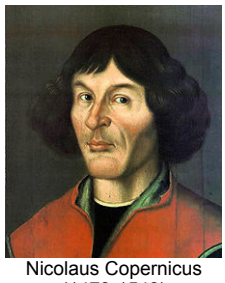
The Copernican and Cartesian Revolutions

Two Revolutions

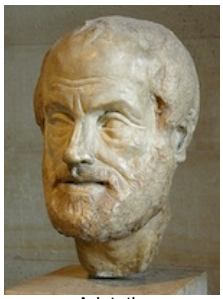

Claudius Ptolemy of Alexandria (c.90-c.168 CE)

Out of all this increased interest in nature and science, this preoccupation with investigation and mathematics and method, the fifteenth and early sixteenth centuries saw take shape a veritable new universe — that is, a very small number of enlightened minds saw it.


Nicolaus Copernicus (1473-1543) [Old City Hall, Torun (Poland)]

Two great revolutions in thought had occurred, and the course of intellectual history since that time is primarily the record of the gradual penetration into the beliefs of men of the significant consequences of those revolutions. The eighteenth century became the period of the "Enlightenment" because these consequences were spreading so rapidly amongst the middle classes; in the late nineteenth century science can almost be said to have struck the popular imagination, and there are few literate men alive in the West today who, even when they preserve habits of thought that descend from an earlier period, do not harbor side by side with these old ideas a belief in the new world of nature.

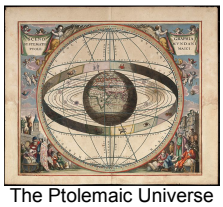
These two revolutions broke the bonds of the medieval world, of the neatly ordered hierarchy of beings all leading up to one supreme power, and made that bandbox affair forever impossible for the emancipated mind. Slowly but surely the various compromises that men effected to ease for themselves the shock of the plunge into the strange new universe have broken down, until today few who think are unaware of the far-reaching significance of the Copernican and Cartesian revolutions. The former seemed at first merely to overthrow the authority of Ptolemy; in reality it swept man out of his proud position as the central figure and end of the universe, and made him a tiny speck on a third-rate planet revolving about a tenth-rate sun drifting in an endless cosmic ocean. The absolute insignificance of man before the mighty and relentless will of Calvin's stern deity seems pomp and glory indeed compared with the place to which he has been relegated by modern astronomy.


Aristotle (384-322 BCE) [Musée du Louvre, Paris]

But following swiftly upon this discovery came the even more momentous Cartesian revolution, which made Aristotle's fate far [227] worse than Ptolemy's: while the latter had been refuted in his own field, the former was swept aside with all his works as quite irrelevant and unimportant. Purposes gave way to mathematics, human will and foresight to immutable and inflexible mechanical order. Throughout the whole vast windy stretches of infinity, in stone and plant and animal, nowhere in this universe was there another being like man, nowhere a being who felt and suffered, loved and feared and hoped, who thought and knew. Man was alone, quite alone, in a vast and complex cosmic machine. Gone were the angelic hosts, gone the devils and their pranks, gone the daily miracles of supernatural intervention, gone even was man's imploring cry of prayer. Somewhere, perhaps, in the distant regions whither the eye of man could not penetrate, somewhere beyond the possibility of attainment by human senses, there dwelt the Great Power that had made all this, a Power inflexible and unalterable by human wishes, yet perhaps a Power whose infinite wisdom had comprehended even lowly man in his great cosmic schemes.

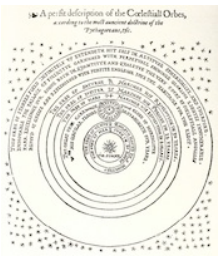

René Descartes (1596-1650) [Musée du Louvre, Paris]

The minds of men remained for two centuries firm in this faith; to give up, in spite of all the absence of any evidence of sense, this deep-felt hope that man was still cared for, that his good had a place in the heart of almighty power, that he was not alone, was more than the soul could bear. Of all that medieval world, one thing alone was left for those who entered whole-heartedly into this great cold universe — the



The Ptolemaic Universe
From: Andreas Cellarius, *Harmonia Macrocosmica* (1660)

faith in a Creator in whose image man was made, in a wise and loving Father who had built all this vast machinery for the good of man. Why he had wasted all this power on puny man was not for man to inquire; if his world lay open to the inquiring intellect, the meaning of his ways was past finding out. This last fond remnant of the Christian epic it was left for the nineteenth century, not indeed to refute, for faith can never be disproved, but to make, for many at least, irrelevant and unimportant. For them, man too became a mere part of this vast machine; its finest flower, perhaps — perhaps a cosmic accident and mistake. That eternal cry of the soul, "Why?" the answer came, *Ignoramus* — nay, *Ignorabimus*.[1]



The New Universe
From: Leonard Digges, *A Prognostication Everlasting* (1576) — a new edition, and with new materials prepared by his son, Thomas Digges (1546-1595)

— John Herman Randall, *The Making of the Modern Mind: a survey of the intellectual background of the present age* (Cambridge, MA: Houghton Mifflin Co., 1940), pp. 226-27.

