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Molecular Biology Processes inside Living Cells

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Description

The bioeconomy concept is proliferating globally. However, the enabling roles of biotechnology may be getting sidelined in the strategies of some countries. A goal for engineering biology is alignment with the engineering design cycle to enable more rapid commercialization. This paper considers several policy options to remove critical technical barriers to commercialization.

Advances in molecular biology, optics, genetics, and bioinformatics have opened the door to mapping, in molecular detail, processes inside living cells. With the ability to observe the individual moving parts of cellular machinery, concepts formerly confined to physics are entering mainstream biology. This article discusses a few ideas of this sort related to chromosome biology, to illustrate what kinds of insights physics might yet bring to our understanding of living systems.

I teach a course for first-year biology graduate students entitled “Quantitative Biology,” created to address a 2005-era impetus from a number of bodies, including the NRC [1], for biology students to receive quantitative training.1 My course is focused on thinking mechanistically about molecules and cells. Picking papers to look at has been easy since every year there has been further development of this kind of thought in the biology research literature: terms like “physical biology,” “Brownian machines,” “phase separation,” “semi-dilute solution,” “random walk,” “Ostwald ripening” and the like increasingly appear in biological papers. Cell biology is being pollinated by 1990s-style condensed matter physics!

This paper will discuss a few concepts which could be useful for the practicing biologist trying to sort out their nanometers from their piconewtons, with a bias towards topics from chromosome biology. I distinguish “biophysics” which tends to worry about in vitro things (biophysics and the more physical end of “biochemistry” are often hard to separate from one another), “biological physics,” which is often used by physicists to talk about stuff that might be related to living things, and “physical biology” which aims to understand what is going on inside living cells quantitatively, using physical law. Recognition and use of the laws of nature mechanics, electromagnetism, statistical mechanics, and quantum mechanics is what separates physics from applied mathematics. The power of physics is the universality of physical law: Exactly the same laws that govern atoms and molecules in inert materials apply to living matter.

Given the increasing strategic importance of systems biology, both from theoretical and research perspectives, we suggest that additional epistemological and methodological insights into the possibility of further integration between traditional experimental studies and complex modeling are required. This integration will help to improve the currently underdeveloped pragmatic-systems biology and system-theoretical biology.

The “epistemology of complexity,” I contend, acts as a glue that connects and integrates different and sometimes opposing viewpoints, perspectives, streams, and practices, thus maintaining intellectual and research coherence of systems research of life. It allows scientists to shift the focus from traditional experimental research to integrated, modeling-based holistic practices capable of providing a comprehensive knowledge of organizing principles of living systems. It also opens the possibility of the development of new practical and theoretical foundations of systems biology to build a better understanding of complex organismic functions.

Emerging science and technology fields are increasingly expected to provide solutions to societal grand challenges. The promise of such solutions frequently underwrites claims for the public funding of research. In parallel, universities, public research organizations and, in particular, private enterprises draw on such research to actively secure property rights over potential applications through patenting. Patents represent a claim to garner financial returns from the novel outcomes of science and technology.

This is justified by the potential social value promised by patents as they encourage information sharing, further R&D investment, and the useful application of new knowledge. Indeed, the value of patents has generated longstanding academic interest in innovation studies with many scholars investigating its determinants based on econometric models. Yet, this research has largely focused on evaluating factors that influence the market value of patents and the gains from exclusivity rights granted to inventions, which reflect the private value of a patent. However, the patent system is a socially shaped enterprise where private and public concerns intersect. Despite the notion of the social utility of inventions as a patenting condition, and evidence of disconnection between societal needs and the goals of private actors, less attention has been paid to other interpretations of patent value. This paper investigates the various articulations of value delineated by patents in an emerging science and technology domain. As a pilot study, we analyse patents in synthetic biology, contributing a new analytical framework and classification of private and public values at the intersections of science, economy, and society.

After considering the legal, business, social and political dimensions of patenting, we undertake a qualitative and systematic examination of patent content in synthetic biology. Our analysis probes the private and public value propositions that are framed in these patents in terms of the potential private and public benefits of research and innovation. Based on this framework, we shed light on questions of what values are being nurtured in inventions in synthetic biology and discuss how attention to public as well as private values opens up promising avenues of research in science, technology and innovation policy.