American Journal of Microbiology 3 (1): 1-6, 2012
ISSN 1948-982x

Microbial Systems Biology: A Road Less Travelled

Soam Prakash and Prem Saran Tirumalai
Department of Zoology, Faculty of Science,
Dayalbagh Educational Institute, Deemed University, Dayalbagh, Agra-28 2110, India

Abstract: Problem statement: Systems biology is an emerging field of science. The branch of system science was conceived and proposed by a biologist at the very beginning, at the conceptual birth of the branch. Systems biology a holistic approach to biology, still remains a field less opted by researchers and science personnels in general. **Conclusion/Recommendations:** In this review, we try to revisit this intriguing branch science since its birth in order draw the attention of the science professionals at large.

Key words: Systems science, systems biology, microbiology, nano-biotechnology

INTRODUCTION

A World without mosquitoes was a discussion by Fang (2010) in the Nature Magazine as a News feature. The author discussed the options of eradicating mosquitoes from the face of earth, with the rationale that the existence of the insect has nothing positive to contribute to the Biome. So tangible yet, so lacking.

In the laudable words of Alexis Carrel, "… royal gifts of science have burst like a thunderstorm upon us while we are still too ignorant to use them wisely. And they may become highly destructive." (From the Nobel Prize winning book, 'Man, The Unknown') (Flammarion, 1998).

Isn't it required that we revisit the science of understanding the dynamics of life, before we play despotic? As aptly stated in the review (Mesarovic and Rosen, 1968). on the book 'Systems Theory and Biology' by M.D. Mesavoric, '…systems-theoretic ideas actually (must) mark a return to the holistic, functionally oriented view of organisms entertained by biologists.

Haven't we taken a hasty reductionist approach in understanding the role of mosquitoes and to have verily taken an unscientific conclusion that mosquito is a pest and nothing more? Has there been a holistic approach in understanding an organism as a part of a system? Have we made an attempt to understand and absorb all that exists around us in totality?

Systems theory and biology: Mostly, it has been customary that the biology of an organism is studied on the basis of how it influences the mankind. In the case of microbes, if a pathogen, the approach in understanding the biology has been on the attributes of its virulence and pathogenicity and the allied and if a probiotic or any other useful microbe, then the approach has been to understand the attributes of its usefulness and how best it could be exploited. Owing to this self-imposed, self-centered, typically reductionist approach and also due to lack of adequate techniques, understanding a microbe, in its true niche and existence, had not been envisaged for long. The result of this despotism adds to the complexity in understanding the already complex and dynamic life. Since much of the true information remains veiled, its application in biology remains remotely executable.

Not in the far past, did a branch of science emerge as the 'System Science' with the genesis of the General Systems Theory (GST) by Karl Ludwig von Bertalanffy, who was a biologist himself. Bertalanffy, (1950) proposed that to "open systems", such as living beings, the laws of thermodynamics were not applicable Thus, GST describes systems with interacting components that were applicable to biology. Denis Nobel, relayed the baton on systems approach forward and brought to light the systemic approach in biology and it was Mihajlo Mesarovic (1968) to formally induct us all to the term, 'Systems Biology'

For time immemorial, biology has been a study on organisms, part by part and lately on molecule by molecule, gene-by-gene. This approach has been coined as 'Reductionist' approach and has so far not yielded to holistic understanding of even the smallest form to the simplest concept of life; leave alone the Dynamism of life, as hinted by Flammarion (1998).

