COSMOLOGY without HEADACHES

(Lecture Series)

(compiling, transcribing, researching, editing always in progress)

LECTURE XVIII: **Isaac Newton Reverse-Engineers God's Clockworks**

First, What Holds the Universe Together?

The very ancients had no problem with gravity so they did not feel a need to explain it. The world was essentially flat for tens of thousands of years, so it just seemed as if weighty things went down and airy things floated on high. Earth and water sought the lower realm while air and fire went upward. Even when the earth became a globe (at least while it was immobile and at the center of the Universe, the weighty things simply tended to gather in the middle (settling inward) and the lighter elements tended to disperse outward, everything pushing its way toward its natural place, with the divine things, the lightest of all, having perhaps no weight—ethereal or quintessential—so they remained above, permanently: the celestial 'bodies' and orbs.

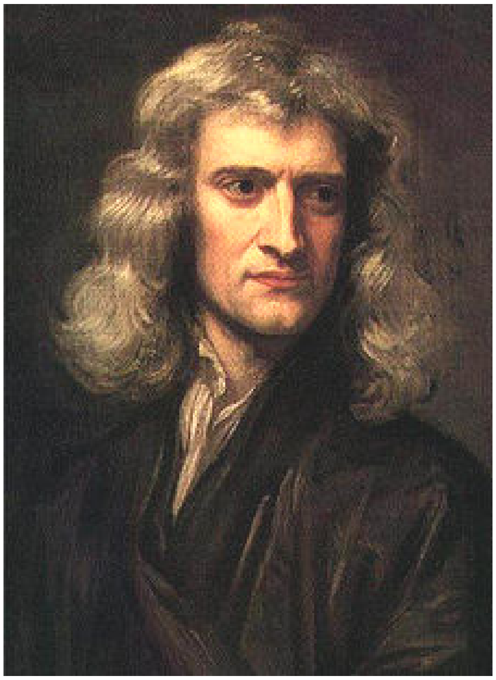
This may have been a major reason the earliest heliocentric ideas were cast aside, since they required an altogether new, even counterintuitive concept of gravity to explain how things were pulled together instead of flying apart. This must also be a big factor in explaining the amazing duration of the Aristotelian/Ptolemaic cosmos. Copernicus could only assign this attraction phenomenon to the will of God, having implanted 'a certain appetency' in the parts to come together. Thus Copernicus left this weakness (though not the only one) in his new concept exposed to ridicule, especially from ecclesiastics—even those of such rebellious nature as Martin Luther, who did not hesitate to call Copernicus a fool, not withstanding his genius as a geometer. On the other hand, despite the inability to explain matter's coalescence, a number of the best thinkers of the Renaissance jumped on the Copernican band wagon—for which some of them paid dearly.

The voyages of Columbus and the circumnavigation of the globe by Magellan had long ago erased any doubt of earth's spherical shape, but they had not brought about its displacement by the sun as the center of everything. If Bruno was too interested in infinity to concern himself with the principles of gravitation, Kepler and Galileo, at least, realized it needed explanation, bending themselves to the task by working out new laws of motion, battering against the aging walls of Aristotelian physics mathematically (particularly Kepler's invention of astrophysics) and by Galileo actually experimenting to prove the Philosopher wrong and to establish (or begin to establish) a new method of knowing. Neither was a man accepting of ideas based on sheer authority. Certainly Galileo came by that characteristic honestly, for his father, too, was just such a person. In a publication of Vincenzo's [*Dialogue of Ancient and Modern Music*], one of his characters says,

> It appears to me that they who in proof of any assertion rely simply on the weight of authority, without adducing any argument in support of it, act very absurdly. I, on the contrary, wish to be allowed freely to answer you without any sort of adulation, as well becomes those who are in search of truth.

[*as quoted in* GALILEO AND THE SCIENTIFIC REVOLUTION *by* Laura Fermi & Gilberto Bernardini; Dover, 2003 (*republication of* Basic Books, NY, 1961); p.16]

Still, Galileo could only assume gravity, not 'explain' it. Nor did he present his anti-Aristotelian physics as universal. Even though he had fairly dispensed with the idea of the planets and stars as being attached to some sort of crystalline spheres, his physics remained earthly. A good many new scientists, as we have seen, explored beyond what Galileo had discovered and others attempted a new, restricted, materialist philosophy to explain the new concepts. But it remained for



Sir Isaac Newton [1642-1726]

to summarize, mathematize, and universalize not only laws of motion and gravity but the whole foundation of what we now call 'classical physics.'

