Systems Literacy: A Toolkit for Purposeful Change

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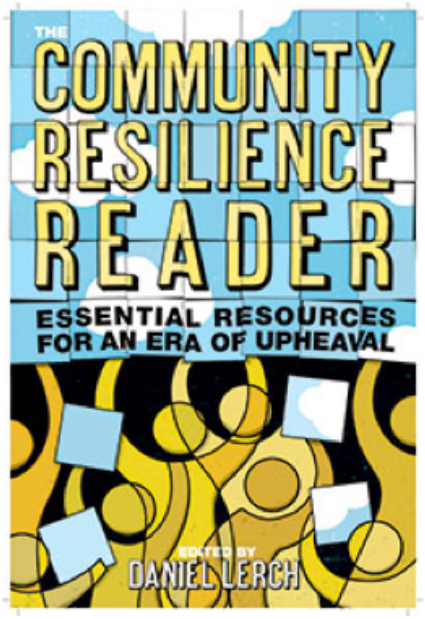

Systems Literacy: A Toolkit for Purposeful Change

Life is full of unknowns, rich with complexities. Two people experiencing a situation might interpret it differently. Even familiar situations might take unpredictable turns.[1]

Systems thinking is a way of seeing patterns amidst the messiness of life. Patterns give coherence to one's experience. A systems toolkit of methods, models, concepts, and metaphors can be used to both interpret such patterns and inform one's actions. For today's challenges – for creating a post-carbon world – familiarity with this toolkit represents a basic and essential literacy.[2]

A core concept in this systems toolkit is *feedback*: the circularity of influence. This circular pattern is instantly familiar. We've all personally experienced vicious circles, like when you can't sleep because you are thinking about the next day's work, and the more you think about it, the more your insomnia is reinforced. An online video goes viral when it reverberates through social media, with initial support building more support in a bandwagon effect. These are examples of *reinforcing* or *positive feedback*. The complementary pattern is *regulatory* or *negative feedback*. My body, for example, regulates its own temperature; and a thermostat similarly monitors and adjusts the room temperature, according to the preference that one sets. (See Figure 1.)

Patterns like these can be found across systems that are ecological as well as social, biological as well as material. A key systems method for learning about a situation is to compare and contrast a similar one, taking the second as a lens or model for looking back at the first.[3] We can learn about one organization by viewing it against others, learn about practices for purposeful change by examining what has worked (or not) elsewhere, and ultimately learn what it is to be human by seeing our lives reflected and refracted both in other species and in digital worlds of our own making.

Through such analogies and distinctions, the pioneers of systems theory sought to get beyond the constraints of academic disciplines, "beyond reductionism," and to develop a "science of synthesis."[4] This approach put them at odds with academic traditions and was one way in which systems critiques challenged basic assumptions of the Western intellectual tradition. Then as now, the stakes could hardly be higher. "The major problems of the world," declared anthropologist Gregory Bateson, "are the result of the difference between how nature works and the way people think."[5]

Examining how nature works, environmental philosopher John Muir famously wrote, "When we try to pick out anything by itself, we find it hitched to everything else in the universe."[6] Muir's words, intuitive and enchanting, can also be misleading. While it's true that nothing can be picked out by itself, it's also true that some hitches are tighter than others. "Everything is not connected to everything," clarified philosopher of science Donna Haraway, "everything is connected to something." In those connections – loose or tight, sometimes reinforcing, sometimes regulating – are life's patterns.[7]

