In silico modeling as an ideal platform for future biological research and discovery

The invention of the computer and subsequent integration into medicine and science definitively changed the manner in which research is conducted and opened the doors to new opportunities for discovery. To date the primary use of computers in biology research has been the analysis and organization of data, while the enormous potential of computational modeling has yet to be fully realized or explored.

At the molecular and microscopic levels, computers are used to model specific protein structures and molecular interactions. At the level of the whole human body, rough models of human structure or movement have been described; yet between the molecular level and whole body level, no accurate, unified computational models of cells or tissues exist, much less organs or complete human systems. Similar to the gaping hole between the theory of quantum mechanics and the theory of relativity, an enormous gap exists between computational models of molecular interactions and gross models of the human body, thus providing an exciting new frontier for discovery.

An accurate mathematical model of a human cell would provide helpful information about the molecular interactions within the cell. The creation of a unified model of a human tissue, depicting the interactions and communications occurring between cells would revolutionize our understanding of molecular and cellular biology in health and disease. Ultimately, a model unifying the molecular interactions within the human cell to the organ systems comprising the human body would immediately bolster our understanding of the etiology and pathogenesis of disease and would provide an invaluable platform for identifying and testing novel therapeutics. The impact of an accurate, unified computational model at the cellular, tissue, and whole body levels would expand the horizons of biology and medicine in incalculable ways.

The development of an accurate model of the human body would redefine the term "personalized health". Leaps in technology have drastically increased the ease and cost effectiveness with which an individual's genome can be obtained. However, nearly all of the interpretations gained from obtaining an individual's genome are based on probability stemming from previous genomic association studies. A computational model of the human body could take an individual's genome, incorporate it into the model and describe at the molecular and systems levels what interactions could be problematic for that individual. Furthermore the unified model could be used to predict the likelihood of severe reactions to medication or interventions.

One of the controversies in basic biological research has been the use of animal models as a platform to develop an understanding of basic biological systems as well as to test the potential of emerging therapeutic options. Both the ethics and the accuracy of these platforms has been questioned. For example, many pharmacologic agents have been developed in mouse models of multiple sclerosis, while only a small fraction of those therapeutics have ever being used to treat humans. The same could be said of many other animal models of human disease. The use of animal models has begun to fall out of favor in many fields due to significant differences between the human body and that of other organisms. Ethically the use of animal models has been questioned because it often requires inducing disease in healthy animals. A model of the human body would solve both the ethical and biological problems that have been associated with using animal models in the past. Provided an accurate and detailed model, potential therapeutics could be tested in silico and proceed straight to human trial, effectively cutting out the time intensive process of verification in animal models. This is critical as the time between the recognition of a potential therapeutic and the availability of that therapeutic for clinical use is currently years to decades, time during which patients health is declining and lives are being lost.

Undertaking such a lofty endeavor will raise questions about whether a unified computational model of the human body is possible. The astounding progress in the use of computational modeling in video games and movies inspires us to believe that this is possible. Only about a half-century after the creation of the first computer game we now have consumer gaming systems capable of modeling complex scenarios with high resolution and detail. Flight simulators are now accurate enough to model actual flight, such that pilots are able to use them for training. Due to the complexity and enormity of the battle scenes in many modern movies, computers have been used to model thousands of detailed individual battles which are then unified into the larger battle scene. A computational model of the human body would work in a similar manner- imagine each individual battle not as combat, but a protein-protein or small molecule interaction and each battle not as two armies, but a single cell comprising the individual interactions. Based on the models of the single cells, larger tissues and eventually an entire body could be pieced together into a coordinated model.

Although this is a formidable and ambitious task, the time is right to begin the development of the computational human model, beginning at the level of the cell. The explosion of technology in the last three decades has made the processing power and memory quantities necessary for such a project tangible, while the completion of the human genome project provided an example of a coordinated international effort to create an invaluable resource for future scientific advancement. Furthermore the rapidly expanding databases containing post-translational modifications, three dimensional protein structures, and binding motifs make the ability to put together and verify an accurate model of the human cell and human body an achievable goal. Determination, cooperation, and coordination on a level beyond that of any previous human pursuit will be required, but it is in these moments that human ingenuity, resilience, and camaraderie have flourished.

The creation of a computational model of the human body would transform how we think of ourselves, how we promote health, and how we ward off disease. An accurate model will identify new therapeutics and create a holistic form of personalized medicine; however, in all likelihood, the most important and valuable applications have yet to be imagined.