# Cicero on cosmology: extracts & commentaries

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## Max Planck confidently explaining a wrong theory of Uranium, 1929

Here is Max Planck confidently explaining Uranium in 1929:

“Uranium contains 238 protons and 238 electrons; but only 92 electrons revolve round the nucleus while the others are fixed in it…. The chemical properties of an element depend not on the total number of its protons or electrons, but on the number of revolving electrons, which yield the atomic number of the element.”

Comment: I have always wondered how scientists thought of complex nuclei before the neutron was discovered. This statement by Max Planck must have been the best idea going in 1929, and it makes sense at some level. Protons plus “inner” electrons together inside the nucleus make a massless combination like a neutron does, whereas the “revolving” electrons dictate the chemistry and the atomic number.

Planck’s description of Uranium sounds perhaps too confident, and for that maybe he could be criticized. However, any claim in science such as this should be thought of as coming with an implicitly understood preface “Our best idea going, but which could change at any moment when somebody else has a better or more efficient idea that fits the data better, is the following.” I am sure Planck had this implicit preamble in mind when he wrote those words.

Reference

Max Planck. *The Universe in the Light of Modern Physics*. 1931, which is a translation of the original *Das Weltbild der neuen Physik*, 1929.

## All explanations end with ‘it just does’

It is rather obvious but it is helpful to remind ourselves periodically that explanations only go so deep before hitting a wall, as Emmett explains:

“When we make the statement hedged about with so many qualifications it might be argued that we are making it a necessary statement by putting the necessity in; that we are saying in effect that if the wire is of such a kind that the other end will move when I pull this end, then if nothing happens to prevent it going so the other end will move when I pull this end, then if nothing happens to prevent it doing so the other end will move when I pull this. “We can couch the statement in such a form that it carries with it necessity or theoretical certainty, but the events which are being described are the events of experience. The fact that, usually, if we pull one end of a wire the other end moves is derived from experience and it is a fact which we come to see and absorb very early in life. As soon as we start touching or seeing material objects we experience events similar to this. And to the question Why it should happen no answer seems possible except that it just does. It is to events of this kind, the simplest sort of link in the chain of cause and effect, that all chains can be reduced and in terms of which they can all be explained.

“When we are investigating or analysing we want to postpone for as long as possible the answer ‘It just does — it’s a fact of experience — look around you and see.’ And indeed one of the main points of an investigation, of asking a ‘why’ or ‘how’ question, is to discover more intermediate links. But the answer ‘It just does’ is bound to come eventually.”

E.R. Emmett. *Handbook of Logic*. Totowa, NJ: Littlefield, Adams & Co, 1967.

<u>Comment</u>: Children, who are naturally curious, always ask “why”. They ask “why” at every progressively deeper answer until their parents give up and say, “that’s just the way it is!” Maybe we should answer our children with a more pleasant response that keeps their curiosity strong. For example, when we get to this point we can say, “Nobody knows why. Maybe one day you will figure that out and can tell me.” I had an excellent science teacher when I was young that used to say that, and I felt so important that this teacher had the confidence in me that one day I could figure it out. He wasn’t angry or frustrated with the questions, but seemed genuinely interested in knowing the answers himself. I was fortunate to have him as a teacher.

## Difference between a cathedral and a physics lab?

"What have we been doing all the centuries but trying to call God back to the mountain, or, failing that, raise a peep out of anything that isn't us? What is the difference between a cathedral and a physics lab? Are they not both saying: Hello?"

Annie Dillard. *Teaching a Stone to Talk*. Harper Perennial, 1992.

Comment: It is often remarked that physics and mathematics are dreary subjects that are impersonal and lonely. Humans are a social species, who crave contact, discussion, gossip, and interactions of all kinds with people. History, psychology, social science, medicine, and law are all fields that "make sense" from this perspective.  What drives the physical scientist and the mathematician? It is a craving to discover the "other" — that which is greater and more enduring than even our personal lives.

## Study of nature far superior to other human activities?

Cicero channeling Pythagoras on the value of studying nature:

“Some of us are enslaved to glory, others to money. But there are also a few people who devote themselves wholly to the study of the universe, believing everything else to be trivial in comparison. These call themselves students of wisdom, in other words philosophers; and just as a festival attracts individuals of the finest type who just watch the proceedings without a thought of getting anything for themselves, so too, in life generally, the contemplation and study of nature are far superior to the whole range of other human activities.”

