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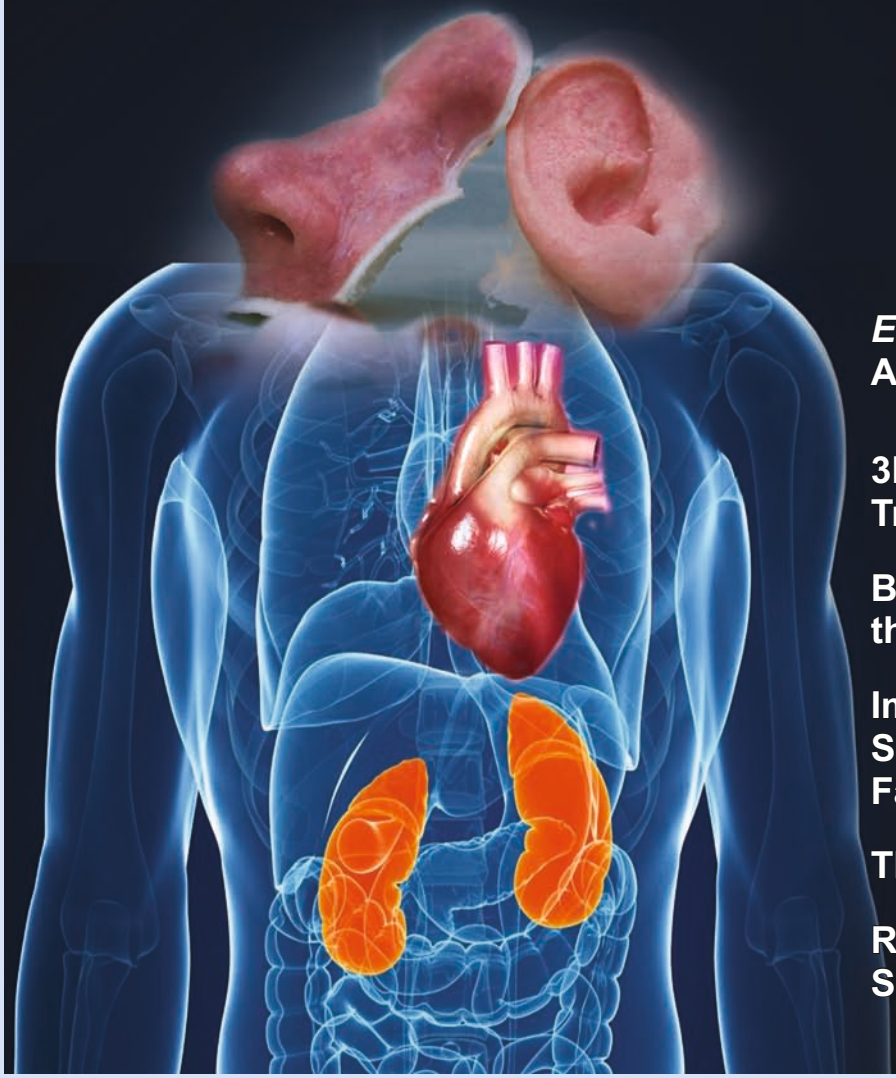
3D Printed Organs for Transplant



... think scientifically, act scientifically... think scientifically, act scientifically... think scientifically, act...

EDITORIAL

Facilitating the Accessible India Campaign

Chander Mohan

Dis'Ability' embodies Ability. The Persons with Disabilities (Equal Opportunities, Protection of Rights & Full Participation) Act, 1995 defines a person with one or more of disabilities like blindness, cerebral palsy, locomotor disability, leprosy-cured, mental retardation, mental illness, hearing impairment, as disabled. Shri Narendra Modi, Hon'ble Prime Minister of India, soon after assuming office, befittingly coined the word *Divyangjan* for person belonging to this disadvantaged section of society and launched the Accessible India Campaign (*Sugamya Bharat Abhiyaan*) to fast track redressal of challenges being faced by them. Department of Science and Technology (DST) was quick to respond to this onerous task by acknowledging that social inclusiveness and empowerment of *Divyangjan* is also realised by access to affordable, reliable and adaptable assistive technologies, tools and techniques. The Rights of Persons with Disabilities Act, 2016 underpins Research and Development (R&D) for provision of affordable and accessible assistive technologies for creating equal opportunities and social inclusiveness of *Divyangjan*.

The need for accelerating the pace of R&D in the field of assistive technologies under its unique initiative – Technology Interventions for Disabled and Elderly (TIDE) – which provides solutions for creating inclusiveness and universal accessibility for *Divyangjan,* was thus put on fast track. DST had supported around 50 R&D projects during the last four years for development of various assistive devices for *Divyangjan* and is now ready to offer several such technologies, tools and techniques for commercialisation.

A Technology Compendium comprising of over 35 such interventions has been developed under TIDE programme of Science for Equity, Empowerment and Development (SEED) Division, by *Vigyan Prasar* (VP). This first-of-its-kind initiative that may create seamless accessibility for *Divyangjan* in differently-built environments, transport and ICT ecosystems is now ready. The objective is to communicate an array of commercially viable interventions developed through financial support of DST to agencies like Department of Empowerment of Persons with Disabilities of Ministry of Social Justice and Empowerment besides technology developers, manufacturers, clinicians, academicians, NGOs and the general public to ensure greater reach and dissemination of such assistive devices. The products and prototypes developed under the TIDE programme cut across all the three verticals of Accessible India Campaign.

The Technology Compendium exemplifies the effort of many researchers, investigators and practitioners who toiled relentlessly for development of these interventions. As Head, SEED Division, DST, and Director, VP, I would like to thank them for their immense contributions and also place on record my gratitude to Committee of Secretaries for identifying TIDE programme to provide solutions to challenges faced by *Divyangjan.* I would also like to thank members of the Programme Advisory and Monitoring Committee of TIDE who have guided, mentored and nurtured the programme over the years. Jai Hind!

Email: chander.m@nic.in

Editor : Chander Mohan
Associate editor : Rintu Nath
Production : Manish Mohan Gore and Pradeep Kumar
Expert member : Biman Basu
Address for correspondence : Vigyan Prasar, C-24, Qutab Institutional Area, New Delhi-110 016
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3D Printed Organs for Transplant

Udayaditya Palety

The concept of creating an artificial organ has been around for a while; for over a decade researchers have been trying to fix the major organ shortage crisis and luckily they are getting closer and closer. In the late 90s researchers at the Wake Forest Institute in USA were able to create the protein building blocks required to build human bladders. Then in 2006 they then went on to actually create synthetic human bladders by extracting cells of patients with poor bladder function and were able to cure them with a transplant.

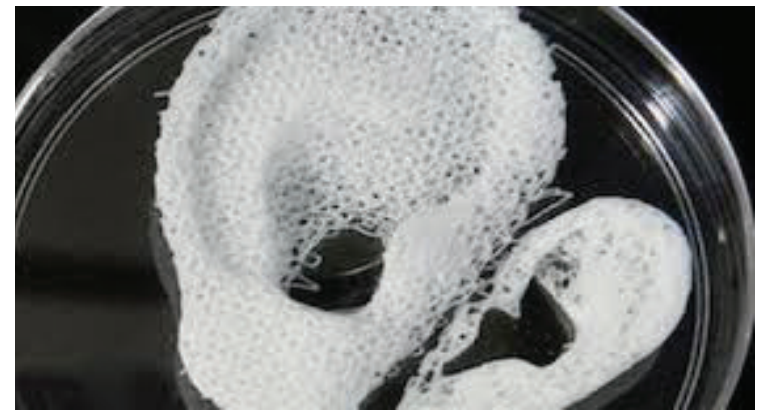
Introduction

Over the last 150 years, the average human lifespan has almost doubled. Most of us don't have to fight wars, neither are there many plagues going around, so we tend to live longer. However, the older we get the more likely our organs are likely to fail, although many people require new organs even at a young age because of organ damage or loss due disease. When a car breaks down we simply replace the damaged parts and drive on. However, with humans it is a bit more complicated. Right now, if you want a new body part you can only get it from other people. There has been a global shortage of donated organs for many years as the number of people requiring new organs has gone up, but the number of organ donors has remained the same, as people usually don't like to donate their organs when they are alive. Hundreds of thousands of people die each year due to the shortage of organs and that number will keep growing. But what if we could make our own organs? What if when someone wanted an organ he or she could just have it specially made for them? This will probably sound like science fiction to most people, but in a few years it might come true.

Background

The concept of creating an artificial organ has been around for a while; for over a decade researchers have been trying to fix the major organ shortage crisis and luckily they are getting closer and closer. In the late 90s researchers at the Wake Forest Institute in USA were able to create the protein building blocks required to build human bladders. Then in 2006 they then went on to actually create synthetic human bladders by extracting cells of patients with poor bladder function and were able to cure them with a transplant. Thomas Boland made history by printing and implanting a bladder into a human patient – the first time such a feat had ever been accomplished.

Complex 3D bio printers didn't exist back then; all Boland had back then was a standard home inkjet printer. So he had the bright idea to replace the ink in the cartridge with a liquid, containing cells. He then used the same liquid to coat the paper too;



Scaffold for a synthetic ear

Udayaditya Palety is a student of class XII in Sriram School, Moulasari, Gurugram. The article is written after he spent a few weeks at IIT Delhi and interacted with faculties and students. Email: udayaditya.palety@gmail.com

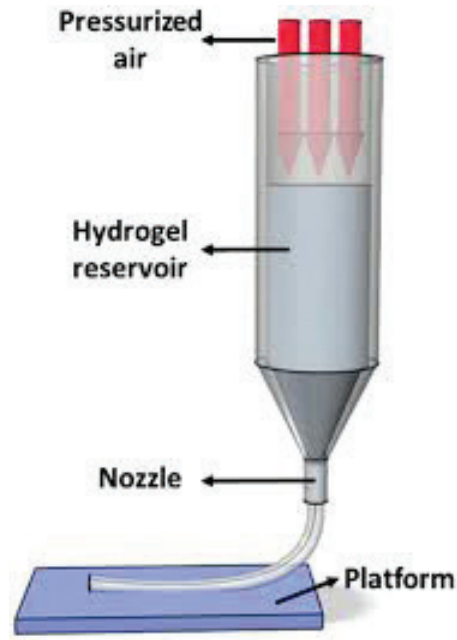
he loaded up the printer again and pressed print. Though organs couldn't exactly be printed using this method, it was a step in the right direction.

