Transdisciplinary Systems Science: Toward a Science of Connection, Integration and Synthesis

Robert Costanza

Science, Vision, and Problem Solving

Practical problem solving requires the integration of three elements: (1) active and ongoing envisioning of both how the world works and how we would like the world to be; (2) systematic analysis appropriate to and consistent with the vision; and (3) implementation appropriate to the vision. Scientists generally focus on only the second of these steps, but integrating all three is essential to both good science and effective policy. "Subjective" values enter in the "vision" element, both in terms of the formation of broad social goals and in the creation of a "pre-analytic vision" which necessarily precedes any form of scientific analysis. Because of this need for vision, completely "objective" scientific analysis is impossible. In the words of Joseph Schumpeter:

> "In practice we all start our own research from the work of our predecessors, that is, we hardly ever start from scratch. But suppose we did start from scratch, what are the steps we should have to take? Obviously, in order to be able to posit to ourselves any problems at all, we should first have to visualize a distinct set of coherent phenomena as a worthwhile object of our analytic effort. In other words, analytic effort is of necessity preceded by a preanalytic cognitive act that supplies the raw material for the analytic effort. In this book, this preanalytic cognitive act will be called Vision. It is interesting to note that vision of this kind not only must precede historically the emergence of analytic effort in any field, but also may reenter the history of every established science each time somebody teaches us to see things in a light of which the source is not to be found in the facts, methods, and results of the preexisting state of the science"[1]

Nevertheless, it is possible to separate the process into the more subjective (or normative), envisioning component, and the more system-

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[1] Schumpeter, J. *History of Economic Analysis*. London: Allen & Unwin, 1954: 41.

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atic, less subjective analysis component (which is based on the vision). "Good science" can do no better than to be clear about its underlying pre-analytic vision and to do analysis that is consistent with that vision.

A Changing Vision of Science

The task would be simpler if the vision of science were static and unchanging. But as the above quote, from Schumpeter makes clear, this vision is itself changing and evolving as we learn more. This does not invalidate science as some deconstructionists would have it. Quite the contrary, by being explicit about its underlying pre-analytic vision, science can enhance its honesty and thereby its credibility. This credibility is a result of honest exposure and discussion of the underlying process and its inherent subjective elements, and a constant pragmatic testing of the results against real world problems, rather than by appeal to a non-existent objectivity.

The pre-analytic vision of science is changing from the "logical positivist" view (which holds that science can discover ultimate "truth" by falsification of hypothesis) to a more pragmatic view that recognizes that we do not have access to any ultimate, universal truths, but only to useful abstract representations (models) of parts of the world. Science, in both the logical positivist and in this new "pragmatic modeling" vision, works by building models and testing them. But the new vision recognizes that the tests are rarely, if ever, conclusive, (especially in the life sciences and the social sciences); the models can only apply to a limited part of the real world; and the ultimate goal is therefore not "truth" but quality and utility. In the words of William Deming "All models are wrong, but some models are useful."[2]

The primary goal of science then is the creation of useful models, whose utility and quality can be tested against real world applications. The criteria by which one judges the utility and quality of models are themselves social constructs which evolve over time. There is, however, fairly broad and consistent consensus in the peer community of scientists about what these criteria are. They include: (1) testablity; (2) repeatability; (3) predictability; and (4) "elegance" (i.e. Occam's razor—the model should be as simple as possible—but no simpler!). But, because of the nature of real world problems, there are many applications for which some of these criteria are difficult or impossible to apply.

[2] McCoy, R. *The Best of Deming*. SPC Press, 1994.

These applications may nevertheless still be judged as "good science". For example, some purely theoretical models are not directly "testable"—but they may provide a fertile ground for though and debate and lead to more explicit models which are testable. Likewise, field studies of watersheds are not, strictly speaking, repeatable, because no two watersheds are identical. But there is much we can learn from field studies that can be applied to other watersheds and tested against the other criteria of predictability and elegance. How simple a model can be depends on the questions being asked. If we ask a more complex or more detailed question, the model will probably have to be more complex and detailed. As science progresses and the range of applications expands, the criteria by which utility and quality are judged must also change and adapt to the changing applications. This is an inherently subjective process that occurs within the peer community of scientists.

Beyond the preanalytic vision of how the world works, we also need to be concerned about our vision of how we would like the world to be—our shared goals. Research concerning the change process in various kinds of organizations and communities suggests that the most effective ingredient to move change in a particular direction is having a clear vision of the desired goal which is also truly shared by the members of the organization or community.[3] Or, as Yogi Berra once said: "If you don't know where you're going, you end up somewhere else." Science and scientists have traditionally not engaged in this kind of social envisioning. However, they need to become engaged if science is to live up to its true potential. But envisioning the future is certainly not the domain of scientists alone. As discussed further on, this process needs to involve everyone in society and is the essence of true democracy.

Consilience among *All* the Sciences and Humanities

"Consilience" according to Webster, is "a leaping together". Biologist E. O. Wilson's book by that title attempted a grand synthesis, or "leaping together" of our current state of knowledge by "linking facts and fact-based theory across disciplines to create a common groundwork for explanation" and a prediction of where we are headed. Wilson believes that:

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[3] Senge, P. M. *The Fifth Discipline: The Art and Practice of the Learning Organization*. New York, Currency-Doubleday, 1990; Weisbord, M. (ed). *Discovering Common Ground. San Francisco*: Berrett-Koehler 1992: Weisbord, M. and S. Janoff. *Future Search: An Action Guide to Finding Common Ground in Organizations and Communities.* San Francisco: Berrett-Koehler, 1995.