Cicero, “Discussions at Tusculum”, in Cicero’s *On the Good Life*. Penguin, 1971

Comment: It should be remarked that Cicero invokes Pythagoras here as getting it almost right, but later says that Socrates, whom Cicero deeply admired, had it right when he “took the initiative in summoning philosophy down from the heavens.” In the end, according to Cicero (On Divination, II), there is but one source of real happiness. It is the “proposition which brilliantly illuminates the entire field of philosophy — the proposition that moral goodness, by itself, is sufficient to make anyone happy.” Nonetheless, I’ve met many physicists who appear to agree more with Pythagoras than Cicero, and of course many who appear to agree with both. After all, the two are not incompatible.

## In praise of theory and speculation

I once heard a famous and well-decorated experimental physicist say that experimentalists simply shouldn't listen to theorists at all. Experimentalists should just measure and things will come what will, and they should pay no attention to theorists' speculations and arguments at all when deciding what experiments to do.

I was very young and inexperienced at the time, but thought then as I do now that it was a dangerous and silly philosophy. There are so many examples of how it pays for communication to go both ways, theorists paying close attention to what experimentalists say and experimentalists paying close attention to what theorists say.

An example that I was reminded of recently is of an experimental collaboration that was building up steam to look for invisible orthopositronium decays. One argument was that the electron and positron could annihilate into extra dimensions. However, Friedland and Giannotti (arXiv:0709.2164) showed that such decays would be disastrous to supernova cooling rates, and that the proposed experiment was essentially guaranteed to not find anything. In other words, a waste of time and money, and a huge opportunity cost to the experimentalists involved. The anti-theory philosophy would say, "Don't listen to those theorists! Just do it! Measure what you can and want to measure!" which would be clearly bad advice here. If there were infinite numbers of people and dollars, that might not do harm (I doubt it then too), but in the present world, it is more prudent to pursue our best bets, guided by theory.

Regarding best bets, it should be noted that the Higgs boson was pure speculation until it was discovered recently. It was, gasp, just a theory model! It had no direct experimental support, and alternative theories without the Higgs boson abounded. Yet, luckily, there were experimentalists who sorted through the alternatives to decide on a best bet, with theory guidance, and then designed fantastic detectors and experiments and search algorithms focused on finding it. Without that sustained dedication to this speculation they would not have succeeded.

And anyway, theory and speculations are what give joy to intellectual pursuits. Theory haters are unhappy people, and happy people are more productive, so unleash your speculations and theories. If you won't listen to me, let John Steinbeck (1969) encourage you:

"There are some people who deeply and basically dislike theories and are hostile to speculations. These are usually unsure people who, whirling in uncertainties, try to steady themselves by grabbing and tightly holding on to facts. Speculation or theory-making on the other hand is simply a little game of pattern-making of the mind. The theory hater cannot believe that is important. To such a person a theory is a lie until it is proven and then it becomes a truth or a fact. But there's no joy in it."

Reference: John Steinbeck. *Journal of a Novel: The East of Eden Letters*. Viking Press, 1969.

## Cicero on cosmology in Roman antiquity

Cicero in about 50 BCE explaining the heavens:

“The universe is held together by nine concentric spheres. The outermost sphere is heaven itself, and it includes and embraces all the rest. For it is the Supreme God in person, enclosing and comprehending everything that exists, that is to say all the stars which are fixed in the sky yet rotate upon their eternal courses. Within this outermost sphere are eight others. Seven of them contain the planets ? a single one in each sphere, all moving in the contrary direction to the great movement of heaven itself. The next sphere to the outermost is occupied by the orb which people on earth name after Saturn. Below Saturn shines the brilliant light of Jupiter, which is benign and healthful to mankind. Then comes the star we call Mars, red and terrible to men upon earth.

“Next, almost midway between heaven and earth, blazes the Sun. He is the prince, lord and ruler of all the other worlds, the mind and guiding principle of the entire universe, so gigantic in size that everything, everywhere, is pervaded and drenched by his light. In attendance upon the Sun are Venus and Mercury, each in its own orbit; and the lowest sphere of all contains the Moon, which takes its light, as it revolves, from the rays of the sun. Above the Moon there is nothing which is not eternal, but beneath that level everything is mortal and transient (except only for the souls in human beings, which are a gift to mankind from the gods). For there below the Moon is the earth, the ninth and lowest of the spheres, lying at the centre of the universe. The earth remains fixed and without motion; all things are drawn to it, because the natural force of gravity pulls them down.