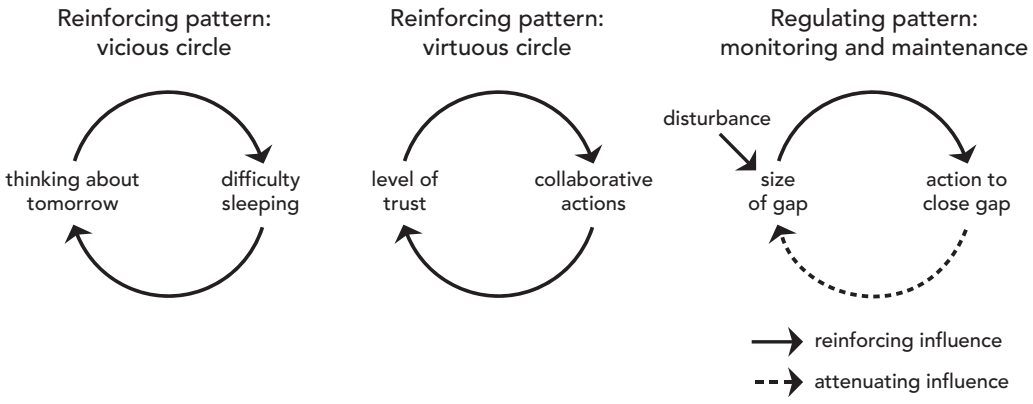

Figure 1: Feedback dynamics
Two familiar examples of reinforcing feedback patterns are shown here: *vicious circles* and *virtuous circles*. The first reads: an increase in thinking about tomorrow leads to an increase in difficulty sleeping, which leads to an increase in thinking about tomorrow. The second reads: an increase in the level of trust leads to an increase in collaborative actions, which leads to an increase in the level of trust. A third, regulating pattern, is also shown. Applied to the example of a thermostat, it reads: an increase in the size of the gap (between monitored and desired temperatures) leads to an increase in action to close the gap, which leads to a decrease in the size of the gap (which then leads to a decrease in action to close the gap, which leads again to an increase in the gap, based on the differential with outside temperatures). Each of these diagrams should be understood as a generalized model, representing what happened at one time, or what tends to happen with all else being equal.[8]

The use of visual imagery – including artworks, maps, graphs, and doodles, as well as the types of diagrams shown here – is an important method in one's systems toolkit. During facilitations and conversations, visual imagery can support collective and comparative *sensemaking* among participants. Through such sensemaking, we reflect on our experiences, negotiate meanings, and imagine or enact new stories.[9]
Illustration: Crystal Rome and Howard Silverman

Purposeful behavior

While the word "feedback" is relatively recent, dating to the 1800s or early 1900s, feedback processes are themselves both timeless and unavoidable.[10] Farmers on marginal lands long ago learned at their peril that as soil quality degrades the land becomes more vulnerable to further erosion. Against this unwinding, rice farmers across Asia, for example, built terraces on steep slopes so as to retain water and maintain soils.[11]

The earliest recorded feedback control device is a water clock from ancient Alexandria. This ingenious mechanism used a float valve to self-regulate a steady drip of water into a holding tank, enabling one to read the time by examining the water level in the tank. A 12th-century Chinese text tells of a similarly inventive tool: a bamboo drinking straw with a weighted stopper inserted into the tube. When sucking either too quickly or too slowly, the stopper would seal the valve, thereby regulating an equitable flow of liquid to each person drinking. In the 18th century, James Watt built a steam engine that self-regulated its velocity with a centrifugal flyball device called a governor. All these early regulatory mechanisms were constructed through experimentation, with little analytical theorizing. That began to change in 1868 with James Clerk Maxwell's paper, "On Governors," and then in the 20th century with technological breakthroughs in areas such as radar, acoustics, targeting, and navigation. Systems understandings that had been around for millennia began to be analyzed, formalized, and re-interpreted.[12]

“All purposeful behavior may be considered to require negative feed-back,” wrote Arturo Rosenblueth, Norbert Wiener, and Julian Bigelow.[13] Wiener, a mathematician, and Bigelow, an engineer, were engaged in the World War II challenge of trying to develop an anti-aircraft missile launcher that could calculate an airplane's trajectory, anticipate its forward motion, and shoot it down. Writing with Rosenblueth, a physiologist, they generalized their experiences and inquiries to biological and social systems. In a 1948 book, Wiener called this new field of practice and study *cybernetics*.[14]