> "the Enlightenment thinkers of the seventeenth and eighteenth centuries got it mostly right the first time. The assumptions they made of a lawful material world, the intrinsic unity of knowledge, and the potential of indefinite human progress are the ones we still take most readily into our hearts, suffer without, and find maximally rewarding through intellectual advance. The greatest enterprise of the mind has always been and always will be the attempted linkage of the sciences and humanities. The ongoing fragmentation of knowledge and resulting chaos in philosophy are not reflections of the real world but artifacts of scholarship. The propositions of the original Enlightenment are increasingly favored by objective evidence, especially from the natural sciences."[4]

Wilson takes an unabashedly logical positivist and reductionist approach to science and to consilience, arguing that: "The central idea of the consilience world view is that all tangible phenomena, from the birth of stars to the workings of social institutions, are based on material processes that are ultimately reducible, however long and tortuous the sequences, to the laws of physics" (p. 266). Deconstructionists and post-modernists, in this view, are merely gadflys, who are nonetheless useful in order to keep the "real" scientists honest.

While there is broad agreement that integrating the currently fragmented sciences and humanities is a good idea, many will disagree with Wilson's neo-Enlightenment, reductionist prescription. The problem is that the type of consilience envisioned by Wilson would not be a real "leaping together" of the natural sciences, the social sciences, and the humanities. Rather, it would be a total takeover by the natural sciences and the reductionist approach in general. There are, however, several well-known problems with the strict reductionist approach to science,[5] and several of its contradictions show up in Wilson's view of consilence.

Wilson recognizes that the real issue in achieving consilience is one of scaling—how do we transfer understanding across the multitude of spatial and temporal scales from quarks to the universe and everything in between. But he seems to fall back on the overly simplistic reductionist approach to doing this—that if we understand phenomena at their most detailed scale we can simply "add up" in linear fashion from there to get the behavior at larger scales. While stating that "The greatest challenge today, not just in cell biology and ecology but in all of science, is the accurate and complete description of complex systems." (p. 85), he puts aside some of the main findings from the study of complex systems—that scaling in adaptive, living systems is neither linear

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[4] Wilson, E. O. *Consilience: The Unity of Knowledge*. New York: Knopf, 1998: 8.

[5] Williams, N. "Biologists Cut Reductionist Approach Down to Size." *Science*. 277, 1997: 476-477.

nor easy, and that "emergent properties," which are unpredictable from the smaller scale alone, are important. While acknowledging on the one hand that analysis and synthesis, reductionism and wholism, are as inseparable as breathing out and breathing in, Wilson glosses over the difficulty of actually doing the synthesis in complex adaptive systems and the necessity of studying and understanding phenomena at multiple scales simultaneously, rather than reducing them to the laws of physics.

The consilience we are really searching for, I believe, is a more balanced and pluralistic kind of "leaping together", one in which the natural and social sciences and the humanities all contribute equitably. A science which is truly transdisciplinary and multiscale, rather than either reductionistic or wholistic, is, in fact, evolving, but I think it will be much more sophisticated and multifaceted in its view of the complex world in which we live, the nature of "truth" and the potential for human "progress" than the Enlightenment thinkers of the seventeenth and eighteenth centuries could ever have imagined. It will also serve to break down the barriers between science, democracy, and religion, by more clearly outlining the roles and limitations of each.

Reestablishing the Balance between Synthesis and Analysis

Science, as an activity, requires a balance between two quite dissimilar activities. One is analysis—the ability to break down a problem into its component parts and understand how they function. The second is synthesis—the ability to put the pieces back together in a creative way in order to solve problems. In most of our current university research and science education, these capabilities are not developed in a balanced, integrated way. For example, both natural and social science research and education focuses almost exclusively on analysis, while the arts and engineering focus on synthesis. But, as mentioned above, analysis and synthesis, reductionism and wholism, are as inseparable as breathing out and breathing in. It is no wonder that our current approach to science is so dysfunctional. We have been holding our breath for a long time!

To reestablish the appropriate balance between analysis and synthesis, we need to transcend disciplinary boundaries. We need to develop a new, more integrative, transdisciplinary approach to science. What follows describes some history and some recent progress along that path.

Science, Ecology, and Economics

Ecology, and especially systems ecology, can be though of as the natural science most concerned with balancing analysis and synthesis. To

study whole systems, one needs to be concerned equally with both sides of the science coin. Likewise, economics should be concerned with understanding and managing complex systems. It is instructive to briefly trace the development of these fields before describing the transdisciplinary synthesis that is now happening.

Ernst Heinrich Haeckel (1834-1919) was the first to use the word "*oecologie"* in 1866. In 1870 he produced the first full-fledged definition of ecology:

> "By ecology we mean the body of knowledge concerning the economy of nature—the investigation of the total relations of the animal both to its inorganic and to its organic environment including above all, its friendly and inimical relations with those animals and plants with which it comes directly or indirectly into contact—in a word, ecology is the study of all those complex interrelations referred to by Darwin as the conditions of the struggle for existence".[6]

Thus even in this initial definition of the field, a deep conceptual relationship with economics is evident. Ecology was, in Haeckel's words, the study of the economy of nature. Economics, conversely, can be thought of as the ecology of humans, with a particular emphasis on how we manage our affairs. But historically the science of ecology evolved out of biology and ethology (the science of animal behavior) and thus had very different intellectual roots from economics. In practical terms, ecology became the study of the economy of that part of nature that does not include humans.