In 1665 a severe plague descended upon London. That year and most of 1666 Newton spent back at the family's Lincolnshire farm to avoid contracting the sickness. Cartoon versions of Newton often picture him under an apple tree being struck on the head by a falling apple, which supposedly suggested to him his understanding of gravity and the entire inverse squares ruling that appears in his *Principia*. While he may have had occasion often to see apples falling in Lincolnshire, it is not likely he was hit by one. But even should one have fallen on his head, as if he had never before noticed that things released at some elevation invariably fall, it is even more unlikely that such an event had anything to do with the formulation of his laws of motion.

Anyway he did not, of course 'discover' gravity. He did certainly, however, whiling away the hours down on the farm, discover a way of calculating its effect. In later writings he remarked "During this year I began to think of gravity extending to the orb of the Moon, and compared the force requisite to keep the Moon in her orb with the forces of gravity at the surface of the Earth" [*found in* GRAVITY *by* George Gamow; Dover, 2002 (*republished from* Anchor Books, Doubleday, NY, 1962); p.37]. In this quote we see that the idea of gravity as a force of nature had become his accepted view. The cause of this force and its operation were not known, of course, and Newton specifically deflects any such questions in his mathematical working out of the laws applicable to the phenomenon, such that his laws become practical in the advance of science, but not explanatory as to 'What is gravity?' or even 'What is force?.' Furthermore, by '**extending it to the orb of the Moon**,' he took **the *first step* toward cosmic application of the laws of motion**; laws that he would later analyze, since this early idea could not be mathematically examined quite yet nor, therefore, published—which delay led to the disputes over who first thought of it and, later, over who first conceived of the mathematics necessary for the analysis. But we do know who first understood such laws because in 1666, other than Newton, no one had the mathematics to formulate them. That is what prevented Galileo and his immediate followers (including mathematics and geometry geniuses like Cavalieri, Pascal, Fermat, even as late as Wallis, and others) from formulating the laws of gravity, though some guesses had been correct. Such mathematics simply did not exist until Newton himself invented his system of 'fluxions.' W.W.Rouse Ball says:

> …all mathematical analysis was leading up to the ideas and methods of the infinitesimal calculus. Foreshadowings of the principles and even of the language of that calculus can be found in the writings of Napier, Kepler, Cavalieri, Pascal, Fermat, Wallis and Barrow. It was Newton's good luck to come at a time when everything was ripe for the discovery, and his ability enabled him to construct almost at once a complete calculus.
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> [A SHORT ACCOUNT OF THE HISTORY OF MATHEMATICS; ch.XVI: *The Life and Works of Newton*; Dover, NY, 1960; p.347]

Even with that, as previously hinted, there was a dispute, now with Leibniz, who independently worked out his own calculus. The dispute was: Who thought of it first, and did the other disputant get the idea from the originator? While there was communication between them concerning this, it seems to be the general opinion of historians that they each invented it independently. Newton may have been first, but he never published anything about his system until after Leibniz had developed his own version. Because Leibniz's system of symbols seemed less abstruse, his had greater utility and spread quickly across Europe. It is his system that has become known as *differential calculus*, but it is essentially the same as Newton's in principle. It was this new mathematics, invented out of necessity to advance the new physics, that made modern science possible.

As you gain knowledge of history you will discover that such nonrandom-like independent concepts and similarity in inventions are not so rare as might be expected. Not to take anything away from Newton—or from Leibniz—but it almost seems as if a time simply comes for a particular idea to be born, and it is discovered almost simultaneously, here and there, and sometimes under quite dissimilar circumstances.

The invention of the calculus constituted *the second step* in universalizing the law of gravity, and ***the third step* was to prove Kepler's third law** (*squares of periods of revolution of planets around the sun stand in the same ratio as the cubes of their mean distances from the sun*). Using his system of fluxions (though they were explained and verified in his *Principia* geometrically, since he expected that his readers would not understand fluxions and that his critics would attack his mysterious and unproven mathematics as a means of dismissing his physics while painting him as a madman), by Newton's calculations his gravitational law of inverse squares provided exactly the answer Kepler had discovered with extraordinary effort using only classical geometry.