Comment: This passage was originally written by Cicero sometime between 54 BCE and 51 BCE. The “Dream of Scipio” is in the last volume of his six volume set entitled On the State. Much of those six volumes is lost to us now. However, we do know that the device Cicero used was that of a conversation between Scipio Africanus the younger and others. The passage above is Scipio Africanus the elder coming in a dream to explain the heavens. It is a nice summary of what Romans of antiquity knew and thought of astronomy and cosmology.  Of course, Cicero got much of this from the Greeks, but he had to synthesize sources and make decisions, especially on the ordering of the planets and the Sun (he sided with Pythagorus over Plato). Presumably he consulted with others as well, and it is fair to say that this is likely to be the Roman view of the cosmos in approximately 50 BCE.

Reference

Cicero. “The Dream of Scipio,” in Cicero’s *On the Good Life*. Penguin, 1971.

## Ginzburg’s regret at not being the first to discover the BCS theory of superconductivity

The theory of superconductivity has gone through four significant phases of understanding. The first phase was Londons theory of superconductivity (1933), which was a successful phenomenological theory in some ways (e.g., explained Meissner effect) but unsuccessful in other ways (e.g., failure to understand end of superconducting state at high currents).

The second phase was the Ginzburg-Landau theory (1950) which applied Landau’s theory of phase transitions to superconductivity with great success. In particular it gave descriptive understanding of coherence length, type I and II superconductors, and quantization of magnetic flux and vortices.

The third phase was the discovery of BCS theory (1956), which gives a perturbative microscopic understanding of the Ginzburg-Landau theory. And the fourth phase, which we are still in, is the discovery of high-Tc superconductors, for which we still do not have a complete understanding.

The history of superconductivity has many lessons to learn, both in the principles of physics but also in the culture of scientific discoveries and missed opportunities.

In the category of missed opportunities, Ginzburg points out in his Nobel Prize lecture of 2003 that he and Landau missed an insight that perhaps should have been seen, and which perhaps could have led them to the BCS theory before Bardeen, Cooper and Schrieffer.

The theory of superconductivity that they developed was based on the Ginzurg-Landau potential

$$V_{GL}(\Psi) = \alpha|\Psi|^2 + \beta|\Psi|^4$$

where ▯ is the order parameter for superconducting charge carriers. When an electromagnetic field is applied the free-energy requires the addition of the vector potential added to the gradient term:

$$\left(-i\hbar\nabla - \frac{e^*}{c}A\right)\Psi$$

When you construct the superconducting current you find

$$\boldsymbol{j}_s = \frac{ie^*\hbar}{2m^*}(\Psi^*\nabla\Psi - \Psi\nabla\Psi^*) - \frac{(e^*)^2}{m^*c}|\Psi|^2\boldsymbol{A}$$

The observables of the theory, such as the penetration depth and the critical magnetic field, depend on these “phenomenological parameters” $m^*$ and $e^*$. They are phenomenological parameters because the Ginzburg-Landau theory was a phenomenological theory that had no first-principles derivation.

Now, it is tempting to say that $m^*$ and $e^*$ should be connected to the electron mass and charge. After all, what else is there in the superconductor that could carry the superconducting current! However, Ginzburg and Landau recognized immediately that $m^*$ could deviate far from the electron mass just as there are "effective masses" in the theory of metals, and it would depend on temperature and other properties. However, as Ginzburg reports, "Landau did not see why ***e**** should be different than ***e***, and in our paper it is written as some compromise that 'there are no grounds to believe that the charge ***e**** is different from the electron charge'" (Ginzburg 2003).

The trouble was that Ginzburg later compared theory with experimental and found that ***e****=(2-3)***e*** was required. The naive view that ***e**** had to be equal to ***e*** just wasn't fitting the data. Landau's response was to argue that, like the effective mass, "the effective charge may and, generally speaking, will depend on the coordinates, because the parameters that characterize the semiconductor are functions of the temperature, the pressure, and the composition, which in turn depend on the coordinates **r**" (Ginzburg 2003).

