We Hear From

Readers are invited to express their views not only on matters published in this medium but also on their independent thoughts published in other science-related topics. Do not allow your ideas to die away. What appears to be naive or bizarre to you may ignite others' thought process and become useful.

Vinod K Gaur, Hony Professor, CSIR Fourth Paradigm Institute, Bangalore talks to Simar Kohli, Founder-member of the RIAZO* Production & Curation Co. on the basis of an Interview for producing a film about

'The Future Earth'

Q. Could you spell out the three things that a lay person should understand about the Universe

Answer: In my view, the first idea that we need to grasp about the Universe is, that it is not *capricious*, meaning that its behaviour is not subject to moods. Indeed, the regularity of many phenomena in the universe and the recurrence of certain structural forms in its diverse realms such as the spirals of galaxies, storms, and sea shells, engenders the belief that the Universe operates strictly according to some Governing *Laws*. And, that these laws are founded on some fundamental *Principles* that may be understood through a systematic enquiry. To discern these principles in the visible works of the universe has been the prime goal of natural philosophers which led to the scientific method aimed at analyzing the processes behind the appearance of phenomena in the universe. This begins with hypothesizing imaginative arguments to explain a natural phenomenon and designing revelatory experiments including thought experiments to test their tenability through observations and deductive reasoning.

Results from a wide range of such investigations lead to the inference that the canonical principles embodied in the infinitely faceted universe are: i) **Parsimony**, that is the *Economy of Means* in its various operations: the shortest path, the least action, the minimum expenditure of energy, and ii) **Constancy** irrespective of the place and time of its operation, that is, *symmetry* with respect to space and time in the universe..

The second idea to grasp about the universe is its openness to try out every possibility at structure formation that the governing laws will allow. The result is the spontaneous generation of a bewildering variety of unique forms in the universe each potentiating further differentiation by enriching the of the gene pool menu. The great diversity of structural forms so created, in turn, greatly expands the

* RIAZO is a production and curating company named after the word ' ri:az' meaning 'practice' in art and music. Riazo is dedicated to the vision of creating a sustainable, just and harmonious planet by catalyzing a fellowship of sensibilities through text, images, illustrations, films and evocative programmes

opportunities for their forging complementary partnerships to self organize into more complex structures, such as the earth itself with its myriad forms of life and their social organizations. An important lesson here that the universe teaches us is to recognize the value of free interplay within a system, constrained only by the canonical laws. For, it is only through new synergies which free interplay can potentially generate, that a system moves forward. A corollary to this proceeding is that progress to higher levels of organization and purpose which can only happen through a higher level of synergy between evermore viable components of a system, depends on the wholesomeness of even the smallest of the constituent subsystems. This condition underlines the critical role of *diversity* in ensuring the stability of an organized system. It is equally true for social systems which, for creative mutations to sustain and embellish civilization, requires a large *gene pool of diversity* , a condition that can only be guaranteed by the ineluctable ethic of caring and protecting its marginalized communities.

The third important idea to grasp about the universe is that its various elements are interconnected at a deeper level which is not immediately obvious. From galaxies down to an atom in our bodies, these elements are multiply connected through a web of energy flows. The haemoglobin molecule in our veins that transports vital oxygen to all parts of the body has an iron atom at its centre that was cooked in the interior of a star from hydrogen and helium which had earlier nucleated out of the primordial energy of the big bang. In another vital chain, the sun's energy is harvested through chlorophyll molecules of the plant world and stored as bond energy of carbohydrates that fuels the growth and survival of the entire animal world. Interestingly the two key molecules of the above chains i.e., the haemoglobin and chlorophyll which perform their respective functions essentially by transporting electrons and delivering them at sites where they are needed, have near identical structures, the former built around the element iron and the latter around magnesium – an example I believe of Nature's practice of the principle of Parsimony.

