Hirsch Hadorn, Gertrude, Holger Hoffmann-Riem, Susette Biber-Klemm, Walter Grossenbacher-Mansuy, Dominique Joye, Christian Pohl, Urs Wiesmann, and Elisabeth Zemp, eds. 2008. *Handbook of Transdisciplinary Research*. Dordrecht, Netherlands: Springer.

Jantsch, Eric. 1972. "Towards Interdisciplinarity and Transdisciplinarity in Education and Innovation." In *Interdisciplinarity: Problems of Teaching and Research in Universities*, edited by Léo Apostel, Guy Berger, Asa Briggs, and Guy Michaud, 97–121. Paris: Organisation for Economic Co-operation and Development.

Klein, Julie Thompson. 2008. "Education." In *Handbook of Transdisciplinary Research*, edited by Gertrude Hirsch Hadorn, Holger Hoffmann-Riem, Susette Biber-Klemm, Walter Grossenbacher-Mansuy, Dominique Joye, Christian Pohl, Urs Wiesmann, and Elisabeth Zemp, 399–410. Dordrecht, Netherlands: Springer.

Kockelmans, Joseph J. 1992. "Toward a Hermeneutic Theory of the History of the Natural Sciences." In *Phenomenology of Natural Science*, edited by Lee Hardy and Lester Embree, 237–264. Dordrecht, Netherlands: Kluwer.

MetaIntegral Foundation. 2013. "What Is Integral Research?" Accessed August 4. https://foundation.metaintegral.org/centers/29/about.

Network for Transdisciplinary Research (TD-NET). http://www.transdisciplinarity.ch/e/Transdisciplinarity/problsolv.php

Nicolescu, Basarab. 2002. *Manifesto of Transdisciplinarity*. Translated by Karen-Claire Voss. New York: State University of New York Press.

Nicolescu, Basarab. 2003. "Definition of Transdisciplinarity." http://www.caosmose.net/candido/unisinos/textos/textos/nicolescu1.pdf

Piaget, Jean. 1972. "L'épistémologie des relations interdisciplinaires" [The epistemology of interdisciplinary relations]. In *Interdisciplinarity: Problems of Teaching and Research in Universities*, edited by Léo Apostel, Guy Berger, Asa Briggs, and Guy Michaud, 127–139. Paris: Organisation for Economic Co-operation and Development.

Stone, David A. 2013. "The Experience of the *Tacit* in Multi- and Interdisciplinary Collaboration." *Phenomenology and the Cognitive Sciences* 12 (2): 289–308. doi:10.1007/s11097-011-9248-5.

Stone, David A. 2014. "Beyond Common Ground: A Transdisciplinary Approach to Interdisciplinary Communication and Collaboration." In *Enhancing Communication and Collaboration in Interdisciplinary Research*, edited by Michael O'Rourke, Stephen Crowley, Sanford D. Eigenbrode, and J. D. Wulfhorst, 82–102. Thousand Oaks, CA: Sage Publications.

David A. Stone

TRANSFORMATIVE RESEARCH

Since the first years of the twenty-first century, an increasing number of governmental science funding agencies around the world have expressed interest in promoting transformative research (TR). Public funding agencies are thus experimenting with different ways to make TR happen. The concept of TR nevertheless remains somewhat elusive and subject to debate among scientists, policymakers, and the general public. The following three questions are prominent in this discussion: What precisely is TR? How is it best promoted? Does it actually deserve support? There is as yet no general agreement on answers to any of these questions.

DEFINING TRANSFORMATIVE RESEARCH

The National Science Foundation (NSF) provides what is often taken as a locus classicus definition: "Transformative research involves ideas, discoveries, or tools that radically change our understanding of an important existing scientific or engineering concept or educational practice or leads to the creation of a new paradigm or field of science, engineering, or education. Such research challenges current understanding or provides pathways to new frontiers" (NSF 2014). This notion of TR as involving radical change and the creation of new paradigms clearly references ideas of the American historian and philosopher of science Thomas S. Kuhn (1996). Yet Kuhn's views of scientific change have been subject to many criticisms. This raises the question whether a Kuhnian interpretation of TR is the best one to take (Frodeman and Holbrook 2012).

Karl R. Popper, for instance, disagreed vehemently with Kuhn's description of "normal science" as simple puzzle solving within a paradigm. For Kuhn, only when scientists are unable to continue to solve puzzles does important scientific progress take place by means of revolutions that establish new paradigms. According to Popper (1970), Kuhn's views regarding the limited value of normal science are actually dangerous to science and to scientific progress. For Popper, science progresses through a critical process of theory conjecture and refutation that operates in all science. For Popper TR is not nearly as rare as Kuhn would imply.

