Nanotechnology (NT) – Why Sri Lanka should pay attention on NT?

The developed world is shifting now from Information Communication Technology (ICT)–Biotechnology Era to the "Nanotechnology" Era. We in Sri Lanka should be aware of current developments in the world, and prepared to face them, because we cannot keep away from the influences of globalization and so-called global open market system.

As we know, "Nano" refers to one billionth, and in the case of measuring scale, 10^{-9} of a meter. However, in nanotechnology, molecular particles up to the range of 100 nm are considered, and are called "Nanoparticles". There are complex molecules of this range, which are amenable to manipulation, and their images can be seen through the Scanning Probe Microscope (SPM).

Physicist Richard Feynman was the first to hypothesize in 1960, that atoms and molecular systems could be potentially manipulated into useful structures and devises. Later in 1986, Eric Drexler in his book "*Engines of Creation: The Coming Era of Nanotechnology*", has given an appropriate definition for this term. Accordingly, the Nanotechnology (NT) is "*the design, characterization, production and application of structures, devises and systems at the scale of atoms and molecules, by controlling the shape and arrangements of nano-scale configurations dependant upon their technological utility*".

In this issue of Vidurava, you will be exposed to more of this new field and its applications in biology, physical sciences, health sciences and engineering. NT has become a force that removes the gap between Biology/ Medical Sciences and Engineering/ Physical Sciences.

Developed countries are spending billions of US Dollars on nanotechnology related Research, Development & Marketing activities. USA has allocated 3.7 billion Dollars for the period of 2005-2008, and within Europe, about 1.25 billion US Dollars are spent in R&D of NT per year. Japan has recently doubled its funding for NT related activities. This is the indication of future potential, and developing countries like Sri Lanka have a bigger chance of getting involved in a wise and intelligent manner to benefit from modern developments. The most important natural resource we have for this purpose is our local Human Resource.

Our Human Resource needs to be advanced urgently on modern technological developments to face the challenging globalized Knowledge-based Economies. Lifelong education is now well accepted and workforce has become "Knowledge Workers". Knowledge workers need "technology compatible management" system as well as "technology compatible infrastructure" to make the new technology a viable process.

Accordingly, the knowledge is only 1/3 of the technology, and the trained Human Resource will leave the country for working in developed countries where compatible conditions are available. We need to understand that modern technologies are initiated and utilized in developed countries where compatible management systems are available. Command, Force and Control based out-dated management system existing in our country cannot sustain modern technologies.

Above all, we have to understand that the "Research and Development" concept is changing into "Research & Marketing" in developed countries. If we know that technology is defined as "systematic application of knowledge in Industry", and Industry is simply defined as "Production and Marketing", it is not difficult to understand the relationship.

If we are not familiar with "Marketing and Management", can we use Nanotechnology and modern technologies for the benefit of our country although the country is rich in Human Resource together with other natural resources?

Kumara Hirimburegama, PhD.

Mother Wasp builds mud-house and stores food: Mud-Nest Building Wasps of Sri Lanka

Wasps, bees and ants are insects that are common in and around most homes and home gardens. According to scientific classification, all of them are members of the Order Hymenoptera. Females of the Order Hymenoptera are well known for their nasty habit of stinging anyone that provokes them or crosses their path. Of the different Hymenoptera, wasps are by far are the largest in size, the most abundant and diverse with a world fauna of over 100,000 named species. Wasps are well known for their prey hunting behavior and the diverse nesting habits. A study carried out by the late Krombein and co-workers of the Smithsonian Institute, USA, identified 459 species of wasps in 153 genera and 16 families from Sri Lanka. However, the nesting habits of only a few of local wasps are known.

Introduction

Wasps make nests in a variety of places, and construct nests of many different shapes and sizes using a variety of substances. The wasps that nest in the ground and dig straight burrows in soil are called the 'digger wasps'. Those that build above ground nests out of paper like substance formed by mixing plant products with their salivary secretions are called 'paper wasps'. Wasps that build nests using mud or clay are called 'potter wasps' or 'mason wasps'. Certain other wasps do not construct nests but nest in hollows of twigs, in crevices of trees, rocks and in pre-existing cavities in man made structures.

Of the many types of nest building wasps, the most conspicuous and commonly seen are the mud nest-building wasps. Even more conspicuous are the mud nests they build. Mud nest building wasps are solitary nesters where individual females build nests by putting pellets of mud or clay together forming differently shaped structures. These female wasps build mud nests in order to lay eggs and raise their young. In appearance, mud nest-building wasps are like any other wasp in having a narrow slender waist in the middle of their body. Their legs are exceptionally long and bear spines. Typically they are black with yellow or orange coloured markings. The female wasps prefer to build their nests in our homes and other buildings we frequent and hence are familiar to most of us. Among these mud nest building solitary wasp species there are only males and females and not queens or workers. The males and females together visit flowers to feed on pollen and nectar and to mate. It is the mated female wasp ready to lay eggs that do the work of nest building and provisioning for the young. Furthermore, each female wasp builds her own nest independent of others.

Construction by the Female

The construction of a mud nest by a wasp is a pleasure to watch. It has to be observed quietly and patiently, as any disturbance would force the wasp to abandon the nest and look out for another nesting place. Mud nest building is carried out during day time when the sun is out. A female wasp ready to build a nest frequents muddy places. She carries a droplet of water to a particular site and mixes it with dry clay or earth using her mandibles. The wasp's saliva helps to bind and strengthen the dried mud and she uses her mandibles to roll it into a mud ball. (These architectural wasps sometimes collect wood fibers, sand grains to cover the mud nest). The female wasp then flies to the nest carrying the mud ball in her mouth between her mandibles, sometimes aided by the front legs. At the site that she has selected for building the nest, she smashes one mud ball against another with her mouth and forehead until the nest is built. Mud nest building wasps spend untold hours carrying countless balls of mud to construct their nests. Female wasp may take 1-3 days to complete a nest. She works during day and rests some where else at night. If she cannot finish the nest before sunset, she will seal the unfinished nest temporarily. The next day she continues nest construction.

During nest building a single room or cell is initially constructed. Prior to the deposition of an egg, the cell is provisioned with prey, which becomes food for the young. Thereafter, an egg is deposited and the cell is sealed. Immediately another room or cell is constructed in the same manner adding to the earlier cell. It continues in this manner until the required number of cells or rooms specific to each wasp species is constructed. The nest thus constructed would have a linear row of brood cells

(rooms) separated by mud partitions. As each egg inside the nest cells hatches, the wasp larva that emerges consumes the food (spiders or caterpillars) provided and grows until the provision is used up. The mature larva then pupates in a silken cocoon spun by it inside the nest cell of the mud nest. The new wasp that emerges from the cocoon chews its way through the mud walls of the nest and comes out. The newly emerged adult wasp is now ready to fly off and fend for itself. Each female may construct more than one nest during her lifetime.

Not a learned behaviour

The ability of mud nesting wasps to construct a specific nest type is due to their innate or inbuilt species specific behavior pattern which they have inherited and are expressions of their genetic make up. Nest building in wasps is an inborn behavior pattern and not a learned behavior. It is amazing how a stereotyped behavior pattern can lead to complex nest building using mud as the raw material. Furthermore, since the mud nests built by wasps are species specific, the nature of the mud nest could be used in identifying the nesting wasp species.

If you happen to open up a recently built mud nest you will find wasp larvae together with some spiders or caterpillars. If the mud nest is old and has a hole in it, it is an empty nest where the wasps that developed inside the nest have completed their life cycle and have left the nest. On opening up such a nest left over provisions such as hard parts of spiders or caterpillars and shed skins of wasp larvae are seen.

These mud nesting wasp species commonly referred to as 'Kumbala' by locals are characterized by the differently shaped mud nests they construct on varied surfaces in buildings. As these mud nests are a conspicuous sight in most buildings including homes, housewives consider these wasps as nuisance. Further, the nests are in unoccupied houses and buildings mud nests of wasps were not found inferring that difficult to remove. However, some householders consider it a good omen to see a potter wasp at work in their home.

Shape of nest relates to wasp species

Mud nest building wasps so far identified from Sri Lanka belong to 3 families of the Order Hymenoptera. The families are; Eumenidae, Sphecidae and Crabronidae. During a recent study seven species of mud nest building wasps belonging to these three families were recorded from houses and other buildings. They are *Delta flavopictum* ("Rankumbala"), *Delta maxillosum*, *Paraleptomenes mephitis* and *Subancistrocerus sichelli* of the Family Eumenidae, *Pison rugosum* and *Pison argentatum* of the Family Crabronidae and *Sceliphron madrasplatanum* of the Family Sphecidae. The mud nests built by these 8 species of wasps have a characteristic shape. According to shape and architecture their nests fall into 3 distinct categories namely, single pot shaped nests, clump of pot shaped nests and tubular shaped organ pipe nests. In addition certain mud nests consisted of a series of globular shaped nests connected together.

The potter wasps are named for the pot shaped mud nests they build which are round or jug shaped with a narrow neck and resemble miniature pottery. Each female depending on the species constructs a single pot or a series of pots whose size, curvature and the nest surface are different.

A pot shaped nest with a wide curvature and smooth surface is built by *Delta maxillosum* (Fig 1). Female *Delta maxillosum* is dark brown in colour with yellowish orange legs and antennae (Fig 2). It constructs 5-6 pot shaped nests placed at equidistance along a straight line. The entire nest is lined with mud where not only the sides of the nest but even the base of the net is of mud. Hence, the mud nest of *Delta maxillosum* is completely enclosed.