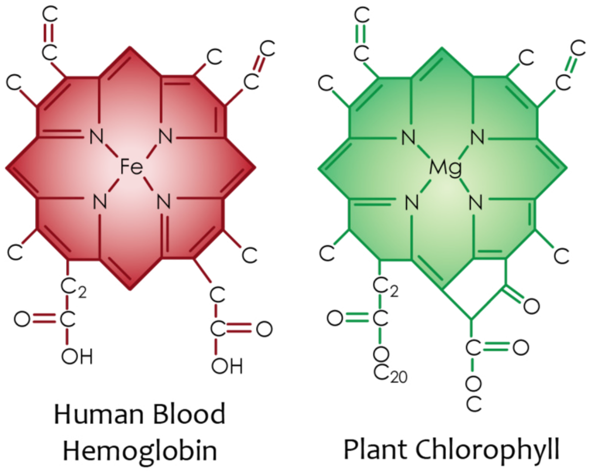

Figure 1 shows the near identical structures of haemoglobin and Chlorophyll, the two key molecules in the chain of processes that virtually transform sun's energy into creating and sustaining the living world

The universe has thus successively built evermore complex network of dynamically coupled structures over the 14 billion years of its existence through the free interplay of their precursors. These composite forms, being comprised of several interactive subsystems such as planet earth, have to ceaselessly adjust their dynamic to feedbacks between the subsystems. In consequence, they are forever transforming, often through catastrophic transitions when accumulated effects of feedbacks reach a tipping point. Change is, therefore, an intrinsic aspect of the workings of the Universe producing a never ending sequence of new futures. But, the Universe is indifferent to the fate of particular existences as mass extinctions of the past geological ages remind us, except for their longevity determined by the tenability of consequent phenomena such as unlimited growth at the expense of diversity. Thus, there is no special place for any particular event or structure in the workings of the Universe. In this respect, human preoccupation with the development of its civilization which, in recent decades has been advanced at the expense of other living forms and their ecosystems, has little likelihood of being favoured for longevity in the Universe.

Q. Are there beautiful or perfect theories in Science ?

Answer : It is an interesting question because it begs two other questions: what is beautiful?, and, What is a theory?

The answer to the first question may appear to be subjective. In my personal experience, however, the 'beautiful' has always been associated with an intensely moving experience, irrespective of the mode of perception: words, music, vision, an empathetic touch, even intervening silences, as if the perception of beauty even though variously formed, shared some canonical attributes to set into resonance a certain special fibre of my being. The possibility of the outer world creating resonances of the mind is of course not entirely unexpected since the very processes that fashioned the universe were involved in the evolution of our consciousness. I, am therefore, inclined to believe that it is the selfsame recognition of parsimony that is recognized as the quintessential attribute of *beauty*: the minimal form, perfect without superfluity, lean yet richly pregnant.

And the theory? It is an imaginative framework of deductive reasoning to explain an observed phenomena that the universe exhibits, which also has the possibility of implying new phenomena whose truth or otherwise can be tested through new observations. Occasionally, however, when new emerging scientific advances discover an exception –a new witness with some irreconcilable evidence, the framework is strained and is eventually replaced by a more expansive theory. Subject to this ever present threat of being deposed, there cannot, therefore, be a perfect theory even as it appears beautiful

Returning to your original question, therefore, and in light of my understanding of its first and last terms, I find the Einstein's theory of General relativity, very beautiful. It offers a deeper vision of the fabric of the universe, which he had earlier shown by his theory of Special Relativity to be woven with the warp and weft of space and time. In this 4 dimensional universe of space (3D) and time (1D) , the earlier theories of classical mechanics and electromagnetism which, whilst successfully explicating a host of apparently unconnected phenomena, had remained mutually inconsistent, found a natural reconciliation. What the General Theory accomplished, was the recognition of another beautiful attribute of the space-time fabric: its support of material bodies in the universe by warping, in the manner of a stretched trampoline surface that dents to hold a ball in the middle. The theory is beautiful because the calculated warping of the space-time fabric deflects the course of moving bodies in the vicinity of matter in exactly the same way as its purported gravitational attraction would do, thus making the erstwhile separate law of gravitation a natural consequence of a warpable space-time universe. It is beautiful because it allows one to deduce further corollaries implicit in its theoretical framework: time dilatation, equivalence of matter and energy, bending of light by massive stars and an expanding universe – all of which have since been confirmed. Scientists, however, continue to search as Einstein did himself, believing in the principle of Parsimony, that there yet remains to be discovered the ultimate theory of everything which would, in a single framework, unify all the fundamental forces of Nature from the strong force that binds the atomic nucleus to the ubiquitous force of gravitation that organizes the whole universe. This search, if and when it is realized, might perhaps come closer to producing a theory which is both beautiful and perfect.