More generally, one can ask precisely what TR is supposed to transform: science or society? The readily classified scientific transformation that took place in geology with the development of plate tectonics has had no societal impact. By contrast the nontransformative science that produced the smartphone has nevertheless been quite socially transformative. In developing countries such as Brazil, Russia, India, and China, transformative research can have quite different connotations than in the advanced countries of Europe or North America.

HOW SHOULD SOCIETY SUPPORT TRANSFORMATIVE RESEARCH?

Although American funding agencies are under pressure to produce more TR, how to do so successfully is far from

obvious. There have been a number of agency-sponsored studies and task force reviews of the concept, and many agencies are experimenting with different approaches to funding TR. The Defense Advanced Research Projects Agency promotes TR via a solicitation that speaks of "transformative apps." The National Institutes of Health (NIH) developed the Transformative Research Projects program, which is now called the Common Fund's NIH Director's Transformative Research Award initiative. In fact, twenty science and technology funding programs in the United States alone, and more around the world, aim to promote TR.

After attempting an environmental scan of US federal agency support for TR, the President's Council of Advisors on Science and Technology (PCAST) concluded that current efforts represented merely a few drops in the bucket: "While this plethora of initiatives, each worthy in its own way, gives an illusion of significant progress [in funding revolutionary research], in truth the sum of all of these programs is tiny, almost invisible, in comparison to each agency's dominant model" of funding evolutionary research (PCAST 2012, 70). Because of this conclusion that not enough has been done to support TR, PCAST recommends the following:

> In addition to specific programs focused on supporting new and emerging areas of research, agencies have developed review criteria and other policies to target funding for ground-breaking, high-reward projects. In our estimation, however, none of these has been sufficient to the magnitude of the problem. We call for a substantially larger effort to support research proposals (1) with potential game-changing impact; (2) that fall outside traditional disciplines; and (3) that are people, rather than project, based. (71)

While science policymakers are turning up the heat on agencies with regard to funding more TR, researchers themselves—that is, those who submit proposals to such funding agencies and who review proposals for them—often treat the term *transformative* as a buzzword, something to be gamed as part of grant writing, but hardly something to be taken seriously. While 35 percent of researchers who participated in a 2007 NSF survey classified more than half of their own research proposals as transformative, only 3.3 percent reported that more than half of the proposals they had reviewed contained TR (Booz Allen Hamilton 2007). These observations raise practical problems for funding agencies under increasing pressure to promote TR:

- If agencies themselves lack full clarity about what the term *transformative* means, how can they identify TR or design policies and programs to facilitate it?

- If researchers fail to take the term *transformative* seriously or even doubt its validity, how can agencies successfully solicit "transformative" proposals from researchers and arrive at well-justified funding decisions (e.g., through peer review)?

Ultimately, these questions raise the larger issue of how to form a coherent and assessable TR policy, whether at the level of individual funding agencies or at national or even global levels (for instance, through the Global Research Council).

SHOULD SOCIETY SUPPORT TRANSFORMATIVE RESEARCH?

A focus on *how* to support TR begs the question of whether TR *should* be promoted. Although there is no consensus on a fully satisfactory definition of TR, there is little doubt that such a definition would include the idea of *change*. But who or what should change whom or what? Why think that change is necessarily and always a good thing—especially with regard to the sort of radical change implied by the idea of TR? Creation science research can make a claim to be potentially transformative but is seldom endorsed by the scientific establishment. The scientific research that produced hydraulic fracturing (fracking) research has been both transformative and criticized.

One possible way to negotiate such challenges is to suggest that the notion of TR should be limited to transformations *within* research. Limiting the notion of TR to research would entail the idea that what is changed is humanity's *understanding* of the world, not necessarily anything in the world itself. But this strategy of separating science from society flies in the face of most recent research in the history, philosophy, and sociology of science, not to mention research in science and technology studies or science policy. To suggest that TR should be limited to transformations within research is also at odds with the NSF's recent review and revisions of its merit review process, which now allow for the notion of TR to be used in connection with its broader impacts criterion, as well as its intellectual merit criterion.

If TR is inevitably connected with society, and if TR implies some sort of change, then TR also raises ethical and sociopolitical questions. Who should count as a peer in reviewing research proposals and deciding which should be funded? Should programs designed to support TR include mechanisms for societal input? Should TR research include some sort of ethical assessment component? Should TR operate under a general principle (Holbrook and Briggle 2014)? If so, should that principle be precautionary or proactionary? The question of

whether society should support TR may need to be addressed on a case-by-case basis.