The technology today

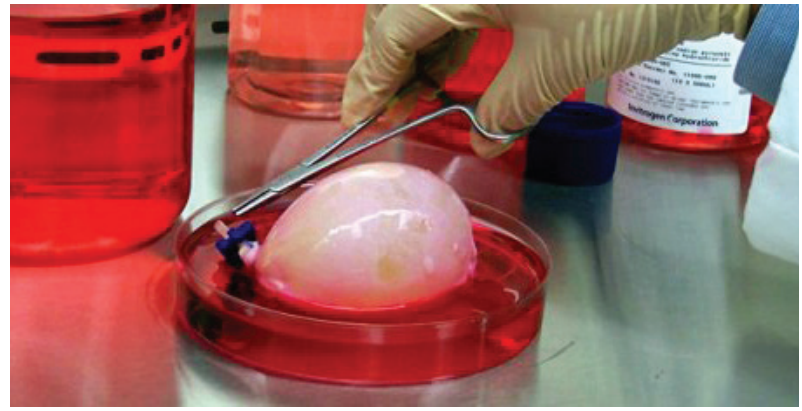
The technology has progressed in leaps and bounds since Thomas Boland and his homemade bio printer. With the advent of the 3D printing the future of artificial organs look bright. However, a fully functioning complex organ which can be used on a patient has not yet been created; scientists still face a variety of challenges. Today scientists can create 'mini' and replica organs which are fully functional for a while but have very short life spans due to inadequate vascular systems. Dummy organs are printed in hospitals and schools to help surgeons and medical students practise. 3D printing is already being used to help patients today with artificial metal and plastic bone structures such as a jaw, hips and even metal knuckles (which can prove to be quite useful in a fight). Printed skin grafts are used today to help people with burnt or damaged skin. Some cosmetic companies use large amounts of 3D printed skin every year to test their products so that their customers don't have to do it for them. Today there are several independent firms and companies that are working on this technology. The American Healthcare Company, Johnson and Johnson have invested in it heavily; firms such as Organovo are working on creating a fully functioning human liver and were able to transplant printed human liver tissue into a mouse. Sichuan Rovotech in china successfully transplanted a part of a printed human artery into a monkey. Though these may not seem like ground-breaking achievements, they're baby steps to achieving a bigger goal. Organovo claims they'll be able to cure chronic liver failure by transplanting printed liver tissue in three to five years – the future really is here!

The basics

Standard 3D printers work by creating layers of the molten plastic or any other substance, till it builds up the desired 3-dimensional shape. Think of it as gluing sheets of paper on top of each other to create a vertical 3D column. A virtual model of the desired structure is first created in computer and the printer then constructs it layer by layer. Using this method the printers can print anything from plastic figurines to shoes to chess pieces to even custom circuit boards.



Basic extrusion printing



A printed bladder

Though things like organs and tissues aren't exactly the same, the process to print them is quite similar. To print something, a model is always required so a blueprint of the organ is created through methods such as Magnetic Resonance Imaging (MRI), or a Computer Tomography Scan (CT scan). These methods help create a virtual 3D model of the organ and help researchers figure out the composition of cells required in different areas of the structure. The cells used are collected from the patient and can be regular or stem cells. These cells are then cultured in the lab and formed into a kind of 'bio-ink', which is then formed into structures called spheroids and put into a cartridge, like the way normal ink is stored in a inkjet printer cartridge. A special printer is required for this, since plastic and live cells aren't exactly the same thing. These printers need to be incredibly sophisticated to be able to print something as complicated as an organ. They cannot put too much pressure on the cells to avoid damaging them while maintaining a moderate temperature so that the cells don't become denatured (stop working). Once the cells are printed into a structure they don't just start working as an organ so they cannot be tested yet or be put inside a person; they need to be put into an incubator called a Bioreactor for a certain period of time so the cells can fuse together and start functioning as a single unit. Though the process may seem more or less straightforward, right now it is much more complicated than that and still requires a large amount of human intervention.

Multiple methods

There are many methods that can be used for successful bio-printing. It is no longer just a guy toying with his printer; in fact there are teams of researchers working every day to make the process more accurate and efficient.

There are two main techniques behind bio-printing, which are indirect and direct printing. Indirect printing involves first printing a sort of a mould or a scaffold into which cells can be placed later. In the early days of the technology these cells had to be placed onto the mould by hand, which was a painstaking and process and limited the complexity of the tissue that could be created. Now, however, with powerful printers and computers this method can be used to create tubes millimetres in diameter. The scaffold is created using collagen which

Continued on page 19

Balancing Methane Level in the Atmosphere

*Shashank Tiwari, Chhatarpal Singh & Jay Shankar Singh**

Methane (CH_4) is considered as the main culprit behind the global warming and the consequent climate change. The atmospheric level of CH_4 has gone up to 1,840 parts per billion (ppb) from 700 ppb since 19th century; i.e., the current atmospheric amount of CH_4 is more than 2.5 times higher than pre-industrial concentrations. So, it is important to find out how to balance the atmospheric methane level at global level.

Methane (CH_4), a colourless and odourless potent greenhouse gas (GHG) and contributing up to one-third to the total global GHG emissions, has been considered as the main culprit behind the global warming and the consequent climate change. The increasing concentration of CH_4 in the environment is a cause of great concern because its global warming potential is up to30 times greater than that of carbon dioxide (CO_2). This means CH_4 in the atmosphere is about 30 times more effective in increasing global temperature than an equal mass of CO_2. In last couple of centuries, the atmospheric level of CH_4 has increased significantly because of an imbalance between global emission and consumption across different ecosystems. According to a report of the Inter governmental Panel on Climate Change (IPCC), the atmospheric concentration of CH_4 has doubled during past 200 years and its concentration is rising by an average rate of 1% per year over the past few years. The atmospheric level of CH_4 has gone up to 1,840 parts per billion (ppb) from 700 ppb since 19th century; i.e., the current atmospheric amount of CH_4 is more than 2.5 times higher than pre-industrial concentrations. So, it is important to find out how to balance the atmospheric methane level at global level.

CH_4 emission at global level

CH_4 is emitted from both the natural and human-generated sources around the globe. Human activity is mostly responsible for the major part of global CH_4 emissions, (which may comprise up to the 63% of the CH_4 emission per year); the remaining emissions are natural. Agricultural livestock, paddy cultivation, burning of fossil fuels, waste disposal practices, landfills, coal mining, natural gas distribution, and biomass burning are human activities that generate CH_4. Whereas natural sources comprise wetlands, oceans, rivers, lakes, estuaries, gas hydrates, vegetation including terrestrial plants, wildfires, arthropods,

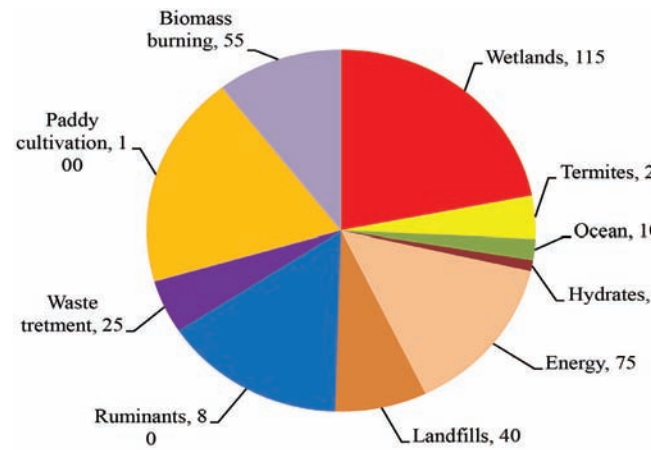


Figure 1: Chief methane emitters at global scale (Mt/yr) (Source: IPCC)

Shashank Tiwari and Chhatarpal Singh are Research Scholars and Dr. Jay Shankar Singh is Assistant Professor, Department of Environmental Microbiology, Babasaheb Bhimrao Ambedkar (Central) University, Lucknow, India. *Correspondence: E-mail: jayshankar_1@yahoo.co.in

wild animals and permafrost, etc. (Figure 1). The human generated CH_4 production has increased steadily since the dawn of the industrial revolution.

Biological CH_4 fermentation

Biologically, CH_4 is emitted by anaerobic bacteria called methanogens and the process may be termed to as methanogenesis. In water-logged and swampy places, CH_4 is produced as the terminal step of the anoxic (absence of oxygen) decomposition of organic matter generating CH_4 and CO_2. The anaerobic decomposition of organic matter and generation of methane in flooded places occur mainly through (a) hydrolysis of polymers by hydrolytic organisms, (b) action of fermentative bacteria to form acid from simple organic compounds, (c) formation of acetate from metabolites of fermentations by homo-acetogenic or cross-feeding bacteria, and (d) CH_4 formation from H_2/CO_2, acetate, simple methylated compounds or alcohols and CO_2.

$$C_6H_6O_{12} \xrightarrow{\text{methanogens}} 3CO_2 + 3CH_4$$

(e.g. Cellulose)

The Membrane Filter (MF) technique offers the advantage of isolating discrete colonies of bacteria. It is a versatile biotechnology to convert polymeric materials to CH_4 and CO_2 anaerobically, which is achieved by the successive breakdown of polymers with a variety of bacteria including acidogens (fermentative bacteria), acetogens (acetate-forming bacteria), and methane-and hydrogen-producing bacteria. Anaerobic bacteria play a very significant role in the formation of stable atmosphere at different stages of methane fermentation. For the advantageous point of view, MF offers an efficient means of pollution abatement and provides a superior means than results achieved via traditional aerobic procedures. Although, the process has been reported and used since 19th century, interest in it has been generated only in recent times. It has been used for the treatment of excess sludge released from sewage-treatment plants and used to treat waste waters discharged from distilleries, tanneries, antibiotic and baker's yeast manufacturing units.

