BIOLOGICAL
ENGINEERING SOCIETY

Newsletter: Volume 1

Contents:

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A letter from the **Editor...**

Dear friends of the Biological Engineering Society,

It is my pleasure to present to you the first Newsletter of the Society. The Society was established in November 24, 2016 with the help of the core team from IIT Roorkee and the leadership of Prof. Sonjoy Ghosh. An earlier attempt to establish this society by Prof. Purnendu Ghosh and the faculty of the Department of Biochemical Engineering Department of IIT Delhi under the mentorship of Prof. Tarun K. Ghosh, the father figure of Biochemical Engineering in India, had stalled because certain procedural problems could not be solved. Therefore, the fact that the Biological Engineering Society is functioning today and drawing the attention of engineers working on biologically motivated problems, speaks volumes for efforts put in by the founder Secretary Prof. Sonjoy Ghosh.

The purpose of this newsletter is to connect the Biological Engineers of India by publishing the work being carried out by our members, to discuss the changing scenario and future trends of the field and how the academia needs to respond with changes in curriculum and to broadcast the latest news and events of the Biological Engineering Society.

In this first edition, we bring to you the work being carried out by Prof. Sonjoy Ghosh on Algae to mitigate CO2 emission and produce biofuels, and the research of Prof. Ramkrishna Sen on Systems and Synthetic Biology to develop genetically modified plants and plant products. Both these areas are important in the context of global warming and climatic changes. Although scientists across the world have been publishing and addressing these problems, the political leaders of the world have at best been in denial. The predicted outcome is worrisome and we as biological engineers need to make our small contributions which we hope will add scientific knowledge in this area that will someday lead to a breakthrough technology for the benefit of the people.

Prof. James Gomes
Editor

A few lessons from the **Engineering of Life...**

Engineering of life is playing a significant role in shaping many of our future endeavours, be they are in the world of medicine, industry, or agriculture. There is so much to learn from life. Take, for example, managing organizations. Life has a history of more than 4 billion years. It exists at different levels, and the levels are organized in a hierarchical fashion. The situations life has faced at different levels and hierarchies, and the experience thus gained, can be of significant importance in the management of an enterprise.

Isn't it amazing that we start working even before we are born? "To become an embryo, you had to build yourself from a single cell. You had to respire before you had lungs, digest before you had a gut, build bones when you were pulpy, and form orderly arrays of neurons before you knew how to think." We are born before we are fully developed, and that's the reason we need years of intensive care before we can fend for ourselves. Tadpoles, on the other hand, are ready to swim, find food and evade predators the moment they are born. But then, we are humans, not tadpoles. There is a message for organisations in this: Don't treat an organisation like a tadpole, treat it as a human being; give the organisation enough time to find food, fight predators, and learn swimming.

Life with varying complexity are available. What is simple for one type can be complex for another. It is thus important to recognise the 'relativity of complexity'. A reasonable guiding factor to deal with the complexity is that the system must be stable, and it must be able to survive amidst chaos and complexity. Survival, thus, dictates the level of complexity an organism or an organisation can withstand. Life become 'live' when atoms and molecules present there in follow a particular configuration, and there is a

certain relationship among them. When the desired link between structure and pattern is broken life becomes a lump. There are different ways to break these links. Besides the natural ways, life can become a lump as a result of mishaps, such as starvation and injury.

There is another kind of death in which cells die by committing suicide. They do it to ensure proper development of the remaining cells. If they remain in the system, the integrity of the organism gets spoiled. Thus, it is essential to remove them. The pattern of death is so orderly that the process is called 'programmed cell death', also known as apoptosis.

"Life cannot exist without death...apoptosis (programmed cell death) is important for an organism to be able to eliminate unnecessary or damaged cells from its body as it has to generate healthy new cells. Moreover, aberrations in apoptosis are now believed to contribute to many common disorders..."

Programmed cell death (PCD) is a natural process, and is essential for our survival. PCD encourages self-destruction of the damaged, diseased, or unwanted cells. Our hand has five fingers, and that is only possible because the cells that lived between them died when we were embryos. PCD ensures a constant turnover of cells in the gut lining and generates our skin's protective outer layer of dead cells. PCD also allows the body to eradicate destructive cells. If there was no PCD, we would face 'runaway cell replication', and that might lead to cancer.

