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Views & Comments

Compromise through Competition: A More Widely Applicable Approach?

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The article by Jinghai Li in this issue of *Engineering* [1] calls for a new approach to how we organize science and technology (S&T), given that we are encountering more challenges than solutions. His paper is a plea and a demand for more transdisciplinary approaches to solving real-world, complex challenges, in the light of the reductionist approach that results in disciplines splintering into ever tighter groupings. His own approach of using mesoscale considerations to link the microscale and macroscale has been demonstrably successful over many years.

Pragmatic engineering opportunism suggests that his mesoscale approach deserves serious consideration and should be more universally applied. Perhaps readers of *Engineering* will consider corresponding in order to highlight examples in which the mesoscale involves disparate mechanisms (two or more), each of which could drive to an extreme, but where in practice there is "compromise through competition" [2]. Such cases are amenable to the Li approach of multiscale modeling. If the principle is found to be more universal, then, in and of itself, it will become the new approach for S&T, as is encouraged by Dr. Li.

Dr. Li and his group have had quite extraordinary success in their approach to understanding complex systems that span wide scales. Much of their success has been in chemical engineering systems. The microscale has been modeled using classical chemical, physical, and biological approaches, while the macroscale has been modeled using appropriate phenomenological models that are subject to boundary conditions operating on the whole system. The great innovation has been the handling of the intermediate mesoscale. Initially, their success involved the use of energy minimization at the mesoscale. They then refined and developed this premise into a principle of determining the dominant mechanisms at the mesoscale, where there is often a competition between two mechanisms—leading to the "compromise through competition" concept. This has been a productive approach.

In calling for the wider application of this methodology, practical limitations should be noted. Few studies in the literature explore the mesoscale, as compared with microscale- and systems-level publications. Of equal importance is the focusing question of whether the mesoscale always involves competition, and if so, whether it is always between two dominant mechanisms. I suspect that more work is required in this area in order to sway the wider scientific community.

At the microscale level, the Li methodology has a reductionist approach, using "fundamental" descriptors based on chemistry, physics, and biology. Since Kepler's work in the 16th century, the reductionist approach has delivered profound insights. That said, it is debatable whether the acknowledged limits of reductionism are compatible with the call for ever more effort at the microscale. As engineers, we intuitively consider something complex to be composed of separate entities, each of which is amenable to description. This perspective implies a separability of entities. However, interactions within complex systems are important, such as the behavior of flocks of birds, or cities, or ecosystems. It is arguable that knowing laws and initial conditions is not enough to *a priori* predict subsequent behavior—the "computational irreducibility" problem. To quote Heylighen et al. [3], "to study complex systems requires the observation of phenomena at multiple scales, without ignoring interactions." This is all very much in line with Dr. Li's pragmatic approach of modeling interactions at the mesoscale.

At a more theoretical level, Bruce Edmonds [4] has long since pointed out that "the abstract reductionist thesis itself is neither scientifically testable nor easily reducible to other simpler problems." Furthermore, there are more pragmatic limitations: All models are, of necessity, finite, so they can never be fully predictive. In addition, there are clear computational limits. To further quote Edmonds, "Quantum mechanics imposes a limit on the amount of information that can be computed by a gram of matter per second. So even with the mass of the universe and all the time until the heat death of the universe, there is a finite limit to computation." Again, a pragmatic approach is required in order to combine appropriate levels of reductionist modeling with holistic considerations—the core of the Li approach.

Thus, from several points of view, we see the Li approach as worthwhile. The challenge, then, is to find more examples from a wide range of problems in which the mesoscale involves compromise through competition. We may well find that there is a principle for transdisciplinarity that changes the way we undertake S&T.

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