The word cybernetics comes from the ancient Greek for "steersman." The person steering a boat must purposefully and iteratively sense her trajectory, compare the current course with an overall goal, and adjust accordingly. This is the basic regulatory (“negative feed-back”) pattern that occurs throughout our lives. As I walk down the street or hallway, I sense and adjust, so as to avoid others in my path; and as I talk with my friends, I watch their eyes and their body language, to see how my words are being received. Then, in the course of these activities, I might have a reflexive, gut-check moment, when I feel the need to re-examine my purposes or goals, or perhaps merely the effectiveness of my approach. Sensing that the winds and waves are unfavorable, the steersman may turn course to head back. Talking with my friends, I may sense that I am not connecting and decide to drop the subject until another day.[15]

This gut-check accounting for purpose matters more in some areas of research and practice than others.[16] The activities of the physicist, for example, will never influence the physical dynamics of planetary motion. Likewise, my prediction, “It looks like a sunny day,” has no effect on the day's weather. In social situations, however, my decisions and actions do have an influence. If I decide to join Twitter, Instagram, or the latest social media platform, I thereby reinforce the platform's network effect: the more people that participate, the more value it provides, and the higher its likelihood of success. “When you cut your hair short,” argued economist Thomas Schelling, "you change, ever so slightly, other people’s impressions of how long people are wearing their hair.”[17]

Given today's challenges, our purposes matter greatly. We all participate in systems that we rely on for our food, water, energy, housing, transportation, education, health care, and so on. But such systems may not be achieving one’s goals or reflecting one’s values. When that is the case, systems literacy can inform one’s efforts toward purposeful change. (See Figure 2.)

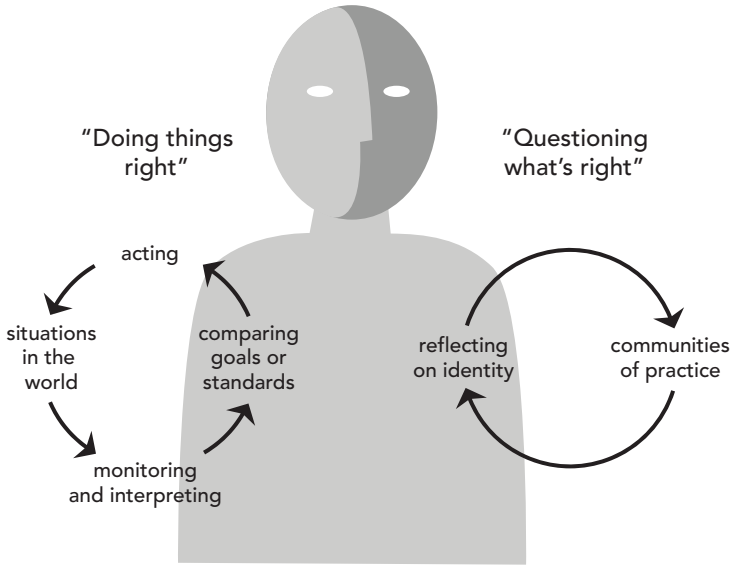

Figure 2: Purposeful Behavior
We are always engaging in situations in the world. In a systems view of routine engagements, one acts and seeks to monitor and interpret the effects of one's actions, given other potential influences on the situation. One then compares the monitored effects with relevant goals or standards, and perhaps one initiates a follow-up action. In such routine engagements, one is concerned with "doing things right."

Then, one might have a gut-check moment. One might feel the need to "check one's moral compass" – to re-examine the goals or standards according to which one engages in the world. To what extent do these goals or standards reflect one's values – one's sense of identity? Unsatisfied with merely "doing things right," one questions: "How am I sensing or deciding what's right?" Perhaps one seeks affirmation, perhaps unconsciously, by observing behaviors or imagining conversations with those in the communities to whom one looks to for experience or values or judgment. Broadening the scope of one's observations may bring fresh perspectives.