Newton was not quite so presumptuous as to include the soul and the mind in his mechanizing and mathematizing of the Universe, but his was certainly a clockwork cosmos. Even light was explained corpuscularly. His presentation was so convincing, and the new physics worked so well, that philosophy—the new 'natural philosophy' would soon be trying to explain the All: the whole of life and the world, and even human behavior, based on mechanics; abandoning metaphysics entirely as fantasy. Although it was not precisely clear this early in the scientific age, *modern* philosophy was being reduced to the handmaiden of science—assuming (and soon to make complicated logical arguments) that truth stood only behind scientifically obtained knowledge, thereby limiting certainty or 'knowing' to the 'truths' found via physics and mathematics. This was not unlike the situation in which *classical* philosophy found itself under the restrictive aegis of theology during the middle ages. Intuition thus became suspect and 'common sense' could no longer be trusted, unless it could be brought into line with this new, strictly mechanical outlook on the world.

It should be recalled here that philosophy originally meant the search for knowledge: knowledge of everything and of every kind, with no restriction. Here is an example of the danger of changing definitions of concepts either without considering the effects or purposefully utilizing such a change to promote a particular agenda. This is why some will refer to modern philosophy as merely 'modern thought'—in recognition that the original definition of philosophy has been abandoned as a failure (and/or is 'dead') and the term should cease to be used to describe what most modern thinkers do.

What about Space?

Newton developed his laws of motion after those of Galileo, stating that the first and most important was that 'every body continues in its state of rest, or of uniform motion in a right line, unless it is compelled to change that state by forces impressed upon it.' But how do we understand such motion or rest except in relation to other bodies? Rejecting Descartes' oneness of universal substance (by which he attempted to explain the concept of force: having to do with the same principle as the primal vortex—matter and space as the same, i.e., as nothing but extension), Newton saw matter as 'mass-points'—a concept still in use—and he opted essentially for Gassendi's idea of emptiness between bodies (leaving force essentially unexplained but quantifiable).

Very well—but where, then, are bodies located? Rectilinear uniform motion cannot be referenced universally by means of purely relative space; plus the idea of rest seems to presuppose an absolute, immovable space. Newton himself tells us:

> Absolute motion is the translation of a body from one absolute place into another; and relative motion, the translation from one relative place into another. Thus in a ship under sail, the relative place of a body is that part of the ship which the body possesses; or that part of the cavity which the body fills, and which therefore moves together with the ship: and relative rest is the continuance of the body in the same part of the ship, or of its cavity. But real, absolute rest, is the continuance of the body in the same part of that immovable space, in which the ship itself, its cavity, and all that it contains, is moved. Wherefore, if the earth is really at rest, the body, which relatively rests in the ship, will really and absolutely move with the same velocity which the ship has on the earth. But if the earth also moves, the true and absolute motion of the body will arise, partly from the true motion of the earth, in immovable space, partly from the relative motion of the ship on the earth; and if the body moves also relatively in the ship, its true motion will arise, partly from the true motion of the earth, in immovable space, and partly from the relative motions as well of the ship on the earth, as of the body in the ship; and from these relative motions will arise the relative motion of the body on the earth.

[*as quoted in* CONCEPTS OF SPACE *by* Max Jammer, 3rd edit.; Dover, NY, 1993 (*republication of* Harvard Univ. Press, Cambridge, Mass, 1969) pp.101-102
from F.Cajori, ed., *Sir Isaac Newton's Mathematical principles of natural philosophy and his System of the world. A revision of Mott's translation*; Univ. of Calif. Press, Berkeley, 1934; p.7—*referred to above and hereafter as* *Principia*]

Now we can see that some of Newton's *laws* are based on assumptions hardly different than Euclid's parallel-lines-never-meet axiom, in that they seem unquestionably true but are unverifiable experimentally. Like Euclid, Newton did not see the need for proof. Such things were not only logical but simply 'experienced' in everyday life. In fact he also refers to them as *axioms*—and, of course, it was Euclidean space that Newton was assuming as real. Henry More's influence is heavy here, having promoted space and God as One in his own strongly argued exception to Cartesian 'extension' as the only reality outside of Descartes' mind. Newton was a religious man and, like More, had no doubt about the existence of non-corporeal, transcendental entities. In fact he was very much interested in the occult, particularly alchemy. He merely wanted to separate metaphysics and the supernatural from the improved practicality of a science founded entirely on physics.