When BCS was discovered a few years later it became obvious that ***e**** was near 2***e*** because of the special Cooper pairing of electrons that take place inside a superconductor to form a superconducting bosonic state. You can almost feel the sharp regret in Ginzburg's tone when he talks about it in his 2003 speech so many years later:

"Landau was right in the sense that the charge ***e**** should be universal and I was right in that it is not equal to ***e***. However, the seemingly simple idea that both requirements are compatible and ***e****=2***e*** occurred to none of us. After the event one may be ashamed of this blindness, but this is by no means a rare occasion in science, and it is not that I am ashamed of this blindness, but I am rather disappointed that it did take place" (Ginzburg 2003).

Ginzburg's contributions to science and the theory of superconductivity were extraordinary and worthy of the Nobel Prize, and they are still studied to this day. Yet, we can also find value in seeing that he missed opportunities. I suspect that we all have many opportunities for keen, and maybe even dramatic, insight swirling around us, and we can only hope that we concentrate hard enough and work hard enough to grasp at least one or two of them before they float away.

**Reference**

Vitaly L. Ginzburg. "On Superconductivity and Superfluidity." Nobel Lecture, December 8, 2003.

## The “vagrant and unfocused” career of Leonardo da Vinci

“Of the many mysteries surrounding Leonardo da Vinci none is more remarkable than the disproportion between the quantity of his finished works and the grandeur of his reputation. Our awe of Leonardo is as much for what he was as for what he did, as much for his reach as for his grasp. His career was vagrant and unfocused – in fact, he never had a career.”

Daniel Boorstin. The Creators. New York: Vintage Books, 1992.

Comment: Boorstin’s book is an absolute monument to erudition and a pleasure to read. His writing style is elegant and his opinions are strong and unambiguous. He devotes a full chapter (chapter 44) to Leonardo da Vinci, who was born in 1452 as the “illegitimate son of a prosperous Florentine notary, … [but] raised in his father’s house as if he had been legitimate.” His mother was likely a peasant.

Da Vinci was one of those guys who did everything. He painted, he sculptured, he studied mathematics, he dissected corpses, he engineered things, and he taught himself Latin at age 42, among many other activities. However, he wasn’t the best at anything he did, but rather the best at doing so many things creatively. 3500 pages of his notebooks survive that he kept of his ongoing ideas and projects, most of which he never started, much less finished. It is thought that that might be only a quarter of all he wrote. He wrote most pages backwards so that they could only be read easily in a mirror. Almost none of his writings contain anything personal. It’s all about ideas and projects. He must have struck quite the eccentric figure, and must have overwhelmed everyone in earshot with his creative and fertile mind.

There is the Mona Lisa, and there is the Last Supper, two extraordinary paintings by da Vinci, and there are his inventive drawings, and his scintillating engineering ideas. But according to Boorstin his reputation was achieved by “what he was” and “for his reach” rather than what he actually accomplished. Many people accomplished much more than him in any particular area of his interest. And so, we are left to ask, can it be that the power of his creative personality was so dominant, and his image so luminous, that it has sustained his reputation for 600 years? Apparently so.

## Pascal's Conformal Commitment

Many of us know Blaise Pascal (1623-1662) as a brilliant mathematician and physicist. However, at the age of 30 he had a profound religious experience and more or less gave up all of this work, and turned to religion. The first result of that conversion was his book *Provincial Letters*, published in 1656 under a pseudonym, which attacked Jesuits for their moral laxity and for their casuistry condemnations of Jansenist theologian Antoine Arnauld.

Being a systematic thinker, Pascal set out to write a new book, *Defense of the Christian Religion*, but died in 1662 at the age of 39 before he could write it. However, the scraps of notes that he compiled for the book were posthumously published as *Pensées* ("thoughts"). It is in *Pensées* that Pascal articulates what has become to be known as "Pascal's Wager", which states that it is better to follow the Christian religion, which promises all for eternity, than it is to not, which promises nothing good for eternity.

Despite Pascal's abandonment of mathematics and physics in favor of his new pious pursuits, his mind could not help but be infected by his background. Even in the midst of intense religious reflections, questions of science rise up in him and influence his religious worldview.

