Darshana Jolts

More on Matter

V V Raman

I regard consciousness as fundamental. I regard matter as derivative from consciousness.
–Max Planck

Mass, Measure of Matter: ***Matter can be measured; this measure is different from its weight.***

A characteristic of matter is its resistance to change in its state of motion. When push comes to shove, matter tends to oppose. It is as if it reacts reluctantly to any effort to change in its state of motion. It has, in the terminology of Hindu philosophy, a *tamasic* quality[1]. The degree of resistance to change may be taken as a measure of the amount of matter contained in the body. We refer to this as the body's mass[2]. Since ancient times matter used to be measured in terms of the weight of a body. It was only after the emergence of modern science that the difference between mass and weight was clearly understood[3].

The conventional unit of mass adopted by the scientific community is the *kilogram*. It is officially defined as follows: "The kilogram (unit of mass) is the mass of a specific cylinder made out of an alloy of platinum and iridium, which is considered as the international prototype of the kilogram, and is maintained under the care of the International Bureau of Weights and Measures in a vault at Sèvres, France[4]."

Every material concentration, whether in the solid, liquid, or gaseous state, consists of a certain amount of matter, i.e., it has a certain mass. As we survey the things around us, some, like particles of dust and grains of sand, have very little mass; while others, like giant boulders and mammoth mountains, are considerably more massive. In other words, things like molecules and atoms have masses woefully minute, while the moon and the sun have masses much more than

[1] In *Samkhya* philosophy, three basic principles (*gunas*) keep the world and the human body in balance: *sattva*, *rajas*, and *tamas*. In terms of their attributed qualities, these would correspond to radiance, activity (kinetic energy), and inertia. In the traditional view, they have also impacts on the human state of body and mind.

[2] It is important to distinguish between the inertial mass thus defined and gravitational mass, but the two are equivalent. This understanding was at the basis of Einstein's general theory of relativity which revolutionized the classical Newtonian notion of gravitation as a force of attraction between massive bodies.

[3] Technically speaking, weights should not be expressed in kilograms, but in newtons.

[4] There is a proposal to re-define the kg in terms of a fundamental constant. This is expected to be done by or after 2015.

anything in our neighborhood, except for the earth itself which, after all, has a stature in the planetary arena.

Astronomers talk about the mass of this planet or that star. But people seldom wonder about how one came to compute the mass of the earth or the moon or the distant sun. This question is important in that if one reflects upon it, one may not as easily declare that science is only one mode of acquiring knowledge about the world, and that modern science is no more than a Western cultural construct. Human eyes have to peer through tubes contrived with lenses and mirrors, the mind has to construct concepts and theories, and investigate the world with the aid of mathematics. It is only when we are fortified by these that we can form fair and precise ideas of how massive celestial bodies are. The conceptual and methodological framework of modern science is as important, powerful, and indispensable as the countless instruments that support it.

Here is one domain where the real excitement of science may be found: the ingenious and imaginative ways by which unreachable entities are brought within our measurable grasp. The not-directly perceived dimensions of perceived reality are tracked down one way or another. It is easy to discourse on the limitations of the scientific method, or extrapolate its results into the speculative theories of distant generations. But no intuitive insight about the nature of things, however penetrating, has ever led to statements of significance on the masses and distances of planets or binary stars, indeed relating to any measurable aspects of the world.

Conservation of Matter: ***The total amount of matter in a closed system cannot increase or decrease.***

When the magician pulls out a rabbit from an (apparently) empty basket, we instinctively feel that he has fooled us. When a revered god-man brings something out of thin air, we say he is performing a miracle. When a trickster makes a coin disappear, we take that to be prestidigitation, for we know that something simply cannot vanish into nothing. Even little children chuckle when they see such sleight of hand. All this because we realize that something cannot come out of, nor disappear into nothing. It is not surprising that many ancient schools of philosophy stated explicitly that matter cannot be created out of or destroyed into nothing[5].