But with everything explained physically, where was the place for God? "It is a little recognized aspect of the scientific revolution," says Margaret Wertheim,

> …that the physicalization of the celestial realm was ultimately clinched by the ephemerality of a mathematical equation. Before Newton's equation, people could continue to argue about the constitution of the celestial bodies, but after the law of gravity had been discovered, that battle was effectively over. Matter now reigned supreme, not just on earth but throughout the cosmos….
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> But unlike Descartes' universe, Newton's was imbued with divine spirit, for, following Henry More, he too associated space with God.
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> [THE PEARLY GATES OF CYBERSPACE: *A History of Space from Dante to the Internet*; W.W.Norton & Co., NY, 1999; p.149]

In fact, as with Copernicus, Newton needed God not simply to build and wind-up the cosmic clock (after which He stepped aside to let it run, as is often promulgated) but to continue His influence upon His creation. Space, Newton thought, if not identical with God Himself, must at least be considered God's "sensorium." Gravity and force and such things that seemed to defy explanation as requiring action at a distance were thus evidence of the continuing presence of the omnipotent and omniscient Creator.

How High is the Sky:

In any case, the universe he described in *Principia*, consisted of the solar system (what was known of it in the 17th century: out to Saturn) and the actually discovered canopy of fixed stars (however distant and thick that might be)—altogether, not nearly as vast as Bruno's imagined infinite expanse dotted with 'island universes.' (Newton likely assumed the late 16th century estimate of 150,000,000 earth radii to Sirius, if he did not generate an estimate of his own, though he must surely have been advised somewhere along the way of Gregory's computations extending the stars to several billions of e.r).

[Show or HAND OUT: Table of distances from Ptolemy (100 B.C.) to Bradley (1728) (*from* Crowe, MODERN THEORIES OF THE UNIVERSE; p.32)]:

Ptolemy:	2nd c. A.D.	20,000 earth radii	
Brahe:	Late 16th c.	14,000 e.r.	
Copernicans of Late 16th c.		150,000,000 e.r.	
Gregory:	1668	1,900,000,000 e.r.	(Distance of Sirius)
Huygens:	1698	660,000,000 e.r.	" "
Bradley:	1728	9,200,000,000 e.r.	(Minimum distance)
Modern estimate:		11,740,000,464,000 e.r.	(± a few tens of billions)

For Newton, then, the material of the universe must have been finite—or, as for Descartes, 'indefinite.' But was there was a center of space? It would seem there had to be if space was absolute. Yet Newton envisioned space as infinite. Even if the material universe was not centered at the sun, the sun's motion in space must be least of all the celestial bodies, since it is the closest body to that unperceivable center. If we are unable to find that precise center spatially, so to measure our velocity against the absolute immobility of space, the sun would do as a reasonable substitute for all practical purposes. In the very largest sense, if we could not know God Himself, by what is in essence an exercise in reverse engineering, we could at least learn how the mechanism of creation worked by mentally—mathematically, that is—taking apart His cosmic clock.

What about Time?

For Newton, despite the infinity of absolute space, this was still a closed universe with a surrounding halo of 'fixed' stars seemingly at rest relative to the lower (inner) orbits of the planets—all of those orbits elliptical with the Sun at one focus, so that it was practically (if not quite) the cosmic center. With the establishment of this absolute immobile space, absolute universal time seemed quite natural. The unfaltering forward march of absolute time carried the suggestion of progress; even the seeds of evolution.