Corresponding Author: Soam Prakash, Department of Zoology, Faculty of Science, Dayalbagh Educational Institute, Deemed University, Dayalbagh, Agra-28 2110, India Tel: +91 9410421149 Fax: +91 562 2801226

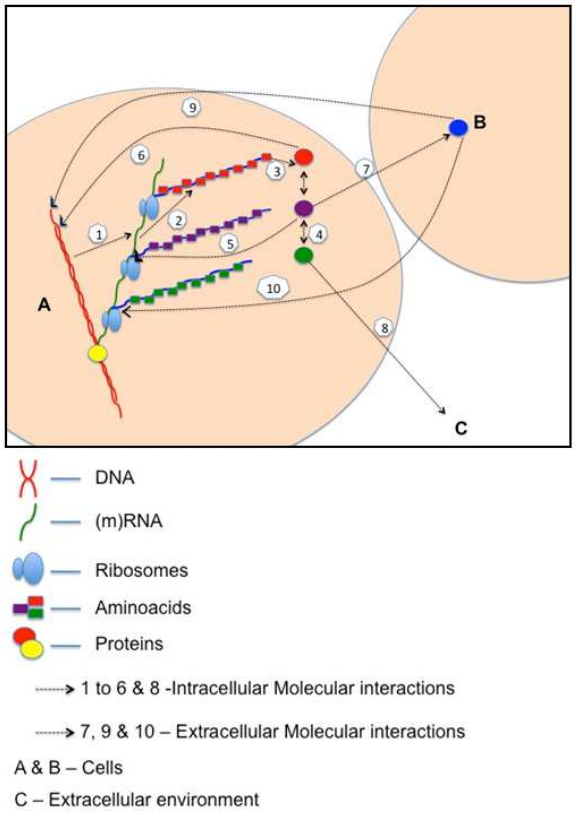

Fig. 1: Intreactomics (intra extracellular)

From the time of Denis Nobel, although in its infancy, there has been a considerable progress achieved in the field of Systems Biology. The stride has been such that, today Systems Biology is hailed as the 21st Century Science' (http://www.systemsbiology.org) it has potentials to deliver in a very short time, more than what biology has delivered since its inception. For a while now, Systems biology in the international research arena has gathered momentum and a number of institutes and universities of repute have plunged into the field (see List of systems biology research groups of the world at the Wikipedia). The list by itself speaks volumes of the vast and ever widening scope and path breaking potentials of this systems movement in biology. Systems biology encompasses and, in fact, can be said to have given rise to many branches of inter-disciplinary bio-sciences. Phenomics, Genomics, Interferomics, Interactomics and Biomics, are to name a few. To emphasise our contention on the scope and potentials of system-theoretic ideas in biology, it is worthy to mention that the trendy concepts on data-mining through genomics, proteomics, transcriptomics, owe their genesis to systems biology. Also to mention the praise worthy Human Genome Project that came to completion a few years ago and the on-going Human Microbiome Project are the outcome of the systems movement in biology (Turnbaugh *et al*., 2007; Potters, 2010). Figure 1 depicts the concept of systems biology.

Sociobiology of microbes, a minuscule but concrete support to systems biology: For ease in understanding the systems biology perspective, we will try and discuss the long-standing and current ritualistic approach in the field of microbiology and the probably applicable systems approach to it. Majority of studies concerning microbes have been done on lab grown pure culture states. Given to understand the fact that microbes seldom thrive as monocultures in nature, wouldn't that be fundamentally misleading to perceive concepts of biology on pure cultures? If we were to consider the gene expression of a pathogen and we conclude from the data generated from pure lab grown cultures, which inevitably is the improbable condition or state of existence of any microbe, then aren't we likely to be misapprehended? A pathogen for instance in intracellular condition need not be the only infectious agent anchored to a particular site, or say, in extracellular condition, a pathogen is very unlikely to be thriving as a pure culture biofilms. Should that be the case, shouldn't we be studying gene expression of the pathogen in the presence of a probable co-existing partner(s)? It is with evidence and experience that we discuss the phenomenon of 'tailored' gene expression of bacteria to the environmental factors. Ooij (2011), in referring to an article in nature by Garbeva *et al*. (2011) states that, microbes tailor their gene responses to surrounding microbes. A similar study was conceived in the laboratory (of Environmental and Advanced Parasitology) of the Department of Zoology, the Dayalbagh Educational Institute, Agra, India, to understand the differential gene expression pattern of a pathogen (*Listeria monocytgenes*) under different states of growth (broth and biofilms) and in the presence of another bacterium (*Bacillus subtilis*), using microarray technique (Tirumalai and Prakash, 2011; Tirumalai and Prakash, 2012). It was observed that the L. *monocytogenes* varied exceptionally in its gene expression not only to different growth states but also to the presence of the other bacterium (The Microarray data are available at the Gene Expression Omnibus database under the accession number GSE27936 (www.ncbi.nlm.nih.gov/geo). If the expression of the bacterium 'A'(*L. monocytogenes*) in the presence of another bacterium 'B'(*B. subtilis*), was way different from the monocultures which was taken as reference and if we knew that microbes in nature seldom exist as monocultures, then how can

