New Frontiers in Scientific Research

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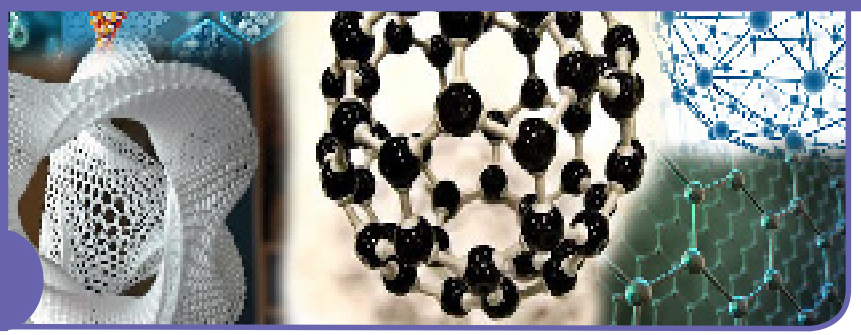
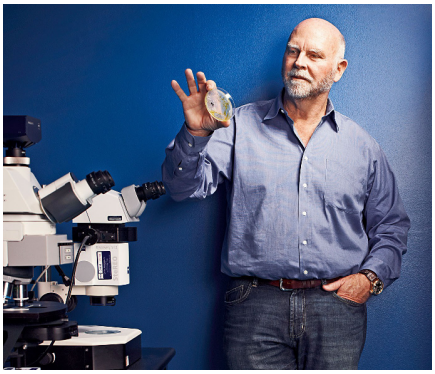


"Every great advance in science has issued from a new audacity of imagination"
John Dewey

As I write this the most expensive research program on earth is set to embark on an even grandeur journey. The Large Hadron Collider (LHC) is set to start with additional energy and power to detect and reveal with even more of an in-depth examination of particle physics in the coming days. This machine which is the largest single machine on earth is situated in Geneva and belongs to CERN (European Organisation for Nuclear Research) which supports an international research program. If an area of research is to be identified that is on the cutting edge of science this is it. The scientists there expect to understand dark matter, and what exactly happened after the 'Big Bang' through the proton beam collisions during this process advancing our understanding of physics into a new level. At LHC, two high energy particle beams will travel at close to speed of light before they are made to collide. The space in which they travel is kept at ultra high vacuum, and the guidance for the beams is by a strong magnetic field maintained by superconducting magnets. To achieve this magnets require chilling at -271.3C which is a temperature lower than at outer space. It is easy to understand how many additional sciences and technology developments should have proceeded to run this one beam collision study for testing advance scientific hypotheses. Realizing these developments would have entailed significant research in earlier days though today the frontiers in these areas have shifted. Data analysis is another frontier as millions of images are taken per second, which now pushes the computing science into grid computing, another frontier area. If one considers research into particle physics is not without any returns, CERN is quick to point out that 25% - 30% of modern world's economic activities are directly or indirectly driven as a result of work done in Quantum Mechanics! While research at CERN is exceptionally expensive as well as at a cutting edge, one can identify cutting edge research in many other subject areas. It is the research and the subsequent new findings that advances the boundaries of these subjects, and at times spawn brand new areas of study.

Research happen in many spheres though all will not take place at frontiers. Hence an understanding of current frontiers too is of importance if one needs to immerse oneself in such an endeavor. Today major research universities actually plan their research engagements accordingly. All subject areas owe their growth to research, and the consequent generation of knowledge. In 20th century perhaps the most important research result was the elucidation of DNA by Watson and Crick, which yielded knowledge on how information is transferred and the way by which nature codifies information – DNA was unraveled. The pathway to derive the answer was not paved in gold, and lots of efforts and sacrifices were involved. The work was also built on the hard work of others, and in this regard Rosalind Franklin whose X-ray images provided clues and whose presentations Watson and Crick listened while travelling from Cambridge to London, played an important role. Science is not a