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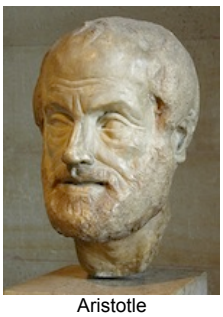
[1] Latin: "We do not know, and we will not know."

Changing Science: From Aristotle to Modernity

Rejection of Aristotelian Science

A major shift in the way science was pursued occurred in the 17th century. Prior to this time, science was "Aristotelian" in the sense that nature (the physical universe) was viewed as teleological and essentialistic.



Aristotle
(384-322 BCE)
[Musée du Louvre, Paris]

To see the natural world as *teleological* was to see all motion or change as goal-oriented, whether this motion was the growth of a plant, the rolling of a stone down a hill, the burning of a piece of wood, or any other change. Things fell not because of gravitational attraction, but because they were striving toward their proper place. An object pushed across a surface — say, a ball across a table — would slow down not because of friction, but because such motion was not natural to it. To view the world as essentialistic was to view each kind of thing (for instance, dogs, human beings, oak trees, stones) as possessing a certain nature or essence that determined its behavior (including, of course, the kind of motion natural to it).

Aristotle's *essentialism* focused on objects that are readily observable, and in this sense his science was highly empirical: if you couldn't see it, taste it, feel it, then it didn't exist. This might seem like a good approach for science to take but, as anyone who has explored the natural sciences will know, the world is rarely as it first appears. The building blocks of nature — whether they are atoms, electrons, waves, quarks, or superstrings — generally are not empirically observable. So while Aristotle's naive empiricism, along with his essentialistic and teleological view of nature, served the natural sciences quite well for a millennium or so, it eventually got muddled down with problems — and this was the state in which Descartes, Galileo, and a few other clear minds found the sciences of their own day in the 17th century.

The New Science

Galileo Galilei (1564-1642) embodied as well as anyone the spirit of the age. His *Dialogue Concerning the Two Chief World Systems* (1632) defended Copernicus's heliocentrism by arguing against the dominant Aristotelian geocentric cosmology. For this he was summoned before the Papal Inquisition at Rome, and on June 22, 1633, was forced to recant his belief that the earth moves (after which he is said to have muttered under his breath: *"Eppur si muove"* — "But it does move"), and was

Galileo Galilei
(1564-1642)

[Musée du Louvre, Paris]

placed for the remainder of his years under house arrest. He is sometimes credited with having invented the telescope, but in fact crude versions were already being manufactured in Holland before Galileo. His achievement, rather, was to improve this instrument (his first telescope — Galileo used the word *perpicillum* — magnified only about 3x, but within a few months he had managed to create a 20x scope) and to use it to study the heavens, whereupon he discovered that the moon has mountains and craters, that the sun has spots, and that Jupiter has moons (none of which is consistent with Aristotelian cosmology). This was in the fall of 1609, and he quickly published his findings in a short work called the *Sidereus Nuncius* or *Starry Messenger* in March 1610, which made him instantly famous. But Galileo's most important contribution wasn't his telescopic observation so much as his emphasis on a mathematical understanding of the world, and his claim that initial observations rarely reveal to us the true nature of things.

Two characteristics of modern science as it was being developed in the 17th century set it apart from the way science had been done in the past: it was based on *experimentation* and it was *mathematical*. The external world of tables and chairs is now something whose true description consists of mathematical formulas. If it can't be captured with numbers, then it doesn't really exist, or at least cannot be the object of science. "The book of nature," claimed Galileo, "is written in the language of mathematics."

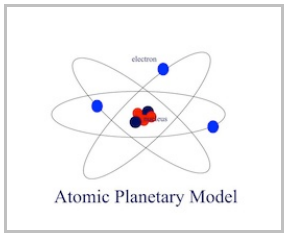
René Descartes (1596-1650) expressed this same understanding of science at the end of his *Second Meditation*, when he claims that our knowledge of bodies comes through the intellect (using mathematics) rather than through the senses:

René Descartes
(1596-1650)
[Musée du Louvre, Paris]

> I know that bodies are not, properly speaking, perceived by the senses or by the faculty of imagination, but only by the intellect, and … I know that they are not perceived by being touched or seen, but only insofar as they are expressly understood.