Methanogens

Methanogens (methane generating bacteria) are spherical (coccoid) or rod-shaped (bacilli) archaebacteria (considered ancient life forms that evolved separately from bacteria). They are anaerobes and are very sensitive to the presence of even very low-level oxygen, i.e., cannot survive under aerobic environment. Over 50 species of methanogens have been isolated from water-logged places, sediments and many such places. Methanogens also thrive in the stomach of ruminants and produce CH_4 from CO_2 and hydrogen released by other microbes residing in their stomach.

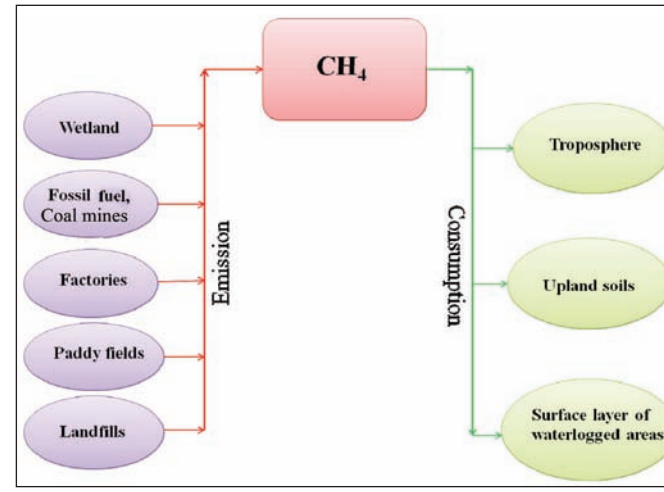


Figure 2: CH_4 emission and consumption in environment

CH_4 consumption at global level

In global perspective, CH_4 is oxidised by chemical and biological processes. The main sinks of CH_4 are photochemical oxidation in atmosphere and microbial consumption at or near the sites of emission. Approximately 90% of the atmospheric CH_4 is oxidised chemically within the tropospheric region with free hydroxyl radicals – 'the detergents of the atmosphere'. Moreover, aerobic upland soils are the second major biological consumers for CH_4 due to the presence of methanotrophic (methane-loving) bacteria. Methanotrophs (CH_4-oxidising bacteria) are an unique biological entity on Earth that help in scavenging CH_4 biologically and play a vital role in mitigating significant amounts of global CH_4 load. It is reported that soil methanotrophic bacteria are associated with the removal of an amount of methane, which comprises up to 6-10% of the global CH_4 consumption. The methanotrophs associated with the roots of rice paddies oxidise about 10-30% of the CH_4 emitted by methanogens in rice field, which are one of the leading producer of the potent GHG.

CH_4 scavengers

Methanotrophs are diverse groups of gram-negative bacteria. They are sole biological sink of CH_4 with proficiency of using CH_4 for their carbon and energy needs. They are cosmopolitan and can be isolated from a wide variety of environments including extreme conditions. On the basis of CH_4 oxidising pathways they have been divided into three types based on the pathways they use to remove CH_4. Methanotrophs contain CH_4 monooxygenase enzyme to oxidise CH_4 into CO_2 through different steps (Figure 3).

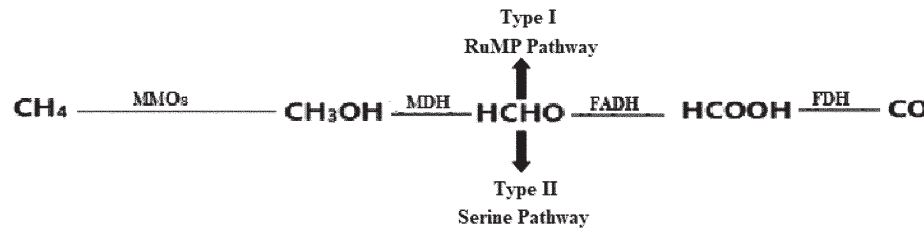


Figure 3: CH_4 oxidation pathway (MMOs: CH_4 monooxygenase; MDH: methanol dehydrogenase; MDH: formaldehyde dehydrogenase; FADH: formate dehydrogenase; FDH)

Reforestations of wastelands can contribute to CH_4 mitigation

The world human population has increased by up to 250% in last six decades and is expected to cross 9.6 billion by the end of year 2050. In order to provide food for all, the production of cereals needs a leap

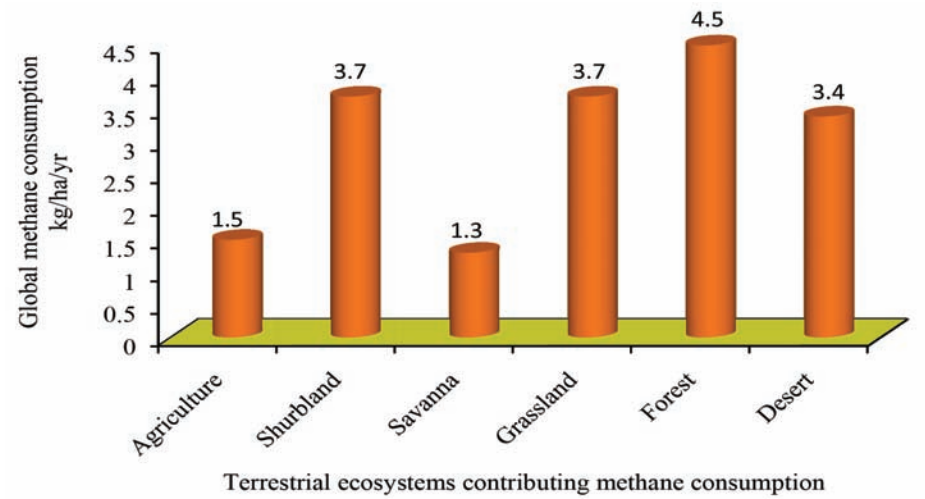


Figure 4: CH_4 sink activity across different land use types(Source: Singh and Gupta, 2016)

of nearly 50% annually. This difficult goal puts heavy pressure on agriculture. The conversion of natural subtropical forest to farmland lowers the CH_4 sink capability of soil. However, the same may be recovered after afforestation. Addition of inorganic fertilisers to fields also disturbs the CH_4 sink activity. In addition, the developmental activities are going throughout the world leading to cutting down of trees as well as releasing large amounts of GHGs into the atmosphere. We cannot stop the blind run of development immediately, but we can think positively regarding the safety measures and remedies. For example, a 10% increase in CH_4 consumption rate may stabilise the current concentration of this potent GHG in the atmosphere.

Many scientific reports summarise that the forest soil is best suited for the growth and functioning of methanotrophs and consequently mitigating global CH_4 budget (Figure 4). It has been discussed that afforestation, reforestation, improved forest management and reduced deforestation considerably contributes to reductions in excess atmospheric CH_4 load.

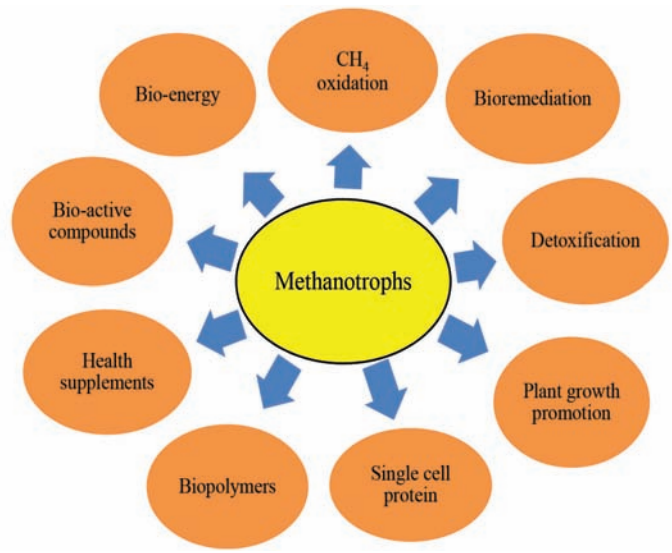


Figure 5: Versatility of methanotrophs in nature

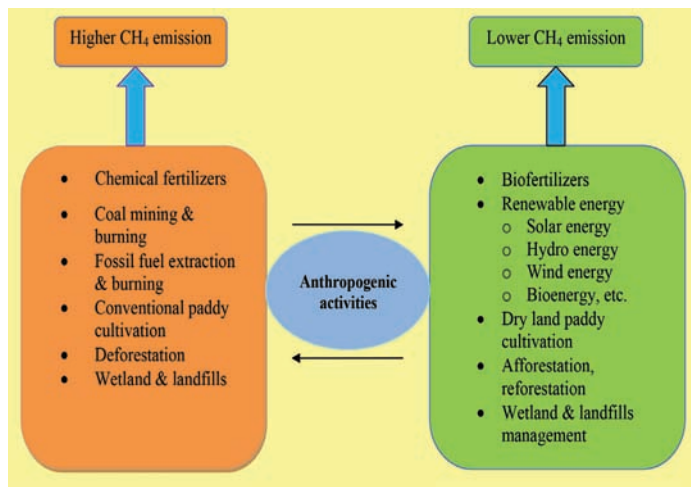


Figure 6: A hypothetical model demonstrating anthropogenic activities related to CH_4 emission

Applied facets of CH_4 scavenging bacteria

CH_4-scavenging bacteria (methanotrophs), an important group of microbes, are generally considered to consume the CH_4. The CH_4-consuming unique enzyme methane monooxygenase present in these bacteria not only destroys CH_4, but also has the capability to degrade/ metabolise several pollutants, viz., heavy metals (Cr, Cd), aliphatic hydrocarbons (dichloroethylene, trichloroethylene, vinyl chloride and chloroform), halogenated hydrocarbons, halogenated benzenes, toluene, styrene, polynuclear aromatic hydrocarbons and transition metals, phenanthrene, anthracene, and fluorine, neurotoxin methyl mercury, etc. (Figure 5).So, these unique bacteria with unique enzyme are contributing significantly at global level in the management of ecosystems and environment.

