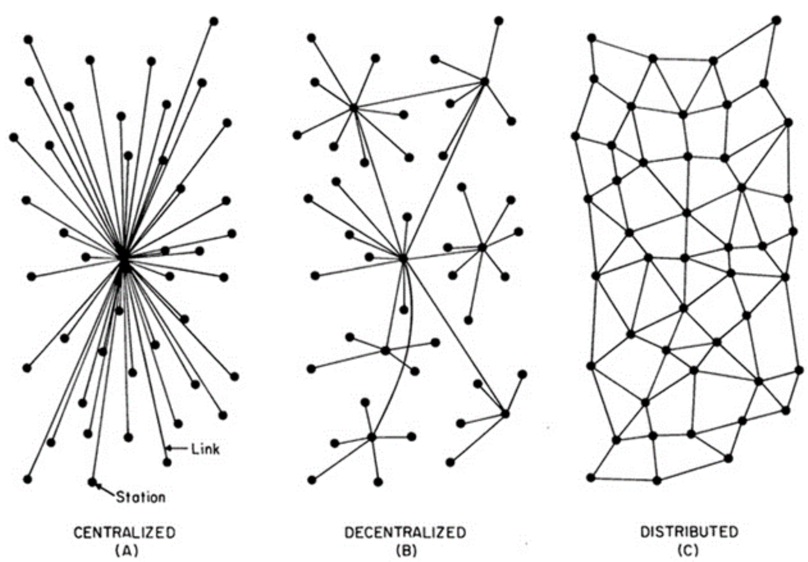
Networked Yet Independent: Modular Connectivity

Do you know your neighbors? Do you share labor and equipment with them? Are you independent enough to survive without these connections? Can those connections be severed if need be? Do information and resources flow freely and openly through your system? Do you maintain good relationships with alternate markets? Can this free flow be staunched in times of crisis?

These questions reflect the sometimes contradictory contributions of modular connectivity to resilience.

For a farm, business or any system to withstand catastrophe, networks inside and outside the system are crucial. Managing connectivity between components is consistently cited as one of the most important factors in resilience of ecosystems and agroecosystems.[1] Those interested in sustainability have often adopted a simplified way of looking at connectedness as illustrated in the adjacent figures. The centralized system relies on the strength of the central node to withstand disturbance. The decentralized system makes possible survival of part of the system by cutting only a few links. The distributed system is more resilient to some types of disturbance (such as an enemy attack on a communication network) but since every node is ultimately connected to every other node introduction of some disturbances, such as fire and disease, result in a system as vulnerable as the centralized system.



Centralized systems are more vulnerable to fluctuations, less able to adapt to changing conditions, and often imply large investment in both the system itself and its supporting infrastructure. Decentralized systems tend to be more flexible and able to adapt to local conditions. Because of these attributes, they often not only operate more efficiently, but also reduce energy use.

In human systems, large, centralized systems are, by necessity, controlled by expert

[1] Stockholm Resilience Centre, 2015. Principles for building resilience. Cambridge.

specialists and organizations that can leverage the requisite capital; as such, they are divorced from democratic decision-making processes.[2] Centralized system also tend to centralize costs and benefits, which often accrue to different parties at opposite ends of the system: costs accrue "downstream;" benefits go to those who control the systems that are "too big to fail." Thus these systems become engines of inequality. Studies of the rise and fall of civilizations shows two types of social trajectories: one characterized by increasing hierarchy, large-scale capital investments, environmental change, and ultimately collapse; the other characterized by local decision-making, incremental change, and long-term resilience.[3]

Connectivity in natural ecosystems is much more complex. In ecosystems, typically each species is closely linked, directly or indirectly, to all others in the system, as shown in the adjacent Figures.[4] Connectivity is especially crucial in resilience to disturbance. For example, after a typhoon or hurricane when coral is damaged, algae can invade and prevent coral from reestablishing themselves. If the coral reefs offshore are connected to near-shore nursery habitat for algae-eating fish, the fish come to the rescue, keep algae in check and enable coral reefs to bounce back.[5]