This amounted to an explicit rejection of Aristotelian teleology and essentialism: the essence of a thing cannot be described mathematically, nor can its purpose or end. What can be reduced to numbers is the size and shape of a thing, and whether it is in motion or at rest. This motion, furthermore, was to be explained in terms of mechanical forces, all of which are quantifiable, and thus amenable to the language of mathematics. Descartes believed that all of Aristotle's talk of formal qualities (being a dog, being furry, being brown) is reducible to these so-called "primary qualities" of size, shape, and motion/rest. Even the four basic qualities of the Ancients (hot, cold, dry, wet) "can be explained without the need of supposing for that purpose anything in their matter other than the motion, size, shape, and arrangement of its parts" (*The World*, ch. 5). Descartes was fully aware of the revolution he was pulling off in his *Meditations on First Philosophy*; in a letter to his friend Marin Mersenne (January 18, 1641) he wrote:

> I may tell you, between ourselves, that these six meditations contain all the foundations of my physics. But please do not tell people, for that might make it harder for supporters of Aristotle to approve of them. I hope that readers will gradually get used to my principles, and recognise their truth, before they notice that they destroy Aristotle's principles.



Atomic Planetary Model

If only to make the world seem even stranger, the basic stuff of this world no longer consists of dogs, human beings, or oak trees, but rather of *atoms* (or *corpuscles*, as they were called by Descartes) — tiny solid objects (invisible to the unaided eye because of their small size), with a definite size and shape. It is the size and shape of these atoms that give them their other properties — for instance, vinegar tastes sour because the "vinegar atoms" have little hooks that prick the tongue. The unobservable features and behavior of the atoms explained the observable characteristics of the larger objects they composed.

The early 20th century saw the rise of a new model of atoms that understand them as consisting of a dense nucleus orbited by electrons, somewhat like the planets of our solar system orbit the sun. The implications of this model are rather startling. For instance, the chair we are sitting on and the floor on which we stand, while they appear to be quite solid, are in fact mostly empty space, the distance lying between the nuclei and their electrons being quite immense. The chair and floor do not appear to be 99% emptiness, but that is what they indeed are, according to the new

Joseph Wright, "An Experiment on a Bird in the Air Pump" (1768), oil on canvas
[National Gallery, London]

science. (This account of physical objects is already out-dated; a more up-to-date scientific account is even more difficult to associate with our normal, non-mathematical experience of "the world.")

The new scientists also came to appreciate the importance of *experimentation*, of testing their hypotheses against the sense-data of experience. The natural world was the object of study, and so it was similarly the final judge as to the truth of scientific claims. If hypotheses are routinely checked against the data of the senses, foolish assertions such as we occasionally find in Aristotle (for example, that men have more teeth than women, or that bees emerge spontaneously from manure) will always be short-lived and quickly disproved. Aristotle was an acute observer of nature, but he often relied on written authority and hearsay, and failed to check this hearsay against nature itself.

Galileo's Telescope

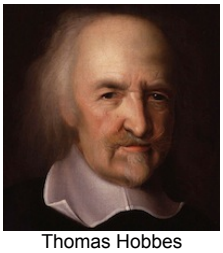

Galileo's Telescope

In 1609 the telescope was a new instrument, though it is not clear just how new it was. Galileo heard that some Dutch lens grinder had combined two lenses in a way that magnified distant objects; he tried various combinations himself and quickly produced a low-power telescope of his own. Then he did something which, apparently, no one had done before; he directed his glass to the heavens, and the result was astounding. Every observation disclosed new and unsuspected objects in the sky. Even when the telescope was directed to familiar celestial objects, the sun, moon, and planets, remarkable new aspects of these old friends were discovered. Galileo, who had been a Copernican for some years before he knew of the telescope, managed to turn each new discovery into an argument for Copernicanism.

The telescope's first disclosure was the new worlds in the firmament about which Donne, only two years later complained. Wherever he turned his glass, Galileo found new stars. The population of the most crowded constellations increased. The Milky Way, which to the naked eye is just a pale glow in the sky (it had frequently been explained as a sublunary phenomenon, like comets, or as a reflection of diffused light from the sun and moon) was now discovered to be a gigantic collection of stars, too dim and too little separated to be resolved by the naked eye. Overnight the heavens were crowded by countless new residents. The vast expansion of the universe, perhaps its infinitude, postulated by some of the Copernicans, seemed suddenly less unreasonable. Bruno's mystical vision of a universe whose infinite extent and population proclaimed the infinite procreativeness of the Deity was very nearly transformed into a sense datum.

— Thomas Kuhn, *The Copernican Revolution* (Cambridge: Harvard University Press, 1957), p. 220.