SEE ALSO *Precautionary Principle; Responsible Research and Innovation; Translational Research; United States National Science Foundation, Broader Impacts Merit Review Criterion; Values in Science.*

BIBLIOGRAPHY

Booz Allen Hamilton. 2007. "2007 NSF Proposer Survey: Frequency Results to All Survey Items." National Science Foundation. http://www.nsf.gov/od/ipamm/ipamm_2007proposersurvey results/nsf_2007proposersurvey_results_070629.pdf

Frodeman, Robert, and J. Britt Holbrook. 2012. "The Promise and Perils of Transformative Research." UNT Digital Library. http://digital.library.unt.edu/ark:/67531/metadc84363/

Holbrook, J. Britt, and Adam Briggle. 2014. "Knowledge Kills Action: Why Principles Should Play a Limited Role in Policy Making." *Journal of Responsible Innovation* 1 (1). Published electronically January 28, 2014. doi:10.1080/23299460.2014.882554.

Kuhn, Thomas S. 1996. *The Structure of Scientific Revolutions.* 3rd ed. Chicago: University of Chicago Press. First edition published 1962.

National Science Foundation (NSF). 2014. "Definition of Transformative Research." Accessed February 24. https://www.nsf.gov/about/transformative_research/definition.jsp

Popper, Karl R. 1970. "Normal Science and Its Dangers." In *Criticism and the Growth of Knowledge*, edited by Imre Lakatos and Alan Musgrave, 52–53. Cambridge: Cambridge University Press.

President's Council of Advisors on Science and Technology (PCAST). 2012. *Transformation and Opportunity: The Future of the US Research Enterprise.* http://www.whitehouse.gov/sites/default/files/microsites/ostp/pcast_future_research_enterprise_20121130.pdf

J. Britt Holbrook

TRANSHUMANISM

In most general terms, *transhumanism* says that the indefinite projection of those qualities that most clearly distinguish humans from other natural beings is worth pursuing as a value in its own right—even if that means radically altering our material nature. This rather open definition of transhumanism nevertheless captures by implication all of those who might be *against* such a movement, not least those—often of a "green" persuasion—who believe that humanity's current global crises stem from our attempts to minimize if not deny our commonality with the rest of nature. In this respect, transhumanism needs to be distinguished from *posthumanism*, which aims to decenter the human as the locus of value altogether, which makes it more friendly to green concerns. Whereas posthumanism may be seen in the broad sweep of Western intellectual history as "counter-Enlightenment," transhumanism is better seen as "ultra-Enlightenment": the former sees the Enlightenment as having gone too far, the latter not far enough.

The word *transhumanism* was coined in the 1950s by Julian Huxley (1887–1975), a founder of the dominant paradigm in biology today, the neo-Darwinian synthesis, which integrates Charles Darwin's account of natural history with the experimental principles of modern lab-based genetics. Huxley, following the lead of his grandfather, Thomas Henry Huxley (1825–1895), accepted that Darwin fundamentally challenged anyone who wanted to uphold the superiority of *Homo sapiens* as a species, given that natural selection implies that all forms of life are limited by their largely innate capacities to adapt to a changing environment. In the end, any given species—including humans—should expect extinction, not immortality. From that standpoint, all the promises made by Christianity and Islam of an eternal "afterlife" looked empty. Nevertheless, the Huxleys believed that there was something fundamentally correct about these religious intuitions—something that Julian thought could be addressed by transhumanism. Whereas his grandfather held that advances in law, medicine, and engineering served to push back, if not reverse, the default tendencies of natural selection, Julian Huxley argued that *Homo sapiens* is the only species equipped to comprehend the entire evolutionary process, in which case we incur a unique moral obligation to administer and direct its future course.

In terms of religious precedents for transhumanism, two of the oldest Christian heresies—both already opposed by St. Augustine in the fifth century CE—stand out for their persistent and countervailing visions of the transhumanist utopia: *Pelagianism* and *Arianism*, each named for their originators, Pelagius (a Celtic lawyer) and Arius (a Libyan bishop). Both Pelagians and Arians believe that it is within the power of humans to achieve godhood, understood as a recovery from humanity's fall from divine grace recounted in Genesis. This shared belief is based on the heterodox Christian idea that the death of Jesus effectively cancelled Adam's sin, putting humans back on course to become embodied deities, much like the very person of Jesus.

Amidst the general anticlerical sentiment of the eighteenth-century Enlightenment, Pelagian and Arian ideas were revived in new combinations as deism and