A somewhat similar thing happens in organisations. New kills the old ones. Economist Joseph Schumpeter called this 'creative destruction'. He argued that innovation replaces (destroys) the established enterprises and makes way for new enterprises. In this age of innovation, enterprises are running at the speed of Moore's law - "high cost to create, minimal cost to produce, and a winner -take-all environment." This scenario suggests that enterprises must take resources away from the losers, and reallocate them to the winners.

One might ask an interesting question - Why some 'built to last' enterprises tend to under-perform and a few 'upstarts' over-perform? In a discontinuous market, Peter Drucker called it 'the age of discontinuity', new entrants are showing promising results. The weak performers, if replaced, can yield better results for the organization. Innovations destroy obsolete technologies, only to be assaulted in turn by newer and more efficient rivals. An organisation can run, even when a part of it is closed. This is also possible in the case of living beings, but they being more integrated and complex, the chances of survival of remaining organisms are comparatively less likely.

Programmed cell death teaches us that by blocking apoptosis development goes awry. It tells us, were it not for the death, we would not even be born.

From a life apart to life together is not easy. But then that is what engineering of life teaches us.

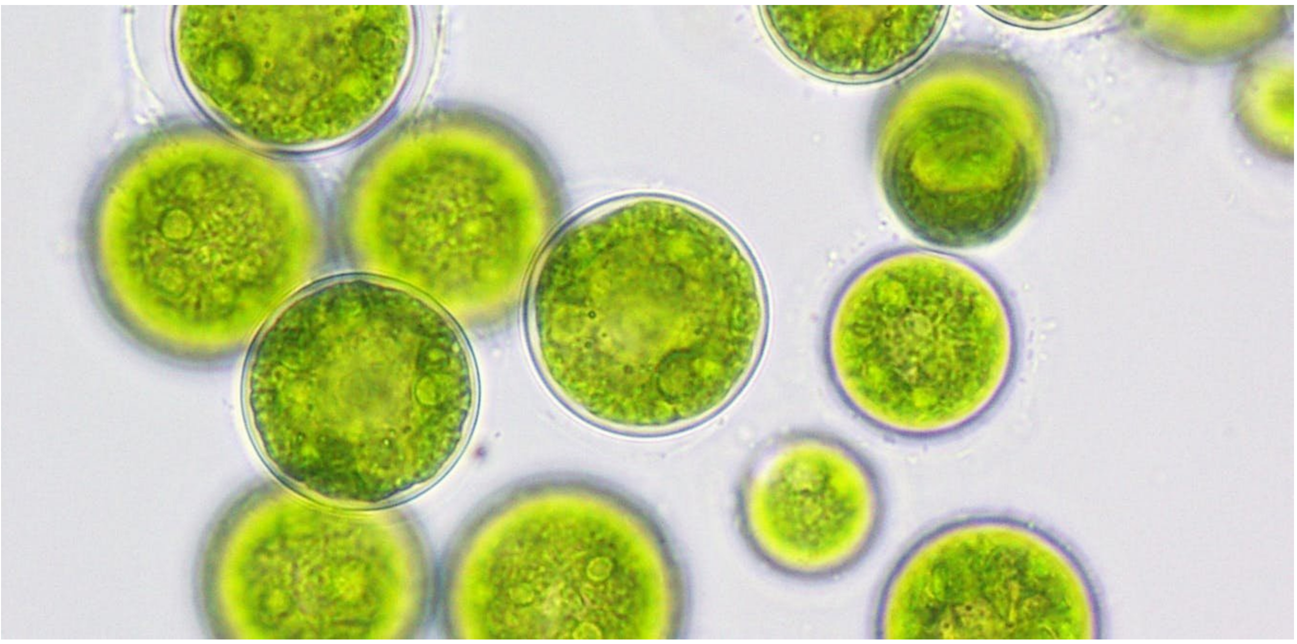
Prof. Purnendu Ghosh
President,
Biological Engineering Society

“Algae:

A potential source for a new industrial revolution

Algae are unicellular or multicellular photosynthetic organism and classified as plants as they make their own food by photosynthesis. But they do not have distinct features as plants like root, stem and leaves with distinct functions. The diversity of algae occurs around everywhere in the planet. They live in freshwater lakes, ponds, soil, rocks, ice, snow, plants and even in fur of animals. Algae consume carbon dioxide (CO2) and emit oxygen through photosynthesis. In total, 40% of global photosynthesis is contributed by algae. Algae cultivation technology does not compete with the agricultural land as they can easily grow on non-crop land. Similarly algae don't requires nutrients and freshwater resources either as they can grow on wastewater also. The large scale algae farming can be achieved by open pond systems or photobioreactor technology. The advantage of photobioreactors includes dynamic control of light, temperature, carbon dioxide, oxygen, evaporation, nutrient availability which improves the biofuel productivity of algae compared with the traditional pond cultivation technology.