Since Haeckel's early definition, many other definitions of ecology emerged based on changing areas of interest and emphasis (McIntosh 1985). When there was a focus on animal populations, ecology was "the study of the distribution and abundance of animals."[7] Later, when ecosystems became a major focus, ecology was: "the study of the structure and function of ecosystems."[8] But what has remained at the core is the relationship of organisms to their environment. As one of the dominant species of animals on the planet, *homo sapiens,* and its relationship to its environment, is obviously well within the scope of ecology by any of its various definitions.

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[6] Allee, W. C., A. E. Emerson, O. Park, T. Park, and K. P. Schmidt. *Principles of Animal Ecology.* Philadelphia: Saunders, 1949.

[7] Andrewartha, H. G. and L. C. Birch. The Distribution and Abundance of Animals. Chicago: University of Chicago Press, 1954.

[8] Odum, E. P. *Fundamentals of Ecology*. 3rd edition. Philadelphia: Saunders, 1971.

From the very beginnings of ecology as a science, there have been continuing attempts to incorporate humans and the social sciences. The work of H. T. Odum,[9] Meadows et al.,[10] Holling,[11] Walters[12] and many others are certainly in this tradition. While these attempts have been very influential (and often controversial) the majority of ecologists continue to ignore humans in their day to day research (although this is now rapidly changing). One might ask why ecologists were not persistent or effective enough in their attempts to extend ecological thinking to *homo sapiens*?

Likewise in economics and the other social sciences there is a history of attempts to bring the natural world back into the picture,[13] but the dominant tendency has been to consider humans to be somehow outside the laws and constraints that applied to other animals and to study humans in relative isolation from the rest of nature.

This fragmentation of science into separate, isolated disciplines is a late 19th and early 20th century phenomenon. Before that time there was significant interaction among all aspects of science and one could say that science was practiced in a "transdisciplinary" way.[14] But by the end of the 19th century the trend to increasing specialization and professionalization in science, including economics and the other social sciences, was well under way.[15]

What has come to be called the "reductionist" paradigm was beginning to hold sway. This paradigm assumes that the world is separable into relatively isolated units which can be studied and understood on their own, and then reassembled to give a picture of the whole. As the

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[9] Odum, H. T. *Environment, Power, and Society.* New York: Wiley, 1971.

[10] Meadows, D. H., D. L. Meadows, J. Randers, and W. W. Behrens. *The Limits to Growth.* New York: Universe, 1972.

[11] Holling, C. S. (ed). *Adaptive Environmental Assessment and Management*. London: Wiley, 1978.

[12] Walters, C. J. *Adaptive Management of Renewable Resources*. New York: McGraw Hill, 1986.

[13] See Hardesty, D. L. *Ecological Anthropology*. New York: John Wiley, 1977; Harris, M.1979. Cultural Materialism: The Struggle for a Science of Culture. New York: Random House, 1979; Dunlap, R. E. "Paradigmatic Change in Social Science: From Human Exemptionalism to an Ecological Paradigm. *American Behavioral Science,* 24 (1980):5-14; Boulding, K. E. *Evolutionary Economics*. Beverly Hills, CA: Sage, 1981.

[14] Costanza, R., J. C. Cumberland, H. E. Daly, R. Goodland, and R. Norgaard. *An Introduction to Ecological Economics.* Boca Raton, FL: St. Lucie Press, 1997.

[15] Coats, A. W. *The Sociology and Professionalization of Economics.* New York: Routledge, 1993.

complexity of science increased, this was a very useful idea, since it allowed dividing up the problem into smaller, more manageable pieces which could be attacked intensively. Chemists could now study chemistry without being distracted by other aspects of the systems they were studying. Also, the rapid increase in the sheer number of scientists that were actively working made it necessary to organize the work in some way, and the disciplinary structure seemed a logical and useful way to do this. But once university departments were set up in the various disciplines, internal reinforcement systems came to reward only work *within the discipline*. This rapidly led to a reduction in communication across disciplines and a tendency for the disciplines to develop their own unique languages, cultures, and ways of looking at the world. Disciplinary speciation through isolation had begun to occur.

In economics, this led to a growing isolation from the natural resource (or land) component of the classical triad of land, labor, and capital, and with it a growing isolation from the natural sciences. Economics departments began to reward theory more highly than applications and the discipline as a whole attempted to pattern itself on physics, which was arguably the most successful example of the advantages of the disciplinary model of organization.

This trend continued through the early and mid 20th century and, by the time of the renewed environmental awareness of the 1970's, economics had become highly specialized and abstracted away from its earlier connections with the natural environment. Textbooks at the time barely mentioned the environment and concentrated instead on the microeconomics of supply, demand, and price formation and the macroeconomics of growth in manufactured capital and GNP.

At the same time, economics was becoming absorbed with professionalization. As A. W. Coats noted:

> "At least since the marginal revolution of the 1870's, mainstream economists have sought to enhance their intellectual authority and autonomy by excluding certain questions which were either sensitive (such as the distribution of income and wealth, and the role of economic power in society) or incapable of being handled by their preferred methods and techniques, or both. These are precisely the questions which are emphasized by their professional and lay critics and, more recently, by many economists who cannot be dismissed by their professional colleagues as either ignorant or incompetent".

The story in ecology was somewhat different. As we have previously noted, ecology is a much younger science, and it has always been more explicitly pluralistic and interdisciplinary. But its roots were in biology

and the trend in biology was much the same as in other areas of science. The initial split into botany and zoology was followed by further specialization into biochemistry, biophysics, molecular biology, etc. In ecology itself there was something of a split between the population ecologists (e.g. Robert MacArthur) who concentrated on individual populations of organisms, and systems ecologists (e.g. E. P. and H. T. Odum) who focused on whole ecosystems. But this split never got to the point of separation into distinct departments and disciplines, although many academic programs took on a decided flavor in one direction or the other.