Though it has grown considerably in size, this still looks a lot like the Kepler/Galilean cosmos by way of Gassendi. So what, generally, did Newton actually provide? Three Fundamental Principles reinforce the foundation of the *Principia*: ***(1)*** **Every particle in the Universe attracts every other particle in accordance with the law of inverse squares** [coincident with his consideration of gravity during the Lincolnshire interlude of 1666]; ***(2)*** **the law of equable description of areas** [proving or verifying Kepler's third law – at least by 1679]; and ***(3)*** the discovery that **a sphere, whose density at any point depends only on the distance from the centre, attracts an external point as if the whole mass were collected at its centre** [the concept of 'mass-points,' 1685]. All of these principles were established through his mathematical concept of fluxions. "The invention of the infinitesimal calculus was one of the great intellectual achievements of the seventeenth century," says Ball, and further:

> It is almost impossible to describe the effect of Newton's writing without being suspected of exaggeration….In fact we may say that it took mathematicians half a century or more before they were able to assimilate the work produced in those [30+] years.
>
> In pure geometry Newton did not establish any new methods, but no modern writer has shewn the same power in using those of classical geometry. In algebra and the theory of equations he introduced the system of literal indices, established the binomial theorem, and created no inconsiderable part of the theory of equations…. In analytical geometry, he introduced the modern classification of curves into algebraical and transcendental; and established many of the fundamental properties of asymtotes, multiple points, and isolated loops, illustrated by a discussion of cubic curves. …
>
> Newton, further, was the first to place dynamics on a satisfactory basis, and from dynamics he described the theory of statics…. The theory of attractions, the application of the principles of mechanics to the solar system, the creation of physical astronomy, and the establishment of the law of universal gravitation…[and] the motion of the earth and moon were worked out as fully as was then possible. The theory of hydrodynamics was created…and he added considerably to the theory of hydrostatics…. The theory of the propagation of waves, and in particular the application to determine the velocity of sound, is due

> to Newton and was published in 1687. In geometrical optics, he explained amongst other things the decomposition of light and the theory of the rainbow; he invented the reflecting telescope…and the sextant. In physical optics, he suggested and elaborated the emission theory of light.
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> …Lagrange described the *Principia* as the greatest production of the human mind, and said he felt dazed at such an illustration of what man's intellect might be capable. …[I]t was a favorite remark of his that Newton was not only the greatest genius that had ever existed, but he was also the most fortunate, for as there is but one universe, it can happen but to one man in the world's history to be the interpreter of its laws. Laplace, who is in general very sparing of his praise, makes of Newton the one exception, and the words in which he enumerates the causes which "will always assure to the *Principia* a pre-eminence above all the other productions of human genius" have often been quoted.
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> [Ball: A SHORT ACCOUNT OF THE HISTORY OF MATHEMATICS; pp.350-352]

Reflecting on his accomplishments Newton famously remarked, "If I have seen farther it is because I have stood on the shoulders of giants".

See more, including absolute space and absolute time in Jammer's Concepts of Space – and in Koyré and perhaps in Kuhn's THE STRUCTURE OF SCIENTIFIC REVOLUTIONS, etc. [maybe both of Kuhn's books are the answer to the 'text book' question—must re-read Structures*])*

Were there problems with Newton's huge concept? You bet! But they were of minor significance when compared to the power of the whole vision, and not nearly so glaring as those left exposed by Descartes. Furthermore, it was expected that all of them would be ultimately resolved and bent to the will of the great Newton. We haven't the time or the experience and training to even discover them all, let alone resolve any of them here. But we ought to consider some of the most obvious:

Other than the metaphysical fallback position of 'God works in mysterious ways His wonders to perform:' (1) *How do these objects or 'mass-points' influence eachother through empty space? How is that mechanistically consistent?* Newton in fact rejected the idea of action at a distance and, as if saying 'Haven't I done enough?' he challenged the readers of his *Principia* (whom he did not expect would be average Joes) to find answers to that, as well to such as the mysteries of magnetism, etc. But he never expected that God would get lost in the process. So, (2) *How does infinity match up with creation? Wouldn't an infinite universe be eternal and not need to be created?* This was a question that may have seemed too heretical to entertain. If asked at all, it was generally ignored and left unanswered—as was Leibniz's claim, (3) *Isn't the idea of absolute space a logical absurdity?*—suggesting even so early that space and time were purely relativistic concepts. Along with a theological defense, Newton opposed his own absolute authority to this objection, as he was unable, or had better things to do than to invent yet another new system of mathematics by which to prove his position.

