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Transcience
Disciplines and the Advance of Plenary Knowledge

By David C. Krakauer
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"Everyone takes the limits of his own vision for the limits of the world."—Arthur Schopenhauer

Scientists, a risk-averse group, tend to eschew announcing their larger aims. After all, it is not entirely licit or proper to say, "we are trying to discern the laws of biology, or why social systems might proceed through sequences of increasing complexity," preferring instead remarks like "we are interested in gene regulation, or how large molecules are synthesized, or why the ancestral Puebloans stored maize." We feel that the larger objectives come across as grandiose and so we retreat into prosaic descriptions of the work we do. In other words, we retreat into disciplinarity, a comfortable and familiar zone of tribal and historical cohesiveness, where the consolation of crowds helps to justify our activities. There is nothing wrong in cleaving to operational particulars, and for those interested in detail, these provide valuable information about what we do. The cost of this maneuver is that it restricts the scope of our inquiries and causes us to lose sight of the numerous extra-disciplinary ideas and methods that have contributed to (and will be required to further) our progress through the thorny branches of science.

As we have systematically overcome our ignorance of the cosmos, we have pushed at the boundaries of natural phenomena, intermittently reaching critical points where the methods of a field have proven inadequate for further progress. New ideas, techniques, and devices imported from other fields have been required to squeeze through explanatory bottlenecks. Sometimes this fusion of fields has been

of sufficient magnitude to warrant the creation of a new discipline (genetics, ecology, etc.), and in time these absorb the insights of others. In this way, scientific disciplines possess something akin to a life cycle, with periods of rapid growth, maturation, sex, and finally senescence and even death. As the pace of life has accelerated, so has the production of disciplines and the rate of their extinction.

Scientists, as a professional order, were not recognized before 1837, when William Whewell coined the term in his *History of the Inductive Sciences*. As for science itself (excepting those who locate its true origins in the European scientific revolution of the 17th century), it is now widely accepted that scientific activities—meaning systematic forms of inductive-deductive process—have been ever present in human society. Best known of the pluralists is perhaps Joseph Needham, who in his *Science and Civilization in China* (first volume appeared in 1954, coauthored with Wang Ling) went to great lengths

INSIGHT FOTO

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to demonstrate evidence of science and technology long before the European Renaissance, extending into the early millennia BC in China. These are efforts at locating concepts; however, we seek to explore their transmutation. It is not so much when and where science and scientists first appeared that interest us, but the pace of scientific transformation. The geocentric model of the solar system proposed by Ptolemy in the *Alamagest* in the 2nd century remained unchanged right up until the 16th century when Copernicus proposed the more parsimonious heliocentric alternative. From Copernicus to Newton was just over a century, and from Newton to relativity, quantum mechanics, string theory, and dark matter, another couple of centuries.

The idea that all animals are preformed in the embryo (like nested Matryoshka dolls) was the dominant theory of inheritance for most of our scientific history. Then, in 1865, the monk Gregor Mendel, while breeding peas, initiated the study of genetics. Genetics itself did not exist as a discipline outside of botany until William Bateson in 1894 coined the term in his *Materials for the Study of Variation*. At this point, the study of inheritance became a subject in its own right. In less than a century we have discovered DNA, regulatory RNA, prions, and the epigenome. Most of these are not studied in genetics departments (many of which were closed or renamed over the course of only a couple of recent decades, giving them a half-life of under a century), but rather in molecular biology, bioinformatics, and systems biology departments.

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ideas are appearing more quickly than we can possibly reorganize careers and departments to respond to them. The solution has been a messy mixed strategy, with new disciplines and journals popping up every year or month, and new ideas shoehorned into awkward groupings within existing departments to cope with the doctrinal flux. I am reminded of Oscar Wilde when he wrote: "Fashion is a form of ugliness so intolerable that we have to alter it every six months."

We have reached a stage where the pace of discovery and the nature of shared knowledge bring the whole venerable exercise of disciplinary fads into question. I believe we are entering a period of transcience, where it is becoming necessary that training in areas with fundamental mathematical, computational, and logical principles should be emancipated from a single class of historically contingent case studies. For example, statistical physics will continue to be every bit as useful in understanding social phenomena as it traditionally has been in studying properties of condensed matter. The same could be said for suitable modification of computational theory and evolutionary dynamics. One of the significant contributions of SFI in this new landscape has been to show how ideas have a far greater compass than their original purpose suggests. Profound ideas are often characterized by considerable generality. Departments are becoming battlements that defend vested interests rather than idea incubators that advance understanding. Transcience is an expression that seeks to recognize the pursuit of plenary or synthetic knowledge as an institutional priority.

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There are those who would argue that without the rigors of traditional disciplinary instruction, we shall be producing researchers capable of little more than shallow metaphor construction. By their reckoning, the correct approach to complex phenomena is to first apprentice ourselves to tried-and-true research projects. This is the familiar "when I was a lad I got up at 4 a.m. and walked 15 miles to work" line of reasoning. The alternative is not to neglect the details of a system, but to recognize that many of our most pressing problems and most interesting challenges reside at the boundaries of existing disciplines, and require the development of an entirely new kind of sensibility that remains "disciplined" by careful empirical experiment, observation, and analysis. We are not losing depth, but are recognizing the full potential of theoretical frameworks of significant universality, and that these should not be limited to communities based on their historical development. Ours is a landscape that can support diversity, and those with disciplinary separation anxiety are free to persist as they are.

The sciences of complexity are our best working examples of transcientific research, but remain restricted in part through the association of complexity with a small class of models. In this issue of the *Bulletin*, we observe the continued maturation of the field of complexity as we accrue more data, hone our intuitions, and extend the scope of our theories. From the study of cities, through conflict, technological innovation, and cognition, we find a multitude of shared patterns amenable to overlapping forms of analysis. This issue is not organized into sociology, biology, engineering, and neuroscience—none of which would provide an adequate classification for the work being described. Readers of the *Bulletin* are fully aware that each of these areas of inquiry will obdurately resist shoehorning into a disciplinary framework, and there is absolutely no good reason to try. Perhaps it is time for our schools, universities, and research institutes to embrace the full implications of this shift in thought, and to redesign curricula and perhaps even demolish a few departments accordingly. We are entering a phase of increasingly transcientific research, and it is time society and academia wake up to the full implications of this reality. ◀