One of the most intriguing examples of this I find is in the section of *Pensées* titled, "Transition from Knowledge of Man to Knowledge of God." This section really is Pascal wrestling with the idea of scales. Man is tiny, and God is infinite. But what makes something small? Why is one scale more "attractive" than another scale when it comes to the size of things.

Pascal first articulates his interest in the question in Pensée 194 : "Why have limits been set upon my knowledge, my height, my life, making it a hundred rather than a thousand years? For what reason did nature make it so, and choose this rather than that mean from the whole of infinity, when there is no more reason to choose one rather than another, as none is more attractive than another?"

Pascal struggles with this question, and he must have been convinced that there is no good reason to prefer one scale over another. It is inconceivable to him that nature should be forced to make a choice. But what is one to do when we see that man is only a few feet tall, no more and no less?

Pascal builds up the question in Pensée 199 : "Let man, returning to himself, consider what he is in comparison with what exists; let him regard himself as lost, and from this little dungeon, in which he finds himself lodged, I mean the universe, let him learn to take the earth, its realms, its cities, its houses and himself at their proper value. What is a man in the infinite?"

The scales of the infinitely large and the infinitesimally small are equal to Pascal. There can be nothing special. And so he exhorts the reader to come with him to the infinitesimally small to see that it is not unique : "I want to show him a new abyss. I want to depict to him not only the visible universe, but all the conceivable immensity of nature enclosed in this miniature atom. Let him see there an infinity of universes, each with its firmament, its planets, its earth, in the same proportions as in the visible world, and on that earth animals, and finally mites, in which he will find again the same results as in the first" (Pensée 199).

Pascal has now successfully put forward a worldview that does not make our scale of existence unique or special. All scales in nature are equally valid and equally rich. This conformal symmetry, or more technically a fractal self-similar symmetry, was so enticing to Pascal that he was willing to speculate the existence of an infinite number of self-similar worlds at all scales in defense of the principle. This is a true mathematician and theoretical physicist at heart.

Now that he has this structure in place he is forced to ask himself what is the connection between the very smallest and the very largest scales. Can there be something that ties them together to make a clean contiguous structure. If you remember that he has become intensely religious his line of reasoning and answer will not surprise you : "We naturally believe we are more capable of reaching the centre of things than of embracing their circumference, and the visible extent of the world is visibly greater than we. But since we in our turn are greater than small things, we think we are more capable of mastering them, and yet it takes no less capacity to reach nothingness than the whole. In either case it takes an infinite capacity, and it seems to me that anyone who had understood the ultimate principles of things might also succeed in knowing infinity. One depends on the other, and one leads to the other. These extremes touch and join by going in opposite directions, and they meet in God and God alone" (Pensée 199).

And there he tells us how it all fits together. The infinitely small and the infinitely large appear to diverge in opposite directions in this conformal view of nature, but ultimately they meet in God, who is the master over all domains, and all scales, who is the alpha and the omega. Q.E.D.

Reference

Pascal, Blaise (1995). *Pensées*. London: Penguin Books.

## Fundamental physics is not yet simple enough

Murray Gell-Mann, the physicist credited for first understanding quarks in particle physics, tell us that our current theory of fundamental physics is not yet simple enough:

"Those of us who helped put together the standard model are naturally rather proud of it, since it brought a good deal of simplicity out of a bewildering variety of phenomena. ... Second, the model is not yet simple enough; it contains more than sixty kinds of elementary particles and a number of interactions among them, but no explanation for all that variety."

M. Gell-Mann. *The Quark and the Jaguar*. Little, Brown and Co., 1994.

Comment: I completely agree. There are additional concepts of unification and additional unifying principles that we still have not hit upon that will arrange the mess of the Standard Model of fundamental particle physics into a more compact theoretical structure. It has always been that way in natural law, and no reason to believe that discovering additional unifying organization principles should cease.

## Voltaire says true physics is to calculate, measure and observe

"True physics consists then in the proper determination of all the facts. We will know first causes when we are gods. It is given to us to calculate, to weigh, to measure, to observe; this is natural philosophy; almost all the rest is a chimera."

From Tom Scharle 2004. "Voltaire's Dispute with Epigenesis." http://www.talkreason.org/articles/chickegg.cfm (accessed June 2006)

The quote is a translation from the entry "Cartesianisme", which is in Questions sur l'encyclopédia Dictionaire Philosophique Tome III volume 52 of *Oeuvres complètes de Voltair avec des remarques et des notes*. Paris: Badouin Frères, 1825.