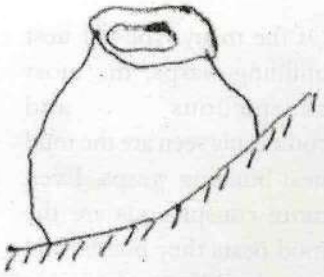

Fig 1 A sketch to show the external appearance of a mud nest of *D. maxillosum*



Fig 2 Adult *D. maxillosum*

Mud nests consisting of number of pots attached to one another, that may look like an elongate or an irregular clump of mud (Fig 3) is

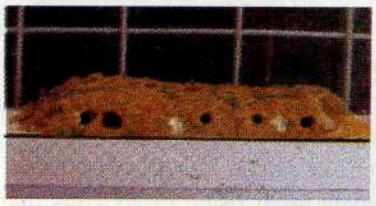

Fig 3 An elongated form of mud nest of *D. flavopictum ("Rankumbala")*

constructed by *Delta flavopictum*. This "Rankumbala" is a well-known mud nester having a dark black body marked with yellow patches and bands of yellow around the stout abdomen (Fig 4). It usually builds its nest at a corner of a wall. A series of pots attached together are constructed by a single female. After completing one nest the female introduces the prey, lays an egg and seals the pot. Thereafter, another pot shaped nest is similarly built on top of the first nest. This procedure is continued until a series of pots are completed. If the space at the site of nest construction is limited, females construct a nest that appears as an irregular clump of mud. Both these forms of nests consist of 2-8 cells arranged parallel to one another. However, very rarely a nest with a single pot, which may be confused with that of *D. maxillosum* is constructed by *D. flavopictum*. Such mud nests can be seen in places where space is very much limited. The base of the nest is not lined with mud but the nest lies on a ring of mud unlike that of *D. maxillosum*.

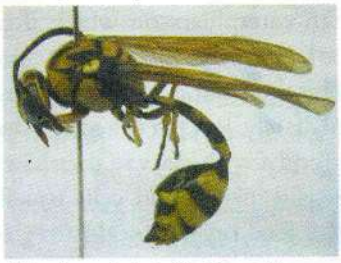

Fig 4 Adult *D. Flavopictum ("Rankumbala")*

Identify Sri Lankan mud-nest builders

Tubular shaped (organ pipe) mud nests are built by the three species, *P. mephitis*, *S. sichelli* and *S. madraspatanum*. Each nest consists of several tubes arranged parallel to each other. Mud nests consisting of 2-3 tubes, 2 cm long and 0.5 cm wide arranged in one plane is built by *S. sichelli*. The completed tubular nest adheres to the substratum (Fig 5). Each tubular nest includes 2 cells of two different lengths separated by a mud partition. The short cell of one tube lies parallel to the longer cell of the adjacent tube. The female *S. sichelli* is a small wasp 5-6 mm in length. A few yellow spots are present on the thorax and a yellow band at the most anterior corner of the abdomen. Wings are hyaline (Fig 6).

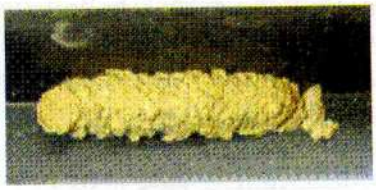

Fig 5 A single completed tube of a mud nest of *S. sichelli*

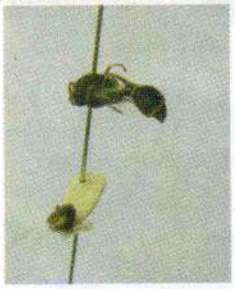

Fig 6 *S. sichelli*

Mud nest consisting of 3-5 tubes held together is constructed by *P. mephitis*. The tubes usually lye parallel to each other except when more than 4 tubes are present. Then the fourth tube lies at right angles to the parallely arranged tubes (Fig 7). The curved opening of the tube is directed away from the substratum unlike that of *S. sichelli* nest. The nest consists of two equal sized cells about 7 mm long and a smaller cell of 4-5 mm length (part of the nest that curves away from the substratum) (Fig 8).



Fig 7 A mud nest of *P. mephitis*



Fig 8 Adult *P. mephitis*

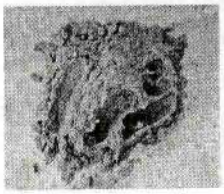

Fig 9 An exposed mud nest of *S. madrasplatanum*

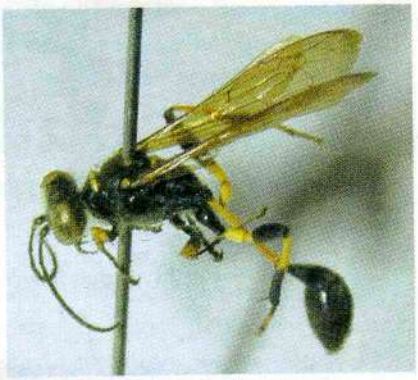

Fig 10 Adult *S. madrasplatanum*

Mud nests consisting of 2-5 tubes arranged parallel to each other is constructed by *S. madrasplatanum* (Fig 9). Each tube represents a single cell which is oval in shape. The tubes are larger than that of the previous two species and may be arranged in one or two plains. The female is a very slender, black wasp with a thread like waist. The petiole connecting the thorax with the abdomen is yellow. Wings are hyaline with a brownish tint (Fig 10).

Mud nests found within grooves or carvings of buildings seen as an irregular shaped clump of mud are constructed by *Pison* spp. The two species of wasps of the genus *Pison* use spiders as food for their young. A globular shaped mud nest having a wavy surface is constructed by *Pison argentatum* (Fig 11). The female is black in colour with silvery pubescence and the wings are hyaline (Fig 12). Mud nests consisting of irregular shaped cells with a pebbled surface are constructed by *Pison rugosum* (Fig 13). Adult of this species is also similar to the adult *P. argentatum*. (Fig 14).



Fig 11 An exposed mud nest of *P. argentatum*



Fig 12 Adult *P. argentatum*

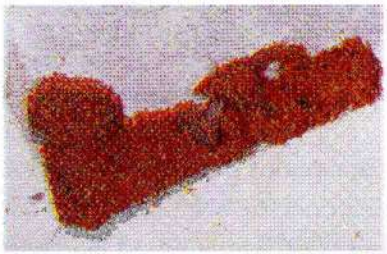

Fig 13 A mud nest of *P. rugosum*



Fig 14 Adult *P. rugosum*

The mud nests of the 7 species of wasps examined were provisioned with different prey types. Wasps such as *Delta* spp., *P. mephitis* and *S. sichelli* of the Family Eumenidae provisioned their nests with caterpillars on which their larvae fed. Members of Family Sphecidae and Crabronidae use spiders. The prey that is caught is stung. The prey is not killed immediately, but paralyzed, so that the prey remains as fresh food for the larvae that hatch out of the eggs. The eggs laid inside mud cells usually hatch in 2-3 days and larvae feed on the food provided by the mother wasp.

Mud nesting wasps are our friends

During a study mud nests of wasps were found in both concealed and exposed surfaces of buildings. The nests of *Delta* spp. and *S. madrasplatanum* were evident only in concealed locations. Nests of *S. sichelli*, *P. mephitis* and the two *Pison* spp. were found in exposed locations receiving direct sunlight. It is noteworthy that in abandoned houses no mud nests of wasps were found. It is interesting to note that these wasps prefer to build their nests admits human activity.

Although the mud nests of wasps may clutter the walls and other surfaces of buildings and homes these wasps carryout a beneficial service. They hunt caterpillars that feed on our vegetable crops. Caterpillars on Lady's fingers ("Bandakka") are favourable prey of mud nest building wasps with which they provision their nests to feed their young. Furthermore, these wasps should be admired and encouraged as both males and females pollinate flowers while feeding on pollen, so crops and wild flowers benefit. Hence, they are valuable insects those should be protected by us, especially from our use of chemicals in the environment. After watching mud nest building wasps at work that involves commitment, dedication and hard work of the mother wasp towards raising another generation, we find it very hard to remove their mud nests in the name of good house keeping. The more we come to know about this fascinating group of insects, greater is our appreciation of their multi faceted role in the nature.



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Nanotechnology:

The Biology and Engineering of Tomorrow

What is Nanotechnology?

Public awareness of nanotechnology has greatly increased in the early part of this new century, with numerous references in popular culture, most notably the "*Grey Goo*" of Michael Crichton's bestseller, *Prey*. There is great confusion and debate as how exactly to define nanotechnology, but for the purposes of this article, we shall adopt the definition: the science and engineering at the dimensions of one to one hundred nanometre (nm), where a nanometre is one billionth of a metre. To give you some perspective of how small this is, imagine a magnifying glass that could make 1 nm appear the height of a letter in this text, using that same magnifying glass would make a human hair appear to be around 200 m wide!

To understand any development in technology, it is always useful to look to its history. In its loosest definition, we can trace nanotechnology to the ancients. When producing the 4th Century Lycurgus Cup the Romans used 70 nm silver colloids to produce colour and sparkle. Is it also possible that the 5th Century masterpieces at Sigiriya did not only use oil based paint, but incorporated metal nanoclusters?

Although the concept of the atom can be traced back to Greek antiquity, with Democritus of Adbera (400 BCE) asserting that all material things are composed of extremely small irreducible particles called atoms, it was not until the English chemist John Dalton (1766–1844) that a firm scientific theory of the atom began to be developed. There were of course many great scientists who went on to further contribute to our contemporary understanding of the world at the nanoscale, but this article does not have space to describe this story, nevertheless we would encourage the reader to read further on the subject.

It is the extraordinary Caltech physicist and Nobel laureate Richard Feynman (1918-1988) that many people cite as the inspiration for modern nanotechnology. In a lecture titled "*There's Plenty of Room at the Bottom*", presented to the American Physical Society in 1959, Feynman outlined the challenges and opportunities afforded by engineering from the atomic scale up.

The Nanotech Revolution: A Panacea for Humanities Woes?