So, with Newton we have achieved the animated, Euclidean, solid geometry universe, all quite rationally supported by his own advanced mathematics. Despite several rather important questions going unanswered, and more yet to be conceived, this was a marvelous and fruitful system; one that could inspire not only scientific advancement but belief. Here was the birth of what would come to be known as classical physics, which, after rapid development, would in turn give birth to all the modern sciences, and to a new philosophy—or at least a new approach to philosophy—and to a radically different understanding of not only the cosmos but of life, nature, and civilization.

In spite of the accolades quoted earlier and similar statements of a great number of scholars, in fact, as Steven Shapin points out, there were anti-Newton attacks from the Continent, even accusing Newton of overturning the mechanical theory of the Universe by introducing the occult (especially regarding his lack of a mechanical explanation of gravity). "Accordingly," says Shapin:

> …there can be no facile generalization about whether the Newtonian achievement should count as the culmination of the mechanical philosophy, as its subversion by the reintroduction of occult qualities, or as the creation of a new practice, to be judged by new philosophical standards. Late seventeenth- and early eighteenth-century philosophers debated just those points about the proper understanding of Newton's achievement. They disputed whether Newton had perfected mechanism or denied it; they debated whether mechanical causes had to be given as the condition for physical explanation. So too do historians, and so too do many present-day scientists.
>
> [THE SCIENTIFIC REVOLUTION (ch.One, p.64)]

So, despite its power and scope, at least for the latter part of the seventeenth century, the affect of Newton's picture was limited mainly to the English, giving them a leg-up in astronomy and the new mechanics, while Continentals continued to be influenced by Descartes' ultimately less fruitful view. On the other hand, due to the greater fluency of Leibnizian differential calculus, mathematics on the Continent left the British (who dutifully continued using the system of fluxions) in their dust, until differential calculus was introduced to students in England and Scotland later in the 18th century—while on the Continent, Voltaire would weigh-in on the side of Newton to suppress the influence of Descartes.

To recap: Newton was essentially an atomist, thus anti-Cartesian. His concept of space has been closely associated with that of Henry More, who concluded it was not only like a void, and an infinite one, but the means (or one means) of God's operation and maintenance of the otherwise mechanical Universe. Limitless is the negative way to say infinite, and the limitless is also centerless. The Sun, the (albeit moving) focal point of our solar system, is seen by Newton as surrounded, though at admittedly enormous distances, by what we have referred to as a halo of stars. Do those stars extend infinitely? If so, we would not be at the center of the universe, and the stars, affected by universally interacting gravity, must not be fixed but in motion as is the Sun. So it seems everything is in relative motion except in relation to the infinite void, relative to which each thing has an absolute motion. That, Newton said, he hoped to find a means of detecting. But the job was by definition impossible, since a void has no natural attributes—has no *nature*—is, in a sense, nothingness, and so is undetectable. And how can nothingness, let alone a nothingness of infinite expanse, mark time? All that is left is relativity, as Leibniz so prophetically contended. But this may not have been apparent to eighteenth-century minds still reeling from the double overthrow of Aristotle and Ptolemy. Newton's strides were, after all, enormous and, as E.T. Bell has pointed out, it took half-a-century for even the best of the mathematicians to catch up to his progress. Thus Newton, who claimed *hypotheses non fingo*, had provided a cosmic schematic consistent enough to support two centuries of ceaseless hypothesizing—and his concept still is a major factor in such activity, all of which has resulted in a new way of life: a kind of civilization never before seen. As Wertheim has written:

