achieved, caused the quantitative modeling of biological processes to become a somewhat minor field.[19]

However, the birth of functional genomics in the 1990s meant that large quantities of high-quality data became available, while the computing power exploded, making more realistic models possible. In 1992, then 1994, serial articles [20][21][22][23][24] on systems medicine, systems genetics, and systems biological engineering by B. J. Zeng was published in China and was giving a lecture on biosystems theory and systems-approach research at the First International Conference on Transgenic Animals, Beijing, 1996. In 1997, the group of Masaru Tomita published the first quantitative model of the metabolism of a whole (hypothetical) cell.[25]

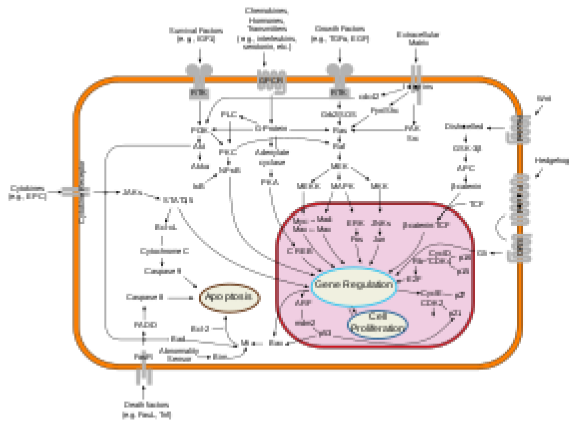
Around the year 2000, after Institutes of Systems Biology were established in Seattle and Tokyo, systems biology emerged as a movement in its own right, spurred on by the completion of various genome projects, the large increase in data from the omics (e.g., genomics and proteomics) and the accompanying advances in high-throughput experiments and bioinformatics.

In 2002, the National Science Foundation (NSF) put forward a grand challenge for systems biology in the 21st century to build a mathematical model of the whole cell.[26] In 2003, work at the Massachusetts Institute of Technology was begun on CytoSolve, a method to model the whole cell by dynamically integrating multiple molecular pathway models.[27][28] Since then, various research institutes dedicated to systems biology have been developed. For example, the NIGMS of NIH established a project grant that is currently supporting over ten systems biology centers in the United States.[29] As of summer 2006, due to a shortage of people in systems biology[30] several doctoral training programs in systems biology have been established in many parts of the world. In that same year, the National Science Foundation (NSF) put forward a grand challenge for systems biology in the 21st century to build a mathematical model of the whole cell.[31] In 2012 the first whole-cell model of Mycoplasma Genitalium was achieved by the Karr Laboratory at the Mount Sinai School of Medicine in New York. The whole-cell model is able to predict viability of M. Genitalium cells in response to genetic mutations.[32]

An important milestone in the development of systems biology has become the international project Physiome.

Associated disciplines

According to the interpretation of Systems Biology as the ability to obtain, integrate and analyze complex data sets from multiple experimental sources using interdisciplinary tools, some typical technology platforms are:



Overview of signal transduction pathways

- Phenomics

  Organismal variation in phenotype as it changes during its life span.

- Genomics

  Organismal deoxyribonucleic acid (DNA) sequence, including intra-organisamal cell specific variation. (i.e., telomere length variation)

- Epigenomics / Epigenetics

  Organismal and corresponding cell specific transcriptomic regulating factors not empirically coded in the genomic sequence. (i.e., DNA methylation, Histone acetylation and deacetylation, etc.).