I should, however, mention here a deeply hidden relationship in the workings of the universe which vastly expands the reign of its two canonical principles that I referred to earlier: *parsimony* and *symmetry*. This was unravelled by the prescient imagination of the much wronged German Jewish mathematician Amalie Emmy Noether who showed that the Conservation Laws of mass, energy and momentum which control all transformations of matter and energy in the universe, are indeed a consequence of these very principles.

Q. Science seems to be a private pursuit. Darwin came up with the theory of evolution almost alone. Is it possible to work like that now?

Answer: The Scientific Imagination is indeed an intuitive activity and in that sense 'private', but intuiting a theory is a highly disciplined activity in that it must be consistent with whatever has already been confirmed by observation and incisive analysis. Every new proposition therefore, howsoever novel in approach, draws upon generations of formulated knowledge and can be traced as Eliot said, *"to old stones that cannot be deciphered"*. Darwin, too, owed a debt to the naturalist Charles Lyell whose theory that the world had gradually changed over long periods of time, had greatly influenced him and perhaps induced him to pack a copy of Lyell's 'Principles of Geology ' in his luggage when he sailed on the Beagle in December 1831. Lyell had based his theory on careful observations of several earth features such as uplifted terraces that suggested a sequence of long acting events. Darwin, an obsessive explorer of the natural world, found his own evidence of Lyell's assertions when taking advantage of the ship's halt in Cape Verde Islands, he discovered a white band of sea shells within a cliff face about 45 feet above sea level, pointing to the long process of their slow deposition as seen happening today, and their subsequent uplift. These geological evidences demanding a long age for the earth must have given Darwin's imagination a free rein to contemplate the evolution of life which would also require billions of years to attain its present state.

An important lesson, however, to be learnt from Darwin's explorations and his prescient theory is the importance of asking the right questions whose answers may lead to a unified explanatory framework capable of elucidating the maze of curious observations. For example, after having observed the fossil records of dead species of mocking birds and the subtle differences in their live samples collected from the different islands of the Galapogos, Darwin began wondering about their interconnections. He posed three significant questions as to how may the living species be connected to i) extinct species, ii) similar species in the same neighbourhood, and iii) species separated by land or sea barriers. And, he cogitated over these questions for several years after his return, as he examined his samples in greater detail. A possible trigger to his ideas of evolution could have been the essays by Malthus who had argued that competition for space and food constantly pruned a population to fit the carrying capacity of the land. Darwin carried this idea further: Since the population of living beings had a tendency to multiply exponentially, outstripping the supportive resources, only those individuals of the species who possess competitive traits will survive the struggle for existence and leave a more viable progeny through a progressively changing contest.

Science seems to me to proceed in much the same fashion today. Puzzling questions are addressed using the extant theory until exceptions begin to appear and some gifted mind looks at the world in a novel way to work out an expanded theoretical framework capable of explaining both the old and the new.

Q. Is there a rat race amongst scientists?

Answer : Indeed, and it has both good effects and not so good. The race, although most of the Indian academia and research institutions are highly relaxed, can turn over an enormous range of data and information which may be useful in various ways, and even spawn new fields of enquiry. However, it also, has a negative aspect in that it pressurizes even enquiring minds to produce quick, publishable results which forfeits for society the possibility of more creative contributions to new Ideas and Approaches.