Hobbes's Mechanical World, Atomistic Self, Artificial State


Thomas Hobbes
(1588-1679)
c.1669-70, oil on canvas
[National Portrait Gallery, London]

Thomas Hobbes (1588-1679), a contemporary of René Descartes and one of the fathers of modern philosophy in England, viewed the universe as a huge mechanical system made up of bits of matter called atoms; and human beings were machines within this mechanical system, and viewed collectively were themselves like isolated atoms; and the civil state was an artificial machine, constructed of these individual human beings:

> Nature (the Art whereby God hath made and governs the World) is by the *art* of man, as in many other things, so in this also imitated, that it can make an artificial animal. For seeing life is but a motion of limbs, the beginning whereof is in some principal part within; why may we not say that all *automata* (engines that move themselves by springs and wheels as does a watch) have an artificial life? For what is the *heart*, but a *spring*; and the *nerves*, but so many *strings*; and the *joints*, but so many *wheels*, giving motion to the whole Body, such as was intended by the Artificer? *Art* goes further, imitating that rational and most excellent work of nature, *man*. For by art is created that great LEVIATHAN, called a COMMONWEALTH or STATE (in Latin CIVITAS) which is but an Artificial Man; though of greater stature and strength than the Natural, for whose protection and defense it was intended.

[*Leviathan*, Introduction]

A human society, for Hobbes, is a set of individuals who come and stay together purely out of self-interest, agreeing to limit certain of their freedoms in order to increase their security, and thus their overall well-being. In Hobbes's mechanistic world, we possess no natural sympathies for one another. We are, by our very nature, radically selfish, concerned only with our own preservation; and thus our natural state is one of constant war, each against all, until we agree to leave that rough state and construct out of ourselves an artificial machine — the Civil State — built from a set of contractual agreements through which we forfeit certain of our liberties.

In this Hobbesian world, individuals are primary, and society exists only insofar as the individuals decide to form themselves into such. The human being existing outside of society — an oxymoron for the Greeks — became paradigmatic for these moderns.

Hobbes describes the transition from the State of Nature to the Civil State:

> Hereby it is manifest that during the time men live without a common power to keep them all in awe, they are in that condition which is called war; and such a war as is of every man against every man. For WAR consists not in battle only, or the act of fighting, but in a tract of time, wherein the will to contend by battle is sufficiently known: and therefore the notion of *time* is to be considered in the nature of war, as it is in the nature of weather. For as the nature of foul weather lies not in a shower or two of rain, but in an inclination thereto of many days together: so the nature of war consists not in actual fighting, but in the known disposition thereto during all the time there is no assurance to the contrary. All other time is PEACE.
>
> Whatsoever therefore is consequent to a time of war, where every man is enemy to every man, the same consequent to the time wherein men live without other security than what their own strength and their own invention shall furnish them withal. In such condition there is no place for industry, because the fruit thereof is uncertain: and consequently no culture of the earth; no navigation, nor use of the commodities that may be imported by sea; no commodious building; no instruments of moving and removing such things as require much force; no knowledge of the face of the earth; no account of time; no arts; no letters; no society; and which is worst of all, continual fear, and danger of violent death; and the life of man, solitary, poor, nasty, brutish, and short. [Part One, Ch. 13, §§8-9]

Leaving this wretched *state of nature* required transferring most of our powers to a central authority, a sovereign king or parliament denoted by Hobbes as "Leviathan":

Frontispiece to Hobbes' *Leviathan* (1651)

> The only way to erect such a common power, as may be able to defend them from the invasion of foreigners, and the injuries of one another, and thereby to secure them in such sort as that by their own industry and by the fruits of the earth they may nourish themselves and live contentedly, is to confer all their power and strength upon one man, or upon one assembly of men, that may reduce all their wills, by plurality of voices, unto one will: which is as much as to say, to appoint one man, or assembly of men, to bear their person; and every one to own and acknowledge himself to be author of whatsoever he that so bears their person shall act, or cause to be acted, in those things which concern the common peace and safety; and therein to submit their wills, every one to his will, and their judgements to his judgement. This is more than consent, or concord; it is a real unity of them all in one and the same person, made by covenant of every man with every man, in such manner as if every man should say to every man: I authorise and give up my right of governing myself to this man, or to this assembly of men, on this condition; that thou give up, thy right to him, and authorise all his actions in like manner. This done, the multitude so united in one person is called a COMMONWEALTH; in Latin, CIVITAS. This is the generation of that great LEVIATHAN, or rather, to speak more reverently, of that mortal god to which we owe, under the immortal God, our peace and defence. For by this authority, given him by every particular man in the Commonwealth, he hath the use of so much power and strength conferred on him that, by terror thereof, he is enabled to form the wills of them all, to peace at home, and mutual aid against their enemies abroad. And in him consists the essence of the Commonwealth....