But we also know that a brand new rabbit can come out of mother rabbit, and a huge tree can grow from a tiny seed. A piece of candle seems to disappear altogether, not by the waving of a magician's hand, but by slow and steady burning. Modern science has discovered that in all such cases, chemical transformations have occurred.

[5] The Roman poet Lucretius wrote in *De Rerum Natura* (l55–l56) *Nil posse creari de nilo:* Nothing can be created out of nothing. It was a tenet of classical Jaina philosophy that a substance is indestructible but its modes can be created and destroyed [Devendra (Muni.), T G Kalghatgi, T S Devadoss, *A source-book in Jaina philosophy* Udaipur: Sri Tarak Guru Jain Gran., 1983].

More significantly, modern science has uncovered the non-vanishing aspect of tangible matter at the quantitative level. *Matter may change form, but not in quantity*. Thus, if we have wood and air in a sealed enclosure, and the wood burns, at the end of the process when all that is left in the container are ashes, carbon dioxide, carbon monoxide and other gases, we will find that the enclosure plus its contents weigh precisely the same after as they did before the burning started. This is a principle of fundamental importance in our understanding of the physical world. This is the quantitative aspect of the 'nothing from or into nothing' principle of common sense and ancient science. We refer to this as the *law of conservation of matter*. In the words[6] of its first formulator, Antoine Laurent Lavoisier, "in every operation, there is an equal quantity of matter before and after the operation."

This *quantitative* truth about matter transformation could not have been known before precision-weighing was introduced in the 18th century as part of the scientific investigation of chemical reactions.

Like a great many scientific insights, the principle of matter conservation had to give place to a more refined version of it. Unlike in inspired cultural history, a good deal of scientific progress consists in improving upon or replacing the ancestral worldviews of past generations about the nature of the world.

Total Matter in the Universe: ***We can dare to estimate the mass of the whole universe.***

The astrophysicist and popularizer of science Arthur Stanley Eddington once said teasingly[7], "I believe there are 15,747,136,275,002,577,605,653,961,181,555,468,044,717,914,527,116,709, 366, 231,425,06,185, 631, 031.296 protons in the universe and the same number of electrons." It really does not matter if the number he gave is exact. What is impressive is the boldness behind it. Measuring mind, which has appeared in the stillness of eternity and is sparkling like the twinkle of a firefly in the utter dark silence of space, declares it has figured out the number of particles in the entirety of the universe! This is far more impressive than a microbe in the entrails of an elephant pronouncing on the dimensions of the beast. Yet this is the kind of thing physicists and cosmologists have been accomplishing. They have measured the world and weighed it too. True, their estimates vary from era to era, each periodic news report modifying or discarding a figure held true for long. Even if we do not know precisely how much matter the universe holds, we do have ways to estimate it by our schemes and systems.

[6] Lavoisier stated this in his classic work *Traité Élémentaire de Chimie* which was published in Paris in 1789, the year of the French Revolution.

[7] Arthur S Eddington, *The Philosophy of Physical Science*, 1939.

The method, in principle, is simple. First we figure out the average mass of a star, then the average number of stars in a galaxy, and then we estimate the total number of galaxies in the universe. All we need to do is multiply these three numbers, and voilà! we have a number for the total mass of the whole universe! Of course, what we derive thus will only be an estimate because our averages and observed numbers are not 100% accurate.

Such estimates serve our purpose in at least two ways: First, they satisfy in part our quantitative curiosity about the world. Second, they enable us to see if the observed data conform to our theories and models about the cosmos at large. But here there has been an impasse.

A Disturbing Divergence: ***Observations and estimates of the total mass diverge substantially.***

Astronomers have been scanning the skies and tracking the rotations of galaxies. They have been measuring with uncanny precision the orbital motions of the minor galaxies that circumambulate our own. More than sixty years ago, Fritz Zwicky surmised from his studies of the motions of galactic clusters that the Milky Way should be far more massive than we had been led to believe by merely estimating the number of visible stars in our system[8]. Indeed the data seem to suggest that our own galaxy must be at least five times more massive than what seems to be the case when only all the shining stars are taken into account!