Q. Earth Science is a new area of science, is there anything about this that should excite us?

Answer: Experiential learning about the earth is age old, going back to the transition of human society from being hunter gatherers to more settled agriculture. Substantial use of planet earth's land as well as mined resources were already underway by the late 18th century when enquiry driven questions about its origin, age, structure and working began to be addressed on the evidence of observations. Some of these early approaches by the dint of keen observation and analysis, laid the foundations for a systematic study. One of the earliest advance was made by James Hutton a Scottish doctor turned farmer who was fascinated by the curious assemblage of rocks such as fingers of crystalline rocks intruding into what was obviously a sedimentary rock formed from the debris of erosion and deposited under water, before being raised to its present position. Or, neatly stratified beds as in the figure below, overlying a stack of older sedimentary rocks tilted to an almost vertical position. Hutton of course realized that the crystalline rocks must have formed from slow cooling of molten rock rising from the earth's deep. And, having observed the slow processes of sediment deposition on the sea shore, he was quick to grasp the sequence of events leading up to the present scene. Molten rocks buoyed up from the interior create topography; wind and falling rain erode elevated areas and the debris are deposited, compacted and upthrust again in a perpetually driven cycle. Accordingly, the earth continually transforms itself by imperceptibly slow processes as can be seen happening today. Thus, invoking the underlying principle of symmetry that rules the universe, Hutton declared that the features of the earth created in the past ages can be understood in terms of the processes operating today, requiring, in turn, that the earth must have existed for a very long time *"No vestige of a beginning, no prospect of an end"*.

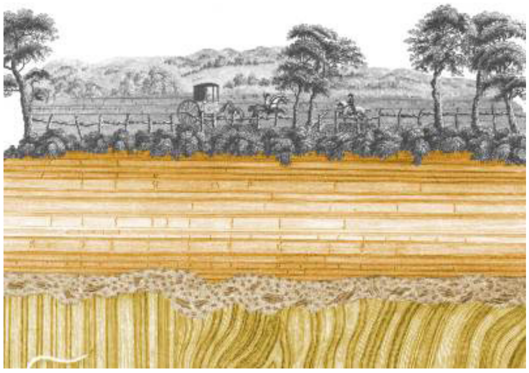

Figure 2 shows a stack of neatly stratified beds overlying another of older and already tilted sedimentary rocks suggesting a sequence of long deposition followed by deformation by earth movements, re-submergence, fresh deposition and uplift to their present position.

These new ideas that Hutton discussed in his book, 'Theory of the earth', published in 1795, stimulated further enquiries in the age and structure of the earth as a physical system. Charles Lyell another Scottish geologist who was born in the year Hutton died, found many evidences of the earth's cyclic processes during his explorations in Europe: rising and falling sea levels, sequential volcanic eruptions happening on top of the earlier ones and successively tilted rock suites. With many such clinching observations, Lyell further consolidated Hutton's ideas into the theory of *Uniformitarianism* which constituted the philosophical bedrock of his book, 'Principles of Geology' that appeared 35 years after Hutton's, and was a part of Darwin's baggage on the Beagle.

Charles Lyell's century, had already inherited revolutionary ideas to explain some of the observed phenomena in the universe through reasoned arguments. Newton's Pricipia formulating the laws of motion and his universal theory of gravitation which applied equally well to both celestial and terrestrial phenomena had appeared in 1687 and Priestley by demonstrating in 1771 how a mouse could be kept alive in a closed jar if furnished with floral accompaniments, had set off the discovery of photosynthesis. This is a key process whereby the earth sustains its living world by capturing the low entropy energy from the sun. Lyell's own book had been preceded by Fourier's 'analytical theory of heat' by 8 years , and his proposition that the earth cooled from a molten state provided an approach to calculate the age of the earth although it would have to wait for over 35 years before Lord Kelvin would attempt to calculate it. And, with Faraday's discovery of the association of electric fields with moving magnets in 1850, and the principles of molecular makeup and breakup, a significant armoury of interdisciplinary science became available for a study of the earth's physical fields and chemical and biological processes.

Q. What are the three most important discoveries in Earth Science?

Answer: I find your insistent use of the number 3 interesting. It is the smallest prime after 1 and 2 which are perhaps too restrictive. The number 3 is a good prelude to the music of primes.