These feedback loops ("doing things right" and "questioning what's right") are sometimes referred to as first- and second-order cybernetics, or single- and double-loop learning.[18]
Illustration: Crystal Rome and Howard Silverman

Identity

We shape the world and the world shapes us — this is a systems perspective on the human experience. An infant develops in relationship with those who rear her. We each become attached to the types of music we enjoy. In politics, my vote for a particular party strengthens my sense of myself as a supporter of this party. We are creatures of habit. One's *identity* develops in affiliation with the social systems – groups, norms, and so on – in which one participates.[19]

In ecological terms, the shape-and-be-shaped pattern of a system with its environment is sometimes called structural coupling or niche construction theory. Each cell and each organism must obtain energetic inputs from its environment, and with each consumption of food and each release of waste it thereby modifies its environment, perhaps to its own detriment.[20] "Organisms do not experience environments," wrote geneticist Richard Lewontin. "They create them."[21]

In biology, consider symbiotic relationships. Looking back in time, all plant and animal life can be traced to the evolution of eukaryotic (i.e., nucleated) cells. It's now widely accepted that eukaryotes evolved through symbiosis: the living together of different organisms or, specifically, the integration of genetic material across organisms.[22] Looking inward, half or more the cells in my body are bacterial, and this microbiome is critical to my own health.[23] "We have never been individuals," maintained developmental biologist Scott Gilbert and colleagues.[24] "We are walking communities," insisted evolutionary theorist Lynn Margulis.[25]

Socially, ecologically, biologically: life is interconnected in complex ways – and these interconnections challenge individualistic understandings of human identity.

Emergent social patterns

"You can't truly want anything," taunted physicist Sean Carroll. "You're just a collection of atoms, and atoms don't have wants." Carroll's quip illustrates the folly of reductionism — of trying to reduce all of life's complexities to physical phenomena.[26]

While I am but atoms, such atoms hardly describe the whole of me. Likewise, the experience of water's wetness is not to be found in its hydrogen and oxygen molecules; and the experience of conversation emerges in and among those who speak and listen. *Emergence* is the phenomenon that a system exhibits behaviors or properties that arise from interactions among its structures or participants. More is different. The whole is more than the sum of the parts.[27]

As a result and in our social lives, events can take us by surprise: new industries are created, energy prices spike, and political waves come and go. Even so and beneath the flux, there are *patterns* – feedback-driven recurrences. Many such patterns are familiar in one form or another; the internet has helped to make them more visible. I've touched on ones like virtuous and vicious circles, bandwagon effects and network effects. Here are two more types.

One emergent pattern is the power-law distribution, also known as the success-to-the-successful model or the 80/20 rule. The pattern is that, in general terms, a minority of the participants account for a majority of the activity (i.e., "20" percent account for "80" percent, though actual figures vary). In 2017, for example, Google, Facebook, and a few other websites and apps account for most internet use. Similarly, a few of the world's languages account for most of the speakers, and a minority of scientific papers account for a majority of citations from other papers. Another instance of this pattern is the recurring tendency of the rich to get richer. If I have a lot of resources — financial assets, social privilege, education, and so on — then these resources enable me to gain more.[28]

Other patterns are based on the viral popularity or bandwagon effect described above. There might be a threshold of collective behavior, in which the situation tips one way or another. For example, one's decision to leave a party or to vote for a particular candidate can be influenced by one's observations of what others are doing. Then the party might suddenly empty out or an unexpected candidate might emerge on top. Furthermore, collective outcomes may not be consistent with individual desires. Neighborhoods can become segregated, even when some people in the city prefer more diversity. Similarly, social media platforms can turn into echo chambers or filter bubbles, in which opposing views are rarely encountered, despite individual preferences to the contrary.[29]