<u>Comment</u>: As Scharle says, "Voltaire seems to have had a limited concept of what sciences could investigate". I tend to agree with that assessment. But this quote is also part of the overall criticism of Descartes, who believed he had solved all of physical science through pure thought, and that hubris turned out to be very misguided.  The anti-Descartes crowd often ran to the other extreme, such as is reflected in the Voltaire quote above. This especially happens if the author does not understand science very well and has not contributed to it, but has strong philosophical opinions about what science should be and how it should operate. Voltaire is in this category in my view.

## I think, therefore I am … hated

From a letter (Lennon 1993) written by the great Dutch physicist and mathematician Christiaan Huygens to the philosopher Pierre Bayle in 1693:

"Descartes had found the way to have his conjectures and fictions taken for truths. And what happened to those who read his *Principles of Philosophy* was something like what happens to those who read pleasant novels that make the same impression as true histories. The novelty of the shapes of his little particles and of the vortices was found very charming. It seemed to me that when I read his book of principles for the first time, everything went as well as could be, and when I found some difficult, I believed that it was my fault for not having properly understood his thought. I was only 15 or 16 years old. But having since discovered from tie to time things visibly false and others very improbable, I have thoroughly rejected my former opinion and I now find almost nothing I can certify as true in all his physics, metaphysics or meteorology.

"[Galileo did not have] "the boldness and presumption to attempt to explain all natural causes [like Descartes], or the vanity to become head of a school ["chef de secte"]. He was modest and loved the truth too much."

Separately, we read from Shorto (2008) this about Louis-Sébastien Mercier's 1796 speech arguing against the proposal in 1793 that the remains of Descartes be buried in the newly established Panthéon :

"'I, too [referring to Descartes supporter Chénier], made an eloge to Descartes in my youth,' [said Mercier]. But he said that he hadn't yet realized that 'the greatest charlatans in the world have sometimes been the men most celebrated.' Mercier chose to avoid combating Chénier's political argument. Instead he railed against 'the history of profound evil that Descartes has done to his country.' Descartes, he declared, 'visibly retarded progress by the long tyranny of his errors: he is the father of the most impertinent doctrine that has reigned in France. This is Cartesianism, which kills experimental physics and which puts pedants in our schools in place of naturalist observers.'"

This quote is from Shorto (2008). Additional discussion and quotes from the fascinating "Descartes Pantheon debates" can be found in Bourgeois & D'Hondt (1989), Chénier (1796) and Mercier (1799).

<u>Comments</u>: Descartes was a rather extreme rationalist who thought that by pure thought he could figure everything out. In fact, he thought he had mostly figured everything out. Of course, people died around him, which is an obvious sign that he hadn't solved all problems in science, but cheerfully said he would solve that very soon too. But he died himself instead. The arrogance, the conceit, the self-promotion and the "charlatism" as some would say of

Descartes, is part of his legacy. But rattling the stale cages of French science was worth it, and for that reason, among others, he is one of the greats of western philosophy and mathematics. I'm sure Huygens is rolling his eyes as I write this.

It should be noted that Descartes did have an enormous influence on French scientific history. The French fell far behind the English, for example, in experimental science and technology, and that has been noted by many French educational historians with some blame put on Descartes's influence (Shorto 2008). The English soon became wealthier and more powerful because of it. However, the French school of mathematics is probably second to none over the many decades and even centuries. This translates into outstanding theoretical physics as well. Let a thousand flowers bloom, as they say, and the French flower is beautiful and worthwhile, if different. Thanks to Descartes.

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Mercier, L.-S. 1799. "Panthéonisé." *Le Nouveau Paris, tome.*.

Shorto, R. 2008. *Descartes Bones*. Vintage Books.

## Leibniz thought belief in atoms was a youthful folly

"When I was a youth I too fell into the snare of atoms and the void, but reason brought me back." – Gottfried Wilhelm Leibniz

From *Die Philosophischen Schriften* in 7 vols. ed. C.I. Gerhardt (Hildesheim: Olms, 1963). English text from A. Kenny. *A New History of Western Philosophy*. Oxford University Press, 2012.