> Over the course of two centuries…an infinite formless universe pervaded by infinite void space had become the basis of Western cosmology. First people had come to accept the idea of void space itself, then they had accepted the celestial domain as a concrete physical realm, and finally they had come to accept that this realm extended to infinity. And all this they had justified on religious grounds.
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> In the long run, however, while the divinization of space had been psychologically necessary to overcome initial resistance to infinity (and to the void itself), a theological view of space was not in truth necessary to the new cosmology. Thus in the eighteenth century, after Newton's death, we witness the spectacle of less religiously inclined scientists stripping away the theological frills from his system. By the middle of that century the new cosmology had been almost totally secularized, and it is this essentially atheistic Newtonianism that has come to dominate the modern West. … In the final analysis, the materialists won the day, and in the Age of Reason man stood not at the center of an angel-filled cosmos with everything connected to God, but on a large lump of rock revolving purposelessly in an infinite Euclidian void.
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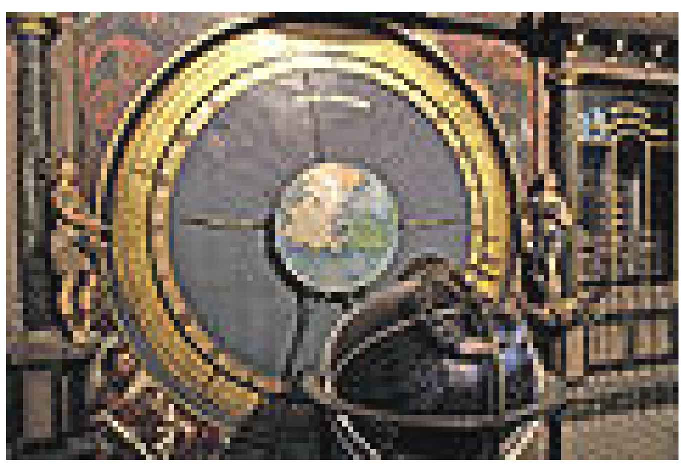
> [THE PEARLY GATES OF CYBERSPACE; p.150]

The ancient view, we recall, as expressed by Aristotle, was that 'Man is a political animal': that society, in other words, was natural, and that within that natural 'motion' lay the potential for civil society and the polis. Long accepted as truth, that idea was eventually brought into question by Machiavelli when he altered the definition of virtue, which had also seemed natural for the ancients as well as necessary for the emergence of civil society. He, however, saw the founding of cities not as something natural, in the sense of something potentially in humanity, but partly due to chance and part by the forcefulness of a founder, and held together by guile supplemented with sheer brutality: the new virtue—suggesting to Hobbes that civil society was an artificial creation of pre-civil humans. In fact he explained it as a contract designed by hypothetical primitives to effect an escape from nature, while preserving the only right that nature seemed to bestow: the right to attempt, by any available means, self-preservation.

The artificial world that was emerging parallel to—or superimposed upon—the natural is illustrated by English mechanical philosopher and chemical experimenter Robert Boyle in his analogy between the Universe and the Strasbourg cathedral clock:



[See appended Wikipedia excerpt]

> The several pieces making up that curious engine are so framed and adapted, and are put into such a motion, that though the numerous wheels, and other parts of it, move several ways, and that without any thing either of knowledge or design; yet each part performs its part in order to the various ends, for which it was contrived, as regularly and uniformly as if it knew and were concerned to do its duty.
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> [*As quoted in* THE SCIENTIFIC REVOLUTION *by* Steven Shapin; Univ. of Chicago Press, 1996 (p.34); *original source not given.*]

By the end of the eighteenth century Cartesian dualism was on the wane.

> The natural world was portrayed as a vast, self-contained mathematical machine, consisting of motions of matter in space and time, and man with his purposes, feelings, and secondary qualities was shoved apart as an unimportant spectator and semi-real effect of the great mathematical drama outside.
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> [*from* Edwin Burtt, *in* THE METAPHYSICAL FOUNDATIONS OF MODERN SCIENCE (p.104) *as quoted in* Wertheim, THE PEARLY GATES OF CYBERSPACE (pp.153-154)]

"For the first time in history," continues Wertheim, "humanity had produced a purely physical world picture, one in which mind/spirit/soul had no place at all."

Thus, with the new physics as framed by Newton in his 'clockwork' cosmos, began the development of, if not the most elevated, at least the most artificial society that has ever existed—and it is becoming ever more so. So artificial, in fact, that we see ourselves in conflict with nature and overcoming her at every opportunity: artificial motion on land, sea, and in the air—and even in space; artificial communication; artificial lighting; artificial heating and cooling; artificial materials; artificial nutrients and flavorings; artificial procreation and genetic alteration; and we are even developing artificial intelligence—and now we crave virtual reality in cyberspace.

We have essentially made Nature, as represented by the Earth, our enemy by making her our slave. It is the way of modern science. And now that she seems, from our perspective, to be in rebellion against us—or sick—we want to help her, revitalize her by scientifically tightening her bonds so that she might recover her more healthy state of servitude to humans.