The world we live in today has been altered dramatically by the seemingly ceaseless march of technology. Some would argue this change has been for the worst, but most would agree that the quality of our lives have been vastly improved. The present state of affairs has been achieved through sudden bursts in technological output, often termed as "Revolutions". The first such explosion, the *Industrial Revolution*, occurred in the Britain between 1780 and 1840 with the development of the steam engine, textile industry and progress in mechanical engineering. This was closely followed by a second revolution in main land Europe (1840-1900) with the establishment of the railway infrastructure and the steel industry. Between 1900 and 1950 the hub of the third revolution was the USA, with the advent of the electric motor, the chemical industry, automobiles and consumer goods. The fourth revolution (1950 to present), the *Electronics Revolution*, has been centred on the Pacific Basin (USA, Japan, Taiwan, South Korea), driven by Silicon Valley in California and the apparent insatiable appetites of consumers for ever more sophisticated appliances.

Given the nature of Nanotechnology, it is possible for developing nations to make a real impact. Thus not only will they benefit from the improved technology, but also build their economies by making an important contribution to the developments. In its 2005 report entitled "Innovation: applying knowledge in development", the UN Millennium Project task force on science, technology and innovation wrote that "*nano-technology is likely to be particularly important in the developing world, because it involves little labour, land or maintenance; it is highly productive and inexpensive; and it requires only modest amounts of materials and energy*".

This is really where our story begins. It is the electronics industry that has, from a technological perspective pushed for ever increasing miniaturisation. The invention of the transistor by John Bardeen, Walter Brattain and William Shockley at Bell laboratories in 1947, made it possible to start this revolution in miniaturisation. Jack Kilby and Robert Noyce took it a step

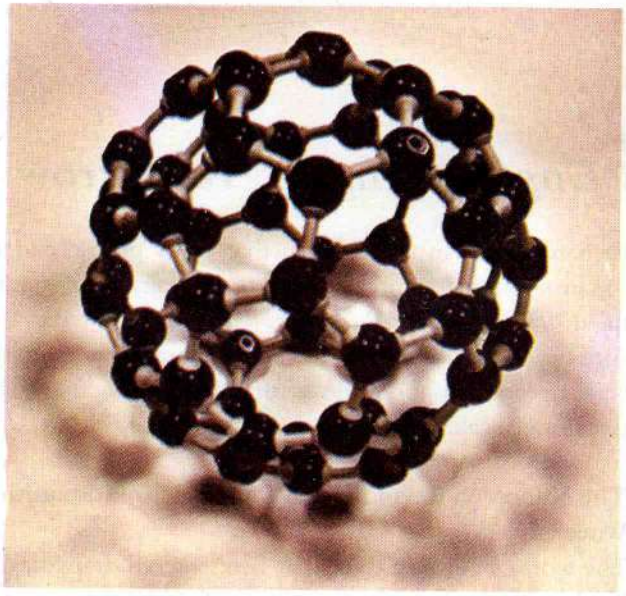

Fig 1 Ball and stick model of a C60 molecule

further in the late 1950's when they both independently conceived the concept of the Integrated Circuit (IC), which allowed all the components of an electronic device to be fabricated on a single crystal of Silicon. This led Gordon Moore the founder of INTEL®, to predict in 1965 a doubling of the number of transistors per IC every 18 months. Moore's law has relentlessly held for the last 40 years and been the driving force for change in IC design. Unfortunately, due to fundamental limits associated with quantum mechanical tunnelling in semiconducting and electronic materials it is envisaged that this miniaturisation of devices cannot continue beyond 2010. To overcome this barrier we must look to the potential offered by nanotechnology.

At the University of Surrey we have active research programmes in allotropes of carbon, specifically **Carbon Nano Tubes** (CNT) and **Buckminsterfullerene** (C_{60}). Research in this field began with the discovery of a stable molecule made up of 60 carbon atoms (see Fig 1) by, Kroto, Smalley and Curl in 1985, which led to them winning the 1996 Nobel Prize for Chemistry in record time. This was closely followed by Iijima's identification of CNT's in 1991, creating a burgeoning field of research unparalleled in science. Why the big interest in C_{60} and CNT's?

The CNT, which is an elongation of the C_{60} molecule, exemplifies all that nanotechnology can offer (see Fig 2). Identical in bonding to that found in soft metallic graphite, carbon nanotubes are single layers of graphitic carbon rolled up into a hollow tube, which is capped by half a football shaped C_{60} molecule. By virtue of its shape and bonding, along its axis this material is 20 times stronger

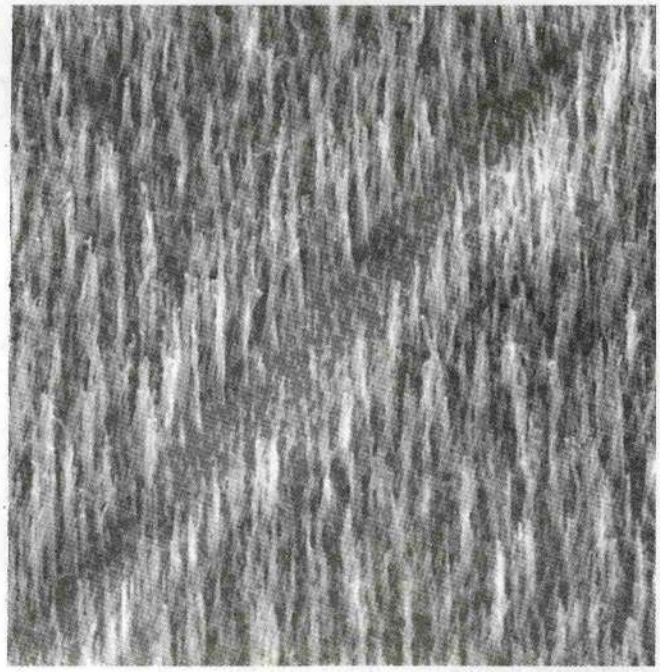

Fig 2 Thousands of carbon nanotubes can be grown over large areas. Each one of these tubes is about 500 nm long and about 80 nm thick

than high tensile steel, half the weight of aluminium, has a current carrying capability a 1000 times greater than copper and can form either metallic or semiconducting derivatives based on how the tubes are rolled up. They also have a conduction mechanism that is not limited by the constraints of bulk materials; electrons travelling along the length of the tube don't experience electrical resistance in the same way as bulk materials. This is known as ballistic transport and is possible due to the one dimensional quantum wire nature of the structure. In terms of heat dissipation, it has a thermal conduction twice that of diamond, once thought to be the best thermal conductor in the world.

The applications of CNTs in medical science, electronics, forensics, and the environment could be far reaching and all pervasive. In the field of therapeutic medicine, buckyballs and CNTs offer ideal platforms for encapsulation of pharmaceuticals, enabling targeted drug delivery, thus reducing doses and removing their often harmful side-effects. In biology, the similar dimensions of DNA and nanostructures are proving to be a intriguing enabler that has given rise to *nano-bio-technology*. Lab-on-a-chip, DNA micro-arrays and novel diagnostics are all making the identification of genetic defects, pathogens and foreign matter cheaper, with increased flexibility and accessibility. In the future it is envisaged we will be able to provide 24/7 unobtrusive monitoring of patients in all environments with novel sensors for blood sugar, EEG, glucose, brain wave etc... on the end of say a 'stick-on–plaster', which may communicate with a processor in your watch.

An extremely pertinent example of where nanotechnology could have an enormous impact is on *energy*. Only recently we have seen tensions that can arise from energy demands, with the stand off between the Ukraine and the Russian gas company Gazprom. This could just be the beginning of such crises, particularly as demand for energy grows with fast developing economies such as China. There is also the environmental impact of our current reliance on fossil fuels. If there were sources of cheap renewable energy, it could develop all countries production base and economies, wipe out poverty and the east-west divide, and provide for medical care for the world population. We at Surrey are looking towards composites of CNTs and organic materials to produce high efficiency large area solar cells that could be produced on a roll-by-roll basis.

The Nano-Nightmare!

History has taught us that no technology comes without problems. The industrial revolution brought about excessive air pollution, culminating in the great smog of 1952 which killed an estimated 12,000 people in the city of London, UK. The methyl isocyanate gas leak in 1984 at the Union Carbide factory in Bhopal, India, killed 3,800 people and several thousand other individuals experience permanent and partial disabilities. Perhaps the defining technology of the 20th Century which still provokes great debate is that of nuclear power and weapons. There is no doubt that the world has been irrevocably changed by the bombs dropped on Nagasaki and Hiroshima in 1945, the "Cold War" (1945 – 1991), the Chernoblyl disaster in the Ukraine in 1986 or the continuing strife between the USA and Iran and North Korea. The one thing all these incidents have in common is that root of the dilemma was not the technology but irresponsible use by man.

What are the possible negative side-effects of Nanotechnology? There has been a lot of press about self-replicating nano-bots that could render the whole surface of the earth to grey goo, but this is just sensationalism, and if such a scenario is possible it is a very long way off. A more imminent cause for concern is the toxicity of nano-particles, partly fuelled by health problems associated with asbestosis. Research has shown that nano-sized particles ingested in large quantities may accumulate in the nasal cavities, lungs and brains of rats and that 'buckyballs' induce brain damage in fish yet, other studies show negligible effects. However further research is needed and is being undertaken, as yet the yield in manufacture of nano-materials is low, thus making it expensive to produce the sizeable quantities that would be required to possibly enter the food chain.

The Future...

Around the world many millions of dollars is being spent on research and technology to find competitive positions in this field. In 2003 alone, the US federal budget spent US$700 million, the UK government spent close to US$170 million, the Japanese and EU spent in excess of $500 million. The state of California alone spent over $100 million for research. The US National Science Foundation predicts that the global market for nanotech-based products will exceed US$1 trillion within 15 years.

