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Editorial

Overview of the modeling of complex biological systems and its role in neurosurgery

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ABSTRACT

Biological systems are complex with distinct characteristics such as nonlinearity, adaptability, and self-organization. Biomedical research has helped in advancing our understanding of certain components the human biology but failed to illustrate the behavior of the biological systems within. This failure can be attributed to the use of the linear approach, which reduces the system to its components then study each component in isolation. This approach assumes that the behavior of complex systems is the result of the sum of the function of its components. The complex systems approach requires the identification of the components of the system and their interactions with each other and with the environment. Within neurosurgery, this approach has the potential to advance our understanding of the human nervous system and its subsystems.

Keywords: Biomedical, Complex, Neurosurgery, System

Biological systems are complex adaptive systems and consist of a large number of interacting elements [Figure 1].[1-6] These systems have distinct attributes such as nonlinearity, adaptability, and self-organization. Nonlinearity is the variability in the response of a system to the same initial conditions depending on its state. Self-organization is the unplanned emergence of order out of apparent chaos. Adaptation is the ability of a system to adjust and learn from experience.[1-6]

Biomedical research has helped in advancing our understanding of certain aspects of the biological systems of the human body but failed to explain their behavior. This failure can be due to the use of the deterministic (linear) approach, which has limitations such as reducing the system to its components before studying it. This reductionist approach assumes that the behavior of a system is the sum of the function of its components, which represents a major flaw because the behavior of complex systems results from the interaction of their components with each other and with the environment. Furthermore, complex systems are far from equilibrium, and their behavior is closely related to the continuous interaction between order and chaos.[1-6]

A model is a description of a system in terms of structure and relationship between its elements. Modeling of biological systems requires dealing with the complexity portended by the essential characteristics of living matter. It goes beyond simple verbal reasoning and might help to answer questions that the reductionist approach failed to address.[1-6] Within the field of neurosurgery, modeling of complex systems can be used to study disciplines such as the cerebrovascular system (both healthy and diseased states) and brain tumors and can potentially resolve perplexing

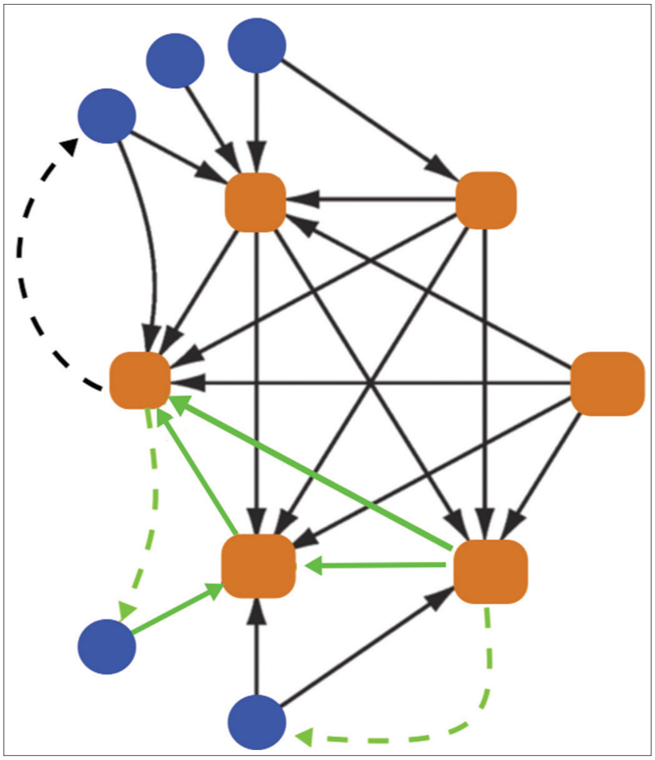

Figure 1: A schematic diagram of a complex adaptive system; the brown squares represent the system's elements whereas the blue circles represent environmental elements. The arrows represent the interaction between the system's elements and the environment.

questions regarding the behavior of these systems. So far, neurosurgery has not shown much progress on that front, possibly due to limitations involving the complexity of the required methodology, resources, time, criteria for funding, and others.