Those bonds may be about to burst, and tightening them may simply hasten that day. If science has caused the problem, will more science be a likely solution? Is this not similar to treating our economic overspending disorder by spending ten times more? One can, of course, claim that it has been 'bad' science and 'bad' spending that has gone awry, and that proper science and proper spending can get us on the right track. Unfortunately, like wisdom, 'proper' can only be discovered after the fact. We cannot know what is good practice until the results are in, and while we may well be around (even if we are to be found in abject poverty and/or victims of famine and pestilence) to find out if we have spent our future properly or improperly, the result of an improper or too hasty application of science in the attempt to 'cure' the Earth may well lead to human disaster.

HANDOUT: Robert A. Goldwin's essay: John Locke [1632-1704] *in* Strauss-Cropsey: HISTORY OF POLITICAL PHILOSOPHY; U. of Chicago, 1987 -- pp.476-511

Strasbourg Astronomical Clock

(Article reproduced from Wikipedia: Strasbourg Cathedral)

The "Pillar of Angels" (on the left) and the Astronomical clock (on the right)

The cathedral's south transept houses an 18-metre astronomical clock, one of the largest in the world. Its first forerunner was the so-called Dreikönigsuhr ("three-king clock") of 1352-1354, located at the opposite wall from where today's clock is. Then starting in 1547 a new clock was built by Christian Herlin, and others, but the construction was interrupted when the Cathedral was handed over to the Roman Catholic Church. Construction was resumed in 1571 by Conrad Dasypodius and the Habrecht brothers, and this clock was astronomically much more involved. It also had paintings by the Swiss painter Tobias Stimmer. That clock functioned into the late 18th Century and can be seen today in the Strasbourg Museum of Decorative Arts.

The clock existing today originated in 1838-1843 (the clock has 1838-1842, but the celestial globe was only finished on June 24, 1843) and was built by Jean-Baptiste Schwilgué in Dasypodius' clock case, and with roughly the same functions, but equipped with completely new mechanics. Schwilgué made a number of preliminary studies years before, such as a design of the computus mechanism (Easter computation) in 1816, and built a prototype in 1821. This mechanism, whose whereabouts are now unknown, could compute Easter following the complex Gregorian rule.

The astronomical part is unusually accurate; it indicates leap years, equinoxes, and much more astronomical data. Thus it was already much more a complex calculating machine than a bare clock. Often the complicated functioning of the Strasbourg Clock made specialized mathematical knowledge necessary (not just technical knowledge).

A mathematical marvel, the clock was able to determine the computus (date of Easter in the Christian calendar) at a time when computers did not yet exist.

Easter had been defined at the First Council of Nicaea in A.D. 325 as "the Sunday that follows the fourteenth day of the moon that falls on March 21 or immediately after". (See also Easter controversy, Ecclesiastical new moon, and Paschal Full Moon.)

Today tourists see only the remarkably sculpted figurines of this clock, but behind this ensemble there is an exceptional mechanism that engages and that represents one of the most beautiful curiosities of the Cathedral.

The animated characters launch into movement at different hours of the day. One angel sounds the bell while a second turns over an hourglass. Different characters, representing the ages of life (from a child to an old man) parade in front of Death.

On the last level are the Apostles, passing in front of Christ. The clock shows much more than the official time; it also indicates solar time, the day of the week (each represented by a god of mythology), the month, the year, the sign of the zodiac, the phase of the moon and the position of several planets. All these automatons are put into operation at 12:30 PM.

According to legend, the creator of this clock had his eyes gouged out afterward, to prevent him from reproducing it. Similar legends are told for other clocks, such as the astronomical clock in Prague.

In the same room, there is a statue of a man resting his elbows on a balustrade (railing). According to legend this was a rival architect to the one who had built the pillar of angels, the architectural feat of the era, who contended that one single pillar could never support such a large vault, and he would wait to see the whole thing come crashing down.[20]

There are several models of the Strasbourg clock, usually with simplified functions. One is in the Sydney Powerhouse Museum [3].

From 1858 until 1989, the clock was taken care of by the Ungerer [*disambiguation needed*] company. This company was founded in 1858 by two brothers who were Schwilgué's assistants. Since 1989, the clock has been taken care of by Alfred Faullimmel and his son Ludovic, for the Strasbourg cathedral. Mr. Faullimmel had been employed by Ungerer between 1955 and 1989.