As to the exciting discoveries in earth sciences, the first is clearly the model of the earth proposed in the 1970s, that satisfactorily explains its space time behaviour such as earthquakes, volcanoes, the occurrence of certain types of rocks and minerals in specific environments, the shape of the continents and their relationship with oceans, as well as its evolution through time. This is 'Plate Tectonics' driven by the earth's internal heat. In regions of high heat accumulation, usually under the blanket of a large assembly of continents, the rocks eventually melt, buoy up, flex the continental crust and break through the surface creating a rift (Figure 3). The erupting rocks which are richer in iron and magnesium, fill the chasm created by the rift, push the continents asunder and eventually cool and subside to form a basin floored by slightly heavier rocks that join up with the world's oceans. As this process continues and the newly created ocean basin expands, the continents on the far side are crumpled and pushed one beneath the other to form mountains. This process continues for about 200 million years till the aging ocean strips on their farther side becoming progressively heavier, founder beneath the edges of the continents they once rifted. The resulting change in the stress field of the finite spherical surface of the earth sets the scene for the next cycle of this process which repeats every few hundred million years constantly moving about the continents and ocean basins into new geographies. In this perspective of Plate tectonics which has passed several validation tests, one is able to explain a host of apparently disparate earth phenomena although puzzles remain which would hopefully be explained as more subtle features of the model are resolved.

STANDARD MODEL OF THE EARTH:
PLATE TECTONICS (1970s)

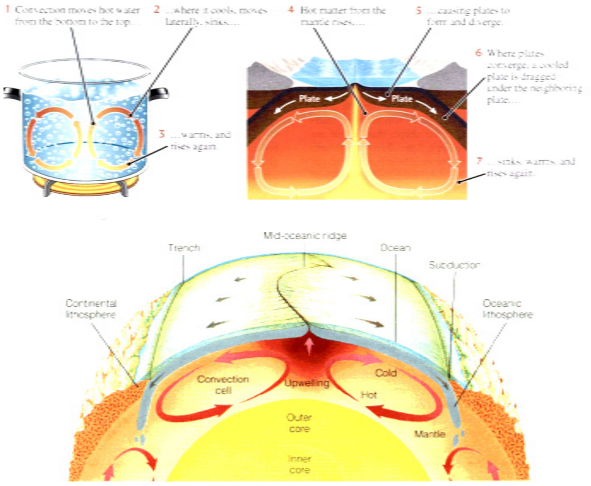

Figure 3a shows an schematic of the Plate tectonics mechanism sustained by the outward flow of the earth's heat and facilitated by just the right (~ 100 km) thickness of the its colder rocky lid. It is thin enough to be ruptured by rising sheets of molten rocks and thick enough to preserve the identity of large fragments which cover the earth as a jig saw mosaic of spherical caps or plates. The progressive expansion of the oceanic plate and the consequent rearrangement of the continental plates to fit the finite surface, eventually configure a new geography of oceans and continents changing the earth's stress and thermal regimes in the process and setting the scene for the next cycle of melt generation and ascent, continental rifting and creation of new oceanic plates

As I explained earlier, development of powerful ideas and new knowledge gleaned by insight or powerful sensing systems, in one context stimulate advances in many others. This is especially true for the Science of the earth. The planet is a composite, multiply connected system of solid and fluid realms with a complex living world nestling within and at their interfaces. Earth phenomena are, therefore, the integral result of processes that are constantly at work in response to feedbacks between these realms. They are special in the sense that they could not have been produced by any of its three subsystems working in isolation. The earth's climate system is a classic example of such emergent phenomena forged by the constant flow of energy and matter within and across the earth's atmosphere, biosphere and the hydrosphere, in response to the non-uniform solar irradiation. Evaporated sea water is blown by circulating winds driven by the thermal disequilibrium, some of which is precipitated on land to fashion and nourish a maze of ecological systems. The plant world in these ecosystems capture the low entropy solar energy to produce biomass necessary for the survival of the animal world and also keep the atmosphere well oxygenated for them to breathe. This view of the earth as an organized system of rock, water and air has been emphasized earlier by visionary individuals, as In the holistic interpretations of nature promoted by the 19th century geographer Alexander von Humboldt and later, the Russian geochemist Vladimir Vernadsky who drew attention to the geological force of the biosphere which by maintaining a dynamic disequilibrium, fuelled its diversity. In the later decades of the 20th century, however, this view acquired an added emphasis as satellite images and earth observation systems, began to produce evocative images of human induced emergent phenomena: disappearance of critical ecosystems, drying of mountain springs, loss of biodiversity, increasing dose of pollutants in the atmosphere, rivers and groundwater. Taking note of these serious indicators of unsustainable development of the designed world, and with the objective of spurring knowledge based design of interventions to arrest their increasing trend, NASA in the early nineteen eighties, constituted an Earth System Science Committee. Some of their works mark a turning point in the modern development of Earth Science. This in my view, whilst not qualifying as a major discovery, will go down in history as a major change of paradigm in the science of the earth.

