentence him live out his declining years under house arrest).

(5) Before Galileo ran afoul of the Roman Inquisition, however, he was undoubtedly the most celebrated physicist working in Europe (a time punctuated by several episodes of pandemic plague, by the way). Central to his new science of mechanics was his wholesale rejection of Aristotle's teleological account of motion. According to Aristotle (whose theories, you'll recall, held sway over the entire later Middle Ages and early Renaissance), there are two kinds of motion in the universe: Celestial Motion (perfectly circular and eternal), and Terrestrial Motion (perfectly rectilinear, but exhausted at rest). Now, the *natural* motion of a falling body was, on Aristotle's view, such that heavier objects would fall faster than lighter ones; only a *violent* motion might interfere with this pattern. By a violent motion Aristotle meant a force applied to a moving body so as to cause it to deviate from its natural path towards its natural place. Since heavy objects have their natural place at the surface of the Earth, they fall naturally there of their own accord: heavy objects, that is, have an inherent directionality.

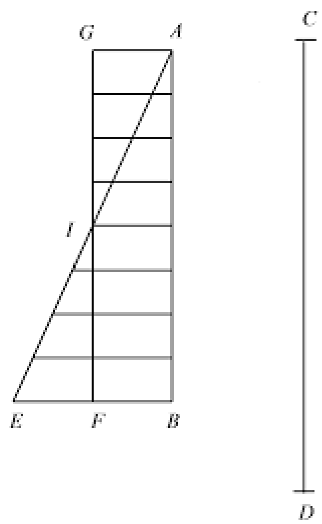
(6) Once gunpowder was introduced to Europe from China, thanks to the travels of Marco Polo, military engineers began building cannons, which brought them to wonder on how to account precisely for the phenomenon of ballistic motion, and to ask, in particular, why the natural motion of a projectile (remember: always in straight lines) appeared to the eye as a curvilinear trajectory. What must be happening, given Aristotle's account of motion, they thought, was a violent rectilinear motion upward at the angle set by a cannon, which sent cannon balls in motion until they used up their *impetus*, and fell straight to the ground.



In 1551, another Italian physicist, Niccolo Tartaglia, demonstrated empirically that a projectile hurled forth by a cannon elevated at 45˚ would achieve a maximum distance of flight. But it was Galileo who proved that the actual trajectory was parabolic, rather than a combination of one violent motion (the upward trajectory, driven by impetus) and a natural motion (the downward descent, after the impetus was exhausted, driven by the natural tendency of heavy objects to fall straight down).

(7) Galileo's proof involved three ingredients.

(a) *The Law of Free Fall*: During equal intervals of time, objects falling from rest traverse distances in proportion to the odd numbers; after successive intervals, objects falling from rest will have traversed distances in proportion to the square numbers. Today, we represent this law as: $S = \frac{1}{2}gt^2$. Here is how Galileo demonstrated his law geometrically:



1. A body falls from C to D
2. Line AB = the total time from C to D
3. BE = the body's greatest speed at reaching D
4. Each parallel line = the speed of the body at a point
5. The sum of all speeds = ABE (for the total distance C-D)
6. F = the midpoint of BE
7. The area of ABFG = the area of ABE
8. Therefore, the area of ABE (= the distance traversed for accelerated motion) = the distance traversed at fixed speed *if* that speed = ½ the maximum, BE.

(b) *The Law of Inertia*: objects moving in perfect rectilinear motion will continue indefinitely unless acted on by unbalanced forces.

(c) *The Principle of Relativity of Motion*: the measurement/perception of a moving body is relative to the motion of the measuring instrument or percipient

(8) Using his two laws and the principle of relativity of motion, Galileo was able to show that there were indeed two motions involved in the parabolic trajectory of ballistic objects, but that there were not Aristotelian natural and violent motions, having no intrinsic tendencies at all: one motion was the result of a linear inertial force (the upward trajectory) combined simultaneously with the quadratic force of gravity.