Counteracting such recurring tendencies is a question of design. Take the rich-get-richer pattern. One mechanism for regulating this tendency is a progressive income tax. Another is a protocol for periodic debt forgiveness, like the "jubilee" custom described in the Bible. Other policy designs might alleviate systemic inequities. One is a universal basic income for all citizens; another is a national fund of shared, common assets, the sale or rental of which provides dividends to all citizens.[30]

New policies or regulations will lead to newly emergent and possibly unanticipated systems behaviors. Thus, in policy and regulatory design, as in other fields of design, experimental, iterative, and adaptive are bywords of good practice.[31] "Social problems are never solved," cautioned design theorist Horst Rittel, writing in 1973 with urban designer Melvin Webber. "At best they are only re-solved — over and over again."[32]

Stability and change

One commonality among all these systemic social patterns is simply time. History matters, and the order of events matters as well. As we live our lives we each form, unconsciously or consciously, both our own identities and the identities of the systems in which we participate. Weighted with history, existing social systems develop a kind of stability or inertia. They reinforce or regulate existing behaviors, relationships, or biases. Powerful interests may seek to perpetuate the status quo. We may feel stuck.[33]

"Creativity is a discontinuity," emphasized management theorist Russell Ackoff. "A creative act breaks with the chain that has come before it." Based on the concept of a discontinuity or threshold, social innovation theorist Frances Westley and colleagues described three leverage points for systemic change in linked social-ecological systems: destabilize undesirable systems, strengthen alternatives, and help individuals and organizations shift their affiliations from one to the next.[34]

Consider the story of 20th-century musical innovator Harry Partch, recounted in sociologist Howard Becker's "The Power of Inertia."[35] Partch created a nontraditional 43-tone musical scale and achieved some recognition, including Guggenheim grants and a concert at Carnegie Hall. He also encountered systemic difficulties. To stage a performance of his music, Partch had to devise a notation for his compositions, had to build his own instruments, and had to teach people to both read the new notation and play the new instruments. The notation, the instruments, and their practiced performance are each components of a social system, sometimes called a package or assemblage or, in the terminology of resilience and transition theory, a *regime*.[36] Notation, instruments practiced performance: each reinforces the utility and value of the others, strengthening the stability of the regime as a whole. With his 43-tone alternative, Partch challenged the dominant regime of classical music composition, but the old regime proved more resilient.

Emphasizing the complexities in this story, Becker noted that whether Partch challenged the fundamental "identity" of classical music couldn't be conclusively stated one way or another. After all, his music was still composed by a composer, for an orchestra, to be performed in a concert hall. The music was packaged and sold in conventional ways. In sum, Partch was an innovator in some respects but not others.

This type of dilemma is quite common. While a key strategy for escaping the stuck-ness of social systems is to strengthen their alternatives, what counts as alternative may be open to

interpretation. Take electric cars, for example. If one is concerned about local air quality, they are great because they emit no particulate pollution. If one is concerned about climate change, they have a lot of potential, depending on sources of electricity. If, however, one is concerned about equity or urban sprawl, then electric cars will seem less innovative. Their adoption does not directly challenge the transportation regime of private vehicle ownership and infrastructure, which is the dominant regime in most parts of the US and many other countries. Electric cars are transformative in some respects but not others.

Faced with such complexities, farmer and essayist Wendell Berry advocated a design approach that he called "solving for pattern." With each action or initiative, seek to simultaneously address as many of one's concerns as possible, without engendering new ones.[37]

Practices for purposeful change

Systems views have significantly influenced contemporary understandings of the world. Looking back from 2016, science fiction writer Bruce Sterling proclaimed, "Cybernetic feedback was Darwin-scale high concept."[38]

In this chapter, I have taken a broadly synthetic view of systems — from cybernetics, dynamics, and complexity, to networks, resilience, and design.[39] I have woven a story of systems pioneers, systemic inquiries, and emergent patterns. Amidst these narrative threads, there is also a story about *practices for purposeful change*. A systems perspective sheds light on such practices – the types of practices that can be used to develop capacities for change in personal, organizational, and social situations.