Given the nature of Nanotechnology, it is possible for developing nations to make a real impact. Thus not only will they benefit from the improved technology, but also build their economies by making an important contribution to the developments. In its 2005 report entitled "Innovation: applying knowledge in development", the UN Millennium Project task force on science, technology and innovation wrote that "*nanotechnology is likely to be particularly important in the developing world, because it involves little labour, land or maintenance; it is highly productive and inexpensive; and it requires only modest amounts of materials and energy*".

What are the 'unknowns'? Is nanotechnology over-hyped? Can it fulfill its promise without comprising society and security? Are its proponents realistic in their claims of what nanotechnology can achieve? Or is it a runaway technology destined to wreak havoc with human health and the natural environment? These are questions that can only be answered with time, but one thing is for sure, nanotechnology will achieve nothing without motivated scientists and engineers willing to take on the challenge. We hope this article will inspire you to take an interest in all areas of science and maybe one day you could be the individual or more likely part of the team that answers these questions!







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Bio-Nanorobotics of Nanotechnology :

Biological flavour of Nanorobotics

The present manufacturing technology is based on creating the objects using techniques such as cutting, carving, molding and welding of materials, which is generally knows as 'top down approach'. For example if we want to make a car body, we have to press the sheet metal using metal forming machines to get the desired shape. In Feynman's talk he mentioned the concept of 'bottom up approach' in which atomic level components are used for manufacturing.



Fig 1 Robert Feynman

Introduction

When talking about *nanotechnology,* it is essential to mention about the history of the nanotechnology. About half a century ago, in 1959, Nobel Prize-wining physicist Richard Feynman first introduced the concept of nanotechnology.

What is nanotechnology?

Before discussing Feynman's new concept a word must be mentioned about the current manufacturing technology. The present manufacturing technology is based on creating the objects using techniques such as cutting, carving, molding and welding of materials, which is generally knows as 'top down approach'. For example if we want to make a car body, we have to press the sheet metal using metal forming machines to get the desired shape. In Feynman's talk he mentioned the concept of 'bottom up approach' in which atomic level components are used for manufacturing.

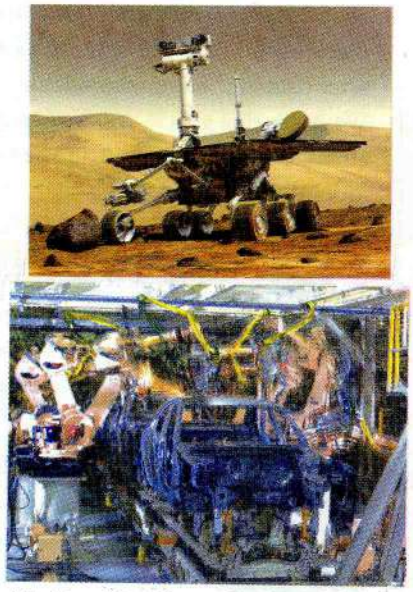


Fig 2 Mass Rover developed for mass exploration (upper), and Robots in car manufacturing plant (lower)

In this approach, the machines are made up of components of single molecules, which are held together by covalent forces that are far stronger than the forces that hold together macro-scale components. Using this approach it is possible to make devices that cannot be achieved due to limitations of the traditional methods.

Current progress of nanotechnology

About four decades after the introduction of the concept, scientists throughout the world are interested about developing nano (10^{-9}) scale devices, which can be used to do tasks that cannot be achieved by classical methods. The introduction of **smart materials** is one of the applications of nanotechnology.

For example, in skyscrapers, cleaning of glasses has been a dangerous, time taking and costly but essential task before introducing self cleaning glass materials, where the glass has a component that will remove the dirt by it self. Other than smart materials, **nanorobots** are the most impressive and demanding research focus of scientists through out the world.

Robots and group work

Before introducing nanorobotics, the background of small-scale robots has to be introduced. In general, robots are machines developed by humans to get a task done; the task may be simple or complex. This may vary from robots used in manufacturing plants to mobile autonomous vehicles used in space exploration.

Basically, a robot consists of several common elements that cannot be eliminated, power source, actuators, sensing devices and computational power (*i.e.* method, processes inputs, and activate outputs). In the past, researchers developed robots that can do variety of tasks with high computational power. These machines are now well established and serving the human kind in various disciplines.

In recent past the interest of researchers in the field of robotics changed from multi-tasking high end robots to

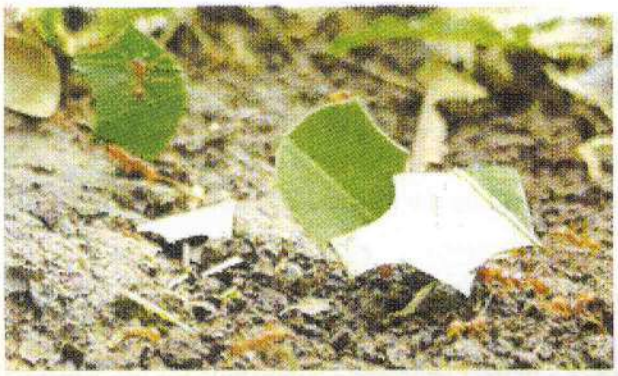


Fig 3 Ant colony doing team work

single tasking, (or can do couple of tasks, but not as previous ones) small in size and low cost robot groups, called as **swarm robotics**. The concept was emerged by studying the biological swarms, such as ants, bees, etc. that are doing enormous teamwork to accomplish a task like nest building, fighting against threats etc.

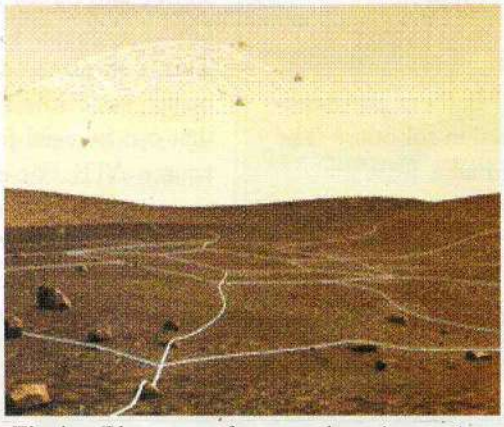


Fig 4 Planet surface exploration using nanorobotics, from artists view (the white lines consists of nanorobots used for data collection)

In the field of robotics the tasks that cannot be done by single robots, such as de-mining, search and rescue missions, are assigned to swarm of robots, with limited computational and sensing power but doing a group work so the limitations can be easily overcome. *Nanorobots* can be specified as a subcategory of swarming robots, buildup of nano-scale components and suppose to do tasks in nano-scale which can be visualized in macro-scale.

Why nanorobotics?

The field of nanorobotics becomes one of top research area, due to massive number of possible applications that have high demand in military, medical and space sciences. For example think of a group of robots injected into blood via a normal syringe and moves inside your body's blood vessels, doing a seek and destroy mission on cancer cells without making any side effects to other elements **(smart medicine)**. Even this is like a science fiction; the research on nanorobotics being conducted throughout the world will make it happen in near future.

The possible applications of nanorobotics apart from the medical sciences lies on military and space exploration, for example a group of nanorobots can be deployed for spying purpose into a hostile area, without knowing to the enemies. Or can use them to search and detonate land mines with themselves. The advantages of proposed nanorobots is that they come with the ability to reproduce themselves, like nano factories, so the cost of elements is very low. In the space exploration fields or underwater explorations, the self-replicate nature of the nanorobotics is highly desirable, because one target of the exploration is to spread vast number of nano-scale robots on the target planet surface and get the information from them.

This is much advanced and reliable method compared with sending a single robot to gather information. In current space travels, maintaining a desired health of the astronauts is a much-discussed problem. The nanorobots are to be used for the enhanced health management and protection system for the astronauts, where the preprogrammed nano-scale robots are injected into the body, so that they can protect the astronaut from possible health threats.

Due to the nature of applications the research activities are very competitive and confidential, so outcomes and progress of the research activities are not exposed to the public media.

Biological Flavour?



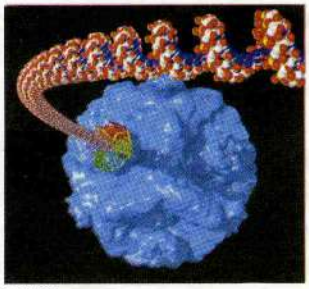
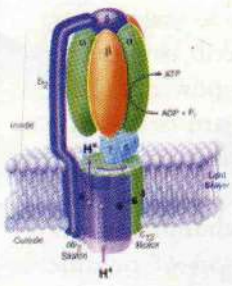


Fig 5 Different models of ATPase motor



Difficulties with nano-scale components

Even though there are many demanding applications for nanorobots the creation of them involves manipulating and working with nano-scale components, which is a very hard as they are invisible to naked eye. Techniques like scanning electron

microscopy (SEM) and atomic force microscopy (AFM) are being employed to establish a visual interface to enable nano-scientists to extend their eyes and hands into the nano-world and also enable new types of exploration and whole new classes of experiments in the biological and physical sciences.

With the facilities to explore the nano-world, scientists faced a great problem in developing nano-scale components for robots, *ie.* the structural elements of the robot, actuators, sensor and processing units have to be developed in nano-scale. Instead of developing artificial components for the parts of the robot, scientists chose the path of using existing nano-scale components.

Machines of mother nature

Existing nano-scale components ... ! Is there any nano-scale components developed to be used in robotics? The answer is YES and they are all around us.....!

Mother Nature has developed a set of molecular machines that have optimized for performance, re-design and tested throughout ages, since the beginning of life on earth. The life and earth relies on those machines, so one should not hesitate to use those machines and components for their designs.