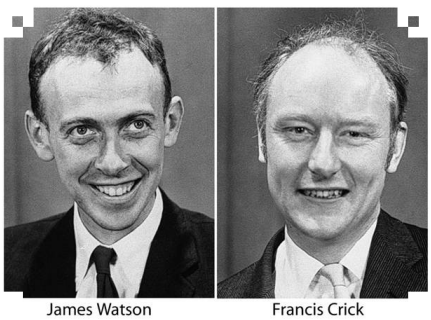
Rosalind Franklin



Venter

lonely enterprise though many a time's research scientists have to identify their own paths against many odds, and this is especially true when researching in the frontiers of science. Identifying the double helix structure of DNA was the start. There still remains the epic task of unraveling the code from 3 billion genetic letters of the human genome. The story of genome sequencing which is a laboratory process that determines the complete DNA sequence of an organism's genome at a single time- too is interesting, from which much can be learnt.

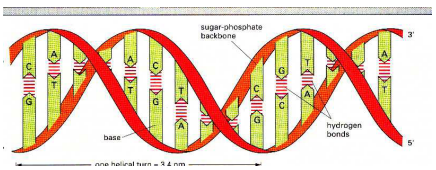
Today research in genomics and stem cell research are frontier areas. Stem cell research is an area that pushes the research frontiers into conflict areas, since ethical issues involving even possibilities of human cloning and designer babies are discussed. This possibility has led governments to declare off limits for certain areas of research. The cutting edge research on using genomics in eradicating



James Watson Francis Crick

diseases through early detection and treatment, as well as in finding cures for the so far known incurables etc. have immense possibilities. Genomics is supported by research on computing systems. It is inconceivable to think about modern day genomics without access to advanced computational facilities.

Human Genome Project (HGP) of United States is considered to be one of the most successful science programs supported by the United States Government. HGP was an international research effort to sequence and map all of the genes - together known as the genome

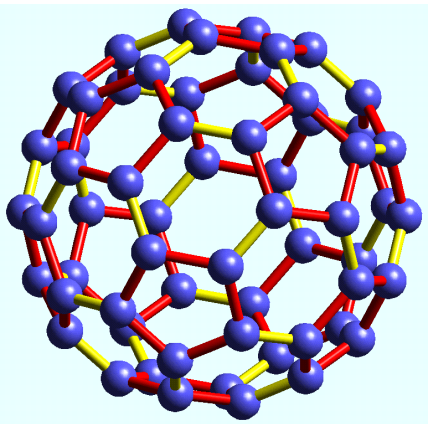


DNA-Helix

- of us, the human beings. The effort which was completed in April 2003 provided us the ability, for the first time, to read nature's complete genetic blueprint for building a human being. Craig Venter is a pioneering researcher who creatively increased the speed of the genome project through the introduction of information technology thereby revolutionizing the process. For Craig Venter who started with the Human Genome project in 1990, a decade of time, effort and intellect had to be invested before this announcement in 2000. Many a member of the team spent time and effort over this decade in deciphering the correct sequence of 3 billion letters.

Another emerging research frontier is Synthetic Biology which is the design and construction of new biological parts, devices, and systems, and is one of the most exciting emerging areas today with boundless opportunities. In 2010, Venter again grabbed the attention of scientists around the world by announcing what he calls the "world's first synthetic life". Venter's novelty had been a synthetic bacterial genome constructed from chemicals in the laboratory. He had then inserted it into a living bacterium. The cell replicated itself into a colony of organisms containing only the synthetic DNA. The replication process gave him the opportunity to claim the creating of the 'world's first synthetic life'. One area of application is production of fuels by specially engineered organisms. The potential prophesied with next generation biofuels certainly is quite interesting. The opportunities are not limited to fuels, but making medicine, combating climate change are all possibilities. Synthetic genomics may be the standard for making anything – a Venter prophecy. May be man will move from genomics to proteome, and another expansion to the frontier may happen. It is the research scientists imagination and the pioneering spirit that defines the frontiers and the research therein.