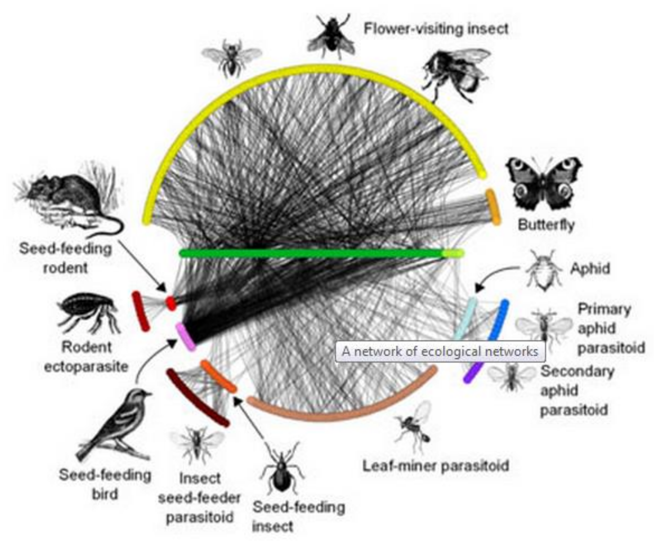


Figure 2. A network of ecological networks showing the animal groups which interact with plants on a British organic farm (Pocock et al., 2012).

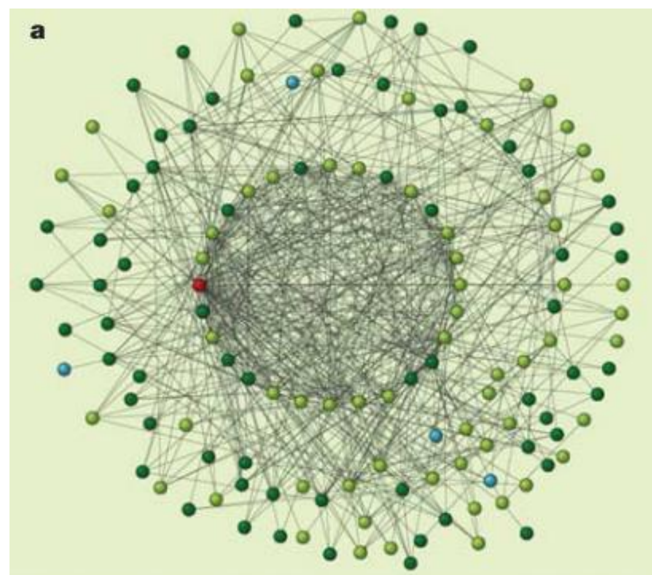


Figure 1 Estuarian food web studied by Montoya et al. (2006). Each node is a species. Node color indicates shortest path linking the most connected species (flounder in red) and each other species in the network.

Our local food system case studies demonstrate the powerful impact of connectivity in agricultural systems. A network of farmers and locavores in Mississippi kept a farm productive and profitable when the owners had to stay away for weeks at a time from the farm to attend to a sick child. Their farm would not have survived without the network

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[2] Lovins, Amory B. Soft Energy Paths: Toward a Durable Peace. New York: Harper Colophon Books, 1977.
[3] Scarborough, V. L., 2003. The Flow of Power: Ancient Water System and Landscapes. Santa Fe: School of American Research Press.
[4] Montoya et al., 2006. Ecological networks and their fragility. Nature. 442:20; Pocock, MJO, Evans, DM & Memmott, J. (2012) The robustness and restoration of a network of ecological networks. Science 335:973-977.
[5] Adam et al., 2011. Herbivory, Connectivity and Ecosystem Resilience. PLOS/One DOI: 10.1371/journal.pone.0023717

connections. Also in Mississippi we spoke with a cooperative in Macon, developed in the 1960's to create a market for black farmers. Their willingness and ability to connect to one another and cooperative agencies throughout the south determined the livelihood of black farmers for decades after the establishment of the cooperative.