In sum, practices for change:

- … help in developing your capacity for action. To act with purpose is, as political theorist Hannah Arendt described, "to take an initiative" and "to set something into motion." Arendt distinguished such action from labor, "forced upon us by necessity," and from work, "prompted by utility."[40] This useful distinction invites the question: are there ways to align one's labor and work so as to support one's purposeful action?

- … help in becoming mindful of habitual entanglements. Pay attention to your own thinking. Develop gut-check sensibilities. Suspend assumptions, and question routines. It's not easy. "The great force of history," wrote novelist and social critic James Baldwin, "comes from the fact that we carry it within us, are unconsciously controlled by it in many ways."[41]

- … are practices of way-finding: making connections, developing potentialities, remaining adaptive, and finding one's flow. Systems scientist Donella Meadows once related, "My experience – having now many times created a vision and then brought it, in some form, into being – is that I never know, at the beginning, how to get there. But as I articulate the vision and share it with people, the path reveals itself."[42]

- … are appreciative. Look for signs of success. Some people somewhere are working in ways that you would value as well. Community organizer John McKnight described beginning his engagements with the question: "What have people who live here done together to make things better?"[43] Philosopher C. West Churchman

> maintained: "The systems approach begins when first you see the world through the eyes of another."[44]

When existing systems have been destabilized, one might well feel a heightened sense of vulnerability. In such times, community support is essential. For when existing systems have been destabilized is also when opportunities for systemic change arise. Another world is possible. Systems that are more equitable and more resilient to environmental change are ours to design and develop.

[1] Note that key systems terms are used in various ways. The terms "complex" and "complexity," for example, may refer to: a tradition or field of systems study, a mathematical theory or approach, a descriptor of situations and systems in the world, and a descriptor of individual perceptions, e.g.: "The complexity of a system is in the eye of the beholder." — C. S. "Buzz" Holling, "Perceiving and Managing the Complexity of Ecological Systems," in *The Science and Praxis of Complexity: Contributions to the Symposium Held at Montpellier, France, 9-11 May, 1984* (Tokyo, Japan: The United Nations University, 1985), p.217.

For an introduction to the study of complexity, see: Melanie Mitchell, *Complexity: A Guided Tour*, (New York, NY: Oxford University Press, 2009).

[2] For the phrase "systems literacy," I am indebted to Peter Tuddenham. Drawing upon 40 years of experience in systems education at The Open University, Ray Ison and Monica Shelley described systems literacy as a curriculum for helping students to recover or foster a systemic sensibility and thereby develop systems thinking in practice ("Governing in the Anthropocene: Contributions from Systems Thinking in Practice?" *Systems Research and Behavioral Science* 33:589–594, 2016).

[3] General Systems Theory, in particular, has emphasized the study of isomorphisms or patterns. See, for example: Robert Rosen, "Old Trends and New Trends in General Systems Research," *International Journal of General Systems* 5:173-184, 1979.
[4] Arthur Koestler and J. R. Smithies, *Beyond Reductionism: New Perspectives in the Life Sciences*, (New York, NY: The MacMillan Company, 1969).

Debora Hammond, *The Science of Synthesis: Exploring the Social Implications of General Systems Theory*, (Boulder, CO: University Press of Colorado, 2003).

For a contemporary example of a reductionism critique, see: Joichi Ito and Jeff Howe, *Whiplash: How to Survive Our Faster Future*, (New York, NY: Grand Central Publishing, 2016).

[5] Gregory Bateson, as quoted in his daughter Nora Bateson's film, *An Ecology of Mind*, 2011, accessed at: http://www.anecologyofmind.com.

[6] John Muir, *My First Summer in the Sierra, 1869*, (Boston and New York: Houghton Mifflin company, 1911), p.243-244.

[7] Donna Haraway, "Anthropocene, Capitalocene, Chthulucene: Staying with the Trouble," Aarhus University Research on the Anthropocene, 2014, accessed at: https://vimeo.com/97663518.