Through all of this, ecologists, more so than any other discipline, have maintained communication across most of the natural sciences. To study ecosystems, one has to integrate hydrology, soil science, geology, climatology, chemistry, botany, zoology, genetics, and many other disciplines. The dividing line for many ecologists has been at a particular species: *homo sapiens.* Even though Haeckel's original definition at least implicitly included humans, and many ecologists over the years have argued and worked to operationalize this integration, for the vast majority of active ecologists, the study of humans is outside their discipline, and thus is left to the social sciences. Indeed, most ecologists have looked for field sites as remote from human activities as possible to conduct their research.

As McIntosh (p. 319) points out:

> "If human factors are beyond ecological consideration, what, then is human ecology? It is not clear whether ecology will expand to encompass the social sciences and develop as a metascience of ecology. The alternative is a more effective interdisciplinary relationship between ecology and the several social sciences."[16]

Systems ecology, conservation biology, ecological economics, ecological engineering, industrial ecology and several other new "transdisciplinary" fields can be seen as attempts to build this more effective interdisciplinary relationship as a bridge to a truly comprehensive science of humans as a component of nature that will fulfill the early goals of science. They are attempts to help rectify the tendency to ignore humans in the natural sciences, while at the same time rectifying the parallel tendency to ignore the natural world in the social sciences.

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[16] McIntosh, Robert P. *The Background of Ecology: Concept and Theory.* Cambridge England: Cambridge University Press, 1985.

What would this transdisciplinary synthesis look like? What follows is a brief overview of the economy from a transdisciplinary perspective.

What is the Real Economy and What is it For?: A Transdisciplinary View

The "economy" we usually hear about refers only to the market economy—the value of those goods and services that are exchanged for money. Its purpose is usually taken to be to maximize the value of these goods and services—with the assumption that the more activity, the better off we are. Thus, the more GDP (which measures aggregate activity in the market economy), the better. Likewise, the more contributors to GDP (such as retail sales and salaries paid to employees), the better. Predictors of more GDP in the future (such as housing starts and consumer confidence) are also important pieces of information from this perspective. Declining or even stable GDP is seen as a disaster. Growth in GDP is assumed to be government's primary policy goal and also something that is sustainable indefinitely.

But is this what the economy is all about? Or more accurately, is this *all* that the economy is about? Or, is this what the economy *should be* about? The answer to all of these questions is an emphatic no. Here's why . . .

Let's start with purpose. The purpose of the economy *should be* to provide for the sustainable well-being of people. That goal encompasses material well-being, certainly—but also anything else that affects well being and its sustainability. This seems obvious and non-controversial. The problem comes in determining what things actually affect well-being and in what ways.

There is substantial new research on this "science of happiness" that shows the limits of conventional economic income and consumption in contributing to well-being. Psychologist Tim Kasser[17] points out, for instance, that people who focus on material consumption as a path to happiness are actually less happy and even suffer higher rates of both physical and mental illnesses than those who do not. Material consumption beyond real need is a form of psychological "junk food" that only satisfies for the moment and ultimately leads to depression, Kasser says.

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[17] Kasser, T. *The High Price of Materialism*. Cambridge, MA: MIT Press, 2003.

Economist Richard Easterlin, a noted researcher on the determinants of happiness, has shown that well-being tends to correlate well with health, level of education, and marital status, and not very well with income. He concludes that:

> "People make decisions assuming that more income, comfort, and positional goods will make them happier, failing to recognize that hedonic adaptation and social comparison will come into play, raise their aspirations to about the same extent as their actual gains, and leave them feeling no happier than before. As a result, most individuals spend a disproportionate amount of their lives working to make money, and sacrifice family life and health, domains in which aspirations remain fairly constant as actual circumstances change, and where the attainment of one's goals has a more lasting impact on happiness. Hence, a reallocation of time in favor of family life and health would, on average, increase individual happiness."[18]

Layard[19] echoes many of these ideas and concludes that current economic policies are not improving happiness and that "happiness should become the goal of policy, and the progress of national happiness should be measured and analyzed as closely as the growth of GNP." Frank (2000) also concludes that the nation would be better off—overall national well-being would be higher, that is—if we actually consumed less and spent more time with family and friends, working for our communities, maintaining our physical and mental health, and enjoying nature.

On this last point, there is substantial and growing evidence that intact natural systems contribute heavily to human well-being. Costanza[20] estimated the annual, non-market value of the earth's ecosystem services at $33 trillion globally, substantially larger than global GDP. The just released UN Millennium Ecosystem Assessment is a global update and compendium of ecosystem services and their contributions to human well-being. A recent analysis across countries has quantified the relative contributions of built, human and natural capital to subjective well-being.[21] These analyses clearly show that the

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[18] Easterlin, R. A., Explaining Happiness. *Proc. Natl. Acad. Sci.*, 100 (19) 2003: 11176-11183.

[19] Layard, R. Happiness: Lessons from a New Science. New York: Penguin, 2005.

[20] Costanza, R., R. d'Arge, R. de Groot, S. Farber, M. Grasso, B. Hannon, S. Naeem, K. Limburg, J. Paruelo, R.V. O'Neill, R. Raskin, P. Sutton, and M. van den Belt.. "The Value of the World's Ecosystem Services and Natural Capital. *Nature* 387 (1997): 253-260.

[21] Vemuri, A. W. and R. Costanza. "The Role of Human, Social, Built, and Natural Capital in Explaining Life Satisfaction at the Country Level: Toward a National Well-Being Index (NWI)." *Ecological Economics* (in press).

environment is not a luxury good, as conventional economics would have it. Just the opposite is the case. The environment (natural capital) provides the *majority* of valuable goods and services that support human well-being.