Fig 6 Different views and model of flagella motor

Adding biological flavour to robotics

Is it possible to find molecular components that can do tasks done by classical robot components? YES, scientists have discovered many molecular level 'components' that can easily replace the mechanical components used in classical robotics, thus such systems are defined as bio-nanorobots. Let's discover what are the components and their biological compatibles.

First, every robot (a machine programmed to do a certain task) needs to have a power source. In macro-scale robots; chemo-electric cells, gasoline engines, fuel cells, or electricity from grid for stationary robots, act as power sources. But for nano-scale machine it is very hard (sometimes impossible) to develop a power source like that. In the machines of nature there always being a power source for almost all living cells, known as **mitochondria**, where the power is generated by combustion of organic molecules (glucose) and stored as ATP, the universal energy storage. The same system is suitable for nanorobotics, where the power source supplies chemical energy to the actuators. The process of ATP synthesis is catalyzed by an enzyme called ATP synthase which connects a phosphate group to ADP via high energy bond, and that energy is being released by the catalytic function of ATPase when ever needed.

ATPase in the above mentioned process acts as a molecular motor (as it rotates in the process) and it can be used as a perfect nano-scale compatible for the actuators such as electric motors in the macro-scale robots. Thus ATPase combined with ATP makes a combined power source and motor in molecular level.

This is similar to the electric motors or the actuators of macro scale robots. There are more biological 'devices' that can be used for similar tasks, using the same power source ATP. For example *'the flagella motor'* of bacteria, seems similar to the human scale motor, but use the decomposition of ATP as the power source. There are other types of nano-machines such as DNA actuators, Viral Protein motors do not use ATP as the power source.

The structural-links of macro-scale robots made up of metal, plastic polymer etc. are replaced by *DNA nanotubes* in nano-scale robots and conventional joints are replaced by ***DNA hinges, Molecular Bonds, Synthetic bonds*** *etc.* While transmission elements are proposed to replace by *Beta-sheets.*

What about sensors and processing unit? It is not a big deal to find sensors for the biological machines, because the nature is full of sensors. Think what they are.....?

For the field of robotics, scientists consider few sensors with simple interfaces, like Rhodopsin, Heat Shock Factor, etc. but the candidates for sensors are still under investigation.

Will it succeed?

It is not a truth to say that there are readily available bio-nanorobots developed, but there are many research activities going throughout the world to accomplish the goal of developing first nano-scale working robot. There

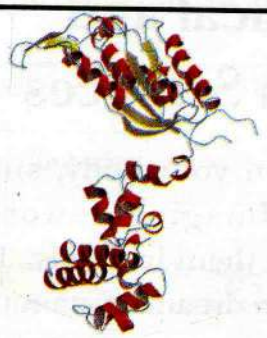


Fig 7 DNA hinge

are still lots of research projects for developing the computational component for the nano-scale machines, and the outcomes are not published yet. Before concluding, it is a must to think about some of the issues that may be raised due to introduction of nano-scale robots. If artificial machines get the abilities such as self replication and self assemblage at nano-scale what would be the out come? Up to now we all, only the living beings had these features. Can a man made machines that go beyond the limitations of nature?



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<Nano-technology>

What is TECHNOLOGY ?

According to many English dictionaries

Technology *is*

"systematic application of knowledge in practical tasks in Industry"

We cannot understand above, if we do not know what is industry!

What is INDUSTRY ?

In most simple terms,

Industry *is*

"Production and Marketing "

Then, TECHNOLOGY is

"application of knowledge in practical tasks in Production and Marketing"

If there is no MARKETING there is no Technology !

Marketing is the critical component of any technology

Nanotechnology in Medical and Health Sciences

Imagine an army of nanosensors roaming around in your body, sniffing and destroying cancer cells, bacteria and viruses. Imagine a workforce of nanomachines picking up damaged cells and repairing them instantly. This might sound like a scene from a science fiction movie. Today's dream of nanotechnology may be the reality in the future!

Nanomaterials and Nanotechnology (NT)

Molecular structures with length measurements upto 100 nanometers or less are called nanomaterials. Nanotechnology (NT) is the creation, manipulation, and application of such materials. Nanoparticles do not behave like solids, liquids, or gases we are familiar with. Their behaviour is guided by the laws of quantum physics. Nanoparticles of the same chemical may have electronic, magnetic, and mechanical properties quite different to the larger particles of the same chemical.



Nanomedicine

Nanomedicine is one of the most promising applications of NT. Nanomedicine might sound like scenes from a science fiction movie. Nanobots (nano-robots) in your veins roaming around, sniffing out and killing cancer cells and nanomachines picking up damaged cells and replacing them, may one day become a reality. Perhaps in the future, nanosensors inserted into your body will remain vigilant for organ malfunction and will alert your family doctor remotely. On physician's instructions, orders, transmitted remotely, the implanted molecular-sized pump will deliver the precisely correct dose of the required medicine directly to the target organ. This is what nanotechnology has in store for the medicine in the future. Scientists are looking at developing nanoscale tools and machines, designed to monitor health, deliver medicines, cure diseases, and repair damaged tissues. The built-in nanosensor in your body will constantly monitor your environment and warn you if the exposure to environmental radiation and toxic agents such as organophosphate compounds are reaching dangerous levels. The advantage of such sensor is that it is small, lightweight, inexpensive, and easily operated. Nanosensors will also help to understand the interactions between genes and the environment and to learn how cells communicate with each other.

Compare the sizes with nanoparticles!

White cell in blood	10000 nm
Bacterium	1000 – 10000 nm
Virus	75 – 100 nm
Protein molecule	5 – 50 nm
Nanoparticles	**1 – 100 nm**
Width of DNA	2 nm
Fullerine	**1 nm**
Atom	0.1 nm

Phases of NT development

NT development is in four phases. The first consists of *'passive nanostructures'*, which are designed to perform one task only. The second phase, *'active nanostructures'* will include drug delivery devices, new types of transistors and sensors. A third phase would feature *'nanosystems'* with thousands of interacting components. The fourth phase, *'molecular nanodevices'* would be composed of systems within systems operating much like a living cell!

Applications of NT currently in use

- Stain repellent clothing: nanofibres keep water from soaking into fabric
- Stronger, stiffer tennis racquets and golf clubs: Hit the ball harder and more accurately because they flex less
- Antimicrobial wound dressings: nanofibres and particles with medically active coatings get to all parts of the wound
- Bouncier tennis balls: Less heat loss in flexing means more energy is restored to the bounce
- Skin care cream: Nanoparticles carry moisture deeper into pores
- Better sunscreen: nanoparticles provide a more even skin coverage
- Car wax: Like skin cream and sunscreen it offers more complete coverage
- Self cleaning windows: Dirt slides down nanoscale coating on he outside of windows
- Tougher paint: Dried matrix is more resistant to impact

Engineered nanoparticles are already being used commercially, in some sporting goods (eg stronger tennis racquets), tyres, building material (eg. self cleaning windows) and in clothing (eg. stain resistant clothing) industry. Newer sunscreen creams contain nanoscale titanium dioxide or zinc oxide particles. Unlike commonly available opaque white sunscreen creams, NT based ones are transparent, but still block ultraviolet rays effectively. Fullerenes are used in many products ranging from pharmaceuticals and semiconductors to coatings used for bowling balls.

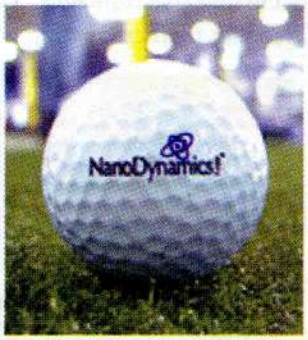

Fig 1 NT engineered golf ball

Immunoisolation

Application of nanotechnology will, in the future, enable the doctors to cure diabetes. Insulin-secreting, islet cells taken from the pancreas of a pig can be transplanted under the skin of a diabetic patient, to correct the lack of insulin. A major problem in this kind of tissue or cell transplant is that the recipient of the transplant developing an immune response against the foreign tissue, and rejecting it. To overcome this, a variety of drugs (immuno-suppressives) are used to curb the immunity. These drugs have the disadvantage of causing infections and cancers. NT engineering can be used to encapsulate the cells, and evade the immune response and rejection. This will protect the transplanted tissue while avoiding the need for toxic, immunosuppressive drugs. Transplantation of encapsulated will be an effective way of treating enzyme or hormone deficiency states in the years to come.

It may also be possible to implant encapsulated neurons in to the brain and then electrically stimulate them to release neurotransmitters. Such an approach would open up new avenues in treating diseases such as Parkinson's Disease (a condition where there the limbs become stiff and hands become shaky) and Alzheimer's disease (a disabling condition, where there is gradual memory loss).

Nanoshells

Nanoscale systems, called the nanoshells, designed to deliver drugs to target tissues, have been developed. A nanoshell is slightly larger than the polio virus. The drug that has to be delivered to the target tissue, for example to the tumour, is incorporated into the nanoshell. These nanoshells are injected and made to accumulate near the tumour cells. An infrared laser beam is then applied. The nanoshells selectively absorb the specific infrared frequency. The polymer gets dissociated and the drug is released to accurately on the tumour tissue. Antibody-attached gold nanoshells have also been developed for immunoassays, a technique used in diagnosing diseases. These nanoshells are capable of detecting subnanogram quantities of antibodies in blood, within 10 to 30 minutes of sample collection, allowing rapid bed-side diagnosis.

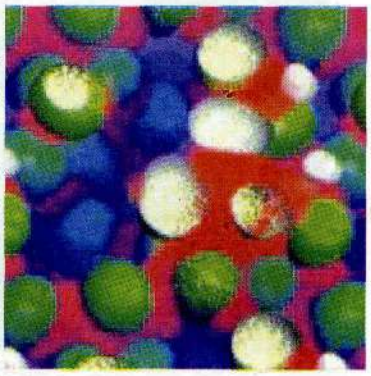

Fig 2 Computer-generated model of the interaction of nanoshells with the target molecules

Nanosieves

Ion transport can be controlled by modifying physical characteristics such as voltage gating, pore size, shape, and the charge. Nanosieves can filter out molecules with different characteristics with great precision. This degree of precision is valuable in certain applications in medicine.