Mathematical models of a biological system can be constructed at a microscopic and or macroscopic scale. The microscopic depiction of a biological system is far more complex than that of a physical system of inert substance. Moreover, a biological system cannot simply be observed and interpreted at a macroscopic level because it shows only the output of the collaborative and orderly behaviors that may not be apparent at a different scale.[1-6]

The microscopic type models the dynamics of interactions between individual elements of a system. This approach generates complexity that sometimes cannot be addressed properly. Also, the large number of elements leads to a large number of equations, which requires large computational power for their numerical solution, rendering the approach too burdensome. For example, a sub-cellular scale model deals with the evolution of the physical and biochemical state of a single cell. It involves cell signaling, proteins, and genes, which makes the modeling process extremely difficult as

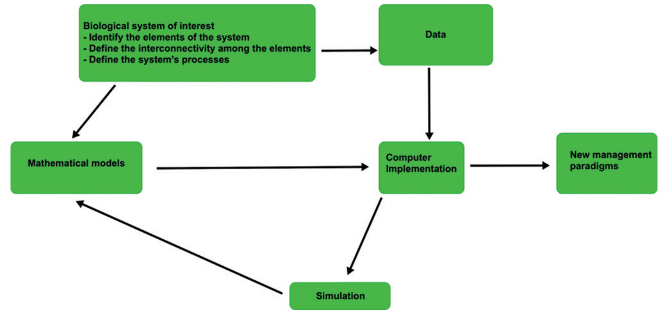

Figure 2: A schematic diagram of the modeling process of complex systems.

many biological details remain elusive.[1-6] The macroscopic type reduces the complexity of a system by dealing with quantities that are averaged locally. The application of this modeling method is possible when the number of elements is so large that even a small volume contains sufficiently large number of elements (e.g., modeling tissues, organs, and organisms).

The modeling process can be broken down into construction, tuning, analysis, and evaluation of the model [Figure 2]. The construction involves the identification of the model objectives, examination of the existing knowledge, constructing a theoretical framework, and identifying mathematical means to develop the model. Tuning entails fitting the model parameters. Finally, analysis and evaluation involve comparing the model results against investigational data and evaluating for inconsistencies.[1-6]

The complexity of biological systems arises from the variability and interconnectivity of their elements and the shared behaviors and properties at different levels. Using the modeling of complex systems in the field of neurosurgery will expand our understating of the human central nervous system and its archetypes and enables us to explain its characteristics and forecast its responses to different external stimuli.

REFERENCES

1. Alemani D, Pappalardo F, Pennisi M, Motta S, Brusic V. Combining cellular automata and lattice boltzmann method to model multiscale avascular tumor growth coupled with nutrient diffusion and immune competition. J Immunol Methods 2012;376:55-68.
2. Chen LC, Yeh HY, Yeh CY, Arias CR, Soo VW. Identifying co-targets to fight drug resistance based on a random walk model. BMC Syst Biol 2012;6:5.
3. Chitnis N, Hardy D, Smith T.A periodically-forced mathematical model for the seasonal dynamics of malaria in mosquitoes. Bull Math Biol 2012;74:1098-124.
4. Ghosh S, Matsuoka Y, Asai Y, Hsin KY, Kitano H. Software for systems biology: From tools to integrated platforms. Nat Rev

Genet 2011;12:821-32.
5. Hofestadt R, Thelen S. Quantitative modeling of biochemical networks. Stud Health Technol Inform 2011;162:3-16.
6. Zhang GL, Khan AM, Srinivasan KN, Heiny A, Lee K, Kwoh CK, *et al*. Hotspot hunter:A computational system for large-scale screening and selection of candidate immunological hotspots in pathogen proteomes. BMC Bioinformatics 2008;9 Suppl 1:S19.

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