So, if we want to assess the "real" economy—all the things which contribute to real, sustainable, human welfare—as opposed to only the "market" economy, we have to measure the non-marketed contributions to human well-being from nature, from family, friends and other social relationships at many scales, and from health and education. One convenient way to summarize these contributions is to group them into four basic types of capital that are necessary to support the real, human-welfare-producing economy: built capital, human capital, social capital, and natural capital.

The market economy covers mainly built capital (factories, offices, and other built infrastructure and their products) and part of human capital (spending on labor), with some limited spillover into the other two. Human capital includes the health, knowledge, spiritual development, and all the other attributes of individual humans that allow them to function and be happy in a complex society. Social capital includes all the formal and informal networks among people: family, friends, and neighbors, as well as social institutions at all levels, like churches, religious groups, social clubs, local, state, and national governments, NGO's, and international organizations. Natural capital includes the world's ecosystems and all the services they provide. Ecosystem services occur at many scales, from climate regulation at the global scale, to flood protection, soil formation, nutrient cycling, recreation, and aesthetic services at the local and regional scales.

So, how has the real economy been doing recently, compared to the market economy? The short answer is, not so good. How do we know? One way is through surveys of people's life satisfaction, which have been decreasing slightly since about 1975. A second approach is an aggregate measure of the real economy that has been developed as an alternative to GDP, called the Genuine Progress Indicator, or GPI.

Let's first take a quick look at the problems with GDP as a measure of true human well-being. GDP is not only limited—measuring only marketed economic activity or gross income—it also counts all of this activity as positive. It does not separate desirable, well-being-enhancing activity from undesirable well-being-reducing activity. For example, an oil spill increases GDP because someone has to clean it up, but it obviously detracts from society's well-being. From the perspective

of GDP, more crime, sickness, war, pollution, fires, storms, and pestilence are all potentially good things, because they can increase marketed activity in the economy.

GDP also leaves out many things that *do* enhance well-being but are outside the market. For example, the unpaid work of parents caring for their own children at home doesn't show up, but if these same parents decide to work outside the home to pay for child care, GDP suddenly increases. The non-marketed work of natural capital in providing clean air and water, food, natural resources, and other ecosystem services doesn't adequately show up in GDP either, but if those services are damaged and we have to pay to fix or replace them, then GDP suddenly increases. Finally, GDP takes no account of the distribution of income among individuals. But it is well-known that an additional $1 worth of income produces more well-being if one is poor rather than rich. It is also clear that a highly skewed income distribution has negative effects on a society's social capital.

The GPI addresses these problems by separating the positive from the negative components of marketed economic activity, adding in estimates of the value of non-marketed goods and services provided by natural, human, and social capital, and adjusting for income-distribution effects. While it is by no means a perfect representation of the real well-being of the nation, GPI is a much better approximation than GDP. As Amarta Sen and others have noted, it is much better to be approximately right in these measures than precisely wrong.

Comparing GDP and GPI for the US shows that, while GDP has steadily increased since 1950, with the occasional dip or recession, GPI peaked in about 1975 and has been gradually decreasing ever since. From the perspective of the real economy, as opposed to just the market economy, the U.S. has been in recession since 1975. As already mentioned, this picture is also consistent with survey-based research on people's stated life-satisfaction. We are now in a period of what Herman Daly has called "un-economic growth," where further growth in marketed economic activity (GDP) is actually reducing well-being on balance rather than enhancing it. In terms of the four capitals, while built capital has grown, human, social and natural capital have declined or remained constant and more than canceled out the gains in built capital.

In the last four years, the decline in domestic GPI has picked up speed. While U.S. GPI was beginning to trend upward again at the end of the Clinton years, the policies of the Bush administration have lead

to a significant worsening of income distribution (thereby further decreasing social capital), an increasing depletion of natural capital, and worsening human capital through decreased spending on education and health and loss of jobs. And the Bush team has certainly not compensated for these negatives with a stellar performance in the built capital component (GDP). While the dollar incomes of some wealthy individuals may have improved over this period, the overall well-being of the nation has significantly declined. Further, the psychological evidence is that even the well-being (as opposed to income) of the wealthy individuals has probably not improved very much and may even have declined. From the perspective of the real economy, the country is in rapidly worsening shape.

Is the news all bad? No. We recently estimated the GPI of the State of Vermont and of Burlington, the state's largest city, and found that Vermont's and Burlington's GPI per capita had increased over the entire 1950-2000 period and is now more than double the national average.[22] This was due to Vermont's attention to protecting and enhancing natural, human, and social capital in balance with gains in built capital—accomplished through the application of strong, local democratic principles and processes still actively at work in Vermont.

The lesson from Vermont, and from similar analyses done at the regional level in other locales, is that there is significant variation across the country in trends in well-being and quality of life, and plenty of good examples we can learn from to improve the overall well-being of the country.

How can we apply these lessons to get out of the real recession in human well-being at the national scale that we have been in since 1975? Several policies have been suggested that would help to turn things around:

- Shifting our primary national policy goal from increasing marketed economic activity (GDP) to maximizing national well-being (GPI or something similar). This would allow us to see the interconnections

[22] Costanza, R. J. Erickson, K. Fligger, A. Adams, C. Adams, B. Altschuler, S. Balter, B. Fisher, J. Hike, J. Kelly, T. Kerr, M. McCauley, K. Montone, M. Rauch, K. Schmiedeskamp, D. Saxton, L. Sparacino, W. Tusinski, and L. Williams. "Estimates of the Genuine Progress Indicator (GPI) for Vermont, Chittenden County, and Burlington, from 1950 to 2000." *Ecological Economics* 51 (2004): 139-155.

between built, human, social, and natural capital and build well-being in a balanced and sustainable way.