Nanopores in ultrafast DNA sequencing

Nanopores can rapidly differentiate between pyrimidine and purine segments in a single RNA molecule. This allows them to discriminate between DNA chains of similar length and composition even if they differ by only one base pair. Such techniques will be a boost to scientists working in the field of genetic engineering.

Single virus detectors

Detecting even a single virus particle with great accuracy is possible with advances in NT. Within the next few years, diagnostic tools incorporating nanotechnologically engineered single virus detectors may be available to the practicing doctor.

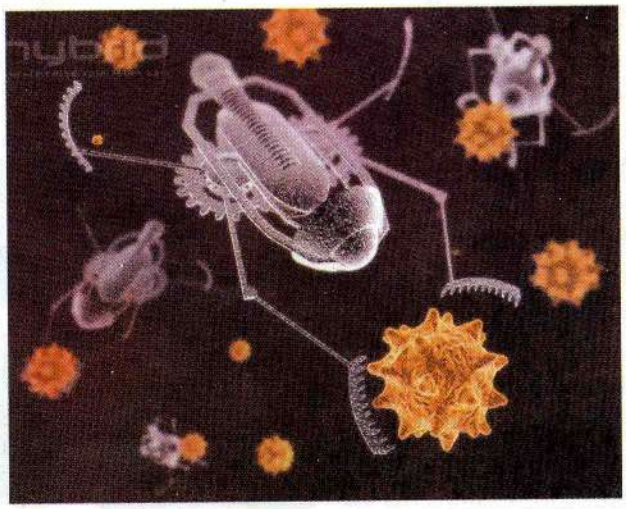

Fig 3 An artist's impression of a virus detecting nanorobot

Biological robots

With as little as 300 genes, it is now possible to engineer bacterial 'biorobotic' bacteria. These 'synthetic' microbes could be designed to produce vitamins, hormones, enzymes, or cytokines used to treat patients. Bacterial biorobots capable of absorbing harmful substances such as poisons and toxins and metabolizing them into harmless products will be possible with advances in NT.

Radio-controlled biomolecules

Tiny radiofrequency antennas, using 1.4 nm gold nanocrystals less than 100 atoms, can be attached to DNA. This will make it possible to control gene expression in living systems via remote electronic switching. Gold nanoparticles are attached to specific nucleotides and added to a sample of DNA. This would then bind to complementary gene sequences and block the activity of specific disease-causing genes.

Respirocytes

An artificial, 'mechanical' red blood cell, called the 'respirocyte' is undergoing development. It is a spherical structure powered by glucose in blood, and capable of delivering nearly 240 times more oxygen to the tissues than the natural red blood cell. In the future, it will be possible to inject oxygen-carrying 'respirocytes' to an accident victim who has lost a large amount of blood, without waiting for blood transfusions.

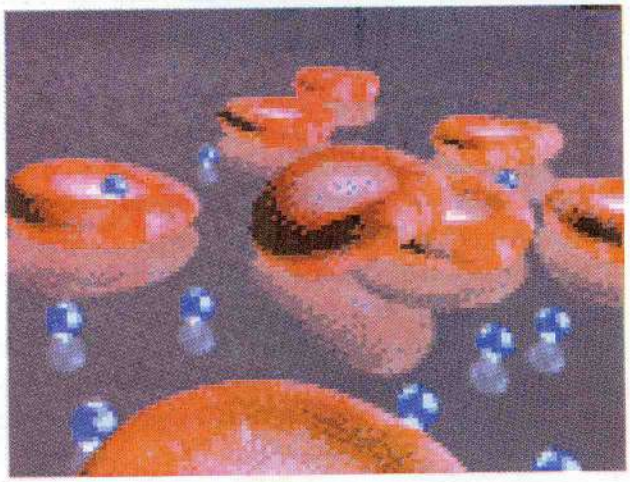

Fig 4 An artist's impression of respirocytes

Microbiovores

An artificial mechanical white blood cell, called a 'microbivore', has been developed. It uses a '*digest and discharge*' protocol to destroy microorganisms. These are predicted to be 80 times more efficient than the naturally occurring macrophages. These would also have a longer life span than circulating white blood cells. Microbivores

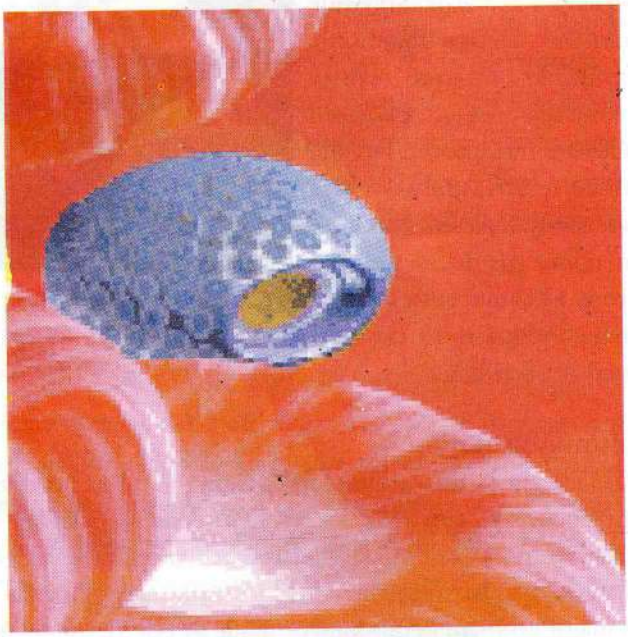

Fig 5 How a microbivore, an artificial white cell may look like!

may be useful to boost defenses against microbes at local sites of infection. Once they have performed their function it would be possible to remove them from the body.

NT for a safer enviornment

NT applications can be used to decrease the generation of pollutants, to 'clean up' existing pollution, and to monitor the environment. Improvements in membrane technology provided by nanomaterials should allow better water filtration, desalination, and wastewater treatment and provide practical solutions to the scarcity of safe drinking water in developing countries.

Health and environmental risks of NT

Potentially large benefits of NT need to be looked at in the context of their possible health and enviornmental risks. The effects of nanoparticles getting into the soil, water, air and into living organisms, either through environmental exposures or by direct applications, remain unexplored. An area of concern is that this NT is moving faster than our ability to evaluate its safety and health risks. Some early research findings are rather worrying. Recent studies suggest nanoparticles may not be as innocent as previously assumed. Some are able to travel readily through the body, get deposited in different organs and even penetrate individual cells. They have the potential of triggering inflammatory responses. Nanoparticles in the environment, known as ultrafine particles, have widely varying shapes, sizes and composition in contrast to engineered nanoparticles which are single, uniform compounds.

Experimental results

In 2004, it was reported that inhaled nanoparticles accumulate in the nasal passages, lungs and brains of rats. When a suspension of carbon nanotubes (one of the most widely used engineered nanoparticles) was placed into mouse lungs, it caused granulomas that interfered with oxygen absorption. When this experiment was repeated in rats, immune cells were found to accumulate around clumps of nanotubes blocking the breathing passages. Oxidative stress (a sign of inflammation) in the brains of largemouth bass exposed to water based fullerenes has raised several health implications.

Safety concerns

It is important that before these products are mass produced and dumped on consumers one needs to be sure they do not cause harm. In 2002, the Action Group on Erosion, Technology, and Concentration (ETC Group), called for a worldwide suspension on research and commercialization of engineered nanomaterials until there are protocols in place to protect lab workers. In the 1990s, the same group has played a key role in the battle against acceptance of Genetically Manipulated Organisms (GMOs).

In summary

Nanotechnology has enormous potential for the benefit of the society. Applications may range from new cancer treatments to new sources of renewable energy. It is vital that different segments of society should work in concert to prevent its true potential being markedly limited or destroyed by real or perceived risks. Problems or questions that are bound to crop up from time to time should to be addressed early and transparently. Past mistakes of rolling out new technology too far ahead of health and safety consideration must be avoided. It is only then that the science of the very small would have a chance of becoming very big.

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For further latest information on Nanomedicine

Read the scientific article (available from the web)

Nanotechnological applications in medicine

Shelton D Caruthers, Samuel A Wickline and Gregory M Lanza

In the journal

Current Opinion in Biotechnology

Volume 18, Issue 1 , February 2007, Pages 26-30.

Some useful websites:

(http://nano.cancer.gov/) (http://nano.cancer.gov/programs/ccne.asp) (http://nano.cancer.gov/programs/nanotech_platforms.asp)
(http://www.nhlbi-pen.info/) of the National Heart, Lung and Blood Institute
(http://ncl.cancer.gov/) to help facilitate the transfer of nanotechnological research into clinical practice, the NCI, in conjunction with the National Institute of Standards and Technology and the US Food and Drug Administration (FDA) has established the National Characterization Laboratory.

THALASSAEMIA -

PREVENTION IS THE BEST OPTION FOR DEVELOPING COUNTRIES - SRI LANKANS CAN CONSIDER "THELASSAEMIA PRONDOMA"

Introduction

To understand thalassaemia, it is important to learn about blood. We have about 5 liters of blood in an adult person (80 ml/kg in a child). Blood has liquid component which is called plasma and cellular component comprising of red cells, white cells and platelets. Red cells are dealing with transport of oxygen from lungs to other organs and carbon dioxide from tissues to lungs. White cells fight infections. Platelets stop bleeding by forming blood clots. Blood circulating all over the body transport nutrients from gut, hormone from endocrine organs, and waste products from all the tissues. Every heart beat pumps about 70 mL of blood and within one minute (beating 75 times) entire blood volume in the body will pass the heart and lung. As 20% of the cardiac output is passing through the kidney, total blood volume will pass the kidney in 5 minutes.