Could it be that we were too hasty in concluding that much of the matter in the physical universe is to be found in flashing stars? Were we right in imagining that only what is visible exists? If a simple stone lies in pitch darkness, and it does not glow, would it be visible? If tenuous gases filled interstellar space and emitted no visible rays, would we observe them? Should matter necessarily be bright to exist in the stretches of space?

If the Big Bang model of how the universe came to be is right, as is believed by a great many cosmologists today, then there seems to be a disturbing divergence between what the theory says and what our estimates based on observations furnish. Indeed, the estimated mass is a paltry one percent of what one would expect from theory.

In the conventional methodology of science, if the results of observation are drastically different from a theoretical model, one replaces the theory and tries to formulate a new one to account better for observational data. But the Big Bang model is so persuasive in other respects that theoretical cosmologists will not easily yield. Instead, they propose that perhaps there is something missing in our collected data. Perhaps some existing matter has been ignored in our census-report.

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[8] Michael Riordan and David Schramm, *Shadows of Creation: Dark Matter & the Structure of the Universe,* New York, 1991.

It is entirely possible that the universe is far more massive than what we had thought. Maybe there is more than mere cosmic dust in the expanse of interstellar space. Maybe there are vast amounts of *dark matter* in the heavens.

But what is this dark matter that, we think, pervades the world? Various hypotheses have been presented: That this was made up of neutrinos that are known to be zooming through every region of space and through every star in the world; that it consists of splinters from the primordial blow-up that caused the universe in the first place, messy discharges that accompanied cosmic birth; that it is simply a grandiose collection of non-luminous rocks and planets, much like the asteroids of our own solar system, and/or sterile stellar debris, worn out remnants of pulsars and pent-up stars, a great many in number, but mere dead-weight in the throbbing stellar multitude[9]. Finally there is the idea that this dark matter is made up of tachyons[10].

Searching for a descriptive acronym, astronomers have hit upon MACHO to describe such matter: *MAssive Compact Halo Objects*. It also conveys the dominant role such matter plays in directing galactic motions.

Antimatter: *Every kind of ultimate material entity has, in principle, a charge-wise and otherwise mirror image.*

Many aspects of perceived reality strike us by symmetries, explicit or implicit. In the petals of flowers, in the shape of leaves, and in the forms of animals majestic; in spatial directions and temporal progression. Even with ethical principles like good and evil, and human experiences like pain and pleasure, there are symmetries that impress the mind. Poets, artists, mathematicians and philosophers, all have described, captured, analyzed and reflected upon this ubiquitous feature in the physical world. Not surprisingly, it has also been forced into the physicist's recognition of the nature of matter.

Recall that the matter we are familiar with in the world of everyday experience is ultimately made up of atoms. The atoms, as noted earlier, consist of electrically charged sub-units: negatively charged electrons and positively charged heavier protons. Now, we may wonder why there is this asymmetry between proton and electron. Why cannot there be a positively charged electron and a more massive negatively charged proton?

It follows from theoretical considerations into the nature of the micro-world that if there is an electron in the physical world, there surely must be another particle, its electrical reflection as

[9] See in this context, Dan Hooper, *In Search of Our Universe's Missing Mass And Energy*, Harper Collins, 2006.

[10] H M Fried and Gabellini, *Astrophysical Implications of Massive, Charged Tachyons*, ArXiv. Heo-th/0709.014.

it were, identical in all respects except for the charge. In other words, there must be a positive electron[11] and a negative proton. In fact, this statement holds for every fundamental particle in the universe. This theoretical conjecture was a conclusion from the mathematical exploration of the microcosm[12]. It was confirmed not long after it was formulated: positive electrons were in fact detected in what are called cosmic ray showers at high altitudes. We describe such reflections of ordinary matter as *antimatter*[13].