This major change in our conception of the earth as an organized system, in my view, has given a new and potentially directive meaning to hunting the planet's archive for discerning its past states, urging both the development of penetrative instrument systems as well as of incisive interpretative frameworks. I believe that the outcome of these ongoing endeavours to construct the earth's historical dimension has the promise to produce the next important discovery of our planet's life and work.

***Q.* All sciences have good and bad applications — which research or discovery in Earth Sciences has done most harm?**

Answer: Scientific explorations and research aim at producing reliable knowledge which in turn, empowers us to make new objects and design new systems in unimaginable ways. This power, as the Buddhist monk said is the key to the gates of heaven and the same key also opens the door to hell. To a curious mind, it may be an aesthetic experience or pointer to another reality. Another may turn it into a transformative product such as the LEDs, or into instruments of inhuman oppression such as chemical weapons. Most often, the harmful effects of a product or system based on new scientific knowledge arises from a deficiency in anticipating the possible adverse impacts, which may have been avoided by rigorous research and assurance tests. Harmful impacts may also sometimes arise from a want of balanced application of synthetic materials, such as the use of chemicals and drugs. These are instances of failure in using scientific knowledge with thoroughness and a critical eye for evaluating both its limitations and limits of applicability.

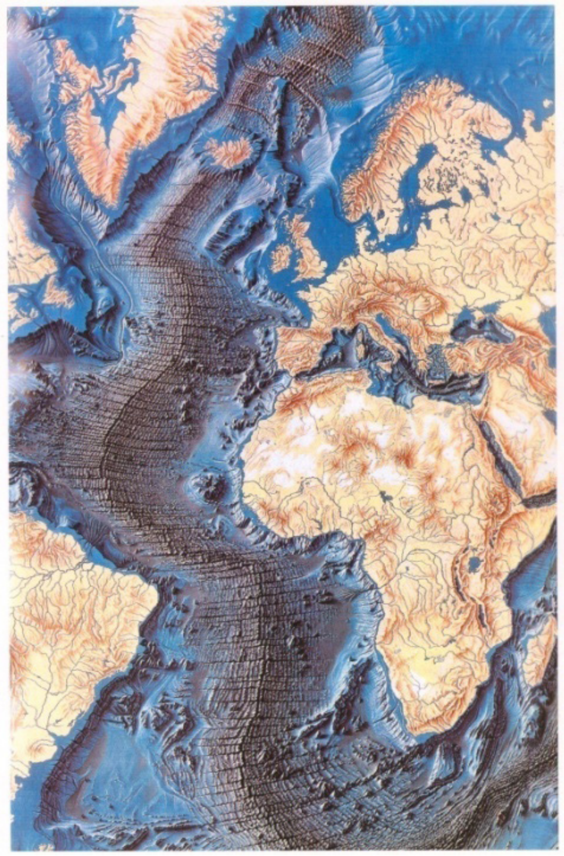

Figure 3b shows how the continents of Africa and south America which were once joined in a single assembly have been rifted apart by an expanding Atlantic Ocean that began as a narrow chasm carved by the rising melts. The volcanic ridge in the mid-Atlantic which marks the site of the earliest rifting, continues to pour out new rock material from the earth's deep to further expand the Atlantic and push the continents apart thrusting them against the Pacific and Indian plates. Iceland which sits atop the northern part of the ridge uses the heat brought up by the rising melts to generate a substantial part of its electrical energy needs and almost the entire requirement of domestic heating.

In this perspective, I believe that the harmful facets of Earth Science research consist in its neglect of the approaches of 'system Science' on one hand and, on the other, of the necessity to abstract phenomena in terms of numbers that would permit quantitative analysis for insightful knowledge. The near absence of a quantitative culture amongst earth scientists in countries like India, render most of their researches meaningless and virtually unusable.