According to the Food and Agriculture Organization (FAO), rice contributes over 43% to India's food grain production. India is second leading country in world with respect to production of paddy after China. China has more than 43 million ha of land area under paddy cultivation and produces approximately 125 million tonnes of rice. It is reported that flooded paddy fields are responsible for emission of CH_4 to the environment.

So, other countries are blaming India regarding the contribution of significant amounts of CH_4 to the atmosphere because of the country's vast flooded paddy agriculture area. At the same it has been reported that dryland paddy agriculture showed CH_4 consumption instead of CH_4 emission. Therefore, Indian scientists are trying to develop new high-yielding dryland rice varieties that may contribute significantly in CH_4 reduction rates in future paddy agriculture. Application of biofertilisers, reforestation of disturbed land and afforestation, etc., may be a good option to reduce CH_4 emission in environment globally (Figure 6).

Importance of Livestock in Socio-economic Welfare of Farmers in India




Dr. Satyavir Singh Malik, Dr. Pankaj Dhaka, Dr. Jai Prakash Yadav, Dr. Manish Kumar*

Agriculture and livestock rearing have been the primary sources of income for a large percentage of Indian population since independence. These sectors have been making an invaluable contribution to the country's Gross Domestic Product (GDP). However, farming sector is facing serious threats from shrinking farmlands owing to population explosion, reducing soil fertility, and factors such as climate change.

India has world's largest livestock population. Currently, animal husbandry accounts for 25.6 percent of farming sector's total contribution to the country's GDP. Yet, livestock rearing has not realised its full potential to benefit farmers due to sluggish scientific and technological development in this area. It is vital as an 'integrated industry' and we need to harmonise modern technology with traditional ways in a planned manner to turn animal husbandry into a viable and continuous source of income for farmers.

Historical contribution of livestock in development of humanity

Livestock rearing has played an important role in the development of humanity. From ushering in the 'agricultural revolution' to 'cultural revolution', the contribution of animal husbandry has been beyond comparison. The 'agricultural revolution' began around 10,000 years ago. Early man progressed from a nomadic lifestyle to permanent settlement after learning to grow plants for food and other requirements. Animals have not only been 'cultural and traditional' companions to humans but also a source of 'balanced diet' for ages. The economic and cultural luxuries made possible by the industrial revolution gave rise to 'modern intensive farming system'. An 'intensive animal husbandry' is an integral part of this metamorphosis. The change has enhanced quality and productivity. But the modernisation of livestock techniques has also raised many challenges related to animal welfare and environment.

Modern significance of livestock trade for developing countries

An increasing paucity of nutritious food is one of the most damning consequences of rapid population growth, urbanisation, changing food habits and an unprecedented economic progress. Livestock trade as a modern vocation is being perceived to provide a solution. Animals occupy around 30 percent area of Earth's geography. Animals are a 'living wealth', especially in rural areas, where they are intrinsic to the economic and cultural lives of farmers. They have fed humans since time immemorial, both vegetarians (dairy products) as well as the non-vegetarians (egg, meat, etc). Food production from animal rearing is indispensable in tackling malnutrition and reducing the number of under-developed children. Animal husbandry is a large source of direct and indirect employment in rural and urban areas. The 'integrated agricultural system', comprising livestock along with crop-production, is helping large populations make their ends meet in the developing world.

Livestock is a dynamic sector in agriculture providing constant opportunities

The authors are associated with the Department of Veterinary Public Health, Indian Veterinary Research Institute, Izatnagar, Bareilly (UP).
*Correspondence Email: pankaj.dhaka2@gmail.com

of economic and social emancipation to humanity. Its multi-dimensional role in human life is shown in Figure 1.

Role of livestock in development of the Indian economy

Ancient Indian scriptures, scripts and inscripts depict not only the economic and social aspects of relationship between humanity and animals, but also the spiritual aspect. Animal rearing is inseparable from the glorious Indian tradition. It has provided sustenance to farmers through means like milk, meat, manure, fuel, wool, leather, etc. In the 'mixed farming system', animal husbandry supports agriculture in direct and indirect manner while fulfilling fundamental necessities of agriculture-dependent population during times of drought and famine.

Agriculture and livestock rearing have been the primary sources of income for a large percentage of Indian population since independence. These trades have been making an invaluable contribution to the country's GDP. However, farming sector is facing serious threats from shrinking farmlands owing to population explosion, reducing soil fertility, and factors such as climate change. As a result, the agriculture sector's share in GDP has faced a constant decline since independence. It has reduced to approximately 50 percent in 1950 to 16 percent in present times. In contrast, livestock trade has continued to make positive contributions to GDP at an impressive rate. Around 72 percent of Indian rural population still considers animal rearing as the main source of income. This bright scenario is highlighted by the fact that India has world's largest livestock pool of around 5,127 lakh. This huge untapped potential makes this sector a beacon of hope for India's economic development. Figure 2 illustrates main trends in Indian farming and animal husbandry sectors.

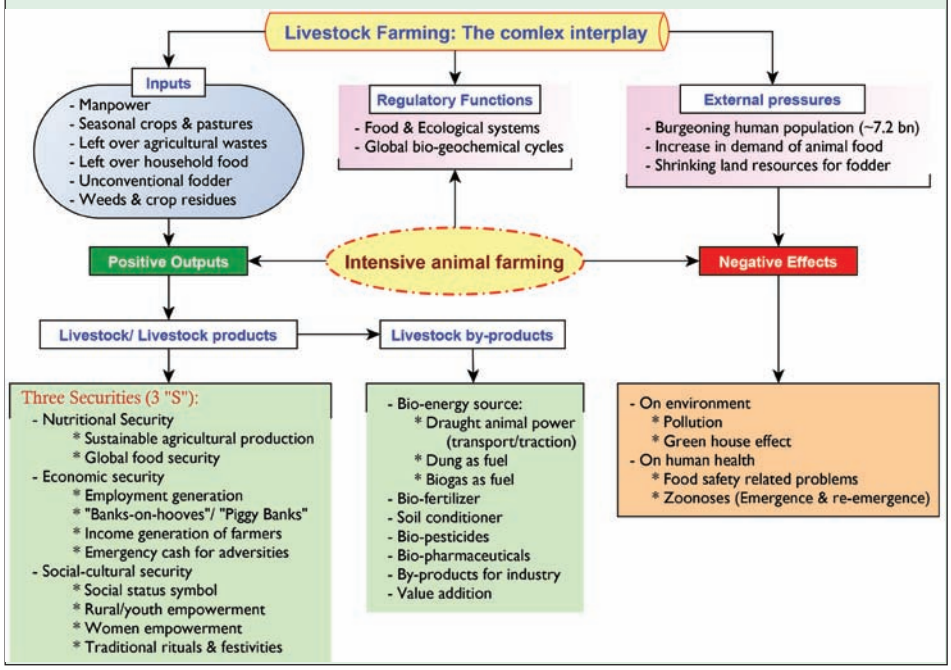
Capabilities, weaknesses, opportunities and apprehensions related to Indian livestock sector

Capabilities related to livestock

According to the 19th livestock census, India has world's highest livestock population (5,127 lakh). It comprises following main species: cattle 1,909 lakh; Buffaloes 1,087 lakh; Goats 1,351 lakh; Sheep 605 lakh; Pigs 102 lakh; Poultry 7,292 lakh.

Livestock rearing is the main source of income for 72 percent of rural population. Participation of women in livestock sector is about 70 percent of total labour. Total contribution to GDP is 4.11 percent (2014-15). Contribution of agriculture-related sectors is 25.6 percent.

Figure 1: Complex interplay in Livestock Farming.



In the production sector, milk production is 1,463 lakh tonnes (highest in the world). A total of 198 milk co-operative socities employ 154.6 lakh farmers. Meat production of 67 lakh tonnes is the fifth highest in the world. Poultry meat production of 30.4 lakh tonnes is the fifth highest in the world. Egg production of 7,84,800 tonnes is the third highest in the world. Fish production is 101.6 lakh tonnes, and wool production 481 lakh kilograms.

Weaknesses in livestock trade

Currently, livestock trade in India is predominantly an unorganised sector and there is uneven expansion of milk and meat production in the country. There is lack of balanced and nutritious fodder and also lack of dissemination of ultra-modern innovations and technological techniques among farmers. There is also lack of expansion of facilities related to animal health and vaccination. Only 25 percent cows and buffaloes benefit from artificial insemination techniques. There is also lack of data related to the economic impact of animal diseases.

In the Indian dairy industry, around 80 percent production is from unorganised sector. Technologically deprived landless farmers are the main contributors. There is a lack of interest in value addition to milk products and follow-up schemes to consolidate gains from the 'White Revolution.'

Religious and cultural ideologies are major impediments to development of meat and related industries. There is also a miserable state of basic infrastructure in majority of slaughter houses which employ unskilled labour force. There are very few registered slaughter houses and import-oriented system. There is also lack of water-based waste treatment plants in most slaughter houses, lack of processes for clean and fresh meat production, and lack of technological innovations and technical skills.