we rely on the data available on the bacterium obtained from lab grown pure cultures ? How are we to derive on to a conclusion without a systems approach to the gene expression pattern of the microbe? Won't such studies verily provide factual data on the object and subject?

In line with a similar object as in the above study, researchers from the domain of 'Integrative Systems Biology' had given a newer approach to this form of science by considering interaction and existence of group-living organism as a system behaviour. Though not the first, Foster (2005), aptly used the term 'Sociobiology' in describing this approach to science, which is a socio-scientific phenomenon with the pursuit of integrating complex data about the interactions in biological systems from diverse experimental sources. This field of Systems Biology (so-called Interactomics), if visualised will provide an elusive space to emerging researchers for participation and contribution. Interactomics, one among the many has been considered here for representing the imponderable potential grandeur of Systems Biology (Fig. 1). As an example and in order to throw more light we here focus on the subject of Interactomics (with the Integrative Systems Biology) we herewith provide details of few references (Foster, 2005; Foster *et al*., 2007; Xavier and Foster, 2007; Nadel *et al*., 2009).

Understanding the Inter and Intra-species interactions with the influence of abiotic factors, was indeed, a holistic and summating approach. Sociobiology, that attempts to unravel existence, as it factually exists, is truly a mastery of the 'science of existence', past, present and beyond.

Nano (Bio) technology in credit to systems approach in biology: The implication of use of Nano (sized) particles has been the cause of the research rush in the area. Nano-gold, the very term is a sensation in science today and use of microbes for synthesising nano-gold is not a veiled fact. While venues of application for nano-materials is emerging in one hand, greener solution for synthesising these nano-materials is also being thoroughly screened for (Narayanan and Sakthivel, 2011). Heavy traffic in the road to nano-bio-technology, indeed, however, the vital point on the wholesome understanding of how and why nano-materials exist or have come to exist is likely to be more intriguing. Wouldn't it be required to have a systems approach in understanding nano-material synthesis? Wont that be more wisely scientific? Although, many reports on the synthesis of nano-materials by microbes and in particular by fungi have gained a stand, with special emphasis on nanoscale structures forming superstructures (Mandal *et al*., 2006; Xie *et al*., 2007), the systemic approach in deciphering the mechanism of formation of nano-materials is yet to be proposed. For instance a single species of fungi is known to produce structurally different forms of the same nano-material under different conditions (Fig. 2). It was with the interest that, like any other science, nano-material synthesis needed a systemic pursuit, the Environmental and Advanced Parsitology Lab made attempt to research the system dynamics of Nano-Gold synthesis (Prakash, 2009; Soni and Prakash, 2011; 2012).

Systems biology, the Indian chapter: All the worth, hyped activities in the international research arena, yet Systems Biology in India has not gathered enough attention. Systems Science is not a science unknown to the research community in India. We have 02 active system science forums to our credit in India (System Society of India and the National Systems conference). Systems movement was brought to life in India by the institution of the National Systems Conference from 1973. Having gathered adequate momentum the systems movement coalesced as the Systems Society of India in 1981 (Satsangi, 2006). Also, in India, beyond science and engineering, researchers have embraced systems approach in the attempt to scientifically rationalise, esoteric religious beliefs (Satsangi, 2006).