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— Thomas Hobbes —

(1) Thomas Hobbes was born in Westport, Wiltshire on the 5th of April in 1588—the year that the Spanish Armada floundered in a great storm off the coast of England. Born prematurely, he would later say that his mother "gave birth to twins: me and fear." He would go on to live long, however, dying at 91 years old. His father, Thomas, was a country vicar. Young Hobbes was educated at Oxford, with his earliest interests in classical literature. He became secretary to Francis Bacon in the early1620s, and then came to serve as a tutor to the Cavendish Family.

(2) In 1629, he took one of the Cavendish boys on a European tour, and while visiting Geneva, he happened to enter the library of a Swiss gentleman, where he noticed a copy of Euclid's *Elements*, laying on a table, opened to Book I, Proposition 47 (the Pythagorean Theorem). By his own account, upon reading the conclusion, he said, "Why this is impossible!" But after tracing Euclid's proof backwards, all the way to the opening definitions and postulates, he became "overwhelmed by the beauty of geometric demonstration."

(3) In 1634, Hobbes traveled to Italy where met with Galileo (who was then 70 years old), just two years after the Condemnation. Over the course of the next three years, he formulated the basic tenets of his philosophy. In 1640, the British Civil War broke out, whereupon Hobbes left England for the Continent where he joined the Royalist cause, and served as tutor to the young Prince of Wales (who would eventually become King Charles II in 1660). Hobbes returned to England in 1650. Shortly after the regicide of Charles I, when Oliver Cromwell took the reins of power in England as its Lord Protector. It was then that Hobbes published his masterwork, *Leviathan*, wherein he proposed to reinvent political science in the same manner as Galileo had reinvented the science of mechanics.

(4) In the *Leviathan*, Hobbes proposed to demonstrate that the dictates of reason *constrain* the Natural Rights of human beings (understood as freedom from contractual obligation) so as to form civil societies; political science is simply the study of how such societies come into being and are maintained. For Hobbes, the dictates of reason are first and foremost matters of means/ends analysis; they emerge from self-reflective goal orientation, and are made possible by language. In short, Hobbes endeavored to show that social contracts derive from reason, not authority (neither the authority of Aristotle nor the Church). We'll conclude our discussion today with a brief overview of Hobbes' project.

(5) The Argument. Hobbes met Galileo in 1634 (when the former was 46 and the latter 70); this meeting precipitated one of the more significant conceptual transfigurations in the history of Anglo-European thought: the reinvention of political philosophy as a species of empirical science.

(6) Galileo's Project. Under several metaphysical assumptions—collectively tantamount to materialism—Galileo endeavored to create a new science of physical motion.

(a) The local/practical object of this science (mechanics) is to assign precise mathematical meanings to the terms mass, force, resistance, velocity, acceleration, etc. so as to permit analysis of physical events under necessary laws.

(b) The global/epistemic object of mechanics is to derive from the representational system an experimental method whose deductive fertility is sufficiently rich so as to explain natural phenomena solely as necessary consequences of extrinsic relations among natural objects.

(c) The metaphysical payoff of the new mechanics is a rejection of intrinsic (teleological) causality along with an overcoming of the inclination to regard event-chains as arbitrary sequences of phenomena.

The centerpiece of the new mechanics is the principle of inertia.

(7) Hobbes's Project. Under several metaphysical assumptions—collectively tantamount to materialism—Hobbes endeavored to create a new science of political motion.

(a) The local/practical object of political science is to assign precise analytical meanings to the terms right, law, nature, contract, sovereign, etc. so as to permit analysis of political events under necessary laws.

(b) The global/epistemic object of political science is to derive from the representational system an empirical method whose deductive fertility is sufficiently rich so as to explain civil phenomena solely as necessary consequences of extrinsic relations among political beings.

(c) The metaphysical payoff of the new science is a rejection of psychological egoism along with an overcoming of the inclination to civil war.

The centerpiece of the new political mechanics is the principle of endeavor: the conatus.

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Next time, we'll turn our attention to the monumental figure of René Descartes. Be well everyone, and, although I imagine you are probably quite tired by now of my continuing to say so, do remember: social distancing continues to save lives, which is presumably why we are still not in JUB 202 presently.