A series of nutraceutical and pharmaceutical products besides chemicals, are now being developed from algae. A renewable nutraceutical bioactive lipid i.e. polyunsaturated fatty acids (PUFAs) have been used for the treatment of arthritis, obesity, Parkinson's disease, and heart disease. Derivatives of PUFA include eicosapentaenoic acid (EPA) which lowers the blood cholesterol level while docosapentaenoic acid (DPA) play a role in the fetal brain development. Algal species of Isochrysis galbana and Phaeodactylum tricornutum, improves the production of Arachidonic acid (AA), which is a derivative of omega-6 fatty acid and is considered as a precursor of prostaglandin and leucotriene synthesis, which play a major role in circulatory and CNS functions. The extracts of microalgae show antimicrobial, antiviral, and antifungal properties while the products of Chlorella sp. and Spirulina sp. are also used as ingredients of different skin care, sun



protection, and hair care formulations. A number of active substances from genera of Cladophora and Ulva are used as pharmaceutical products such as Kahalalide-F, which is now being used in clinical trials against prostate and breast cancers. Algal chemistry also helps in development of novel drug molecules such a bioactive compound called cryptophycin 1 isolated from blue-green algae has shown anti-carcinogenic properties. Similarly various carotenoids obtained from Chlorella species have suppressed colon cancer development. The neuroprotective abilities of Spirulina maxima is used for neurotoxicity prevention from MPTP (1-methyl- 4-phenyl-1, 2, 3, 6-tetrahydropyridine) and reduces oxidative stress. The green algae Chlamydomonas reinhardtii has been used for large-scale production of therapeutic proteins VEGF (vascular endothelial growth factor), HMGB1 (high mobility group protein1) of human fibronectin. Compared to mammalian cell cultures, this is a cost efficient method for the production of large scales therapeutic proteins.

Algae cultivation technology has the potential for biofuel generation, carbon dioxide sequestration and source for animal nutrition simultaneously. The scope of investing in algal research, especially on biofuel, is promising, because algae can produce between 7,500 and 19,000 litres of fuel per acre, far more than any other renewable feedstock. India is a growing market for micro algae such as Spirulina, which is now given as a pharmaceutical product. There is scope for both small-scale (as cottage industries) and large-scale algal farming in the country. With its wealth of diverse freshwater and marine algae, including seaweeds, India can play a major role in algal farming and can become a world leader in algal cultivation technology sector.

Prof. Sanjoy Ghosh and Prof. Shailendra Singh Khichi
Biochemical Engineering Laboratory
Department of Biotechnology
Indian Institute of Technology Roorkee
Roorkee 247667, Uttarakhand, India

Metabolic Engineering, Systems Biology and Synthetic Biology: Imparting More Biological Engineering Dimensions to Life

1. Metabolic Engineering, Systems Biology & Synthetic Biology: A Macro Overview

Today, we see tremendous and rapid progress piggybacking on electronics and information technologies. The nineteenth and the twentieth centuries had seen considerable development in the chemical and physical sciences. Biological sciences, per se, have been slow to develop and had taken a back seat for long. Scientists, the world over, are trying to develop bioligcal solutions to various scientific problems due to the negative effects caused by the physico-chemical solutions. Despite this continued effort, these biological solutions have not been viable due to their expensive nature. The era of Quantitative Biology (Metabolic Engineering, Systems Biology and Synthetic Biology) has dawned to counter this, and it will prove as revolutionary as physics was in the twentieth century.

Metabolic engineering considers metabolic and cellular system as an entirety and accordingly allows manipulation of the system with consideration of the efficiency of overall bioprocess, which distinguishes itself from simple genetic engineering. Systems biology, which is 'quantitative, predictive and dynamical biology', is a reliable computational model of the cell, and an 'Integrative Systems Physiology' model of the organism. 'Synthetic biology' refers to the creation of new artificial systems from the understanding of integrating parts to create a whole system. Mostly driven by the

advances and developments in systems biology, synthetic biology has become a field of its own only recently.