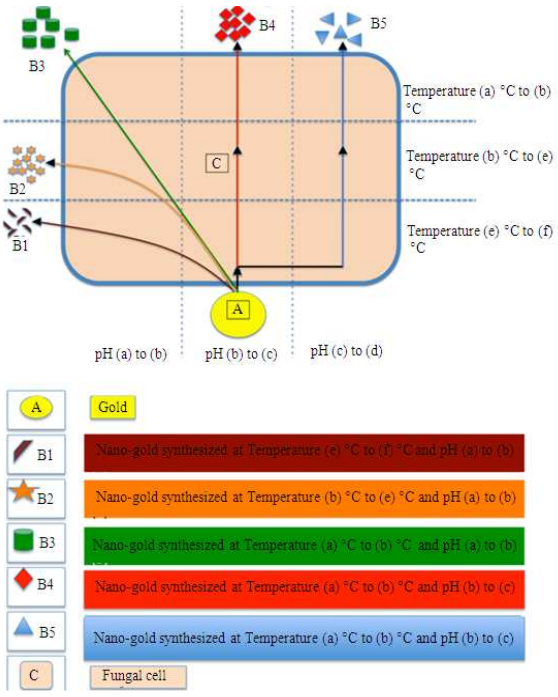

Fig. 2: Nanogold synthesis by fungi

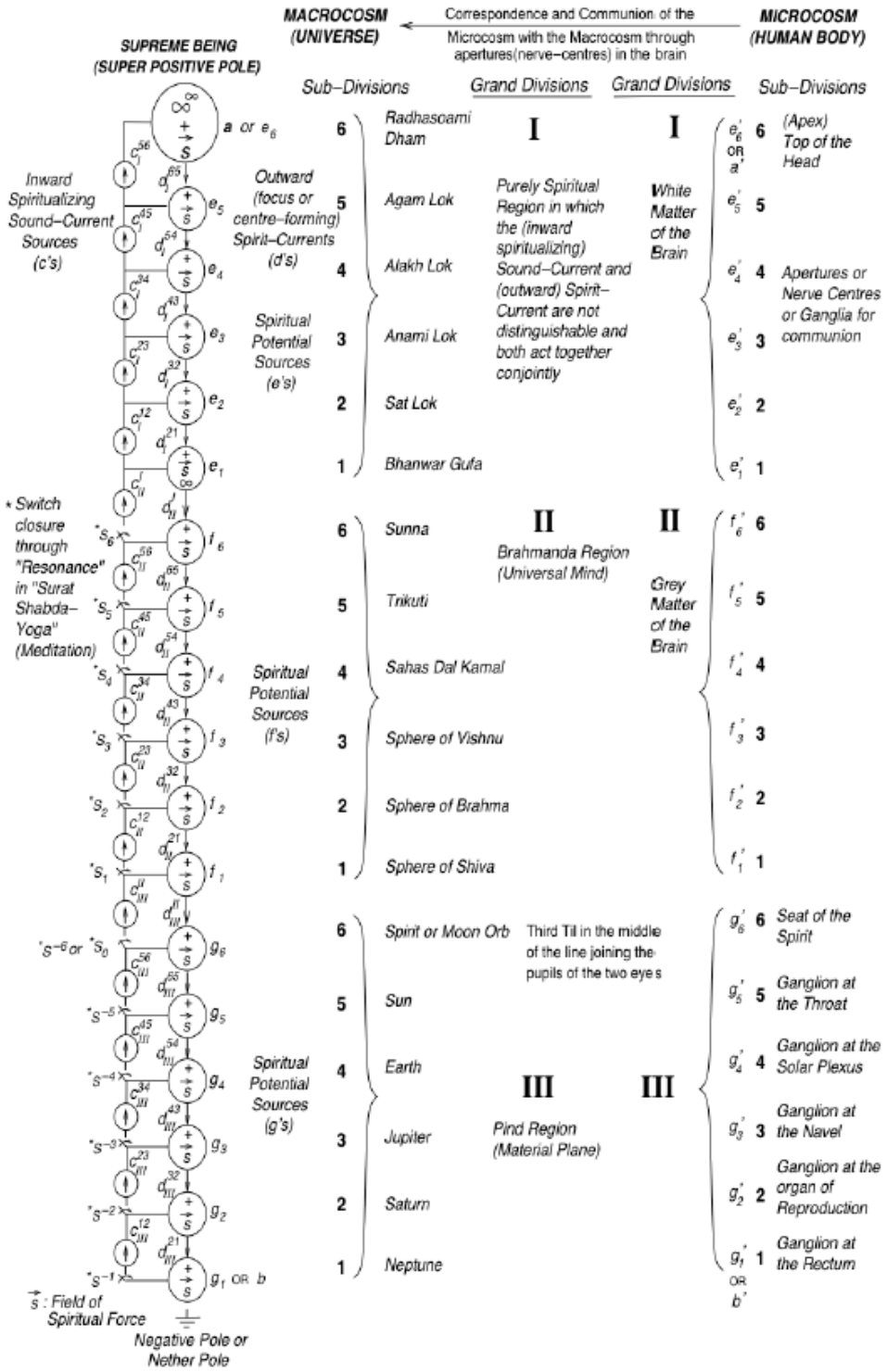

Fig. 3: A pictorial excerpt from the article by Prof. P.S. Satsangi on the General

Figure 3 is an excerpt from the 'general systems on the application of physical system theory as a rudimentary modelling framework for "Esoteric" macrocosmic/microcosmic systems in the domain of

spiritual consciousness', substantiating the great heights, systems science has transcended to, in India. While systems science has been progressing in leaps and bounds, only 03 premier institutes in India, viz. Bose Institute (Kolkotta), Institute of Genomics and Integrative Biology (Delhi) and Centre for Synthetic and Systems Biology (Kerala) to be specific, have taken to research in systems biology. Though with the immense potentials we cherish, biology had and continues to have, a reductionist approach, which has been so, for ages. We are being recognized globally for achieving great heights in molecular level biology; however our approach lacks the holism. We may have mastered the most vital, 'problem defining' factor and equipped ourselves with the best of techniques, yet we lack in our holistic approach. The dynamism and complexity with high degree of uncertainty in biology is known. With this fundamental fact, would we be able to decipher 'Truth, the ultimate object of Science', without a holistic approach?

Truly, holistic functionally oriented view of organisms entertained by biologists, prior to the emergence of biochemistry and molecular biology, a view which was displaced by the rapid growth of these fields, 'must' mark a return (Mesarovic and Rosen, 1968).

ACKNOWLEDGEMENT

We offer our thankful submissions to Most Revered, Prof. P.S. Satsangi for giving us his consent to use his pictorial excerpt. We are also grateful to Mr. S. Krishnananda, Dayalbagh for his suggestions in improving the presentation of the manuscript.

REFERENCES

Bertalanffy, L.V., 1950. The theory of open systems in physics and biology. Science, 111: 23-29.

Fang, J., 2010. A world mosquitoes. Nature News Feature.

Flammarion, C., 1998. The Unknown. 1st Edn., Kessinger Publishing, Kila, Mont., ISBN: 0766104745, pp: 508.