Possible opportunities in animal husbandry

Approximately 60 percent of India's population is less than the age of 30. Most of this chunk of youth is directly or indirectly associated with the farm sector. Indian government has announced several plans for farmers' welfare in line with the objectiveof doubling farmers' income by 2022, which

include allocation of Rs 1,87,223 crore for rural and agriculture-related sectors in Union Budget 2017-18 and allocation of Rs 40,000 crore in NABARD fund.

National schemes for development of livestock include:

- National Livestock Mission
- Livestock Insurance Scheme
- National Agriculture Development Programme
- Welfare schemes for fishermen
- Allocation of Rs 3,000 crore for 'Blue Revolution' scheme, and
- Various national schemes for protecting indigenous livestock breeds.
- For development of dairy industry, the following programmes have been initiated:
- National Programme for Bovine Breeding & Dairy Development scheme;
- National Dairy Plan (Phase-1); and
- Dairy Entrepreneurship Development Scheme.

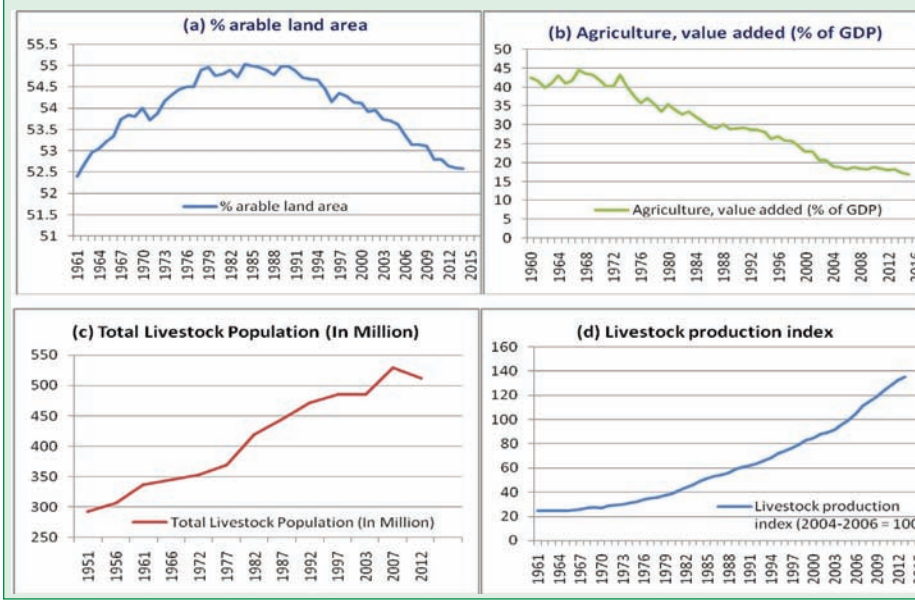
Another factor that needs to be taken into account is changing preferences of consumers. According to World Bank data, demand for milk, meat borne protein in India is likely to double by 2050. This is likely be due to a shift of population from vegetarian to non-vegetarian food habits, increasing demand for fast food, junk food and ready-to-eat food, and demand for low-protein meat and dairy products.

Inclusion of scientific innovations and technological methods in production would be possible only through enhancement of genetic and reproduction quality of livestock, development of disease-resistant and adaptive breeds (indigenous and transgenic), modernisation of infrastructure and processes related to livestock trade. There is also the need for linking rural and urban retail chains through e-portals and other resources and establishing modern slaughter houses and dairy plants for adding value to the products.

Apprehensions related to animal husbandry

Globalisation policies to attract foreign direct investment (FDI) to boost business can pit a largely unorganised animal husbandry sector against stiff competition from foreign companies. Domestic products may face a tough challenge from low import duties on foreign products.

Figure 2: Trends in Indian agricultural and livestock farming: World Bank data[8]



There are problems related to food and nutrition also. For example, India ranked 97 among 118 countries in the 'World Hunger Index' released in 2016, 38.7 percent of India's children below the age of five suffer from malnutrition. 28.5 percent of India's total population faces starvation.

There is also significant loss from different livestock diseases. Various livestock-related epidemics and local diseases cause economic loss to farmers, making them more insecure. The 2014-15 report of the National Institute of Veterinary Epidemiology and Disease Informatics (NIVEDI) estimated mortality loss due to lethal diseases like HemorrhagicSepticemia (HS) at Rs.27,647 and Rs.31,901 in indigenous cattle and local buffaloes respectively, per animal. The study revealed that the loss due to the foot-and-mouth disease (FMD) was around Rs.23,193 crore during 2013-14. Similarly, a disease called Peste des petits ruminant (PPR) caused a loss of approximately Rs.1,611 crore by afflicting goats and sheep.

In addition, there is also loss due to diseases which can be transmitted to humans from animals (zoonosis). About 868 of total 1,415 known human diseases are zoonotic. These are infectious diseases of animals that can be naturally transmitted to humans. The fear of such diseases could adversally impact livestock breeding. For example, a zoonotic disease called Brucellosis is responsible for a loss of 3.4 billion dollar in India. Another such disease called bird flu 'H5N1' remains a threat to humans as well asthe poultry sector, with outbreaks of the pandemic resulting in huge economic losses to the poultry sector.

Another problem that Indian farmers face is the decreasing number of indigenous breeds which are more disease tolerant and well adapted to Indian climatic conditions. Many foreign breeds of cattle, famed for their production capacity, are replacing the germplasm of indigenous breeds. Also, as the agriculture sector is becoming less profitable, the rural youth is finding it difficult to make their ends meet. They are moving to cities in search of employment.

Pro-active steps for reforming livestock sector

Modern science and technology has made constant progress possible in livestock production and related sectors. Besides preserving indigenous breeds, it requires consistent and appropriate improvements in animal health, reproduction and nutrition. Latest cutting-edge biotechnology and genomics techniques are capable of developing more adaptive and disease-resistant breeds. They can prove to be far more beneficial than breeds developed through natural reproduction and selection. New inovations and effective technology can turn animal products and wastes into valuable market commodity.

Continued on page 24

The Internet of Things

Satadru Chakroborty

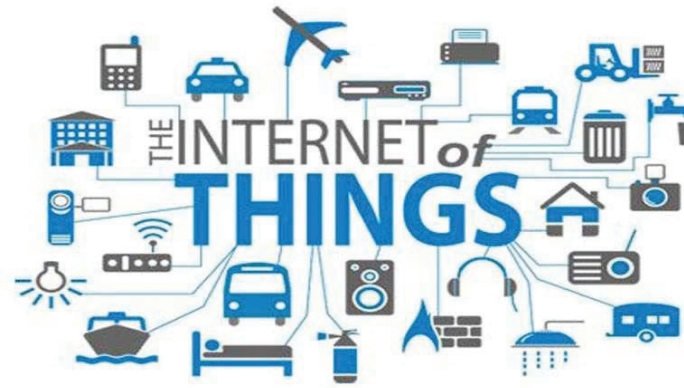
IoT is a network of several devices connected together through Internet. IoT enables collecting data from the environment and exchanging that data. IoT is poised to bring revolution in healthcare, education and business. However, information security in IoT is a cause of concern and needs robust security measures to harness true potential of IoT

Introduction

The Internet of Things is a group of several devices or systems (including machines, houses, vehicles, etc.) interconnected through Internet, which enables several devices or systems to collect data from the environment and exchange that data among them. The term Internet of Things (IoT) was first coined by Kevin Ashton, a British technology pioneer in 1999, while he was working in Auto-ID Lab or Centre. He coined this term, referring to a global network of Radio-Frequency Identification (RFID)-connected objects.

From Figure 1 we can see that all things related to our society are interconnected through Internet, and this concept is called the Internet of Things. As it links several machines or devices or systems, it has various names given by different industries or companies, but the concept is same. The names include the following:

1. M2M (Machine to Machine)
2. Internet of Everything (CISCO System)
3. World-Size Web (Bruce Schneier)
4. Skynet (Terminator Movie)



Where can we find IoT?

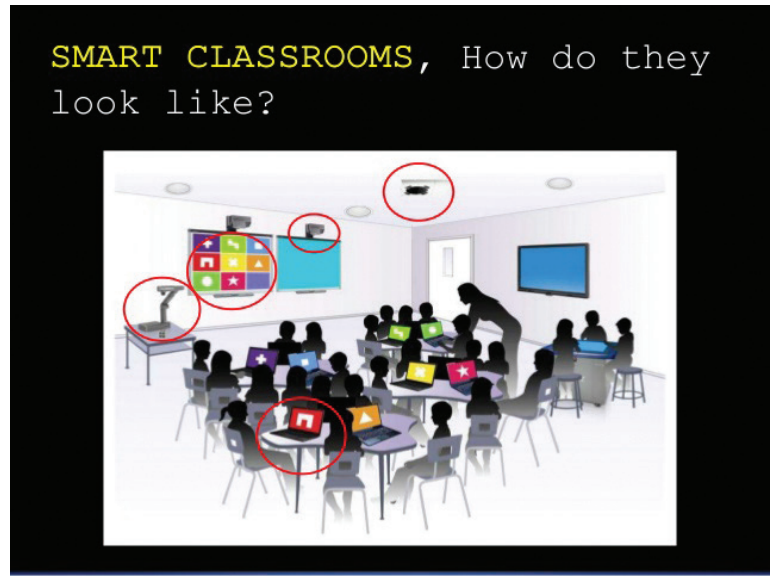
IoT or the Internet of Things is everywhere, mainly because it is a network of several devices connected through the Internet. As several devices or machines or systems of daily life are connected through Internet, we can say that IoT is everywhere. For example, we can describe a smart classroom concept, which is a part of IoT. And the classroom is called smart because it uses the concept of IoT, which make the classroom smart.