2. Metabolic Engineering, Systems Biology & Synthetic Biology as Promising R&D and Enabling Technology Platforms

Computational approaches to bio-engineering aims to construct novel biological entities (cells, tissues, whole organisms) that bring together diverse biological coomponents to achieve desired functions. Some key applications that represent immediate R&D goals and are expected to emerge in immediate near future have been detailed below.

2.1. Healthcare: Biopharma and Biotherapeutics

This is questionably the most crucial problem to which the power of synthetic biology may be brought to bear. The applications of new synthetic systems to human health include biopharma and live-cell therapies for Predictive, Preventive, Personalized, and Participatory (P4) medicine: biosensor-based diagnostics, engineered bacteria to target specific pathogens, enhancing bio-pharmaceutical production, understanding and regulating commensual microbial consortia, and the use of live biological agents for drug delivery or immune modulation. Yet, the regulatory barriers for live-cell therapies remain high.

2.2. Plants for Value Added Products

Metabolic engineering in plants involves the modification of endogenous pathways to redirection of one or more enzymatic reactions to produce new compounds or improve/retard production of known compounds. In the past few decades, progress in Agrobacterium-mediated transformation has led to the emergence of various transgenic technologies, including overexpression of recombinant protein in plants, knockdown of targeted gene through RNAi approach, targeted genome editing, and generation of marker-free transgenic plants. Various binary and super binary vectors have been developed in past few decades, which overcome hurdle of genetic transformation in higher and recalcitrant plant species. In addition, the use of different strains of Agrobacterium and other parameters during optimization of plant transformation protocol also enhanced genetic transformation efficiency. This recent advancement of genetic engineering tools has boosted agricultural biotechnology and overcome the limitation of conventional plant breeding methods. The recently developed genome-editing tool based on 'CRISPR/Cas-mediated genome editing' is being applied to various plant species including crop and woody plant. Using this tool we can generate 'marker- or transgene-free' genetically modified plants, which are therefore more acceptable for field release. Thus, it is expected that in the near future, GM plants with minimal genomic modifications can be developed and released to meet growing needs.

2.3. Energy

In the race to biofuel development, synthetic biology and metabolic engineering appears as an expected partner. These fields have witnessed rapid progress in recent times in the case of Saccharomyces cerevisiae and led to the construction of highly engineered metabolic pathways, strongly regulated metabolic networks, efficiently engineered native and synthetic control elements, and efficient recombinant vectors. Development of mathematical models for studying the complex metabolic pathways is also extremely important. Well-established synthetic biology approaches in S. cerevisiae can be a boost to other non-conventional yeast species (like Hansenula polymorpha, Kluyveromyces lactis, Pichia pastoris, and Yarrowia lipolytica) by rewiring the metabolic pathways related to biofuel production. In summary, biofuel production by engineered yeast through synthetic biology requires several synthetic biology pipelines and models. This can be used for predicting metabolically optimal pathways, gene constructs, and metabolite screening. The developments in different 'omics' technologies can serve as tool for future synthetic biology of non-conventional yeast.

2.4. Environment

There are already field-scale studies on the use of microbes to process toxic or hazardous materials, ranging from oil spills to nuclear radioactive waste. These applications typically rely on discovering natural populations of microbes that colonize contaminated areas. New directions involve actively engineering these microbes to more efficiently carry out the desired breakdown processes. The current limitation is a regulatory one: the uncertainty in the consequences of releasing engineered microbes at large scale in the open environment. Recent efforts in the areas of cell-free approaches for sensing, regulation, and metabolic pathway implementation, as well as for preserving and deploying cell-free expression components, embody key steps towards realizing the potential of cell-free systems for environmental sensing and remediation.

3. *National Status*

Even though Quantitative Biology is still in its nascent stages, India, with its growing base of excellence in life sciences research, is well poised to take up the challenge to build up this field and become globally competent. Scattered activities in this field from specific groups across national institutes have been supported by Government agencies such as CSIR, DST and DBT and few private ventures. As an indicator of future growth in engineering a biological revolution, MIT's International Genetically Engineered Machines Competition (iGEM) is an eye opener. The first team from India to participate at iGEM was from the National Centre for Biological Sciences, in 2006; in 2011, four teams represent India and it grew to ten teams by 2017. Recently, the Planning Commission Task Force on SSBRN, Govt. of India has recommended creating

six Network Centres for Synthetic Biology research at NCBS, Bangalore; IGIB, New Delhi; IICB, Kolkata; Bose Institute, Kolkata; IISc, Bangalore and CMMACS, Bangalore towards developing translational capabilities. The task force has also recommended various initiatives that would develop the state of this field in India.