Foster, K.R., 2005. Hamiltonian medicine: Why the social lives of pathogens matter. Science, 308: 1269-1270. DOI: 10.1126/science.1108158

Foster, K.R., K. Parkinson and C.R. Thompson, 2007. What can microbial genetics teach sociobiology? Trends Genet., 23: 74-80. PMID: 17207887

Garbeva, P., M.W. Silby, J.M. Raaijmakers, S.B. Levy and W. Boer, 2011. Transcriptional and antagonistic responses of Pseudomonas fluorescens Pf0-1 to phylogenetically different bacterial competitors. ISME J., 5: 973-985. PMID: 21228890

Mandal, D., M.E. Bolander, D. Mukhopadhyay, G. Sarkar and P. Mukherjee, 2006. The use of microorganisms for the formation of metal nanoparticles and their application. Applied Microbiol. Biotechnol., 69: 485-492. PMID: 16317546

Mesarovic, M.D. and R. Rosen, 1968. Systems theory and biology. Science, 161: 34-35. DOI: 10.1126/science.161.3836.34

Mesarovic, M.D., 1968. Systems Theory and Biology. 1st Edn., Springer-Verlag, Berlin, pp: 403.

Nadel, C.D., J.B. Xavier and R.K. Foster, 2009. The sociobiology of biofilms. FEMS Microbiol. Rev., 33: 206-224. PMID: 19067751

Narayanan, K.B. and N. Sakthivel, 2011. Synthesis and characterization of nano-gold composite using Cylindrocladium floridanum and its heterogeneous catalysis in the degradation of 4-nitrophenol, J. Hazar Mat., 189: 519-525. PMID: 21420237

Ooij, C.V., 2011. Microbial ecology: Strong fences make good neighbours. Nat. Rev. Microbiol, 9: 150-151. DOI: 10.1038/nrmicro2527

Potters, G., 2010. How the human genome project opened up the world of microbes. Nature Educ., 3: 34-34.

Prakash, S., 2009. Fungi and Nano gold: Does it need a systemic approach to synthesis? Poster session. Proceedings of the Applied Systems Research XXXVIII National Systems Conference, Nov. 27-29, Agra, India.

Satsangi, P.S., 2006. Autobiographical Retrospectives: Generalizing physical system theory for applied systems research from real physical systems through "Conceptual" Socio-Economic Environmental Systems to "Complete" (Physical - Mental-Spiritual) Creational System. Int. J. General Syst., 35: 127-167.

Soni, N. and S. Prakash, 2011. Factors affecting the geometry of silver nanoparticles synthesis in *Chrysosporium tropicum* and *Fusarium oxysporum*. Am. J. Nanotechnol., 2: 112-121. DOI: 10.3844/ajnsp.2011.112.121

Soni, N. and S. Prakash, 2012. Efficacy of fungus mediated silver and gold nanoparticles against Aedes aegypti larvae. Parasitol Res., 110: 175-184. PMID: 21647674

Tirumalai, P.S. and S. Prakash, 2011. Expression of chitinase and Chitin Binding Proteins (CBP's) by *Listeria monocytogenes* J0161 in biofilm and co-culture broths. Afr. J. Microbiol. Res., 5: 5188-5193. DOI: 10.5897/AJMR11.929

Tirumalai, P.S. and S. Prakash, 2012. Time-dependent gene expression pattern of *Listeria monocytogenes* J0161 in biofilms. Adv. Genomics Genetics, 2: 1-18. DOI: 10.2147/AGG.S26335

Turnbaugh, P.J., R.E. Ley, M. Hamady, C.M. Fraser-Liggett and R. Knight *et al*., 2007. Feature the human microbiome project. Nature, 449: 804-810. DOI: 10.1038/nature06244

Xavier, J.B. and K.R. Foster, 2007. Cooperation and conflict in microbial biofilms. PNAS, 104: 876-881. DOI: 10.1073/pnas.0607651104

Xie, J., J.Y. Lee, D.I.C. Wang and Y.P. Ting, 2007. High-Yield synthesis of complex gold nanostructures in a fungal system. J. Phys. Chem. C., 111: 16858-16865. DOI: 10.1021/jp0752668