***Q.* What kind of inputs do scientists need from sociologists, and the other way around?**

Answer: I believe that the basic approach to gaining and validating knowledge is the same in all fields of enquiry: disciplined hypotheses formulations to explain processes and phenomena, followed by investigations designed to test their tenability. Only, the contexts are different: the physical world or social systems. Of course, they do set different conditions for the search for evidence to validate them. But for the sustenance of the designed world, it is important that the complementarities of both physical and social sciences are brought to bear on the evaluation of value of a new application.

Researches in natural Sciences impact society in unimaginable ways: through the invention and production of new materials, drugs and chemicals or information and communication systems. Many of these have proved highly beneficial to society such as the production of life saving drugs or biodegradable plastics but there also lurk within such new infusions, the possibility of their unscrupulous or uncritical exploitation for enhancing gains. Social scientists, who, hopefully, possess a more intimate understanding of the complexity of human society and their ecosystems should be admirably placed to analyze the expected societal responses to infusions of new products and systems entering society as well as their possible adverse impacts. They can, thus help society develop resilience against these dangers. In particular, social scientists would do well to include as a part of their discipline, formulation of methodologies to evaluate social impacts of new products and services aimed at catalyzing legislation that would protect society against their adverse impacts by demanding 'proof of sustainability' as a precondition for the grant of permits and licences.

***Q.* Is traditional knowledge at par with scientific learning, sometimes?**

Answer: Traditional knowledge is based on generations of experiential learning. Even though it lacks the force of authority that the supposedly deductively validated scientific knowledge has, it has the unique advantage of having faced and reconciled a wide range of situations arising from generations of natural and social contingencies. Fusion of carefully screened traditional knowledge with theoretical and observation based knowledge should therefore prove invaluable for understanding and assessing the behaviour of complex systems such as farm lands. Therefore, logical approaches to assimilating traditional knowledge into physical models require an added urgency. Modern scientists are indeed becoming conscious of this condition and some efforts in this direction are underway.

***Q.* Should we listen to farmers and the communities who live closest to nature?**

Answer: Most certainly, yes

***Q.* Can personal behaviour influence changes on a larger scale?**

Answer: I believe that the genuineness and authenticity of an exemplary life cannot but carry conviction and influence a great many people. History has many examples to show that whilst most of us are unable to live by the tenets of truth, justice and independence of judgement, we admire those who embody these traits and values.

Q. What is the anthropocene?

Answer: The earth evolved from an inert assemblage of planetesimals to its present vibrant stage through long periods of slow steady transformations punctuated by briefer catastrophic events as envisioned by Hutton. These events wiped out massive proportions of existing life forms, even as the surviving few led the evolution forward to more complex forms. Geologists used the fossil records of these transitional events to divide the earth's 4.5 billion years of history into 5 broad ages, with finer divisions as life forms began to exert greater influence on the earth environment by their ability to use solar energy to create and maintain chemical disequilibrium necessary for productive activity. Thus, our own age, the Cenozoic from the Greek Kainos meaning 'new life' to mark the ascendancy of mammals and birds, began 65 million years ago after the extinction of the mighty dinosaurs. Thereafter, about 30 million years ago, the earth environment began to cool after Antarctica was separated from the tip of South America by Plate Tectonics, and isolated from the warm waters of the southern ocean by the free flow of the circum Antarctic waters through the newly created Drake passage. Hominids gradually evolved through the last stage of the Cenozoic age, called the Pleistocene, marked by further cooling of the earth about 3.5 million years ago due to the narrowing of the Indonesian seaway by the northward movement of the Australian plate. But, they did not become a major force in modifying the planetary environment until the Industrial revolution in the 17th century. The term Anthropocene was recently coined to highlight the planet scale transformation of the environment by massive engineering of land and mined resources, ponderously garnered by the earth over millions of years, and the predicament posed by the runaway trend of the human world.

Q. What would the post-anthropocene world look like?

Answer: The post anthropocene world, in my view, could assume one of two scenarios, depending on the relative strengths of the processes of degeneration and regeneration which are simultaneously at work in both natural and social systems. One of the most remarkable development in the anthropocene has been the growth and influential use of human intelligence and creativity, the latter especially, catalyzed by the spirit of liberalism. These have the potential to steer society towards a truly humane state unparalleled in history. To miss this opportunity could push the earth system, with us as helpless passengers, towards another catastrophic transition. The quality and sincerity of our response today will determine which of these two possible courses would unfold in the future. This is a challenge that can be met by the growing generation: to stay the spectre of a possible catastrophe by a radical shift in the reigning paradigm of the designed world.