[8][8] On feedback dynamics and diagrams, see:
-- Donella Meadows, *Thinking in Systems: A Primer*, (White River Junction, VT: Chelsea Green Publishing Company, 2008).
-- George P. Richardson, "Problems in Causal Loop Diagrams Revisited," *System Dynamics Review* 13:247-252, 1997.
-- Peter M. Senge, *The Fifth Discipline: The Art & Practice of The Learning Organization*, (New York, NY: Currency/Doubleday, 1990).

[9] On visual imagery, sensemaking, and the use of models see:
-- Hugh Dubberly. "How Do Models 'Work' in Design & Research? A Model of Modeling," 2011, accessed at: http://presentations.dubberly.com/Model_of_Modelling.pdf.
-- Barbara Maria Stafford, *Echo Objects: The Cognitive Work of Images*, (Chicago, IL: University of Chicago Press, 2007).
-- Karl E. Weick, *Sensemaking in Organizations*, (Thousand Oaks, CA: Sage Publications, 1995).

[10] *The Compact Oxford English Dictionary* (2nd edition, 1991) dates the hyphenated word feed-back to 1920. Online etymological sources date the word, in hyphenated and two-word form, to 1909 and 1865 respectively. See: https://en.wikipedia.org/wiki/User:Trevithj.

[11] For a systems-based study of rice farming, see: Stephen Lansing, *Perfect Order: Recognizing Complexity in Bali*, (Princeton, NJ: Princeton University Press, 2006).

[12] On the historical development of feedback control devices, see:
-- Otto Mayr, *The Origins of Feedback Control*, (Cambridge, MA: The MIT Press, 1970).
-- David A. Mindell, *Between Human and Machine: Feedback, Control, and Computing before Cybernetics*, (Baltimore, MD: Johns Hopkins University Press, 2002).
-- George Richardson, *Feedback Thought in Social Science and Systems Theory*, (Waltham, MA: Pegasus Communications, 1991).

[13] Arturo Rosenblueth, et al., " Behavior, Purpose and Teleology," *Philosophy of Science* 10:18–24, 1943, p.2.

[14] On Norbert Wiener and cybernetics, see:
-- Flo Conway and Jim Siegelman, *Dark Hero of the Information Age: In Search of Norbert Wiener – The Father of Cybernetics*, (New York, NY: Basic Books, 2005).
-- Norbert Wiener, *Cybernetics or Control and Communication in the Animal and the Machine*, (Cambridge, MA: The MIT Press, 1948).
-- Jean-Pierre Dupuy, *The Mechanization of Mind: On the Origins of Cognitive Science*, (Princeton, NJ: New French Thought/Princeton University Press, 1994/2000).

[15] For a contemporary perspective on cybernetics, see: Paul Pangaro, accessed at: http://www.pangaro.com/definition-cybernetics.html.

[16] On incorporating purpose, reflexivity, and/or complexity into scientific research and practice, see:
-- Hilary Bradbury, "Introduction: How to Situate and Define Action Research," in Hilary Bradbury, ed., *The Sage Handbook of Action Research (3rd edition)*, (Thousand Oaks, CA: Sage Publications, 2015).
-- Karl H. Müller and Alexander Riegler, "Second-Order Science: A Vast and Largely Unexplored Science Frontier," *Constructivist Foundations* 10:7-15, 2015.
-- Stuart A. Kauffman and Arran Gare, "Beyond Descartes and Newton: Recovering Life and Humanity," *Progress in Biophysics and Molecular Biology* 119:219-244, 2015.

[17] Thomas C. Schelling, *Micromotives and Macrobehavior*, (New York, NY: W. W. Norton & Company, 1978), p.28.

