Specialized Science

While specialization in science brings many advantages, it can have serious drawbacks as well

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Every man gets a narrower and narrower field of knowledge in which he must be an expert in order to compete with other people. The specialist knows more and more about less and less and finally knows everything about nothing.

—attributed to Konrad Lorenz

The weight of scientific knowledge pressures those working in specific disciplines to specialize further, following a pattern that resembles the guild system of the Middle Ages. Despite advantages such as efficiency, standard setting, and the potential for greater rigor, however, specialization carries risks of monopoly, monotony, and isolation. Science requires specialized knowledge bases that, inevitably, become too much for any individual scientist to master. Emphasizing microbiology, a field vulnerable to balkanization, we consider specialization and offer measures to mitigate its detrimental effects.

Specialization permits the development of expertise with obvious economic benefits. For example, according to Adam Smith’s treatise *An Inquiry into the Nature and Causes of the Wealth of Nations* (1776), workers who develop specialized skills increase their efficiency and productivity. However, overspecialization encourages conservatism and stifles innovation. Moreover, the benefits of specialization are tempered when specialized groups become isolated, resist innovation, and engage in destructive competitiveness.

Each discipline in the sciences generates voluminous information. In microbiology, for example, ASM publishes 11 journals, each devoted to subspecialties. Further, researchers interested in specific microbes tend to attend specialized meetings and not to interact collaboratively. Those in immunology tend to focus narrowly, even though the immune system is highly interconnected, rendering human-defined boundaries problematic.

An Economic View: Advantages and Disadvantages in Specializing

In *Wealth of Nations*, Smith famously described the 18-step process in a pin factory, for which specialists perform each separate step. This and similar concepts from economics are helpful when analyzing specialization in science. For example, advantages of specialization, much as Smith noted, include efficiency, faster production, improved quality, and partitioning knowledge into manageable units. Scientific training is similarly specialized, with graduate programs channeling students into ever narrower areas.

The infectious diseases specialty, for example, arose from a demand for doctors with expertise in antibiotics. AIDS further raised this demand, and today an estimated 7,500 board-certified doctors specialize in infectious diseases in the United States.

The disadvantages from too much specialization mirror problems resulting from the division of labor in the economic sphere. Although rotating jobs solves that problem for industry, job rotation is not applicable to science. Consequently, many scientists live and die in their chosen fields of expertise. Indeed, many identify with their fields and develop social connections accordingly.

Subspecialties become social units that define norms and help advance one’s career, including receiving favorable reviews of funding proposals as well as awards and honors. Thus, acceptance into a field carries some of the benefits of the guild system, whereby accepted scientists are considered experts and given considerably more latitude than newcomers. Conversely, newcomers struggle to break into fields, especially if they bring ideas that are contrary to accepted views. Once an individual becomes established in a field, changing fields carries a disproportionate cost that results in a de facto lack of mobility. Scien-
tists who strive to bridge two fields do so at their peril, for they run the risk of being considered “other.”

Monopoly is another disadvantage of specialization. In science, a monopoly can emerge with regard to information, access to reagents, access to facilities, or collaborative interactions. Specialization can lead to unique reagents that not all individuals will share. Monopolies can also arise in the context of working with dangerous microbes, which officials may confine to scarce containment facilities, excluding investigators whose institutions lack such facilities. Although we do not advocate the relaxation of safety rules, they may serve to create monopolies.

Part of the mania around the impact factor in the biological sciences may have roots in specialization, reflecting how scientists come to rely on surrogate markers to critically evaluate work. This adapted use contrasts sharply with the impact factor’s origin as a bibliographic tool for librarians.

A recent study of National Science Foundation-supported, multi-institutional research projects reveals an inverse relationship between numbers of institutions involved and successful project outcomes. Yet, the benefits of transdisciplinary research can be considerable. Just as economists document the critical role of generalists, scientific leadership may benefit from individuals with broad vision and an ability to synthesize observations from diverse fields.

The Microbial Archipelago

Many microbiologists begin and end their scientific lives working on the same organism and, in the aggregate with other colleagues, form intellectual islands in a microbial archipelago. These efforts within specialty fields delineated by phylogenetic boundaries can lead to preferences for single-organism conferences that promote even more specialization. Highly specialized journals that serve specific fields attract smaller readerships and tend to have lower impact factors than more-general journals. Yet paradoxically, some specialized scientists prefer to publish their work in more-general journals with higher impact factors.

Societies focused on microbiology also struggle with the microbial archipelago. The membership of ASM is organized among divisions, many of which are similarly delineated by phylogenetic boundaries, resulting in a proliferation of divisions as fields grow and become further subspecialized. ASM is reevaluating its structure altogether, aiming toward a more integrative cross-disciplinary structure that deemphasizes divisions. This reorganization was catalyzed by the realization that microbiology is a transcendent discipline, and such a divisional structure that partitions knowledge and interactions sacrifices valuable opportunities.

Two landmark scientific discoveries that transformed microbiology were the development of antibiotics and the discovery that DNA confers heredity. Both were made possible by transdisciplinary research. Current efforts linking the microbiome to many aspects of human health also very much depend on researchers from multiple fields, including microbiology, immunology, metagenomics, physiology, and bioinformatics. Despite its youth, microbiome-related research is already becoming highly specialized and further subdivided. Yet, the emerging consensus is that transdisciplinary research and team science will be critically important for the future of this effort.

Strategies To Ameliorate the Consequences of Scientific Specialization

Specialization in science is a necessity due to the enormous amount of scientific information, and specialization clearly confers significant advantages to the scientific community. However, although specialization is and will remain a fact of life, the disadvantages of extreme specialization might be mitigated. Here are several strategies to do just that.

- Broaden postgraduate training
- Offer cross-field fellowships and transdisciplinary research awards
- Provide plain-language summaries of journal articles
- Create new opportunities and other changes to promote transdisciplinary interactions

Adam Smith rightly foresaw the benefits of specialization in complex human endeavors. However, specialization carries a price, and a healthy enterprise, whether a factory, a laboratory, or a global community, requires both the expertise of specialists and the broader vision of generalists. If specialization may be advantageous for increasing our productiveness in a given field of activity, overspecialization may develop one-sidedness, stunt our growth, and render impossible the attainment of true and general philosophic conceptions, said the chemist Leo Baekeland, whose invention of Bakelite ushered in the era of plastics. Efforts to remove barriers between scientific disciplines thus are likely to yield substantial benefits.

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