Thus, an atom of anti-hydrogen will be made up of a negative proton with an orbiting positive electron. If such matter exists, one may envision anti-planets, anti-stars, and anti-galaxies somewhere out there constituting an anti-universe all by itself! But there are technical (conceptual) difficulties in accepting the existence of stellar and galactic globules of anti-matter.

Then, where is one to get a grain of anti-sand, say, just to see and study? It turns out that matter and anti-matter, like fire and water, simply cannot co-exist. When there is an encounter, they destroy each other instantaneously. Anti-matter is more than inflammable. It can vanish and make vanish any speck of ordinary matter it may come in contact with: both will be transformed into a flash of insubstantial radiation. That is one reason why we do not detect such anti-materials in the world around.

Yet, in the complex mammoth furnaces of present day physics, known as particle accelerators, physicists routinely create anti-matter to understand more about the nature of the material world[14]. Bits of anti-matter come and go in fleeting swiftness, but leave enough trails for us to study their properties. They are also emanated from the nuclei of radioactive elements[15].

[11] The positive electron is known as positron.

[12] The existence of the positron followed from P A M Dirac's classic paper in which he derived a relativistic equation for the wave function of the electron: 'The Quantum Theory of the Electron'. *Proceedings of the Royal Society of London. Series A, Containing Papers of a Mathematical and Physical Character,* Vol.117, pp.610–624, 1928. This is comparable to Maxwell's discovery of electromagnetic waves via his equations. In technical *particle physics* one talks about *charge conjugation*, by which one means that in any elementary-particle interaction we replace every particle by its antiparticle. It turns out that when this is done the rate of the interaction is not affected in any way. This phenomenon is referred to as charge-conjugation (or simply C-invariance). This holds for all *strong* and *electromagnetic interactions*, but not for *weak* interactions. For a popular treatment of this topic, see Kenneth Ford, *World of Elementary Particles*, Blaisdell Publishing Co., 1963.

[13] For more on this, see Frank Close's excellent book, *Antimatter*, OUP (2009). The science fiction *Star Trek* has popularized the idea of matter-antimatter. Here a spaceship is fueled by matter-antimatter annihilation.

[14] High energy accelerators periodically report the creation of small quantities of anti-particles and anti-matter. It has been estimated that it would cost more than 250 million US dollars to produce 10 mg of positrons, and several trillion dollars to produce a gm of anti-hydrogen.

[15] Positron Emission Tomography (PET) is a technique for examining tissues. It uses radioactive isotopes such as Carbon-11 and Nitrogen-13 that emit positrons. In 2005 there was a report to the effect that positrons had been used to attack malignant cancer cells in rabbits.

Now one may ask, why is there this imbalance in the cosmos where positive protons and negative electrons dominate, rather than their anti-pairs? It is believed that this was not always so. In the very distant epochs of cosmic infancy, when the universe was hot beyond imagination and as yet barely beginning to manifest itself, there were equal amounts of both. And then something happened which brought about a complex symmetry-breaking mechanism which caused more particles (such as we know them) than anti-particles to emerge.

So here we are, condemned to eke out our existence in this world of matter where electrons are negative and protons positive. It is very likely that if the symmetry had been broken in the other's favor, we would be wondering why we were in that other kind of world.

Annihilation and Creation of Matter: ***Matter can be created and destroyed.***

In 1851, basing himself squarely on the findings of the scientists of his own era and relying on intuitively suggestive views, Herbert Spencer, an eloquent spokesman for science in the 19th century, proclaimed[16] that "The annihilation of matter is unthinkable … that the creation of matter is unthinkable...". How naïve or downright wrong the emphatic assertions of generations past sometimes sound from the vantage point of current knowledge!