[18] This description of purposeful behavior draws upon sources that include:
-- Chris Argyris, *On Organizational Learning (2nd edition)*, (Oxford, UK: Blackwell Publishers, 1999).
-- Daniel Kahneman, *Thinking, Fast and Slow* (New York, NY: Farrar, Straus and Giroux, 2011).
-- Ray Ison, *Systems Practice: How to Act in a Climate Change World*, (London, UK: Springer, 2010).
-- Weick, *Sensemaking in Organizations*.
-- Etienne Wenger, *Communities of Practice: Learning, Meaning, and Identity*, (Cambridge, UK: Cambridge University Press, 1998).

[19] On identity, see:
-- Peter J. Burke and Jan E. Stets, *Identity Theory*, (Oxford, UK: Oxford University Press, 2009).
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[20] On ecological theories of structural coupling and niche construction, see:
-- Fritjof Capra and Pier Luigi Luisi, *A Systems View of Life*, (Cambridge, UK: Cambridge University Press, 2014).
-- John F. Odling-Smee, et al., *Niche Construction: The Neglected Process in Evolution*, (Princeton, NJ: Princeton University Press, 2003).
-- Thomas C. Scott-Phillips, et al., "The Niche Construction Perspective: A Critical Appraisal," *Evolution* 68:1231-1243, 2014.

[21] Richard C. Lewontin, *Biology as Ideology: The Doctrine of DNA*, (New York, NY: HarperCollins Publishers, 1991), p.109.
[22] This paragraph draws particularly on the work of Lynn Margulis. On Margulis's definitions of symbiosis and symbiogenesis, see:
-- Lynn Margulis and Dorion Sagan, *Acquiring Genomes*, (New York, NY: Basic Books, 2002).
-- Lynn Margulis, "Lynn Margulis 2004 Rutgers Interview," accessed at: https://www.youtube.com/watch?v=b8xqu_TlQPU.

-- Jan Sapp, "Too Fantastic of Polite Society: A Brief History of Symbiosis Theory," in Dorian Sagan, ed., *Lynn Margulis: The Life and Legacy of a Scientific Rebel*, (White River Junction: VT, Chelsea Green Publishing, 2012).

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[23] For a recent review of microbiological sciences, see: Ed Yong, *I Contain Multitudes: The Microbes Within Us and a Grander View of Life*, (New York, NY: HarperCollins Publishers, 2016).

[24] Scott Gilbert, et al., "A Symbiotic View of Life: We Have Never Been Individuals," *The Quarterly Review of Biology* 87:325-340, 2012, p.325.

[25] Charles Mann, "Lynn Margulis: Science's Unruly Earth Mother," *Science* 252:378-381, 1991, p.378.

[26] Sean Carroll, *The Big Picture: On the Origins of Life, Meaning, and the Universe Itself*, (New York, NY: Dutton, 2016), p.113.

[27] On emergence, see:
-- P. W. Anderson, "More Is Different," *Science* 177:393-396, 1972.
-- Steven Johnson, *Emergence: The Connected Lives of Ants, Brains, Cities, and Software* (New York, NY: Touchsotone, 2001).

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-- Eli Pariser, *The Filter Bubble: How the New Personalized Web Is Changing What We Read and How We Think*, (New York, NY: Penguin Press, 2011).
-- Schelling, *Micromotives and Macrobehavior.*

[30] For introductions to these policy designs, see:
https://en.wikipedia.org/wiki/Jubilee_(Christianity)
https://en.wikipedia.org/wiki/Basic_income
http://dividendsforall.net/

[31] On systems and design, see:
-- Howard Silverman, "Designerly Ways for Action Research," in Hilary Bradbury, ed., *The Sage Handbook of Action Research (3rd edition)*, (Thousand Oaks, CA: Sage Publications, 2015).
-- John Thackara, *How to Thrive in the Next Economy: Designing Tomorrow's World Today*, (London, UK: Thames & Hudson, 2015).

[32] Horst W. J, Rittel and Melvin M. Webber, "Dilemmas in a General Theory of Planning," *Policy Sciences* 4:155-169, 1973, p.160.

[33] On time, stability, and inertia, see:
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