The Chemical Sciences and Health: Strengthening Synergies at a Vital Interface

**ABSTRACT:** The indispensable contributions to health made by the chemical sciences have become increasingly constrained by three systemic factors. These involve fragmentations: in the way that the chemicals sciences are structured, practiced, and inter-related to aspects of health; in the combination of public and private efforts delivering medicinal products; and in the regulatory systems which oversee health-related issues across health, food, and the environment. Interlinked systemic reforms are advocated, involving (1) recontextualization of the chemistry/health interface through creating a recognized field of “the chemical sciences and health”; (2) determined and comprehensive efforts, by countries wishing to retain or strengthen their pharmaceutical development capacities, to reinforce their education, research, and innovation eco-systems; and (3) adoption of an integrated approach to the regulation of pharmaceuticals, food, and the environment.

**MEETING 21ST CENTURY HEALTH CHALLENGES REQUIRES THE CHEMICAL SCIENCES TO DO EVEN MORE**

The chemical sciences and health have long shared a productive and coevolutionary partnership. This has accelerated in the last two centuries, through creative synergy between the chemical and biological sciences, to dramatically enhance life expectancy and quality. For example, chemistry has been central to developing safe, effective medicines for communicable diseases and noncommunicable diseases (NCDs), as well as agents for diagnostics and medical imaging and materials for prosthetics and medical devices.

The contributions that the chemical sciences can make to better health are not limited to their medically related roles. They also encompass helping to meet all the UN Sustainable Development Goals (SDGs), many of which have an impact directly or indirectly on health. Beyond the specific targets embodied in the SDGs, there are a number of current and emerging global threats to health, and effective synergistic responses from the chemical and biological sciences will be central to overcoming them. These include meeting the challenges of emerging and re-emerging communicable diseases and the growing incidences of NCDs and age-related physical and mental degenerative disorders; mitigation of and adaptation to climate change; and finding new approaches to filling the needs of an expanding global population, including requirements for improved agricultural production, clean water, and sanitation and better methods of family planning for women and men.

The chemical sciences underpin health through multiple channels (Figure 1): contributing education, research, and practice in “the chemical sciences for health”; supporting pharmaceutical and other health science industries and also food, agriculture, and fisheries; and providing the basis for monitoring, protection, preservation, and cleaning of the environment. There are regulatory systems overseeing these vital areas for our overall health.

**RECOGNIZING AND OVERCOMING SYSTEMIC BARRIERS**

The oncoming health and sustainable development challenges demand that the chemical sciences continue and increase their capacity to contribute to solutions. However, despite the history of outstanding successes, in the future chemistry’s role in delivering solutions is likely to be significantly less than optimal. In particular, there are three critical fragmentations that, as indicated in Figure 1, in our view necessitate systemic responses.

1. **Compartmentation in the Science.** There are disconnections in the chemical sciences that need to be bridged, at both intra- and interdisciplinary levels. Historically, the subdivision of chemistry into analytical, inorganic, organic, and physical branches has created internal silos of organizational structuring, teaching, and funding, with limited dialogue between them. Furthermore, new subdisciplines have been emerging at the interfaces with adjacent sciences, resulting in organizational units, modules, and degrees related to areas such as medicinal/pharmaceutical chemistry, clinical chemistry, biopharmaceutical analysis, biomaterials, nutrition, medical imaging, and environmental analytical...
chemistry. While focus can be justified by the need for selectivity within an ever-expanding academic discipline, it has disadvantageous implications for teaching, research, and application which need to be overcome.3,4

A unifying framework is needed, an overall vision of the multidimensional roles and capacities of the chemical sciences in achieving better health, as represented in the system overview presented in Figure 1. A solution to create a recognized subject of “the chemical sciences and health”, based on new, integrated education programs. These will provide the intellectual underpinning for trained graduates and researchers with a solid, broad platform of knowledge and skills to engage in cross-disciplinary work applied to health. They will promote convergence of diverse knowledge streams in the chemical sciences and harness these convergences to enhance the innovative contributions of the chemical sciences.