Today it is general knowledge that Spencer's statement is not quite true. We have come to know that matter too can be destroyed. In 1905, two years after Spencer passed away, Einstein propounded his famous theory of Special Relativity one of whose corollaries is that matter and energy are equivalent and can be inter-converted. What this means is that firm and tangible matter can be annihilated, that is to say, literally blown out of existence, with the consequent production of an equivalent amount of energy[17].

In the accelerators of high energy physics countless elementary particles (the ultimate units of material reality) are being continuously created by human ingenuity. If it will add to human pride, let us note that it is not simply in bringing back a dying person to life and health that humans play God: one might add that when they create matter out of apparent nothingness, or crush solid stuff into ethereal naught, then also frail humans imitate their Creator.

Matter and Life: ***Many ultimate blocks of life can be synthesized in the laboratory.***

It is an ancient and continuing controversy: Is there more to life than mere matter? Are creatures simply automata, robots running around, powered by chemical, instead of electric, batteries? Is man a mere machine, his brain secreting thoughts as his liver secretes bile[18]? Is life just a system

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[16] Herbert Spencer, *First Principles of a New System of Philosophy*, D Appleton, New York, p.158, 1864.

[17] The most famous formula of modern physics, $E = mc^2$, embodies this result.

of bio-molecules, functioning as per the laws of chemistry, more complex surely than the most sophisticated gadget, but in essence not much different? Are we mere blobs of flesh and bones, or something more?

The debate dates back to the dawn of philosophical reflections. We all know the material dimension of life, but not all agree on its possible non-material aspects. It is easy to define the characteristics of life and decide the difference between life forms and machines on that basis, but this solution becomes fuzzy at the lowest rungs of life, and at the highest levels of machines. A significant partial answer to the age-old question came in the 19th century when the chemist Friedrich Wöhler synthesized urea, an organic compound, from ammonium cyanate, a laboratory chemical[19]. He famously wrote[20] to fellow chemist Jacob Berzelius: "I can no longer, as it were, hold back my chemical urine; and I have let out that I can make urea without needing a kidney, whether of man or dog."

The rest, as the expression goes, is history. Since then, more and more of the substances normally secreted in living organisms have been routinely synthesized in bottles and beakers. Today, as Victor Weisskopf put it[21] succinctly, "Chemical analysis has shown beyond a shadow of doubt that living objects contain the same kinds of atoms as non-living things."

Beyond that, probing through its own spyglass of concepts and data, science has come up with its own version of the genesis of life from brute matter. Known as *chemical evolution*, this scheme rests on the principle that many of the fundamental attributes of life may be tracked down to the properties of complex chemical structures (biochemical molecules), and on the fact that under appropriate conditions some of these molecules may be synthesized in nature or in the laboratory. The two most important types of such fundamental molecules are proteins and nucleic acids. These are very large-size molecules at the atomic level. They result from chain-like combinations of a number of smaller molecules which more or less resemble one another. The question then is: How did the first proteins and nucleic acids come about?

It is suggested that in the remote past, more than three billion years ago, and barely a billion years after the formation of our planet, there were lands barren and waste, volcanoes steaming and puffing sulfuric fumes, and oceans of salt-free waters. The earth's atmosphere consisted

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[18] This was the simile used by the eighteenth century thinker Pierre Cabanis: *Le cerveau sécrète la pensée comme le foie sécrète la bile*: The brain secretes thought as the liver secretes bile.

[19] See in this context, John H Brooke: "Wöhler's Urea and its Vital Force – A Verdict From the Chemists," *Ambix,* Vol.15, pp.84–114, 1968.

[20] Quoted by Robin Keen in "Friedrich Wöhler", DSB, XIV, New York, p.474b, 1975 .