4. Concluding Remarks

The new paradigm of synthetic biology on the twin levers of metabolic engineering and systems based biological approach is expected to be a global game changer in the research, development and business (R&DB) in the areas of healthcare, energy, environment and water. The relevant industrial sector has to be mature enough to derive the benefits of such R&DB activities. Though synthetic biology has made rapid strides in the US and Europe; in India, the field is still at its infancy and has started crawling with the development of a very few institutional clusters and major investments. The immediate goal should be to build a base of research expertise and infrastructure to create the capabilities and competence in the desired niches. With the help of more public and private funding and also financial support from the Venture Capitalists (VCs) and the kind of push for “Make-in-India” and “Start-up-India” with positive investment scenarios around the biotech start-ups, things are bound to look up and change in the right direction within the next decade. Though India has miles to go to carve its own niche in the global platform, appropriate Government policies and investments in under and post-graduate education and training, as opposed to narrow technical training, is the need of the hour for global strategic positioning.

Prof. Chinmay Hazra and Prof. Ramkrishna Sen
Bioprocess & Bioproduct Development Laboratory,
Department of Biotechnology,
Indian Institute of Technology Kharagpur,
West Bengal 721302
E-mail: chinmay_hazra@yahoo.com; rksen@iitkgp.ac.in

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Bioprocess & Bioproduct Development Laboratory, Indian Institute of Technology Kharagpur

Bioprocess & Bioproduct Development Laboratory (BBD-L) led by Prof. Ramkrishna Sen, came into being in 2005 and is an integral part of the Department of Biotechnology, IIT Kharagpur. BBD-L is a vibrant and multi-disciplinary community of researchers engaged in R&D activities in red, white, green and blue biotechnology, encompassing Healthcare, Energy and Environment, with a focus on Green Process & Product Development for anticancer biomolecules; Marine bacterial green-surfactants & polymers; Microbial and microalgal biofuels and value added products with concomitant carbon-dioxide sequestration from flue gas and waste valorization in biorefinery models in search of global solutions for sustainable energy and environment. The R&D endeavours undertaken by this laboratory have been supported by several funding agencies like DST, DBT, NJB, CSIR, MoES and SERB (Govt. of India) and industries, namely, PfP Technology LLC., Houston, USA; DSS Corp., Kolkata; TATA Steel Ltd., Jamshedpur; Triphase Pharmaceuticals Ltd., Mysore etc. We have been able to establish collaboration with foreign Universities like Columbia University in the City of New York, Manhattan, USA; University of California, Berkeley, USA; University of Pennsylvania, USA; North Carolina A&T State University, USA; Royal Holloway University of London & University of London, London; University of Ulster, Northern Ireland; University of Melbourne, Australia; The University of Auckland, New Zealand; University of Minho, Portugal; Stellenbosch University, S. Africa; Technical University of Munich, Germany; University of Padova, Italy etc.)

The PI of the BBD-L is Dr. Ramkrishna Sen, who is a Professor in the Department of Biotechnology, IIT Kharagpur. Earlier, Prof. Sen worked as Assistant Professor in BITS, Pilani and as Manager (R&D- Biotech) in Cadila Pharmaceuticals Ltd., Ahmedabad. He served as a Fulbright Visiting Faculty in Columbia University in the City New York, USA. Prof. Sen is a Bioprocess Engineer by training and profession. So far, 18 Ph.D and 35 MS/M.Tech Students received their degrees under his supervision. Right now, he is guiding 12 Ph.D, 1 MS, 5 M.Tech project students. He has about 180 publications in international and national journals, books and conference proceedings and 13 patent applications including one US, one European and one PCT to his credit. He is serving as a member of the editorial board of two international journals. Prof. Sen has completed 18 sponsored and 2 consultancy projects and currently, has 4 sponsored and 1 consultancy projects. He published a book ‘Biosurfactants’ (Springer, USA). Prof. Sen has been honoured with Distinguished Alumnus award by Jadavpur University, Calcutta (2017), Fulbright Visiting Professor Award (2013-14); Runner-up prize in National Awards for Technology Innovation, Govt. of India (2012) and UKIERI (British Council) Grant for exchange Visits (2007). He has extensively travelled abroad and delivered lectures at many reputed universities. He is a founder member of Biological Engineering Society (India). He is also a life member of Indian Institute of Chemical Engineers and member of European and Asian Federations of Biotechnology. Prof. Sen is now administering as Chairman (GATE-JAM), IIT Kharagpur. Please visit the lab website: http://www.bbdl.iitkgp.ac.in/ for detailed information.