In this classroom (Figure 2) we can see several devices such as lights, nest cam or drop cam, projector, laptops, thermostat, and digital TV marked in red circles, which are connected together through a network or we can say through Internet. Generally in normal classrooms the above-mentioned devices are not connected with each other. So, they are called normal classrooms. But

Satadru Chakraborty is an engineer. He did B.Tech in the field of Computer Science and Engineering from University Institute of Technology, Burdwan University in 2017. Email: rikiuit18@gmail.com

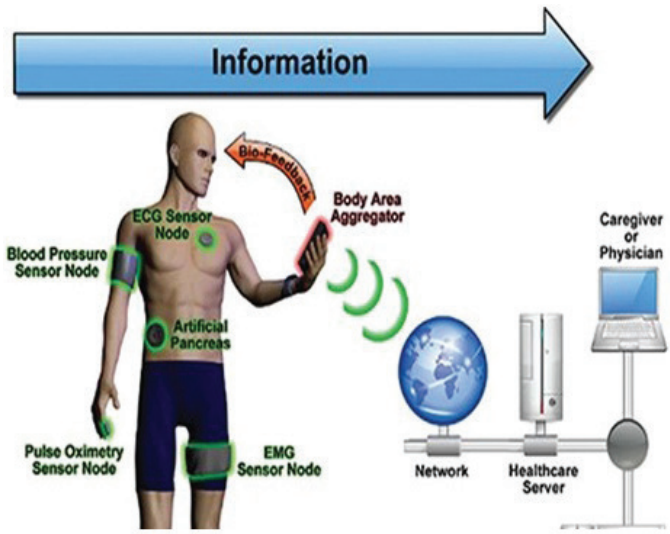
here in the above picture, as all the devices or systems are connected with each other through Internet, it is called a smart classroom, which is only possible with the concept of IoT.

There are many advantages of a smart classroom. For example, we all know that in every classroom there will be some students who may have a vision problem and are not able to see far objects or writings on the board. But in a smart classroom the laptop of each student is connected to a network to which the projector is also connected. So all the information displayed in the board in the classroom iseasily visible to the students on their own laptops. In this way the problem of students with vision problem can be solved.



Let us see another example where the concept of IoT helps in a major field of human activity like health care. In figure 3 we can see a person wearing a health tracking wristband, which is a product of IoT concept. And this band is continuously tracing and gathering information about that person's health condition and transferring it to the network where it is recorded. From that network the information is being transferred to the mobile phone of the same person as a notification, so that he/she can provide his/her bio-feedback in his/her mobile phone. Now suppose the condition of the person suddenly shows deterioration (heart-attack, stroke, asthma-attack, etc.) then he can be easily saved by this IoT concept in the following way.

In the above case, whenever a health condition arises, a bio-feedback is generated in the mobile phone of the person as a notification that alerts him/her as an "Emergency". Now if the person is able to click on that button then he or she will be connected to the nearest hospital or nursing home, which is connected to the same network. And whenever the person does so, the hospital or nursing home will be able to trace his address by using his or her IP address by which he or she is connected to that network. And so they will be able to send an ambulance immediately to that address of that person to pick him up from that place and save his or her life. Not only this, suppose after picking up by ambulance the person faints and is not able to communicate with the attending doctor and suppose no member of his family is present at that time, then also the doctor can get all the required information he needs about the patient's health to diagnose him/her and take necessary steps.



So, we can see that the IoT concept in the medical field has a great advantage and can save lives by timely action.

Top applications of IoT

Some fields where the concept of IoT has been implemented are the following:

1. Traffic monitoring
2. Health/medical field
3. Security
4. Transport and logistic
5. Daily life

Risks of IoT

- As IoT is a network of several devices connected together through Internet, it is exposed to some risk. For example, a hacker can access all the personal and health information by hacking into the network. Any device connecting to the Internet with an operating system comes with the possibility of being compromised, in turn becoming a backdoor for attackers into the enterprise.

Security in IoT

- To improve security, an IoT device that needs to be directly accessible over the Internet, should be segmented into its own network and have restricted network access.
- Security experts have warned of the potential risk of large numbers of unsecured devices connecting to the Internet since the IoT concept was first proposed in the late 1990s.
- The best way to give security to IoT is to secure the network in which the several devices are connected rather than giving security to the devices.
- It will be good if the security is implemented in an encrypted manner, so that if a hacker in any way is able to hack the network he will not be able to get the required information as it is encrypted.

Future scope

The Internet of Things (IoT) has been a hot topic and today has several billion devices interconnected through it. IoT is a simple concept that enables devices to

communicate intelligently through the Internet and turns devices into smart devices. According to a recent report, the number of IoT devices installed has reached 4.2 billion units worldwide, and it is predicted that the number may increase about six-fold by 2020. With billions of connected devices, IoT will provide vast amounts of actionable data in real time. Organisations of all kinds and across all industries can use this information to create new operating models, bring products to market faster, and develop more efficient business processes.

As the Internet of Things continues to develop, further potential is estimated by combining related technology approaches and concepts such as cloud computing, Big Data, future Internet, robotics and AI technologies. However, the Internet of Things is still maturing, and there are a number of factors, that limits the full exploitation of the IoT. Some of these factors are:

- There is no clear approach for the utilisation of distinctive identifiers and numbering spaces for various kinds of determined and volatile objects present in the global scale.
- There is limited further development of IoT reference architectures.
- There is no clear approach for enabling innovation, trust and ownership of data in the IoT.
- There are difficulties in developing business potential in the IoT domain.
- There is need for large-scale testing and integration environments, having complex sensor networks which stimulate innovation through reflection and experience.

It is very obvious that overcoming these hurdles would result in an enhanced exploitation of the Internet of Things potential by a stronger cross-domain interactivity, awareness and utilisation of an infinite problem-solving space. ■

Letter to Editor

I have been reading the magazine Dream 2047 since year 2000.It is a fantastic science magazine.I am a regular subscriber of this fabulous magazine. Most of the articles are informative.It is very good to see the magazine in both languages Hindi and English.Especially articles in Hindi (translated) is good medium to give science knowledge to Hindi Language readers. I have been receiving your magazines since 2002. Thanx a lot for sending such a beautiful Magazine.Now reading July 18 edition in which it is told that Environment is supreme we must give our pure support to protect it.

Naresh Kumar
#2834/2 Jagadhri Gate
Ambala City
Haryana

The Importance of Livestock in Economic and Social Welfare of Farmers in India *(Continued from page 27)*

Possible steps for increasing farmers' income through livestock

It is well established that agriculture and livestock rearingare intrinsically linked together, both in direct and indirect way. Demographic pressures have led to distress in farm sector. With its potential, livestock sector can be the much-needed panacea to support people dependent on agriculture. This field plays a positive role in nation's economic development by their social inclusion and economic upliftment. Income generated from livestock is no less than a boon for such people, especially during natural calamities like famine.Various studies show a shift in consumer base from agricultural food products to animal food products. Consumers are opting for the latter to fulfil their nutritional needs, especially as a source of high quality protein.

It has been found in a study thatalmost 46 percent of farmers with no animals were found to be malnourished. The per capita availabity of cultivable land is constantly decreasing in the country. An unequal distribution of land is turning a large proportion of rural population into landless labourers. Livestock can not only fulfil necessities of such people, but also generate income. Foreign breeds of cattle have undoubtedly helped in ushering the 'White Revolution'. However, they have hampered the development of indigenous varieties. Many indigenous breeds have exceptional yield and strong immunity against diseases. Animal husbandry has faced neglect in government policies and schemes over the years. This sector has remained deprived from the full benefits of government initiatives.

Livestock sector can be the open sesame means for emancipation of landless and marginal farmers and in rural development as well as poverty reduction. Its role in the welfare of farmers is invaluable. It is need of the hour to make them technologically equipped, skilful and market-oriented for their empowerment. The government needs to take effective steps for value addition of animal products and by-products. These include investment in food processing, establishing integrated markets (for coherent movement of products), encouraging e-trade and building animal health centres.

It is necessary to upgrade animal husbandry departments and enchance technical skills of related employees in all states. This will ensure a smooth dissemination of modern technology to farmers. We can save our livestock from epidemics by right analysis and forming policies based on epidemiological facts. Farmers need to be informed about animal vaccination at regular intervals. Animal husbandry departments should share relevant information with farmers through cellphones and other electronic mediums and send alert messages to raise awareness about diseases.

We need to implement policies and projects keeping in mind the above mentioned facts, if we are to reach the aim of doubling farmers' income by 2022. We must identify strengths and opportunities of our livestock sector and remove weaknesses and apprehensions to fully tap its growth potential.

(English translation by Shri Deepak Sharma) ■

VIDYARTHI VIGYAN MANTHAN : 2018 - 19

"India's Largest Science Talent SEARCH for NEW INDIA Using Digital Devices"

Vidyarthi Vigyan Manthan (VVM) is a national science talent search programme for New India organised by VIBHA (Vijnana Bharati), in collaboration with Vigyan Prasar-an autonomous organisation under the Department of Science and Technology, Government of India and NCERT- Ministry of Human Resource Development. VVM is a National program for educating and popularizing science among school students of VI to XI standards. VVM aims to identify and nurture the bright minds among the student community, who are keen on subjects related to science.

STRUCTURE OF VVM (JUNIOR AND SENIOR):

1. **School Level Examination:** VVM is a unique online examination to be conducted at national level. The registered students will take the exam using his/her own device namely a laptop/ tablet / smart phone (mobile with any OS) AND HIS/HER OWN INTERNET CONNECTIVITY. The school level examination will be conducted nationwide, on 25 November or on 28 November 2018 (option to choose) at the given time. Evaluation of student will be based on their individual performance at every level.
2. **State Level Camp (SLC) :** Top 20 rankers per class per state will be identified to participate in the one or two days State Level Camp (SLC). The camp will be organised anywhere within the state.
3. **National Camp (NC) :** From each State Camp, top two students from each class i.e. total 12 students per state, will be invited to a two-day National Camp.