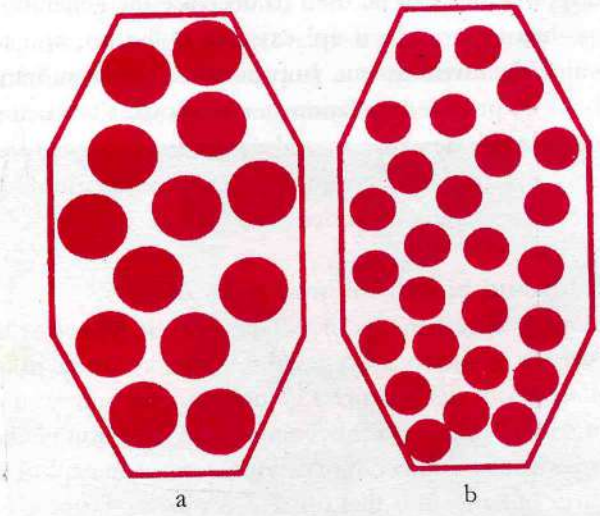

Fig 2 Size difference of red blood cells of (a) an ordinary person, (b) Thalassaemia affected person

Red blood cells

Thalassaemia is a disorder of red blood cell. There are five million red cells in one milliliter of blood. Red blood cell is a biconcave cell that can change its shape in order to pass through small blood vessels. Hemoglobin gives the redness to red cells. It is the most important constituent within the red cell that will transport oxygen. In one red cell there are 300 millions of these hemoglobin molecules. These hemoglobin molecules have two components; heam and globin. In thalassaemia production of globin is defective. That will lead to premature breakdown and ineffective production of red cells resulting in anemia (lack of redness in blood).

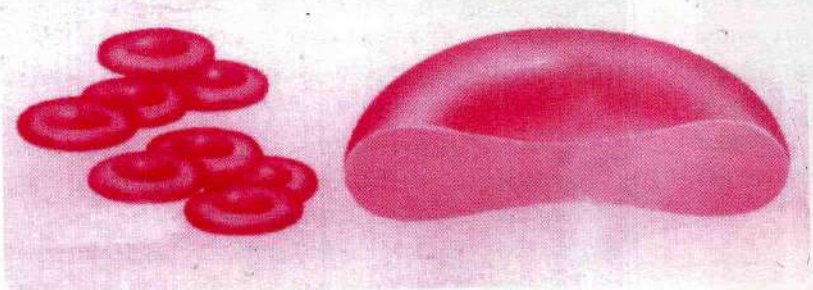

Fig 1 Normal red blood cells (rbc). Enlarged cross sectional view shows the biconcave shape

Genetics and inheritance

Globin is a protein. Synthesis of proteins in our body is controlled by genes. Reason for non production or inadequate production of globin chains is a genetic defect. Thalassaemia is an inherited disorder of blood leading to premature break down of our red cells causing anemia.

We inherit our genetic material from our parents at conception. These genetic materials are found inside the nucleuses within the chromosomes of almost all the cells in our body. Everybody has 22 pairs of chromosome. In a pair, one chromosome comes from father and the second comes from mother. In addition to this, in males they have one X chromosome (from mother) and Y chromosome (from father). In females they have two X chromosomes one from mother and the other from father.

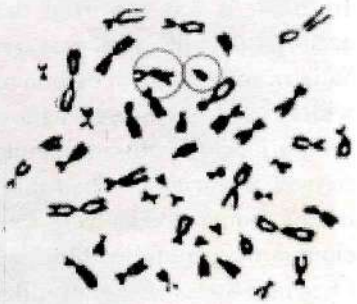

Fig 3 Chromosomes: Chromosomes inside a cell can be visualized by using a technique called karriotype, pictures are taken by electron microscopy. There are 22 paid of chromosomes and X and Y chromosomes in a female

Defective gene is acquired from only one of the parents in some disease conditions. They are called dominant inherited disease. **Disease like thalassaemia, will manifest only if two defective genes were inherited from both parents. This is called a recessive disease. We have a pair of genes to perform one function. We inherit them one each from mother and father. One of them being defective will not produce any symptom. Those who are carrying only one defective gene are called carriers. Even though carriers are not symptomatic, they have a risk of having an offspring with a disease like thalassaemia if they happen to marry another carrier.**

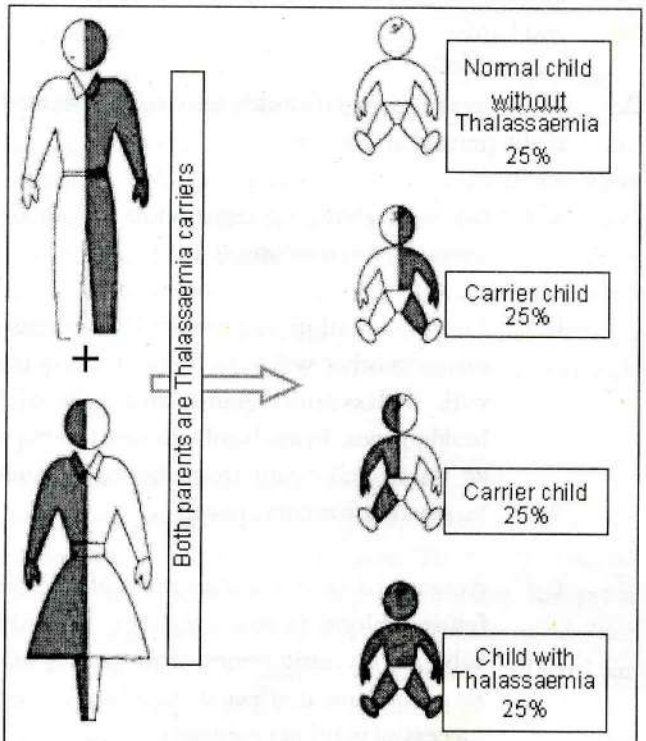

Fig 4 If father and mother both are Thalassaemia carriers, there is a 25% probability of having a child with Thalassaemia, 25% probability to have a healthy child, and 50% probability for a carrier child.

Figure 4 shows how a marriage between two thalassaemia carriers produces a child with thalassaemia. If two thalassaemia carriers (represented as half shaded figures) marry, they have a 25% risk of having a baby with thalassaemia. 50% of their babies will be thalassaemia carriers like their parents. There is only a 25% chance of having a non-carrier normal baby.

How do we prevent having a Thalassaemia Child? The only way for a thalassaemia carrier is to marry a non-carrier. Then none of the children will be affected (Fig. 5). Therefore, marriage between a thalassaemia carrier and a non carrier is the safest approach to prevent birth of a thalassaemia child.

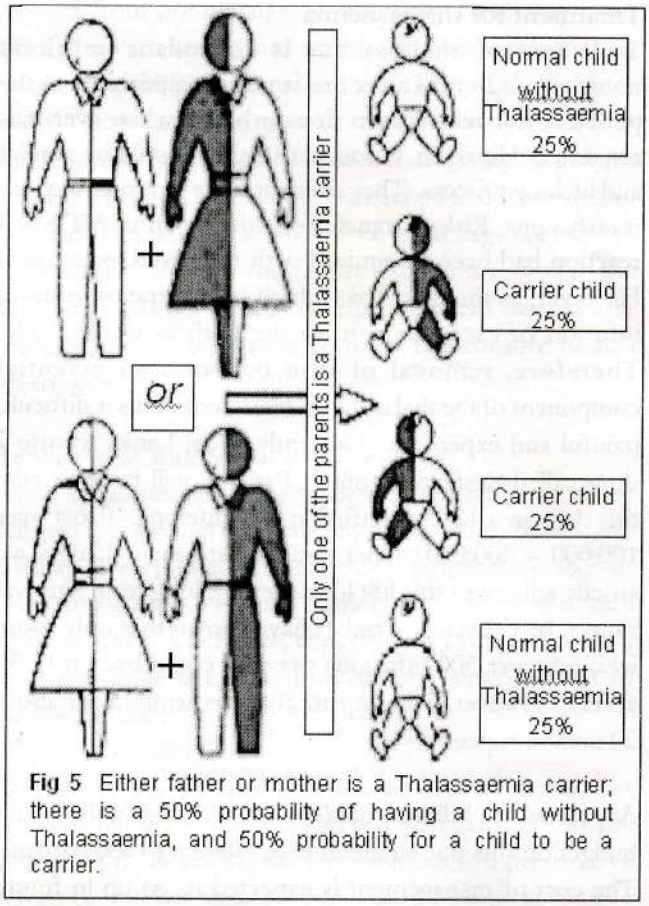

Fig 5 Either father or mother is a Thalassaemia carrier; there is a 50% probability of having a child without Thalassaemia, and 50% probability for a child to be a carrier.

Thalassaemia effects

When a thalassaemic baby is born to a couple who are both carriers, red cells in the baby's blood will get dissolved prematurely and red cell production will be defective leading to anemia; inadequate hemoglobin and red cells. This will affect all the functions of the body including the growth. Child will be pale and lethargic. He will have shortness of breath. Attempt at producing more red cells by expansion of bone marrow will lead to deformities and fractures of bones. Production of red cells in the liver and spleen will lead to massive enlargement of both organs.

At the same time in response to anemia, the gut of the baby will start absorbing more iron even though the child does not having iron deficiency. There is no natural system of iron removal from the body. Iron in excess is toxic and will lead to damage the heart, liver and pancreas leading to heart failure, cirrhosis and diabetes.