- Reforming the tax system to send the right incentives by taxing negatives (pollution, depletion of natural capital, over consumption) rather than positives (labor, savings, investment). Recent tax reforms have decreased well-being by promoting a greater income gap, natural resource depletion, and increased pollution.

- Reforming international trade to promote well-being over mere GDP growth. This implies protecting natural capital, labor rights, and democratic self-determination first and *then* allowing trade, rather than promoting the current trade rules that ride roughshod over all other societal values and ignore all non-market contributions to well-being.

- Further reforming campaign finance laws so that the needs and welfare of individuals are more fully and accurately expressed in the national democratic process, rather than the needs and welfare of those who currently fund political campaigns. As Prugh et al.[23] have argued, implementing strong democracy (as opposed to the weak and ineffective sham of democracy we currently see at the national scale) is an essential prerequisite to building a sustainable and desirable future.

Ultimately, getting out of the 25-year recession in well-being we are currently in will require us to look beyond the limited definition of the "economy" we read about in the newspapers, and recognize what the real economy is and what it is for. We must not allow deceptive accounting practices—analogous to those that caused the Enron and WorldCom debacles—to paint an inaccurate and ultimately destructive picture of how "well" we are doing. Alternatives are available, but they need significant further discussion and research.

With nothing less than our current and future well-being at stake, we can certainly afford to devote greater effort to learning how to adequately understand and measure it. If we want the things that really matter to our well-being to count, we must learn how to recognize and count them, and use that information to inform policy in a real democracy.

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[23] Prugh, T., R. Costanza, and H. Daly. *The Local Politics of Global Sustainability*. Washington, DC: Island Press, 2000.

Table 1. A Short Taxonomy of Social Traps (from Cross and Gyer 1980).

Cause of Trap	Examples
Time Delay	Discounting, smoking, drug addiction in general.
Ignorance	Slot machines, gambler's fallacy
Sliding Reinforcer	Pesticide overuse
Externality	Pollution, prisoner's dilemma
Collective	Tragedy of the (open access) commons
Hybrid	

Social Capital, Social Traps, Ethics, and Religion

The previous discussion has identified natural and social capital as key contributors to human well-being. Social capital allows societies to function. One of the ways it does this is by eliminating, or at least controlling what have been called "free rider problems," "social dilemmas," or "social traps." A social trap is any situation in which the short-run, local reinforcements guiding individual behavior are inconsistent with the long-run, global best interest of the individual and society.[24] We go through life making decisions about which path to take based largely on "road signs," the short-run, local reinforcements that we perceive most directly. These short-run reinforcements can include monetary incentives, social acceptance or admonishment, and physical pleasure or pain. In general, this strategy of following the road signs is quite effective in getting us where we want to go. Problems arise, however, when the road signs are inaccurate or misleading. In these cases we can be trapped into following a path that is ultimately detrimental. For example, cigarette smoking is a social trap because by following the short-run road signs of the pleasure and social status associated with smoking, we embark on the road to an increased risk of earlier death from smoking-induced cancer. More important, once this road has been taken it is very difficult to change to another (as most people who have tried to quite smoking can attest).

Social traps can result from several causes. Table 1 is a taxonomy of these causes,[25] along with some representative traps associated with each. Cigarette smoking, for example, is mainly a time-delay trap re-

[24] Cross, J. G., and M. J. Guyer. *Social Traps*. Ann Arbor: University of Michigan Press, 1980; Platt, J. "Social Traps. *American Psychologist*. 28 (1973): 642-651; Teger, A. I. *Too Much Invested to Quit*. New York: Pergamon, 1980; Costanza, R. "Social Traps and Environmental Policy. *BioScience*. 37 (1987): 407-412.

[25] Cross and Guyer, 1980.

sulting from the fact that the positive and negative reinforcements are separated in time.

Traps can also arise out of simple ignorance of the relevant reinforcements, from the change of reinforcements with time (sliding reinforcer traps), from the externalization of some important reinforcements from the accounting system (externality traps), from the actions of some individuals affecting the group in adverse ways (collective traps), or from a combination of these causes (hybrid traps).

Social traps are ubiquitous in everyday life and have become the basis for some important social psychology research.[26] For example, the "prisoner's dilemma" game is a famous externality trap that has been used recently to study the conditions under which cooperation can evolve.[27] In the prisoner's dilemma game two players must each choose either to cooperate or defect. If they both cooperate, they both reap a moderate reward (say three units each). If they both defect they both get a much smaller reward (say one unit each). If one cooperates while the other defects, the cooperator gets nothing (the "sucker's payoff") while the defector gets a reward larger than that for mutual cooperation (say five units). Under these conditions, if the players only meet once and cannot communicate with each other, the optimum strategy is to defect. For if one has no information about the other player, one must assume the worst to avoid the sucker's payoff. The situation changes radically if the game is played several times with the same participants. Then each player has the record of their opponent's past behavior to go on, and the optimum strategy is not obvious. It is interesting to note that real people playing the prisoner's dilemma game, even in the "one-off" version with no information about their opponents, will more often than not choose to cooperate rather than defect.[28] This behavior demonstrates the influence of social capital. People are acculturated to trust others in social situations. In fact, there have been experiments that show that the *only* people who behave like the predictions of the short-sighted, narrowly self-interested economic model are economists.

Axelrod[29] held a computer tournament pitting various submitted strategies against one another in a round robin tournament of the it-

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[26] Brockner, J. and J. Z. Rubin. Entrapment in Escalating Conflicts: A Social Psychological Analysis. New York: Springer-Verlag, 1985.