Research Themes And Interests:

•Green process & product development for healthcare, energy & environment

•Microalgal & microbial biorefinery – Algal and Yeast biomass based biofuels & biorenewables with waste valorization , carbon capture & sequestration (Bio-CCS): thereby nurturing a holistic vision towards deriving energy and environment solutions by addressing

technological, environmental, economic and societal challenges.

•Bioprocess integration, intensification & optimization: Bio-inspired new generation processes/products/technologies for sustainable development

•Biochemical & Bioprocess engineering

•Enzymes and biofuels technology

•Environmental & Marine Biotechnology

•Probiotics and Nutraceuticals

Second Annual Biological Engineering Society (BES) Conference

26,17 October 2018; IIT Bombay

The second annual meeting of the Biological Engineering Society (BES) will be held at Indian Institute of Technology Bombay, Mumbai on 26-27 October 2018. The conference will also act as the platform for the Annual General Meeting for the Society. The meeting is being organized by Profs. Ganesh A. Viswanathan, Sameer R. Jadhav, Abhijit Majumder, K. V. Venkatesh, Supreet Saini (all from the Chemical Engineering Department at IIT Bombay); Profs. P. S. Punekar, P. J. Bhat, Prashant Phale (all from the Biosciences and Bioengineering Department at IIT Bombay); and Prof. Anirban Roy (Chemical Engineering at BITS Goa). The meeting will have sessions on various aspects of bioengineering such as metabolic engineering, protein engineering, bio-materials & engineering, systems & synthetic biology, among others. The organizing team proposes to have oral talks from invited speakers, a student talk session, and a student poster session. The team also proposes to have participation from Government and Industry, in addition to the leading Institutes in the country. More details of the event can be found at: https://www.che.iitb.ac.in/bescon2018/. For more details, please contact Supreet Saini (Associate Professor, Chemical Engineering, IIT Bombay at *saini@che.iitb.ac.in*; or Sanjoy Ghosh (Professor, Biotechnology, IIT Roorkee at *besi.secretary@gmail.com*).

A report on the First National Conference of Biological Engineering Society: BESCON 17

The first National Conference of the Biological Engineering Society (BES) was convened at Netaji Subhas Institute of Technology, New Delhi during 8th – 9th September, 2017 on an ambitious theme "Biological Engineering in the 21st Century". Professionals from across the spectrum of academia and industry participated in the event. It was heartening to see enthusiastic participation of students and young scientists from across the country. The conference witnessed around 200 delegates in attendance sharing their work, exchanging ideas, networking among themselves and laying down the foundation for the future growth of Biological Engineering in the country.

Professor T. K. Ghose, a father figure of biological engineering in the country, had been fondly remembered for his legendary contribution to the field. The Biological Engineering Society elected Professor T. K. Ghose as the first 'Fellow of the Society' in recognition to his life-long contribution in the field.

Eminent speakers from reputed institutions, like, IITs, NII, JNU, BISR, CSIR and DBT organizations presented their ground breaking work, showing how the application of technology and engineering principles and practices on biological systems can bring about amazing solutions for today's complex problems in environment, health, agriculture and industry. Four scientific sessions: (i) Systems and Synthetic Biology, (ii) Bioprocessing, (iii) Biological Engineering in Drug/Small Molecule Discovery, and (iv). Environment, Bioenergy and Bioseparation were organized wherein 16 invited eminent speakers delivered there lectures.

The inaugural session was graced by the dignitaries that included Chairman, BOG, NSIT and President BES, Professor P. Ghosh. Prof. Ashok Dubey delivered the welcome address. Secretary BES, Prof Sanjay Ghosh introduced the BES to audience with its background, establishment and main objectives. An inspiring Presidential Lecture on "Can there be a better engineering product than life" was delivered by Prof. P. Ghosh.