SYLLABUS FOR VVM:

Content	Contribution Junior & Senior (Class VI to XI) (Multiple Choice Questions)			Curriculum
	Questions	Marks	Duration	
Science and Mathematics from text books	50 (1 marks each)	50	120 minutes	NCERT Curriculum
Indian Contributions to Science	20 (1 marks each)	20		VVM Study Material*
Life stories of Dr. Meghnad Saha and Srinivasa Ramanujan	20 (1 marks each)	20		VVM Study Material*
Logic & Reasoning	10 (1 marks each)	10		General Reading
Total	**100**	**100**		

*VVM Study Materials will be made available in PDF format on www.vvm.org.in by 30 August 2018. No printed copies will be provided

KEY POINTS:

1. **Eligibility** : Students from classes VI to XI studying under CBSE, ICSE, and State Boards.
2. **Language of Exam** : English, Hindi, Tamil, Telugu & Marathi
3. **Exam Centre** : Registered School & specified centres
4. **Fee** : Rs. 100/- (without late fee) , Rs. 120/- (with late fee)
5. **Registration** : Online on www.vvm.org.in
   Registrations Open : 16 July 2018
   30 September 2018 (Without Late Fee), 15 October 2018 (with Late Fee)
6. **Mode of Payment** : 1) ONLINE payment on website 2) RTGS / NEFT/ CHALLAN PAYMENT
   * No Cash / DD / Cheque will be accepted

For more information you can log on to website www.vvm.org.in

ADDRESS FOR COMMUNICATION:
Vijnana Bharati : A-4, First Floor, Gulmohar Park, August Kranti Marg, Opp. Kamla Nehru College Bus Stop (Main Road), New Delhi - 110049

CONTACT DETAILS:
Mobile No. : 97178-77701
Landline No. : 011-49032436
E-mail Id : vvm@vibhaindia.org

VIGYAN PRASAR
A-50, Institutional Area, Sector-62, NOIDA - 201309, U.P. , INDIA

NCERT
Sri Aurbindo Marg, New Delhi-110016

Recent Developments in Science and Technology

Biman Basu

Scientists from Physical Research Laboratory, Ahmedabad have discovered a large exoplanet orbiting a Sun-like star around 600 light-years away. Scientists used the indigenously designed 'PRL Advance Radial-velocity Abu-sky Search' (PARAS) spectrograph. Only a few spectrographs that can do such precise measurements exist around the world and most are found in the USA and in the Europe. The discovery will help in understanding the formation mechanism of such large planets that are too close to a star.

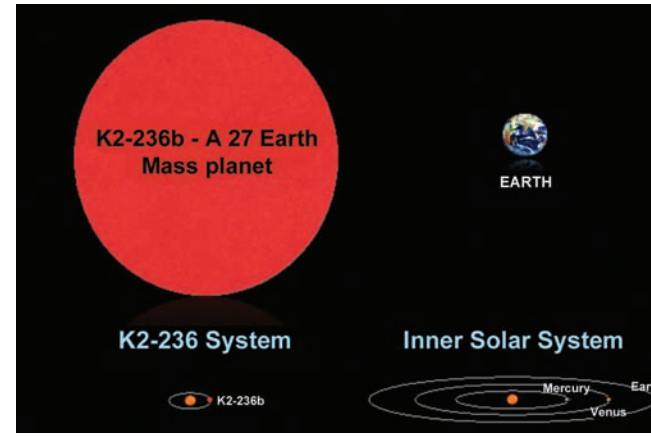
Indian scientists discover an exoplanet

In an exciting first, an Indian team of scientists have discovered a large exoplanet orbiting a Sun-like star around 600 light-years away. The team from the Physical Research Laboratory (PRL), Ahmedabad made the discovery using the indigenously designed 'PRL Advance Radial-velocity Abu-sky Search' (PARAS) spectrograph to measure and confirm the mass of the new planet. This is the first of its kind spectrograph in the country, which can measure the mass of a planet going around a star. Only a few spectrographs that can do such precise measurements exist around the world and most are found in the USA and in the Europe. The precise and stabilised high-resolution spectrograph PARAS was integrated with the 1.2 m telescope at PRL's Gurushikhar Observatory in Mount Abu, Rajasthan for making the observations.

The team led by PRL's Abhijit Chakraborty observed the target for about 18 months and made calculations that suggested the planet to be smaller in size than Saturn but bigger than Neptune. By measuring the amplitude of wobbling of the host star, the mass of the planet was found to be about 27 Earth masses and the radius six times that of Earth. Only 23 such systems (including the present one) are known with such precise measurement of mass and radii to this date.

The scientists estimate that 60% to 70% of its mass could be made up of heavy elements like ice, silicates and iron. With a surface temperature of 600°C, the new exoplanet has been named EPIC 211945201b (or K2-236b). The host star has been named EPIC 211945201 or K2-236. The planet was found take only 19.5 Earth days to go around the star. The scientists did not directly observe the planet but monitored the changes in the wavelength of light emitting from the star using PARAS to deduce the presence of another body in its star system. According to the scientists, being seven times nearer its star in comparison with the Earth-Sun distance and being extremely hot, K2-236b would certainly be uninhabitable (*Astronomical Journal*, 8 June 2018 | DOI 10.3847/1538-3881/aac436).

Exoplanet discovery is nothing new. In fact, it has become a hot area for research in recent years. NASA's *Kepler* satellite has already discovered 3,786 confirmed exoplanets in 2,834 exoplanetary systems.



Planet size comparison of K2-236b and Earth

The author is a former editor of the popular science monthly *Science Reporter*, published by CSIR, He is a winner of the 1994 'NCSTC National Award for Science Popularisation'. He is the author of more than 45 popular science books. Email: bimanbasu@gmail.com

The PARAS spectrograph was designed and developed by the members of the Astronomy and Astrophysics Division of PRL. The primary aim of PARAS is to search for planets around dwarf main-sequence stars. It has wavelength coverage of 400 nm to 680 nm. (Credit: PRL)

But this is the first discovery of an exoplanet made by Indian scientists, and with this discovery India has joined a handful of countries, which have discovered planets outside our solar system. The PRL scientists actually worked on a planetary candidate based on data from NASA's *Kepler*-2 mission. However, the key part of exoplanet discovery is confirming its planetary nature for which an independent measurement of the mass of the body was required, which the PRL team managed to achieve to clinch the discovery. According to the scientists, this discovery is of importance for understanding the formation mechanism of such large planets that are too close to the host star.

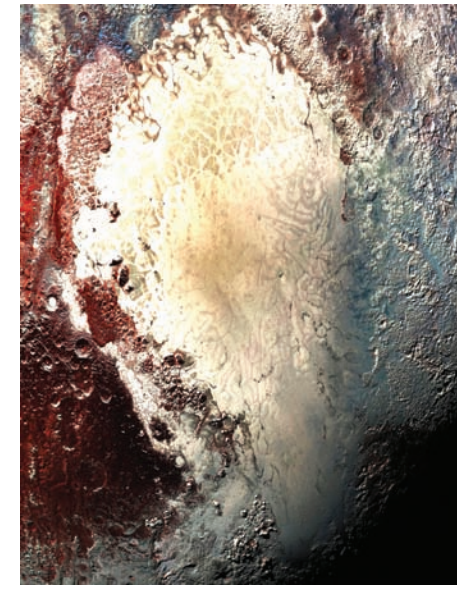
Pluto was formed from 1 billion comets

Pluto was considered the ninth planet of the solar system till 2006, when because of its small size and similarity with other objects discovered beyond Neptune, it was relegated to the status of a 'dwarf planet'. Till recently, scientists typically thought that Pluto was born in the usual way for a planet: in the ancient infancy of the solar system, a rocky core formed amidst a slew of gas and dust, and gravity slowly accreted more and more material, leading to a small spherical ball we now call Pluto. But more recent findings in the 1990s of other small icy objects like Pluto in the Kuiper belt (a vast region of icy objects beyond Neptune) suggested some other, more unique origin of Pluto.

The historic fly-by by the NASA spacecraft *New Horizons* in July 2015 gave new insight into the structure and nature of Pluto. Now, based on astonishing images sent back by the *New Horizons* spacecraft, researchers from the Southwest Research Institute (SwRI), Texas, USA, have come up with a new theory about the dwarf planet's origins after taking a close look at Sputnik Planitia, the vast nitrogen-ice glacier that constitutes the left lobe of Pluto's famous heart-shaped feature. Sputnik Planitia shows an especially strong signature of nitrogen near the equator. The SwRI scientists have put forward a theory that Pluto may be an agglomeration of a billion comets (*Icarus*, 23 May 2018 | DOI 10.1016/j.icarus.2018.05.007).

The new theory builds upon the observations made by the *Rosetta* space probe of the European Space Agency (ESA). The *Rosetta* mission orbited Comet 67P/Churyumov-Gerasimenko from 2014 to 2016. The orbiting spacecraft also dropped a lander named *Philae* onto the icy body, pulling off the first-ever soft touchdown on a comet's surface. The *Rosetta* spacecraft made the first measurement of molecular nitrogen at a comet, providing clues about the temperature environment in which Comet 67P/Churyumov–Gerasimenko formed. The detection of molecular nitrogen is particularly important since it is thought to have been the most common type of nitrogen available when the solar system was forming. In the colder outer regions, it likely provided the main source of nitrogen that was incorporated into the gas planets. It also dominates the dense atmosphere of Saturn's moon, Titan, and is present in the atmospheres and surface ices on Pluto and Neptune's moon Triton.

