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Key Points:
- Researchers bring multidisciplinary systems thinking and analysis to solve complex problems in creative new ways
- Solutions require the collaboration of geophysical scientists, public health professionals, and psychologists

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Convergence in the Geosciences

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Abstract The 21st century presents unprecedented challenges if society is to continue to provide abundant energy, water, and food, and high quality housing and medical care to a growing global population. Deforestation and aquifer depletion are at unsustainable rates, and use of fossil fuels is leading to unprecedented climate change. Geoscientists can confront these challenges by expanding partnerships with other disciplines. "Convergence," the integration of engineering, physical sciences, computation, and life sciences to benefit health, energy, and the environment, has been successfully developed for biomedical research. It is time for the geosciences to embrace convergence, as our future depends upon it.

Suppose on your annual visit to your doctor's office, your doctor diagnosed you with some dreadful, life-threatening disease, and then sent you home to die. You would probably be very disappointed with that doctor and perhaps with the entire medical establishment. In fact, the reason why the National Institutes of Health has enjoyed such broad, bi-partisan support for its budget is not just because the biomedical research community has advanced the diagnosis of ailments substantially (which it has), but also because it has delivered cures for those ailments, or at least the hope of a longer, more productive life.

By analogy, our planet is the patient of the geoscientists, and for the most part the diagnoses have only become increasingly dire as to the many afflictions that jeopardize the quality of life of humans on Earth. No wonder many have grown weary of bad news. Consequently, the geosciences have been under siege, singled out for special congressional oversight and targeted for budget cuts. Consider instead the very different situation if in addition to providing the diagnoses, the geoscientists also put forth practical, affordable solutions that society readily embraces. For this to happen, geoscientists should take a page out the biomedical playbook and embrace convergence.

Convergence has its roots in the early part of the 21st century in a proposal that collaboration between nanotechnology, biotechnology, information technology, and cognitive sciences would help improve human performance [*Roco and Bainbridge,* 2002]. This model was embraced and implemented in the biomedical sciences with the goal of making health care more affordable. Biomedical researchers had their basic paradigms in place to guide them for how the major systems in the body work and the tools to explore those systems. But they needed to provide more affordable solutions to a host of afflictions in the face of rising health care costs. By working with engineers, physical scientists, and computational experts biomedical researchers brought multidisciplinary systems thinking and analysis to solve complex problems in creative new ways [*Lane,* 2011]. In a similar vein, geoscientists have good models for Earth's primary systems and excellent tools for probing them. What we need are the partnerships with the life science community to find holistic solutions for a living planet that benefit from advances in biotechnology, with the engineering community to apply innovative solutions to major challenges, with economists to ensure that those solutions are affordable, and with social scientists to understand the barriers to human acceptance of new directions.

Convergent approaches to problem solving go beyond interdisciplinary research. Investigators collaborating on an interdisciplinary project generally reside in disciplinary departments; whereas, convergent research is accelerated because the collaborating researchers are housed in institutes dedicated to convergence. Their students are trained in highly complex, multidisciplinary problem solving, rather than just taking a course or two beyond their major field. Special funding devoted to convergence research avoids the double or triple jeopardy when investigators from different fields must apply to their disciplinary panels for funding in order to collaborate.

Convergent-like approaches have been introduced to the geosciences, especially in confronting natural disasters. For example, the remarkable reduction in earthquake fatalities in nations such as Japan, Chile, and the United States is the result of convergent-like research partnerships between geologists,

seismologists, earthquake engineers, architects, social scientists, and public officials. These partnerships have resulted in improved maps of earthquake risk areas, estimates of strong ground motion, engineering designs for earthquake resistant structures, and revised building codes compliant with those designs. The Southern California Earthquake Center has been devoted to this type of research through the National Science Foundation's Science and Technology Centers funding program.

Many other topics in the geosciences would benefit from convergent approaches. For example, consider the issue of environmental health. More than ten million people die annually from environmental factors, and the most common problems are air, water, soil pollution, and chemical exposure. Current approaches to addressing these issues are generally costly and disruptive. Cleaning badly contaminated soil involves excavation and incineration, at the cost of $1500 per ton or $26 million per Superfund site. In too many cases the responsible party is no longer in a position to fund the costs, so they fall to the taxpayer. Usually the best and cheapest approach is to prevent the contamination from happening in the first place, hence involving the input of industrial process engineers working with economists and environmental scientists. When that is not an option, other solutions are to limit exposure to vulnerable populations or improve the public health response for those who have been affected. These solutions require the collaboration of environmental toxicologists, microbiologists, hydrologists, public health professionals, and psychologists.

There is every reason to believe that engineers will be ready and willing to partner in addressing geoscience issues. The National Academy of Engineering has launched the Grand Challenges in Engineering program (http://www.engineeringchallenges.org), a commitment to prepare 20,000 new engineers with societal aspirations. Several of the current themes are relevant to the solutions that geoscientists seek: access to clean water, manage the nitrogen cycle, develop carbon sequestration methods, and make solar energy affordable. The program has expanded internationally through partnerships with the Chinese Academy of Sciences and the British Royal Society.

There have been some notable institutions already established on convergent themes. For example, the Earth Institute at Columbia University blends research in the physical and social sciences with education to find practical solutions for a more sustainable world. The institute includes experts in geoscience, law, public health, public policy, and business. The Broad Institute, founded jointly by MIT and Harvard to advance treatment of human disease, has put a higher premium on technology and collaboration with engineers. Geoscientists need to be open to partnerships with both social scientists and engineers. Convergent science is more likely to thrive if dedicated funding streams prevent collaborators from having to submit separate grant proposals, if university administrators develop policies that encourage convergent research, if promotion and tenure policies recognize these contributions, and if students are educated in complex, system-level problem solving.

If more geoscientists started working in this matter, what outcomes might ensue? At the very least, new partnerships will arise between dissimilar disciplines, and new career paths will emerge for students. We might find new industries clustered around convergence institutes in the geosciences. My hope is that geosciences will be increasingly perceived as contributing to competitiveness, resiliency, health, and quality of life, and thus widely viewed as part of the solution, not part of the problem.

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