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Views & Comments

Reconciling "Micro" and "Macro" through Meso-Science

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In the early 1990s, I was asked to review a manuscript by Professors Jinghai Li and Mooson Kwauk (Chinese Academy of Sciences) in which the energy minimization multiscale (EMMS) concept was introduced. This theory had been presented at various conferences and had been the object of Li's PhD thesis. On reading the manuscript, my first thoughts were that the concept was indeed a very interesting one, but that it was not more than an academic curiosity elegantly elucidated. The theory presented was rigorous; however, I never imagined at the time that such a theory could have a practical impact. After about two decades, I must admit that I was wrong: EMMS has flourished. Li and his team have even been able to apply it in an industrial context and to demonstrate that this theory enjoys a generality that permits it to be applied in a variety of circumstances, thus contributing to disparate technical fields such as software development and virtual process engineering.

While the mesoscale is a general concept, Li calls for the development of a "meso-science": a new approach to organizing scientific knowledge. This is a huge (revolutionary) assertion, as was emphasized recently by Li in this journal [1]. The book *From Multiscale Modelling to Meso-Science* [2] represents the synthesis of three decades of activities undertaken by Li and coworkers; this book is an excellent account of the importance of meso-science, on which the existence of the EMMS paradigm lies. The book is a clear account of how the phenomena that we observe in engineering are a consequence of the principle of "compromise in competition," which was reviewed recently [3]. The work of Li shows the mesoscale as a characteristic not only of engineering but also of many other scientific areas.

A number of intellectual efforts aim to take a bottom-up approach to evidence and theories in order to "reassemble" their elements and thereby obtain a sensible description of the whole system. Indeed, some small-scale theories exist on their own, without the background of a macroscopic phenomenological theory against which they might be tested. The challenge of all sciences is to achieve an accurate and complete description of complex systems. Scientists have broken down complex systems into their constituents—helped greatly by the advance of experimental techniques that make it possible to unveil the existence of invisible particles such as the boson. The challenge now lies in recomposing and reassembling the fundamental constituents. Statistical theories, for example, represent a possible reassembling route; however, they are certainly not the only possible solution. It is important to stress that some concepts are more universal than we used to think, and that such concepts can be applied to different fields and on different levels. (It is worth noting here that Kauffman [4] hypothesized a new form of statistical mechanics in which the elements are not particles but systems.) Nevertheless, systems are much more complicated than they might appear: When dealing with complex systems and expressing behavioral complexity, a diversity of levels of organization and structure exists—levels that cannot be ignored.

The challenge to "reassemble" complex systems implies an ability to explain the "macro appearance" of a system in accordance with its micro constituents. Such a "reassembling" would not be possible without passing through an intermediate scale that exists between the "small" (i.e., the microscale) and the "large" (i.e., the macroscale): the mesoscale. The mesoscale, as clearly articulated by Li, "blocks" a number of phenomena, resulting in poor understanding of the behavior of all the macroscopic phenomena that we observe in engineering applications. When studying complex systems, the various approaches can be broadly divided into two limiting situations. On one end of the spectrum, for example, one can find theories such as the Maxwell and Boltzmann theory, which worked to prove the existence of molecules. By presenting the theory of gases as a set of mechanical analogies, Boltzmann admitted that bodies are indeed composed of very small particles throughout. In contrast, on the other end of the spectrum, bottom-up efforts aim to "reassemble" the elements and obtain a sensible description of the whole.

The next problem is one of representation in terms of simplification, or the reduction of complexity: as Li elegantly articulated it, "compromise in competition."

Li's work is a call for a multidisciplinary approach toward knowledge. Unified learning has always been a common dream among scientists. The Ionian Enchantment (an expression coined by the physicist and historian Gerald Holton) is the belief in the unity of sciences: The world is ordered and can be explained by a number of natural laws. In a letter to his friend Marcel Grossmann, Einstein said: "It is a wonderful feeling to recognise the unity of a complex of phenomena that to direct observation appear to be quite separate things."

The voluminous body of work produced by Li's group culminated in the excellent book mentioned earlier [2], which is the first complete attempt made toward the "unity" of learning by an engineer. I call for an adoption of this approach, not only in the way in which

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we study complexity, but also in the training of the next generation of researchers.

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