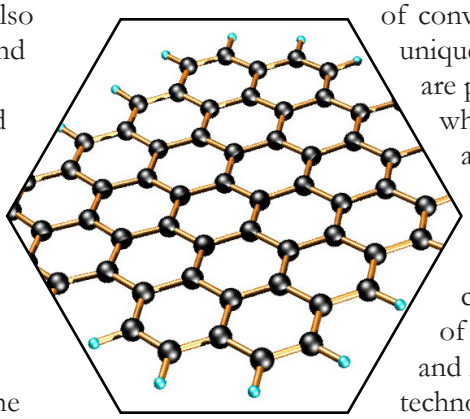
Nanotechnology is considered by many to usher in a new



Bucky Ball

world through its wide ranging opportunities. It is a science that is opening up numerous windows and all aspects of our lives are supposed to be touched and enhanced as a result of creative use of this technology. When Smalley, Kurl and Kroto discovered carbon buckyballs, it was not simply another addition to the family of carbon allotrophes. The buckyballs are set to revolutionise medicine and may even offer solutions to the modern scourge – cancer. Prof Ijjiam's subsequent research contribution with carbon nanotubes (CNT) could well transform construction, energy storage and transport, water desalination etc. Research has revealed the exciting properties of this material – thermal, structural and electrical etc. Research is now being carried out on applications and commercialization. Wearable electronic devices, shatterproof screens have already emerged into the commercial arena using CNT's. This stems from applied research and product developments. Each such development also requires retooling of manufacturing systems as well.

Going with carbon research, 2013 Nobel Physics prize when awarded to Andre Greim and Konstantin Novosolov marked the celebrated entry of another material – graphene. The European Union has currently initiated a research program with a funding of 1 billion Euros across 27 member states on graphene. Graphene is considered to be the material for the 21st century and research efforts are significant. Graphene has the potential to replace silicon as the material of choice in computer chips. However, Prof Novosolov has stated that he wants to peel of layers as he did with carbon with other elements of the periodic table. What additional frontiers may be opened up in material science can only be guessed! It is important to realize that this type of advanced research with material systems also require research and development of new and enhanced instrumentation systems. Series of research and development efforts led to instruments that enabled human beings to access the nano world thereby relegating the more humble optical microscopes perhaps to school laboratories. System developments such as Scanning Electron Microscopes and Scanning Probe Microscopes which are the workhorses for nano research, in turn yielded Nobel prizes for their respective developers. Thus it is seen that research and development in different areas coexist that enable growth, and when the frontier advances excitement beckons.



Graphene

The most advanced areas of research can be termed as frontier research. It still is basic research. You can seek frontier research in applied research areas as well. Basic research in Science and Technology is of critical importance though in circles where more economic ideas prevail, the discussion is almost taboo. Frontier research in any case requires research at and beyond the frontiers of understanding. What the economists see is the inherent risk of such ventures.

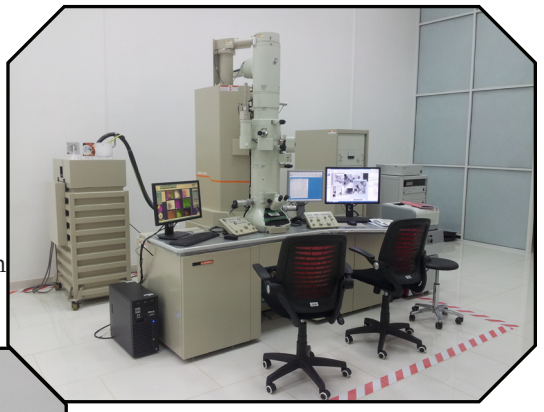
When research is at frontiers there is the blurring of discipline boundaries. In today's context multi disciplinary teams come into the fore. Today there is so much excitement at subject interfaces. The three dominant technology areas – information technology, biotechnology and nanotechnology are spawning many an area in areas of convergence. Almost unique developments are prophesied where all three are covered. Bioinformatics was the result of the convergence of biotechnology and information technology. Nanobiotechnology and bionanotechnology areas result from the interface of bio and nanotechnologies. The area where triple convergence occurs is an exciting frontier to be considered.