Treatment for thalassaemia

Treatment of thalassaemia is dependant on blood transfusion. In Sri Lanka this is not a big problem as the public is not reluctant to donate blood when ever it is requested. However, blood transfusion should be regular and lifelong process. They need monthly or more frequent transfusions. Risk of transfusions like hepatitis, AIDS and reaction had been minimized with improved techniques. However, as the blood has a high concentration of iron, infusion of excess iron in to the body is unavoidable. Therefore, removal of iron becomes an essential component of the thalassaemia treatment. This is difficult, painful and expensive. Currently in Sri Lanka we use a drug called desferrioxamine. Patients will have to take this drug in a 12 hour infusion daily lifelong. (Cost over 100,000 – 300,000/= per patient per year). Unless we strictly adhere to this life long therapy, long term survival cannot be expected. Studies have shown that only those who get over 300 infusions per year could live up to 50 years. However, living up to 50 years would cost about 20 million rupees.

At present the Ministry of Health spends 5% of the health budget on this one single disease affecting 1500 patients. The cost of management is expected to go up in future due to unavoidable cost escalation as we are prolonging the life of patient with an incurable disease leading to accumulation of patients. Many countries, developing and developed, all over the world are using another drug called deferiprone, which is cheaper and considered more effective when used in combination with desferrioxamine. Unfortunately, use of this less expensive drug has been given up by our medical practitioners prematurely due to few case reports of side effects without further evaluation.

Thalassaemia prevention

As this genetic disease is incurable and the cost of management unaffordable, prevention is the only option of managing thalassaemia in Sri Lanka. Thalassaemia prevention should be considered as a way of looking after thalassaemia carriers rather than a programme to eliminate the burden of thalassaemia from a society. This approach will eliminate the feeling of discrimination and ill treatment by medical authorities towards thalassaemia carriers.

Thalassaemia carriers have a problem of running a risk of marrying another carrier and producing a child with thalassaemia. This problem is hidden until their carrier status is checked. **This can be done by a simple blood test called red cell indices for carriers.** This test will measure the volume of red cell (called MCV). Normally it is above 80. Patients with thalassaemia or iron deficiency MCV is below 80. **Both conditions need evaluation and treatment. Accuracy of this test is about 95%.** Scientists are presently evaluating more precise and cost effective tests.

Options available for thalassaemia carriers:

1. Teenage screening and promotion of safe marriages – This is the best option for Sri Lanka. Options that could be adopted when some body is checked after marriage or selecting partner are much difficult and harder.

2. Checking the partner if already selected and decided. If the partner also a carrier;

    a. Consider giving up registration and finally leading to separation

    b. Pre-implantation diagnosis (Thalassaemia carrier mother will have 50% of the ovum with thalassaemia genes, and 50% with healthy genes. In this highly advance technique an unaffected ovum from the mother will be selected for conception)

    c. Antenatal diagnosis and abortion of affected fetuses (blood sample are taken from the baby at very early stages of pregnancy and abort the baby if affected. Considered very successful in other countries)

    d. Limiting the number of children (having 1-2 children instead of 4 children will bring down thalassaemia incidence by 50%)

    e. Take the challenge of looking after a baby with thalassaemia

        1. Bone marrow transplant – Will achieve total cure. Cost only 3 million Rupees. Carried out in India.

        2. Blood transfusion and long term chelation – Life long therapy. Cost 20 million Rupees to live up to 50 years.

Thalassaemia prevention in Iran

Thalassaemia prevention strategy in Iran has set an example for all the developing countries. They implement the project with the basic knowledge of genetics, avoid marriages between carriers. They have tested all the couples when they come for registration of their marriage. Man is tested first. If he is not a carrier, marriage will take place without further testing of women as there is no problem even if she is a thalassaemia carrier.

However, if the man is a carrier then the women is also tested. If she is not a carrier again the marriage takes place with no further testing. If both are carriers, then they are counseled. They will be explained the gravity of the problem and they are allowed to make a decision about their marriage.

Fifty percent of the couples have decided to avoid the marriage and others have restricted their family size. Incidence of thalassaemia in Iran has come down form 1200 before intervention, to 72 cases in 2002. However, as authorities have found significant number of carriers are proceeding with their marriage, abortions have been legalized since 2001. Difficulty in changing the decision when it is offered as late as time of registration is well understood.

Thalassaemia prevention in Cyprus

Thalassaemia prevention in Cyprus started in 1972. At present they don't have new cases. They have offered screening, pre-marriage counseling and abortion. In Cyprus every body is tested and given a card to indicate his/her carrier status; A green card for non-carrier, red card for carrier and violet card for undetermined person. If two persons carrying a red card come for registration of the marriage they are referred to a doctor to explain the problem and they are given options to make decisions about their marriage and family.

Teenage screening for safe marriage

Concept of teenage screening for safe marriage would be the best for Sri Lanka. Considering the experiences in Iran and Cyprus, my suggestion for Sri Lanka is to offer screening and counseling before the young people select their partners. This the basic principal of ***"Uva Thalassaemia Prevention Project"*** *proposed by me in year 2002. Iran has achieved most of its results while abortions were not legalized.*

Pre-marriage counseling is a step forward from antenatal diagnosis and abortion. Teenage screening is another step forward from pre-marriage counseling. Detecting them when they are teenagers, well before they select their partners would leave them with another option; that is to select a non carrier partner to marry. This would be a better and socially accepted option than giving up already decided marriages. Checking horoscope and looking into case and other social factors before a marriage is a custom in Sri Lanka. Parents and family also get involved in the decision making. **Introducing 'medical horoscope reading' would be a new concept to promote health marriages!**

Benefit is at individual level

When a thalassaemia carrier is detected, benefits he or she will gain is as great as detecting any other serious but curable disease. Even though thalassaemia is an incurable disease, problem of a thalassaemia carrier could be solved with 100% efficacy. Therefore, checking for carrier status will have individual benefit irrespective of what the rest of the society is doing.

Attitude of the medical practioners should be just like detecting any other major health problem with appropriate intervention. Revealing the carrier status to a person well before they select their partner would be a great help to an individual and his family,. Therefore, medical doctors should take microcytosis as an important finding and evaluate it properly to conclude whether it is iron deficiency or thalassaemia trait. For this there is no need to have an on going thalassaemia prevention programme in a country.

Is it essential to detect all the carriers?

For a successful prevention programme, detection of all the carriers will be ideal. However, Iran thalassaemia programme has screened only the males and proceed to check female partner only if the male is a carrier. Majority of thalassaemia carrier females would have undergone the marriage without even knowing it. This would be a great relief for females in the Iranian society. This definitely brings down the cost of screening by significant amount.

In Sri Lanka, if we promote to make sure one of the partners (irrespectively of male or female) of a couple to be a non carrier the concept will be more flexible, where even a male carrier also can under go marriage with out been tested.

Safe marriage

When we consider thalassaemia or any other recessively inherited conditions, of one of the partners in a couple is

not a carrier the couple will be safe as far as ihherited condition is considred. When oever we talk about screening programmes, traditionally we talk about detecting all the carriers,. However, as thalassaemia is not a contagious disease, missing carries are not going to spread the disease, Therefore, promoting safe marriages would be more practical and easy option.

If we promote and try to achieve safe marriages rather than detecting all the carriers, majority of the carriers (95% in a society with 5% carriers) will marry somebody who is not a carrier by chance. This will be of great help to thalassaemia carriers as majority of them will not face a problem in finding a partner. Challenge for authorities when launching a thalassaemia prevention programme would be to establish correct attitudes of the society towards marrying a thalassaemia carrier.

Individual responsibility

People living in a thalassaemia prevalent society has an individual responsibility to get them selves checked for their carrier status. While the government should provide much required facilities and support, everybody should screen themselves as it will be for their own benefit. Therefore, such a programme will be sustainable if we have a correct education and approach towards this problem. Even very poor people of Sri Lanka spend large sum of money to arrange their weddings. Therefore, some of this money could be converted for a very useful testing for their own benefit.

Responsibility of medical practitioners

Any medical doctor practicing in thalassaemia prevalent society has the responsibility and duty to evaluate and reveal the thalassaemia carrier status of his/her patients and advice them about the options available depending on the available resources of that country. The routine MCV, MCH should be done once in a life time on all the teenagers just like checking blood pressure or blood sugar in adults. If complied advice given to a thalassaemia carrier will be 100% effective in prevention of having children with thalassaemia.

Responsibility of health authorities and rights of thalassaemia carriers

Our population has 2-4% thalassaemia carriers. Majority of them are distributed in thalassaemia prevalent provinces, North Central, Wayamba and Uva. Their problem is hidden unless they are tested. As the condition is affecting such a large number of people (nearly one million persons) it is the duty of the Ministry of Health to look in to this problem. The carriers have the right to know their problem and solutions available for it.

Following health care policies are proposed for our country;

1. All the people should be given facilities to test their blood for thalassaemia carrier status (at least in Thalassaemia prevalent provinces).
2. For registration of a marriage at least one of the partners should be non carrier person. "having a green card" or
3. The couple should undergo a session of counseling before proceeding with a high risk marriage. High risk marriage is defined as;
   - i. A marriage between two persons who were not screened,
   - ii. Between two thalassaemia carriers
   - iii. Between one unscreened and one thalassaemia carrier.

Only two out of 1000 marriages are expected to be high risk marriages. Therefore, a policy of this nature should not cause any problems in the society.

Responsibility of parents, marriage brokers and horoscope readers

At present 20% of the proposals are given up due to the mismatching horoscopes. Considering thalassaemia carrier status and avoiding a marriage between two thalassaemia carriers has a very strong scientific basis. **Giving up a proposal between two thalassaemia carriers is a very wise decision to avoid a life time agony to a child and a family. Therefore, matching the THALASSAEMIA PORONDAMA would be an essential component to other factors that we consider in selecting partners. However, the final responsibility lies with the man and woman those two who are going to marry and produce healthy children.**

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