[27] Axelrod, R. *The Evolution of Cooperation.* New York: Basic Books, 1984.

[28] Frank, R. *Passions within Reason: The Strategic Role of the Emotions*. New York: W. W. Norton, 1989.

[29] Axelrod, 1984.

erated prisoner's dilemma. He found that a simple strategy called tit for tat, which cooperates on the first move, then does whatever its opponent did last time, won the tournament. In the iterated prisoner's dilemma, one can fall into the always-defect trap by not looking beyond the current move. If a strategy is too shortsighted it misses the opportunity to reap the benefits of mutual cooperation. Tit for tat was only a little more farsighted (one move) than all defect, but this was enough to dramatically improve its performance without making it too susceptible to being suckered.

It turns out that there are several other strategies that would have won the tournament had they been entered. One of these cooperates on the first move and then looks at the entire past history of its opponent's moves to generate a time-weighted expected value for the opponent's next move. A strategy almost identical to this (called downing) was entered but lost because it defected on the first two moves. In the iterated prisoner's dilemma, it pays to assume the best of your opponent, at least until you have been proven wrong, and to have a good memory.

The "tragedy of the commons" (actually the tragedy of open access) is another well-known social trap used to study overexploitation of natural resources (Hardin 1968). The classic open access trap goes something like this. There is an open access resource (say grazing land). Each individual user (rancher) sees his individual cost for consuming an additional unit of the resource (adding one more animal) as small and constant, and much less than the private benefits (from selling an animal). However, the overall cost to all the users of each additional resource unit consumed (animal added) increases exponentially as the resource is stressed. Eventually, one additional animal (which costs its owner no more than the first) leads to the destruction of the resource (which costs the animal's owner and the rest of the ranchers tremendously). The tragedy of the open access commons is a collective trap that occurs because the costs and benefits apparent to the individual are inconsistent with the costs and benefits to the collective society. It is interesting to note that real "commons" (common property resources with access limited to a specific community, but shared by members of that community) are often very effectively managed using rules and norms set up and enforced by the community. In these cases social capital (in the form of the rules, norms, and institutions of the community) is an effective way to escape the open access social trap.[30]

[30] Dietz, T., E. Ostrom, and P. C. Stern. "The Struggle to Govern the Commons." *Science*. 302 (2003): 1907-1912.

Edney and Harper[31] experimented with a simple game designed to test people's behavior in an open access game. In this game a pool of resources is represented by poker chips. The resource pool is renewable; it is replenished after each round in proportion to the number of chips left in the common pool. The objective for each player is to accumulate as many chips as possible from the common pool. At each round players can take either one, two, or three chips. If all players take three chips per round, the resource pool is quickly depleted, and the players end up with far fewer chips than if they had all taken only one chip per round, since doing so would have allowed the resource pool to replenish itself. This game is a trap (and a good analogy for many real-world open access resource problems) since the short-term, narrow incentives (to take as many chips as possible each round) are inconsistent with the long-term incentives (to accumulate as many chips as possible by the end of the game).

Escaping from Social Traps

Cross and Guyer[32] list four broad methods by which traps can be avoided or escaped from. These are education (about the long-term, distributed impacts); insurance; superordinate authority (i.e., legal systems, government, religion); and converting the trap to a trade-off, i.e. correcting the road signs.

Examples of education as a means of escape from social traps are the warning labels now required on cigarette packages and the warnings of scientists about climate change impacts. People can ignore warnings, however, particularly if the path seems otherwise enticing. One only has to observe the way the science of global warming has been misrepresented and obfuscated by those whose interests would be inconvenienced by the warnings. The main problem with education as a general method of avoiding and escaping from traps is that it requires a significant time commitment on the part of individuals to learn the details of each situation, and uncertainty about these details can be manipulated for political purposes. Our current society is so large and complex that we cannot expect even professionals, much less the voting public, to know the details of all the existing traps. In addition, for education to be effective in avoiding traps involving many individuals, all the participants must be educated. For example, in the renewable

[31] Edney, J. J. and C. Harper. "The Effects of Information in a Resource Management Problem: A Social Trap Analog." *Human Ecology* 6 (1978): 387-395.

[32] Cross and Guyer, 1980.

resource game mentioned earlier, if any one of the players starts taking three chips per round the others must follow suit, because if any one player consumes three chips per round, the other players will do individually worse by restricting their consumption to one per round than if they consume three per round, in a manner similar to the prisoner's dilemma. The trap can only be avoided if all the players restrict their consumption to one chip per round, which requires that they all are educated about the nature of the trap.

Governments can forbid or regulate certain actions that have been deemed socially inappropriate. This is the superordinate authority approach to avoiding social traps. The problem with this approach is that it must be rigidly monitored and enforced, and the strong short-term incentive for individuals to try to ignore or avoid the regulations remains. A police force and legal system are very expensive to maintain, and increasing their chances of catching violators increases their costs exponentially (both the costs of maintaining a larger, better-equipped force and the cost of the loss of individual freedom and privacy).

Religion, Social Capital, and Social Traps

Religion can be seen as a much less expensive way to avoid certain social traps. If a moral code of action and belief in an ultimate payment for transgressions can be deeply instilled in a person, the probability of that person's falling into the "sins" (traps) covered by the code will be greatly reduced, and with very little enforcement cost. Religion, and systems of ethics in general, can be seen as a form of social capital (as discussed earlier). Social capital is the glue that holds communities together and allows them to function. Religious glue is particularly strong.