Q. What is the most important conservation work going on in India at the moment?

Answer: The more vocal if not necessarily the most accepted conservation project today, happens to be 'obscurantism'. But I fondly hope that it would be self limited by its implicit degeneracy and would eventually set off a debate leading towards greater Enlightenment.

Q. What research projects will benefit the largest numbers of communities?

Answer: The Science of Mitigating the Impact of natural and man-made hazards: earthquakes, landslides, cyclones, floods, droughts, epidemics, and market deceit through rigour and thoroughness of scientific enquiry which is the most urgently wanting quality of our academic endeavours, corroborated by the near absence of Indian institutions in the global league or of originality in the worlds list of new inventions or discoveries.

Q. Future wars will be fought for water, not oil. Do you agree?

Answer: Wars are always about Control: land, people, Energy, Resources or any of these as an excuse for something else such as testing war-worthiness of weapon or for boosting the demand for their Sales. These are often politically promoted by the mightier through disinformation as the Iraq war. Bandhs and protests (Mini wars) over water sharing often happen quite frequently in India, whilst the potential for better management practices for equitable sharing by the contending parties through transparently generated scientific information on basin wise availability, remains unrealized. I believe that recent advances in our ability to understand the totality of the water regime on earth and the imperatives of its optimal management would force societies to devise better solutions than war. But who can predict the capricious human.

Professor Vinod K Gaur

Vinod K Gaur is an Honorary Scientist at the CSIR Fourth Paradigm Institute at Bangalore. Whilst his research interests beginning with his doctoral work at Imperial college in the late nineteen fifties, primarily relate to addressing problems of the Earth System, they are lighted by his passion for philosophy, especially logic and aesthetics. At the institute, Gaur lectures to doctoral students on 'Reasoning and Quantitative thinking', amongst other subjects. His current researches include: enquiries into the style of Himalayan deformation around its syntaxial bends and Inverted estimation of carbon fluxes. Over the past 4 years he has been closely associated with the design of hydrological researches towards refinement of India's water budget and development of hydrological forecasts towards maximizing the efficiency of water use in the country.

For many years in the early part of his professional career, Professor Gaur taught at the University of Roorkee . Later, he was persuaded to engage in management of scientific research first as Director of the National Geophysical Research Institute and later as Secretary to the Government of India, but returned to Academia at the earliest opportunity to pursue his passion for applying modern approaches to address some burning issues of Earth System Science. Thus, he initiated the first seismo-tectonic experiments in the Himalaya, producing a quantitative evidence of its plate tectonic convergence, and the state of stress. Amongst other firsts accomplished by Gaur, are the tomographic images of the undercarriage of the Deccan traps, and those of the Archaean crust beneath Hyderabad, as well as the Indo-Eurasian convergence rates, and Carbon flux estimations through Inversion of ultra high precision measurements of atmospheric CO_2 concentrations at the Indian Astronomical observatory in Ladakh, where he set up India's first such station.

Professor Gaur is a Fellow of the Indian national Science Academy, the Indian Academy of Sciences and the Third World Academy, and in recognition of his contributions, honoured by the Shanti Swarup Bhatnagar Prize and the Flinn Award of the American Geophysical Union, amongst others.

Ms Simar Kohli
Founder-member of the RIAZO Production & Curation Co

Simar Kohli, a Jamia Millia Islamia alumnus, is a hydro-sociologist and filmmaker living in Bangalore. In 2014, she began working on RIAZO, a production and curation house, creating content on water, planetary culture and future-ready-now leadership, whilst working as a consultant for research and documentation projects on ancient Indian philosophy and cultural traditions. In 2016, she initiated Lifetide, a collective for water abundance, which will create films, publications and events on water, while mobilising citizen Change Agents to protect the watersheds they depend on. When not passionately engaged with students at Surana College on "Culture, Diversity & Society", she has been working with Professor Vinod Gaur on the production of a film **"The Future Earth".**

Communicated by **Purabi Mukherji**,
Member, Editorial Board,
Indian Science Cruiser