It is possible to derive an idea of where frontiers lie by looking at the emerging disruptive technologies. A Mckinsey Study recently indicated twelve disruptive technologies with trillion dollar impact possibilities to the global economy. This also implies areas of frontier research of today.

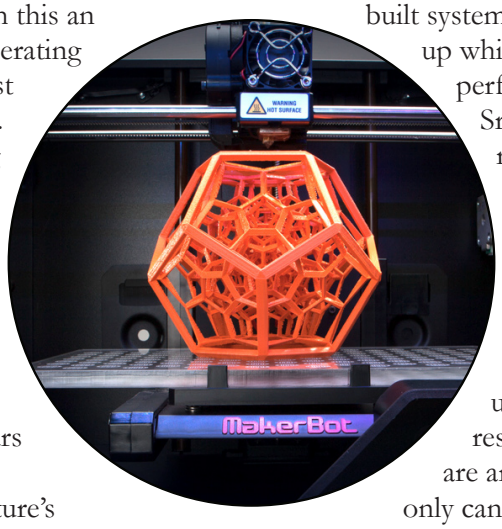
The areas identified are mobile internet, automation of knowledge work, internet of things, cloud, advanced robotics, autonomous and near-autonomous vehicles, next-generation genomics, energy storage, 3-D printing (additive manufacturing), advanced materials, advanced oil and gas exploration and recovery and renewable energy. One can identify that the emergence of these certainly would cause disruptions within the existing systems. As an example 3-D printing is poised to advance into bioprinting where organ

transplants will be made obsolete as what is missing or diseased will be 3-D printed with stemcell technologies. Advances in mobile technologies will bring in remote health monitoring and addressing any issues to be a normal activity. It is also easy to see that these are groupings, and within an individual sector many novel areas could be present. In renewable energy harnessing the sun is a priority as this points to energy self sufficiency to many an economy. While researchers are looking beyond the silicon PV cells what excites a researcher is that an ordinary plant leaf is receiving more than 10 million billions of photons of light each second. Human made molecular energy circuits which can capture, regulate, amplify and direct solar energy are receiving significant interest. We should not forget that most of the sun belt tropical countries including Sri Lanka currently faces significant issues with energy. Following from this an area that is generating quite an interest is Biomimetics. We are coming to understand that nature has so much to offer, and being a system which had millions of years in history, the richness of nature's embedded systems has much to offer. Janine Benyus who is the biomimetics pioneer, suggested making use of nature as a model and as a mentor and finally nature as a measure. The latter is to make use of what is present in nature to measure one's own systems as what is present today in nature, after all these are results of 3.8 billion years of evolution. This is already happening in Nanotechnology. Lotus effect, Salvinia effect and ghekko's feet are excellent examples already captured by science through understanding. Nanotechnologists look at self assembly as the final mechanism to built systems from bottom up which nature has perfected. Sri Lankan researchers through networking can engage in frontier research. If we strategically understand the research space there are areas where not only can we participate, but perhaps lead too. Biomimetics offer significant opportunities. The combination of indigenous medicinal systems with modern science is another area. If Sri Lanka understands the value of strategic investments as had been shown with Sri Lanka Institute of Nanotechnology (SLINTEC), host of other areas definitely can open up with possibilities such as advanced nanomaterials and applications, information technologies in interfaces, and renewable energy systems (biogas, microbial fuel cells etc.). With so many opportunities for engagement one should have an eco system which encourages and rewards young researchers to take on the seemingly impossible tasks than stick to well traversed pathways.

Scanning Electro Microscope (Courtesy - SLINTEC)



Transmission Electron Microscope (Courtesy - SLINTEC)



3D printing Machine

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