Course title: Introduction to Systems Biology

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Objective

Systems biology is an emerging field that aims to understand biological systems and organisms at the systems level rather than focusing on only a small number of components. This helps understand the biological mechanisms at a deeper level which is necessary for effectively developing applications that would benefit the human society. Systems biology is interested in investigating the working principles of transcriptional, signal transduction and metabolic networks and how organisms utilize them for sensing and responding to environmental signals. In addition, improper functioning or damage to these networks can lead to human diseases. Studying complex biological systems require new experimental and data analysis techniques. One such technique is Next Generation Sequencing (NGS). NGS has revolutionized the field of Biological Science, Biotechnology and Medicine through generation of large scale datasets. Analysis of these datasets require new bioinformatic techniques which are rapidly being developed. Based on the principle that we understand a system well only when we can build it ourselves, synthetic biology has become an integral part of systems biology. Designing and building synthetic biological networks (or circuits) help us understand biological systems much better and have enormous potential for future applications. This course aims to provide a glimpse into these upcoming and important areas of Biological Sciences as well as to give students an exposure to recent advances in technology that are changing the face of Biotechnology and Medicine.

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Content

1. Introduction and basic concepts in Biological systems (2 Lectures)
2. Genotype-phenotype mapping
   - Concepts of genotypes and phenotypes, genotype networks and fitness landscapes (3 Lectures/exercise). Hands-on experience on genotype-phenotype map construction would be provided.
3. Gene regulation networks
   - Negative and positive regulation in transcription networks (3 Lectures/exercise)
   - Feed-forward loops (2 Lectures)
   - Oscillatory circuits (2 Lectures)

4. Optimality and robustness

   - Robustness in biological systems (2 Lectures)

   - Principles of optimality (2 Lectures)

   - Stochasticity in biological processes (3 Lectures/Exercise). Hands-on experience of data

analysis investigating stochasticity.

5. Next generation sequencing (NGS) and its applications
   - NGS technologies (2 Lectures),
   - Bioinformatic tools and techniques for high-throughput data analysis (4 Lectures/exercise). Hands-on experience with dataset handling and analysis would be provided.
   - Applications of NGS (3 Lectures/exercise)

6. Microarrays (gene expression arrays/CGH arrays) (3 Lectures/exercise). Hands-on experience on data analysis

7. Metabolic networks and flux analysis
   - Metabolic networks ad flux analysis (3 Lectures/exercise)
   - Metabolic engineering (2 Lectures)

8. Introduction to synthetic biology (3 Lectures)

Text books:

1. An Introduction to Systems Biology: Design Principles of Biological Circuits (Chapman & Hall/CRC Mathematical and Computational Biology) by Uri Alon

2. High-Throughput Next Generation Sequencing, Methods and Applications. (Springer). Editors: Kwon, Young Min, Ricke, Steven C. (Eds.)

3. Palsson, Bernhard O. Systems Biology: Properties of Reconstructed Networks. New York: Cambridge University Press, 2006.

4. Synthetic Biology: Tools and Applications. (H. Zhao, ed.) Academic Press, 2013

5. Optimization Methods in Metabolic Networks. Costas D. Maranas and Ali R. Zomorrodi. John Wiley & Sons, 2016.

Further reading and references

1. Systems Biology: A Textbook, 2nd Edition (Wiley). Edda Klipp, Wolfram Liebermeister, Christoph Wierling, Axel Kowald.

2. Kitano H. Systems biology: a brief overview. Science. 2002 Mar 1;295(5560):1662-4.

3. Ross J, Arkin AP. Complex systems: from chemistry to systems biology. Proc Natl Acad Sci U S A. 2009 Apr 21;106(16):6433-4. doi: 10.1073/pnas.0903406106. Epub 2009 Apr 20.

4. Nature Reviews Genetics Journal: Series on applications of next-generation sequencing.

http://www.nature.com/nrg/series/nextgeneration/index.html