13. Hodgkin, Alan L; Huxley, Andrew F (28 August 1952). "A quantitative description of membrane current and its application to conduction and excitation in nerve" (https://www.ncbi.nlm.nih.gov/pmc/articles/PMC1392413). Journal of Physiology. 117 (4): 500–544. doi:10.1113/jphysiol.1952.sp004764 (https://doi.org/10.1113%2Fjphysiol.1952.sp004764). PMC 1392413 (https://www.ncbi.nlm.nih.gov/pmc/articles/PMC1392413). PMID 12991237 (https://www.ncbi.nlm.nih.gov/pubmed/12991237).
14. Le Novère, Nicolas (13 June 2007). "The long journey to a Systems Biology of neuronal function" (https://www.ncbi.nlm.nih.gov/pmc/articles/PMC1904462). BMC Systems Biology. 1: 28. doi:10.1186/1752-0509-1-28 (https://doi.org/10.1186%2F1752-0509-1-28). PMC 1904462 (https://www.ncbi.nlm.nih.gov/pmc/articles/PMC1904462). PMID 17567903 (https://www.ncbi.nlm.nih.gov/pubmed/17567903).
15. Turing, A. M. (1952). "The Chemical Basis of Morphogenesis" (http://www.dna.caltech.edu/courses/cs191/paperscs191/turing.pdf) (PDF). Philosophical Transactions of the Royal Society B: Biological Sciences. 237 (641): 37–72. doi:10.1098/rstb.1952.0012 (https://doi.org/10.1098%2Frstb.1952.0012). JSTOR 92463 (https://www.jstor.org/stable/92463).
16. Noble, Denis (5 November 1960). "Cardiac action and pacemaker potentials based on the Hodgkin-Huxley equations". Nature. 188 (4749): 495–497. Bibcode:1960Natur.188..495N (http://adsabs.harvard.edu/abs/1960Natur.188..495N). doi:10.1038/188495b0 (https://doi.org/10.1038%2F188495b0). PMID 13729365 (https://www.ncbi.nlm.nih.gov/pubmed/13729365).
17. Mesarovic, Mihajlo D. (1968). Systems Theory and Biology. Berlin: Springer-Verlag.
18. Rosen, Robert (5 July 1968). "A Means Toward a New Holism". Science. 161 (3836): 34–35. Bibcode:1968Sci...161...34M (http://adsabs.harvard.edu/abs/1968Sci...161...34M). doi:10.1126/science.161.3836.34 (https://doi.org/10.1126%2Fscience.161.3836.34). JSTOR 1724368 (https://www.jstor.org/stable/1724368).
19. Hunter, Philip (May 2012). "Back down to Earth: Even if it has not yet lived up to its promises, systems biology has now matured and is about to deliver its first results" (https://www.ncbi.nlm.nih.gov/pmc/articles/PMC3343359). EMBO Reports. 13 (5): 408–411. doi:10.1038/embor.2012.49 (https://doi.org/10.1038%2Fembor.2012.49). PMC 3343359 (https://www.ncbi.nlm.nih.gov/pmc/articles/PMC3343359). PMID 22491028 (https://www.ncbi.nlm.nih.gov/pubmed/22491028).
20. B. J. Zeng, "On the holographic model of human body", 1st National Conference of Comparative Studies Traditional Chinese Medicine and West Medicine, Medicine and Philosophy, April 1992 ("systems medicine and pharmacology" termed).
21. Zeng (B.) J., On the concept of system biological engineering, Communication on Transgenic Animals, No. 6, June, 1994.
22. B. J. Zeng, "Transgenic animal expression system – transgenic egg plan (goldegg plan)", Communication on Transgenic Animal, Vol.1, No.11, 1994 (on the concept of system genetics and term coined).
23. B. J. Zeng, "From positive to synthetic science", Communication on Transgenic Animals, No. 11, 1995 (on systems medicine).
24. B. J. Zeng, "The structure theory of self-organization systems", Communication on Transgenic Animals, No.8-10, 1996. Etc.
25. Tomita, Masaru; Hashimoto, Kenta; Takahashi, Kouichi; Shimizu, Thomas S; Matsuzaki, Yuri; Miyoshi, Fumihiko; Saito, Kanako; Tanida, Sakura; et al. (1997). "E-CELL: Software Environment for Whole Cell Simulation" (http://web.sfc.keio.ac.jp/~mt/mt-lab/publications/Paper/ecell/bioinfo99/btc007_gml.html). Genome Inform Ser Workshop Genome Inform. 8: 147–155. PMID 11072314 (https://www.ncbi.nlm.nih.gov/pubmed/11072314). Retrieved 15 June 2011.
26. American Association for the Advancement of Science, [1] (http://www.sciencemag.org/content/314/5806/1696.full), Science
27. Ayyadurai, VA; Dewey, CF (March 2011). "CytoSolve: A Scalable Computational Method for Dynamic Integration of Multiple Molecular Pathway Models" (https://www.ncbi.nlm.nih.gov/pmc/articles/PMC3032229). Cell Mol Bioeng. 4 (1): 28–45. doi:10.1007/s12195-010-0143-x (https://doi.org/10.1007%2Fs12195-010-0143-x). PMC 3032229 (https://www.ncbi.nlm.nih.gov/pmc/articles/PMC3032229). PMID 21423324 (https://www.ncbi.nlm.nih.gov/pubmed/21423324).