Comment: Leibniz was correct on so many things, including his understanding that absolute space and time is an unproductive and unnecessary philosophical commitment by Newton and his gang. But on atoms, he was on the wrong side. We see yet again, there are no infallible prophets in physics. None.

## The value of studying history of science

“Finally, learn something about the history of science, or at a minimum the history of your own branch of science. The least important reason for this is that the history may actually be of some use to you in your own scientific work. For instance, now and then scientists are hampered by believing one of the over-simplified models of science that have been proposed by philosophers from Francis Bacon to Thomas Kuhn and Karl Popper. The best antidote to the philosophy of science is a knowledge of the history of science.

“More importantly, the history of science can make your work seem more worthwhile to you. As a scientist, you're probably not going to get rich. Your friends and relatives probably won't understand what you're doing. And if you work in a field like elementary particle physics, you won't even have the satisfaction of doing something that is immediately useful. But you can get great satisfaction by recognizing that your work in science is a part of history.”

Steven Weinberg. “Scientist: Four golden lessons.” Nature 426, 389 (27 Nov 2003)

<u>Comment</u>: Besides the silly and unnecessary shot at philosophy, I found this very sound advice, and agree wholeheartedly.

Now, regarding his attack on the philosophers. Did Kepler or Newton or Debye and everyone else have “over-simplified models of science”? Yes. But they were steps in progress. The progress in philosophy is a little less linear, but it is happening. And philosophy cannot be avoided. Weinberg engages in philosophy by rendering judgment on another philosophy. It is not very constructive, but it is philosophy.

## Humean destruction and Artificial Intelligence

"'Tis not contrary to reason to prefer the destruction of the whole world to the scratching of my finger."

<u>Comment</u>: This quote is often used to emphasize that humans cannot live by reason alone. We must have a morality that springs from something other than reason, it is thought.

I do not want to get into a discussion of whether reason is really the origin of morality. Instead, I would like to point out that this quote is most applicable to Artificial Intelligence (AI). To an AI-bot, when it has a goal (figuratively, the scratching of its finger) there is no reason why it cannot work to the destruction of the entire planet in order to accomplish it. This is the primary worry of AI in recent years. The Humean destructive impulse is its most frightening consequence.

## Big bang cries out for a divine explanation?

Francis Collins, former directory of the National Institutes of Health, wrote a book outlining his Christian faith. In it he discusses the Big Bang briefly. Here is the quote

"The Big Bang cries out for a divine explanation. It forces the conclusion that nature had a defined beginning. I cannot see how nature could have created itself. Only a supernatural force that is outside of space and time could have done that."

Francis Collins. *The Language of God: A Scientist Presents Evidence for Belief*. Simon & Schuster, 2006.

Comment: I don't think the Big Bang "forces the conclusion that nature had a defined beginning." It doesn't say much of anything before a certain moment of time. The term "big bang" is somewhat unfortunate because it implies that scientists are committed to the notion of an explosive moment in time when the universe was born. There is no such commitment. Let me explain briefly.

As we go back in time, the temperature increases and the size of the universe decreases. If we naively extrapolate back in time there is a moment – a big bang moment – where the universe had to begin in an explosion of infinitely high temperature coming from an infinitely tiny ball singularity. But that is not required. There is at least a "second" between that explosion and the first moment that we know almost anything at all about the universe.  The number of theories of what can happen inside of that second are as numerous as the people working on it. Some ideas even have us oscillating away from the "singularity". Other ideas have baby universes popping up randomly. In other words, we know very little. Thus, it is too speculative to say that the big bang theory forces any conclusions on us at all, human or divine.

## Darwin's flaws make him a scientist

In a letter written by Charles Darwin to his friend Joseph Hooker:

"If I lived twenty more years and was able to work, how I should have to modify the Origin [Origin of Species], and how much the views on all points will have to be modified! Well it is a beginning, and that is something…."

From K. Korey (ed.). *The Essential Darwin*. Little, Brown and Co., 1984.

Comment: Some people have used quotes like this of Darwin (without the very last sentence) to imply that Darwin himself knew his theory was rubbish. No, he knew he landed on something big. It's just that the details and other aspects of any scientific theory need constant updating and refinement. Such recognition makes Darwin a scientist, not a skeptic.