First Session:

The first scientific session began with the lecture by Prof. Biplab Bose (IIT-Guwahati) who talked about PI3K/Akt pathway to emphasize on signal discrimination by controlling the flow of signal through different branches of a pathway. Using experimental and mathematical modeling, he showed manifestation of negative feedback which controls the flow of signal from Akt to SK61. The second talk on 'Regulation of metabolic pathway fluxes by synthetic biology approaches' was delivered by Prof. Guhan Jayaraman (IIT-Chennai) where he reflected on regulation of metabolic pathway fluxes by switching alternately between growth-promoting fluxes and product formation fluxes. He emphasized on the use of riboregulators for switching between desired and competing metabolic pathways for Hyaluronic Acid

(HA) biosynthesis in *Lactococcus lactics* for HA production. The last talk of the session was on 'Synthetic and systems microbiology and metabolic engineering approaches for industrial enzymes' by Prof. Pratyush Shukla (MDU, Rohtak) where he described the well-known techniques of enzyme modeling, simulation and metabolic rewiring of yeast cytosolic pyruvate carboxylase 2 (PYC2) using Chinese hamster ovary (CHO) cells. His work revealed how PYC2 engineering in CHO cells can lead to high titer and quality of recombinant therapeutic proteins, opening up avenues for development of advanced technologies for better production of recombinant therapeutic proteins using bacterial system.

Second Session:

The second session on 'Bioprocessing' was convened post-lunch with a talk by Dr. U. C. Banerjee (NIPER, Mohali). Dr. Banerjee spoke on the "Development of Bioprocesses using Nanobiocatalysts as Enzyme Source for the Synthesis of Chiral Drugs and Drug Intermediates". He recommended the use of nanobiocatalysts (NBC) as better biocatalysts to overcome challenges of lower stability, less enzyme loading, diffusional limitations, enzyme stability and reusability of the enzymes in large-scale bioprocesses that leads to higher operational cost. He discussed various chemoenzymatic reactions using a series of oxidoreductase, lipases and nitrilases from different sources for the synthesis of many hypertensive drugs and drug intermediates, esters, cardio-vascular drugs and chirally pure alcohols. Dr. Banerjee cited his studies on the synthesis of phototheranostic agents that were immobilized on various nanocarriers for use in the photodynamic therapy and concluded that NBCs can improve the efficacy of different bioprocesses. Dr. D K Sahoo (IMTECH, Chandigarh) gave the second talk on 'Biopharmaceutical Process Development: a Case Study on *Escherichia coli* as Host for Production of Therapeutic Proteins'. The prokaryotic expression system of *E. coli* was discussed as the most commonly used host for expression of a wide variety of recombinant proteins with therapeutic and industrial interest especially of those that do not need post-translational modifications. Dr. Sahoo further suggested that investigations on the influence of dissolved oxygen content on expression level of the desired product will help in better understanding of process. He recommended the study of different parameters such as medium composition, nutrient concentration and availability, rate of feeding, concentration of inducer and antibiotic (selection pressure), plasmid stability and formation of inhibitory by-products in detail for each process and expression hosts to improve the productivity of therapeutic proteins. The next lecture was delivered by Dr. A. K. Panda (NII, New Delhi) on 'High Throughput Recovery of Bioactive Protein from Inclusion Bodies of *Escherichia coli*'. He discussed solubilization of inclusion body protein using different organic solvents such as propanol, β-mercaptoethanol and trifluroethanol that resulted in higher recovery. The proof of principle was established by using human growth hormone as model protein. The fourth presentation of session was by Dr. P. Mondal (IIT Roorkee) on 'Phytoremediation of Arsenic, Fluoride and Manganese containing Wastewater'. The effectiveness of *Vetiveria zizanioides* for simultaneous phytoremediation of arsenic, fluoride and manganese from synthetic wastewater using a batch scale floating platform unit was highlighted in the talk. Dr. Banwari Lal (TERI, Delhi) presented the final talk of the session on 'Emerging Challenges in Environmental Microbiology'. He discussed the potential of an indigenous bacterial consortium designated as KT-

Oilzapper by assembles of selected bacteria species, isolated from oil contaminated sites of Kuwait Oil Company (KOC), Kuwait for the biodegradation of total petroleum hydrocarbon in the oil contaminated soil by 98.00 to 99.29 % in a case study of 70 x 70 m of oil contaminated site, both at surface and subsurface level (upto 1.5 m depth), near Gathering Centre 2 (GC-2), Burgan, South Kuwait Oil Field of KOC, Kuwait. He concluded that bioremediation of oil polluted sites can be efficiently carried out by using KT-Oilzapper.