2. Disintegration in the Pharmaceutical Industry. Since the 19th century, industry has played the central role in bringing new pharmaceuticals into clinical use, picking up initial leads from basic research conducted either in-house or in academia and taking candidate compounds forward through lead optimization, development, toxicology, formulation, and preclinical testing into clinical trials, registration, production, and distribution. However, the pharmaceutical industry in high-income countries has undergone a profound metamorphosis during the last 2–3 decades, paradoxically involving a combination of condensation and fragmentation. Mergers and acquisitions have enabled very large companies to acquire the high-earning in-patent drugs of smaller ones to sustain their profitable portfolios, while leading to a substantial reduction in the number of large players. Moreover, these have increasingly dismantled their traditional vertical integration, divesting themselves of R&D functions in favor of purchasing existing, in-patent products or highly promising candidates for late-stage development as “blockbuster” drugs. In the new, horizontal disintegrated model, it has been left to others (often “biotech” start-ups originating from university groups) to do the early stage lead discovery and development to create the promising candidates.5 Often, the start-up is “absorbed” along with its promising invention.

Simultaneously, there has been major growth of the pharmaceutical industry in India and China. While this was initially focused on low-cost generics, in both emerging economies there are increasing efforts to develop innovation and create new intellectual property.6,7

Some analysts have argued that metamorphosis in the pharmaceutical industry has had mixed results,8 while others consider that it has not been to the advantage of people’s health,9 since it led to a decline in the numbers of new drug entities coming into use annually and a narrowing of focus on blockbuster drugs while middle-sized markets, “orphan diseases” and “diseases of the poor”, were neglected. Furthermore, the shift in job opportunities in the relevant sciences that will accompany the geographic relocation of pharmaceutical R&D to South and East Asia10,11 may decrease the popularity of these sciences in Europe and North America, weakening their traditionally strong capacities and intellectual leadership in research for health.

The solution to this challenge will not be straightforward, as it is driven by the way that economic reward and innovation systems function at national and global levels. If the high-income countries with traditionally strong pharmaceutical development capacities wish to retain their industries and leadership roles in the field, they will need to bolster the critical systemic elements that are weak or declining. This must include ensuring well-designed education programs relating to the chemical sciences that create a pool of talent with skills honed in conducting interdisciplinary and trans-disciplinary research; well-funded academic centers that can create new leads to health products; innovation hubs that foster early stage drug development; and national innovation systems and innovation financing that encourage the growth of independent middle-size companies that have options beyond buy out when they create promising candidate products and high-value new licensed drugs. A focus on developing “the chemical sciences and health” can help provide the guiding light for such a movement.

3. Disconnections in the Regulatory Sector. There is no global, comprehensive approach to the regulation of drugs, food, and the environment, although they represent three overlapping systems with many shared issues and problems. The need for more integrated approaches12 has been demonstrated by many recent concerns over problems such as the widespread contamination of land and water with pharmaceuticals13 and the emergence of antimicrobial resistance to antibiotics.14

One way forward could be to bring together the regulation of drugs, food, and the environment under a comprehensive and integrated umbrella—a World Organization for the Regulation of Food, Environment and Drugs (WORFED)—taking an integrated, comprehensive global approach to the regulation of the three sectors. The chemical sciences would play central roles in enabling such an organization to carry out its functions, informing the standards set and their legally enforceable basis, and providing the tools to undertake the inspections necessary to underpin global regulations.

■ CONCLUSION

The chemical sciences have a central role to play in ensuring better health for everyone. To achieve this role optimally, it is argued that three critical fragmentations need to be addressed. First, greater integration is needed within the relevant science disciplines, with the development of a recognized field of “the chemical sciences and health”. Second, a systemic effort by countries is needed to counter the negative effects of disintegration in the industrial pharmaceutical sector, through attention to the structural and financial incentives for innovation. Third, a new approach is needed to integration in the regulatory systems governing food, agriculture, and drugs. The most effective approach will be one that simultaneously tackles all three areas.

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**Notes**

Views expressed in this editorial are those of the authors and not necessarily the views of the ACS.

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