The SwRI scientists found an intriguing similarity between the estimated amount of nitrogen inside Pluto's nitrogen-ice glacier and the amount that would be expected if Pluto was formed by the agglomeration of roughly a billion comets or other Kuiper Belt objects, similar in chemical composition to 67P, the comet explored by *Rosetta*. "We've developed what we call 'the giant comet' cosmochemical model of Pluto formation," said Dr. Christopher Glein of SwRI's Space Science and Engineering Division. "Our research suggests that Pluto's initial chemical makeup, inherited from cometary building blocks, was chemically modified by liquid water, perhaps even in a subsurface ocean". He further added, "Using chemistry as a detective's tool, we have been able to trace certain features we see on Pluto today to formation processes from long ago. This leads to a new appreciation of the richness of Pluto's 'life story', which we are only starting to grasp".



Sputnik Planitia is deep basin with a nitrogen ice sheet; it may be a few kilometres thick. (Credit: (NASA/Johns Hopkins University Applied Physics Laboratory/Southwest Research Institute)

A seed that could bring clean water to millions

Scarcity of drinking water is a major problem in most countries today. According to figures released by the United Nations, 2.1 billion people lack access to safe drinking water, the majority of whom live in developing countries. In most countries purifying water is an expensive proposition. Now scientists have developed a cheap alternative that uses a widely available natural plant material. Researchers at Carnegie Mellon University and Pennsylvania State University in USA have developed a refining

Moringa oleifera fruits (top), seeds (bottom)

process using extracts of seeds of *Moringa oleifera* that could soon help provide clean water to many in water-scarce regions. The method uses sand and proteins from the *M. oleifera* plant to create a cheap and effective water filtration medium, termed "f-sand" (*Langmuir*, 22 March 2018 | DOI: 10.1021/acs.langmuir.8b00191).

Moringa oleifera is a fast-growing, drought-resistant tree, native to the southern foothills of the Himalayas in north-western India It is widely cultivated in tropical and subtropical areas where its young seed pods (commonly known as drumsticks) and leaves are used as vegetables, and many parts of the tree are used in traditional herbal medicine.

M. oleifera seeds contain a natural protein called *M. oleifera* cationic protein (MOCP) that can be used as an antimicrobial flocculent material for water clarification. However, the seeds also release other water-soluble proteins and organic carbon, which increase the concentration of dissolved organic matter in the water. The presence of this dissolved organic carbon supports the regrowth of pathogens in the treated water, allowing bacteria to regrow after just 24 hours. This puts a great limitation on the availability of safe drinkable water.

To get over this limitation, Stephanie Velegol of Pennsylvania State University had the idea of combining the use of Moringa protein with sand filtration methods common in developing countries. By extracting the seed proteins and adsorbing them on the surface of silica particles (the principal component of sand), she created the antimicrobial functionalised sand, or 'f-sand', which both kills microorganisms adhering to particulate and organic matter and reduces turbidity. These undesirable contaminants and dissolved organic carbon can then be washed out, leaving the water clean for longer and the f-sand ready for reuse.

While the basic process was proven and effective, there were still many questions surrounding creation and use of f-sand. For example, would isolating certain proteins from the *M. oleifera* seeds increase f-sand's effectiveness? Are the fatty acids and oils found in the seeds important to the adsorption process? What effect would water conditions have? What concentration of proteins is necessary to create an effective product? Bob Tilton and Todd Przybycien of Carnegie Mellon University decided to find the answers as they could have big implications on the future of f-sand.

After exploring all possibilities of enhancing the effectiveness of using *M. oleifera* extracts for water purification, including effects of water hardness, fractionation of the seed proteins, and fatty acid extraction, the researchers were able to arrive at conclusions that could have major benefits for those in developing countries looking for a cheap and easily accessible form of water purification.

Tilton and Przybycien found that fractionating the proteins had little discernible effect on the proteins' ability to adsorb to the silica particles, meaning this step was unnecessary to the f-sand creation process. They also found that much like fractionation, removing the fatty acids had little effect on the ability of the proteins to adsorb. This is significant because people in the region can remove and sell the commercially valuable oil and still be able to extract the proteins from the remaining seeds for water filtration. The researchers further found that proteins were able to adsorb well to the silica particles, and to coagulate suspended contaminants, in both soft and hard water conditions. This means that the process could potentially be viable across a wide array of regions, regardless of water hardness.

The new research thus suggests that sands can be effectively modified with *M. oleifera* proteins using small amounts of seed extract under various local water hardness conditions and that the modified sand would be stable on repeated use for water filtration. The work of these researchers puts this novel innovation one step closer to the field, helping to forge the path that may one day see f-sand deployed in communities across the developing world.

A virtual brain - The benefits of brain modelling

Simulations are used in many fields of science. Pharmaceutical companies have been using molecular modelling to understand the behaviour of medicines and guide the design of new drugs. Aeronautical engineers heavily rely on modelling to design aircraft and no aircraft prototype goes into real flight without passing the simulation tests first. The

Structural brain network of a patient with a meningioma (orange). Distinct regions of the brain are depicted as spheres, with larger size indicating increasing relative importance within the network. (Courtesy: Hannelore Aerts)

human brain is another complex system that can benefit from modelling and simulations. Modern neuroimaging techniques allow scientists to explore the anatomy and function of brain areas as small as a group of neurons. Moreover, the computational hardware available is becoming powerful enough to gather the colossal amounts of data generated by the brain. Nevertheless, acquiring raw brain data in itself is not very useful unless we understand its meaning and can use it to our benefits.

The Virtual Brain is an open-source software that has made the task of understanding and organising brain data in a useful way much simpler. It is a neuro-informatics platform that tries to simulate

the brain organisation on the macroscopic level of detail. It takes a network approach on the largest scale, by manipulating network parameters, in particular the brain's connectivity. This tool is based on the idea of taking advantage of available functional and structural brain data generated by imaging techniques such as MRI, functional MRI (fMRI) and trans-cranial magnetic stimulation. The Virtual Brain simulates brain's behaviour as it is commonly observed in clinical scanners such as EEG, MRI, fMRI, etc. The Virtual Brain embraces and extends novel concepts from computational, cognitive and clinical neuroscience in order to drastically reduce the model's complexity while still keeping it sufficiently realistic – and delivering the same output as clinical brain-scanners.

During trials in Belgium using the Virtual Brain on tumour patients, researchers at Ghent University modelled the brains of 25 tumour patients and 11 controls. They found that the software could accurately predict the effects of the tumour on brain connectivity. Doctors hope to combine neuroimaging data with Virtual Brain modelling to improve surgical planning and outcomes in the future. This could allow doctors to plan surgery that gives the best chance of removing a tumour while keeping the rest of the brain tissue intact. The conventional procedure for mapping tumours is to use non-invasive imaging techniques such as functional medical imaging (*eNeuro*, 29 May 2018 | doi.org/10.1523/ENEURO.0083.2018).

The Virtual Brain is a great tool for research that will allow doctors to monitor the dynamics of communications between different brain regions and see how the functions of the brain are related to its structure. Scientists can use the Virtual Brain to understand how changes in the brain structure affect neuron communications and in turn lead to modifications in behaviour and cognitive processes. According to the researchers, another utility of the Virtual Brain is the capability to track normal and physiological brain modifications between different life stages; for example, to understand how a newborn brain can grow up to become mature and capable of very complex functions and cognitive process. ■

3D Printed Organs for Transplant *(Continued from page 33)*

is a biodegradable biomaterial which disappears over time when the cells fuse together.

In direct printing the bio-ink is directly printed layer by layer to form the structure with gels used to keep the structure in place till the cells fuse together. This method can create more precise structures but is more difficult and requires more time. A combination of these methods can also be used to create a fully functioning and vascularised system – which basically means that the organ will have a network of blood vessels that will allow it to carry nutrients, oxygen, etc., within itself. The indirect method can be used to create the main structure while the direct method can be used to create the finer vessels within. Researchers are trying to make both these methods as precise and effective as possible.

Along with different methods, different types of printers are also used. Extrusion printers use a syringe to place the bio-ink in layers; these can form very small high-precision structures. Inkjet printers are also used; these are what Boland used to take the very first cellular print. They push bio-ink by generating small air bubbles to create pressure in a similar method to what a home printer does. In future, however, neither of these methods or printers may be in use, as newer more exciting technologies are being developed that seem to delve deeper into the realm of science fiction.

synthetic human skin tissue

Laser assisted bio-printers are one such example; they involve using a pulsed laser beam to produce pressure bubbles, this method is able is able to provide a high resolution and deliver cells in a more precise way. Though it is not fully usable yet, it may be the primary way to print organs in the future.

Challenges

Despite the rapid progress in bio-printing in the last decade or so, there are still many challenges faced by researchers. Vascularisation is very important to create an artificial organ; an organ cannot function if it is not vascularised, just as a car cannot function without a fuel intake and an exhaust system. The organs that are printed today are partly vascularised but not to the level that is required for them to function inside a human body. A complex organ such as liver consists of millions and millions of small blood vessels, some of them a few nanometres in diameter (one thousand-millionth of a metre). The complex organs created today have very short life-span and cannot be put inside a living person. No computer software exists today that can fully map an organ like the liver and no printer can yet fully print one. Researchers today also lack the knowledge required of an organ to guess the various different cell compositions needed to create an organ that is identical to one in our bodies.

Conclusion

Bio-printing is a very exciting technology. It is a technology that truly has the power to change the world and help the millions suffering today due to the lack of functioning organs. Many challenges still lie ahead and creating a fully functioning organ is still remains a distant dream, but as the rapid progress in the field has shown it is certainly not impossible. With a conservative guess we may only be 5-10 years away from the first artificial organ transplant. Even when it becomes available, probably it won't solve all the problems related to organ donations we face today, and it would still be very expensive for a long while. ■