Third Session:

The third scientific session, dedicated to the emerging field of 'Biological engineering in drug/small molecule discovery', commenced on the 2nd day of the conference. Prof. S. S. Ghosh (IIT Guwahati) started the session with a talk titled 'Emergence of Cancer Theranostics' which gave a fascinating insight into cancer theranostics. He shared his extensive knowledge on various multifunctional theranostic nanoformulations including chitosan-gold nanoclusters for suicide gene therapy and tracking gene delivery into cells, nano ensemble POC devices, etc. Dr. Supreet Saini (IIT Bombay) gave the second talk on 'Coordinated control of virulence factors and antibiotic resistance in enteric bacteria' where using *Salmonella* as a model system, he discussed about the control strategies that the bacteria use for effective and fail-safe expression of virulence factors for causing infection. He explained how expression of virulence factors is closely tied with loci which, in enteric bacteria, confer antibiotic resistance thereby helping us to identify targets for intervention. The third talk of session was given by Dr. Anirban Roy (BITS, Pilani, Goa campus) on 'How we can tune the biological response of a membrane surface? An investigative study' where he discussed in detail various membranes and the evaluation of their physical and biological properties for biomedical engineering applications like hemodialysis. The final talk of the session was on 'Lower Terpenes and aromatherapy' by Prof. Mohammed Ali (Jamia Hamdard, New Delhi). He spoke about various isolation procedures of essential oils from plants, insects and animals and individual components of essential oils followed by an elaborative discussion on the composition and uses of various essential oils and their components. The science of aromatherapy was also discussed in the talk.

Fourth Session:

Post lunch, the last session (Session IV) was on the theme 'Environment, Bioenergy and Bioseparation'. The first talk of the session was delivered by Dr. D. K. Tuli (Chair DBT-IOC Centre for Bioenergy Research Faridabad) on 'Lignocellulose ethanol-Current status and impediments'. He presented current status of ethanol in India and suggested use of lignocellulosic based ethanol to overcome feedstock limitation. A technology platform for lignocellulosic ethanol has been created in the country with active participation of DBT and involvement of private sector with the establishment of two pilot plants and announcement of four large scale plants, 400 tons feed per day, by Ministry of Petroleum and Natural gas. Prof. T. R. Sreekrishnan, (IIT Delhi) gave second talk of the session on 'Biology of Wastewater management'. He shared his extensive knowledge on various approaches like use of hybrid anaerobic reactor, rotating biological contactors, use of xylananse enzyme produced by white rot fungus, etc. for treating the waste through advanced process technologies to reduce its environment impact. He emphasized on the use of metagenomic tools for preparing community profile map of mixed microbial consortia to be used in reactors for waste management. The final talk of the session was on the topic 'Indigenous environment friendly mercury-free plasma UV Lamp technology: A Solution for mercury disposal from UV- Lamps by Dr.Ram Prakash (CEERI's Incubation-cum-Innovation Hub, Jaipur). He discussed the hazardous effects of mercury and mercury based UV lamps for water disinfection. He presented a new indigenous technology comprising mercury free VUV/UV lamp with a novel structural design and an optimized gas mixture developed by CSIR-CEERI as a much superior alternative for the presently used mercury based lamps in water disinfection systems. The developed technology has immense potential to replace UV light sources used in household water purifier systems, storage/sewage/wastewater treatment plants and municipality water treatment plants and at the same time save environment as well.

The Scientific Session-IV was followed by a Panel Discussion on 'Curriculum and Career- Biology based Engineering'. The panel consisted of Dr. A. K. Panda, Prof. A. K. Dubey, Dr. Aradhana Srivastava, Prof. Prashant Mishra, Prof. T. Satyanarayana and Prof. T. R. Sreekrishnan. Each of the panelists presented their views on the topic. It was felt that the current biotechnology curriculum has more of biology component and less of engineering & technology parts as a result of which, the percentage of employment in biotechnology-based jobs is less. This calls for revamping the current curriculum with appropriate level of engineering and technology components to meet the biotechnology industry demand.

The general body of BESI decided during its meeting on 8th September, 2017 to hold the next conference of the society, BESCON – 2018 at IIT – Mumbai with Dr. Supreet Saini as Convener.

Prof. Ashok K Dubey,
Netaji Subhash Institute of Technology,
New Delhi 110078
Convener, BESCON – 2017

BIOLOGICAL ENGINEERING SOCIETY

WORK IS WORSHIP