Strong glue is good for some applications, but not for all. The problems with religion as a means to avoid social traps are: (1) the moral code must be relatively static to allow beliefs learned early in life to remain relevant later, and (2) it requires a relatively homogeneous community of like-minded believers in order to be truly effective. Thus this system works well in culturally homogeneous societies in a world that is changing relatively slowly. In modern, heterogeneous, rapidly changing societies, religion (or at least the current suite of religions) cannot adequately handle all the newly evolving situations, nor the conflict between different cultures and belief systems. A new synthesis and integration of science and religion is necessary.

Integrating Science, Democracy, and Religion

In light of the previous discussion, we can see that science, democracy, and religion have different and complementary roles. They are not

alternative paths to new knowledge. Science (but I would argue, transdisciplinary, systems science) is the way to generate new knowledge about how the world works. Democracy, ethics and religion are ways to address the vision of how the world should be, and are forms of social capital that help achieve this vision, while also contributing to quality of life in the present. However, just as the "pre-analytic vision" of science is constantly changing, the vision of how we would like the world to be must also change and evolve. It, of course, must be informed by fundamental principles of fairness, justice, sustainability and efficiency, but it requires an ongoing *democratic* discussion. Organized religion needs to be more flexible about this envisioning process, and participate actively in creating and sustaining the discussion, rather than maintaining a dogmatic, paternalistic stance.

Actively seeking to influence the vision people hold of the good life and individual preferences is not inconsistent with a democratic society. Quite the contrary, in order to operationalize real democracy a two tiered decision structure must be used (Figure 1). This is necessary in

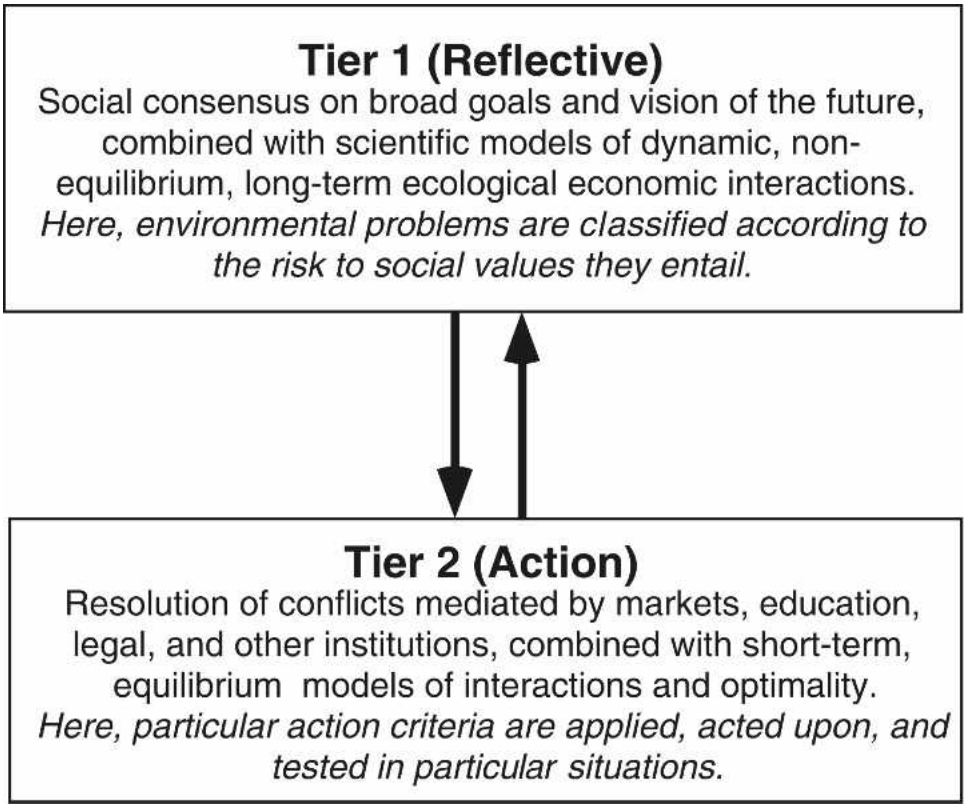

Figure 1. Two-tiered decision structure (from Norton et al. 1998)

order to eliminate "preference inconsistencies" between the short term and the long term and between local and global goals, a phenomenon described above as a "social traps." There must first be general, democratic consensus on the broad, long-term goals of society. At this level "individual sovereignty" holds, in the sense that the rights and goals of all individuals in society must be taken into account, but in the context of a shared dialogue aimed at achieving broad consensus. Once these broad goals are democratically arrived at, they can be used to limit and direct preferences at lower levels. For example, once there is general consensus on the goal of sustainability, with agreement by all the major stakeholders in society, then society is justified in taking action to change local behaviors that are inconsistent with this goal. It may be justified, for example, to attempt to change either people's preferences for driving automobiles or the price of doing so (or both) in order to change behavior to be more consistent with the longer term sustainability goals. In this way we are utilizing the foresight that we possess in order to modify short-term cultural evolutionary forces toward achieving our shared long-term goals. If ecology, economics and other social sciences are to adequately address problems of sustainability, it will be necessary to develop models that make preference formation and reformation an endogenous part of the analysis, and to develop mechanisms to modify short term cultural forces in the direction of long term sustainability goals.

Religion has a huge potential role to play in this process, but it cannot play this role in isolation from the knowledge being generated by science or the shared envisioning that is the true role of democracy. Likewise, science cannot set social goals, but it can help lay out scenarios of plausible possible futures for people to choose from. We need to first envision a sustainable and desirable future before we can hope to achieve it. Integrative, transdisciplinary science working together with vision-focused democracy and enlightened, adaptive religion can help us to first create the shared vision of a sustainable and desirable future, and then help to get us there.

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