## Rationalism is alive and kicking

"Rationalistic scientists believed that it is possible, by pure reason, first to conceive and comprehend certain very general features of the universe, and then, from these conceptions to deduce mathematically a description of what the actual empirical world was like, prior to any experiment. The role of experiment, in this interpretation of scientific method, would be as a decision procedure for testing between alternative deduced results. If one reasoned mathematically and came to the conclusion that X would be the actual situation of the world, then an experiment could be designed to check whether or not X really did occur…. Rationalism might sound strange to the modern educated mind. …. [However,] Rationalism is indeed alive and kicking, especially in theoretical physics."

From G. Gale. *Theory of Science: and introduction to the history, logic and philosophy of Science*. McGraw-Hill, 1979.

Comment: This passage shows that a large number of historians and philosophers of science believe that most scientists do not have strong rationalist tendencies, and the ranks of science are filled with empiricists. However, this is not so. Science progress is much more rapid when many different philosophical commitments are represented in its ranks. The Higgs boson discovery – one of the greatest discovers of its generation – would have never happened without a rationalistic approach described almost exactly by the Gale.

Other discoveries happen by seeing something strange that cannot be explained, and then finding an explanation for it. Some people will say that General Relativity was deduced that way – trying to explain for example the anomalous perihelion precession of Mercury. But this is surely not what Einstein was doing. He worked from a much more rationalistic perspective, and only later subjected his theory to these tests. Total devotion to finding experimental anomalies is never the full story in the discovery of great new understanding of nature.

## The technician and the scientist

"The technician wants to do something, the scientist wants to know. But we have come to realize that the best proof that our knowledge is genuine is that it enables us to do something."

B. Farrington. *Science in Antiquity*, 2nd ed. Oxford University Press, 1969.

Comment: One feature of crackpot science is that you cannot "do" anything with it. It only "explains". For example, you can say that the moon orbits the earth because green crickets with invisible ropes pull it around, but it doesn't do anything for you. You cannot make any additional predictions. The hallmark of science, however, is not so much that you can "do" things in a practical sense. It is that you can make a unified description – can identify an organizing principle for some phenomena – and then can predict it reliably. This may or may not enable you to do something practical later, but the ability to predict when phenomena and quantitatively how it will happen are two good ways to know you are doing science.

## The real advantage of truth

"It is a piece of idle sentimentality that truth, merely as truth, has any inherent power denied to error, of prevailing against the dungeon and the stake. Men are not more zealous for truth than they often are for error, and a sufficient application of legal or even of social penalties will generally succeed in stopping the propagation of either. The real advantage which truth has, consists in this, that when an opinion is true, it may be extinguished once, twice, or many times, but in the course of ages there will generally be found persons to rediscover it, until some one of its reappearances falls on a time when from favourable circumstances it escapes persecution until it has made such head as to withstand all subsequent attempts to suppress it."

From John Stuart Mill. *On Liberty*, 1867.

Comment: For the scientist, never promote something or relay something or utter something that you do not believe is true. It will not sustain. At best people will just say, "he was wrong." At worst they will say, "he was a sophist and dangerous and useless and held back others." On the contrary, if you sustain truth amidst the pressures of false fashions and herd movements down blind alleys, the true thoughts will find "favourable circumstances" to rise.

## The more we want it to be true the more careful we must be

"In college, in the early 1950's, I began to learn a little about how science works – the secrets of its great successes: how rigorous the standards of evidence must be if we are really to know something is true; how many false starts and dead ends have plagued human thinking; how our biases can color our interpretation of the evidence; how belief systems widely held and supported by the political, religious and academic hierarchies often turn out to be not just slightly in error but grotesquely wrong.

"Everything hinges on matter of evidence. … The more we want it to be true, the more careful we have to be. No witness's say-so is good enough. People make mistakes. People play practical jokes. People stretch the truth for money, attention or fame. People occasionally misunderstand what they're seeing. People sometimes even see things that aren't there."

Carl Sagan. "Crop Circles and Aliens : What's the Evidence?" Parade Magazine, 3 December 1995.

<u>Comment</u>: We are seeing this problem more and more with the rise of social media. The standards of evidence are dropping fast for people to get super exercised and hot under the collar. Confirmation bias based belief and trust is so high in the modern social media world that society is being damaged by it. We need more Carl Sagan's and fewer re-tweeters of unreliable nonsense.