[21] Victor F Weisskopf, *Knowledge and Wonder: The Natural World as Man Knows It*, Anchor Books/Doubleday & Co., New York, p.199, 1963.

largely of hydrogen, ammonia, methane, and a few other gases. Gigantic clouds and torrential rains rose and fell, seeping salts from land to pristine sea. In the mammoth laboratories of the earth's oceans and airs, kindled by heat and lightning, by radiations from the sun and by other excitants, the turbulent chemistry of the early molecules churned out the first organic structures. Carbohydrates and amino acids were thus concocted. These increased in complexity as further reactions took place. The waters of the period constituted what is described as a *primordial soup* in which mutual interactions of the components gave rise to molecules of ever-increasing size and intricacy. Energy trapping mechanisms came into play. After a myriad patterns and permutations, mysterious entities with the property of self-replication emerged. These again grew in numbers and variety, until at last nucleic acids and proteins were formed. The miracle of life had begun[22]. This fascinating idea with some empirical support is not universally accepted by all biologists.

Matter and Mind: *Mind emerges from the brain.*

What is this fleeting entity under the human skull that inquires and analyzes, reflects and reasons, comprehends, calculates and creates? What is this mind that is at the root of all our philosophies and literature, religions and sciences? Is it merely a consequence of the ultimate structures that grid the brain? Is it, in other words, just physics and chemistry at extraordinarily complex levels? Is it a mere macro-property of molecular vibrations?

Poets and philosophers have spoken about the powers of the mind. Manilus of ancient Rome declared[23] majestically: "Nothing can withstand the powers of the mind. Barriers, enormous masses of matter, the remotest recesses are conquered. All things succumb. The very heaven itself is laid open."

Every accomplishment of the human spirit has involved the mind. Illnesses have been controlled and cured by the powers of the mind. Tales, ancient and modern, have painted mind-power over brain(matter)-power. Some believe that there can be a mind without body. In certain mythologies the mind leaves the body, travels far and wide, and comes back like a homing pigeon. In others, it can suck in information about events occurring in far away places, or about events yet to transpire. It has been argued on the basis of quantum mechanics that the mind is an open system and can work more wonders than it already has. But on the basis of what is normally observed, more often than not, it is man who goes to the mountain than the other way around.

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[22] This theory of chemical evolution has not been universally accepted by all biologists.

[23] Marcius Manilius, *Astronomica*, Bk i, 541.

We can throw a monkey-wrench in the normal functioning of the mind by polluting the brain. A modicum of mescaline will do the job. When disease invades the brain, or brain cells age, the mind withers too. Destroy the matter composing the brain, and off goes the mind with it. All the talk of mind over matter is true only up to a point. One is obliged to concede that mind is subservient to matter. Ultimately, matter triumphs, at least on our scale.

All this does not negate the fact that more marvelous than the routine life-throb of the universe is the human mind: a flicker perhaps in the cosmic sea, but a mysterious light it is that shines brighter than any galaxy, for, but for mind, all the grandeur and glory of the world would remain unsought, un-experienced, and unsung. All our knowledge, understanding and experience of matter results from consciousness. In this sense, Planck (in the quote at the beginning of this essay) correctly echoed the Hindu view.

So science suggests that matter is more powerful, and that mind emerges from matter, but it is equally appropriate to claim that mind is more meaningful, for, as the poet said[24]:

Man's mind's a mirror of heavenly sights,
A brief wherein all marvels summèd lie,
Of fairest forms and sweetest shapes the store,
Most graceful all, yet thought may grace them more.

[24] Robert Southwell, 'Look Home', lines 3–6.

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On the Nature of Heat: Vol.16, No.2, pp.190–199, 2011;
Sound: The Vehicle for Speech and Music, No.3, pp.278–292, 2011;
Light: The Revealer of Chromatic Splendor, No.4, pp.359–371, 2011;
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V V Raman is Emeritus Professor of Physics and Humanities at the Rochester Institute of Technology, Rochester, New York 14623, USA. He is available for giving Skype lectures in Indian universities.
Email: vvrsps@rit.edu
http://en.wikipedia.org/wiki/Varadaraja_V._Raman