Social capital and connectivity. In social ecological systems, the types of connectivity have been thoroughly explored under the rubric social capital. Three types of social capital (**Bonding, Bridging** and **Linking**) help communities withstand disturbances such as hurricanes, drought, climate change, market shocks, and violent conflict.[6]

> **Bonding** social capital is seen in the strong relationships between community members. It engenders trust, reciprocity, and cooperation, and is often drawn on in disasters, where survivors work closely to help each other to cope and recover. Trust is cited as crucial in many reviews of resilient communities.[7]
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> **Bridging** social capital connects members of one community or group to other communities/groups. It often crosses ethnic/racial lines, geographic boundaries and language groups, and can facilitate links to external assets and broader social and economic identities. Bridging social capital makes a direct contribution to community resilience in that those with social ties outside their immediate community can draw on these links when local resources are insufficient or unavailable (Wetterberg, 2004). High levels of connectivity between different social groups can increase information sharing and and bring in outside perspectives and new ideas to local issues.
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> **Linking** social capital is seen in trusted social networks between individuals and groups interacting across explicit, institutionalized, and formal boundaries in society. Linked networks are particularly important for economic development and resilience because they provide resources and information that are otherwise unavailable. This type of social capital is often conceived of as a vertical link between a network and some form of authority or power in the social sphere.

Networks, social capital and development. A vast literature exists on the success of networks of small and medium-sized enterprises in coordinating manufacturing and marketing to increase profitability[8]. Prominent examples of transformation of regional economies through such networks are the Mondragon region of Spain[9] ; north central Italy[10] ; the dense social networks of East Asian economies such as Japan, Korea, Taiwan, China[11] ; Co. Monaghan, Ireland[12] ; Silicon Valley, Route 128 in Boston, Toulouse, Baden-Wurtemburg, Bavaria, Jutland, and many others[13].

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[6] Frankenburger et al., 2013. Community Resilience. USAID, Westat.
[7] Carpenter et al., 2012 General resilience to cope with extreme events. Sustainability, 4:3248-3259.
[8] Levin, 1993; OECD, 1999
[9] Whyte and Whyte, 1991
[10] Blim, 1992
[11] Kenworthy, 1997
[12] Mottiar and Ingle, 2007
[13] Storper, 1995

Such observations have led to a significant increase in policy strategies which seek to build such networks[14]. Such rural development efforts have also increased political effectiveness of local farmers in Rondonia[15], Chiapas[16], Kentucky[17], Arkansas[18], and many other regions[19]. The political impact on regional rural development policies extends far beyond the marketing, processing, or credit ventures which were the original goals of the networks.

Where rural networks of small enterprises have transformed local economies, consistently present is an atmosphere encouraging competition of ideas and innovation[20] and cooperation between entrepreneurs[21]. The consistent social characteristics of successful entrepreneurial networks and successful rural communities have been labeled as 'network capital'[22] , 'social networks'[23] , 'guanxi networks and guanxi capital'[24] and as 'social trust'[25] . All these concepts are variants of the concept of social capital which has a history of use in print since at least 1916[26] . The social atmosphere which encourages innovation, competition of ideas, and cooperation between entrepreneurs requires all three types of social capital, **Bonding, Bridging** and **Linking**. Much like a resilient system which requires all components to be resilient, not just a few, to build robust and healthy social networks all three types of social capital are inherent to success.

The use of such social capital is seen to explain success of various ethnic groups including Chinese in the Mississippi Delta[27] , Lebanese in West Africa, Armenians in Europe and US, Koreans in US inner cities, Indians in New Zealand, Palestinians in California and many others[28] . Bonding social capital corresponds to the few strong connections characteristics of resilient systems. To be sure though, there is risk inherent in developing a network or system that is too linked, too bridged, or too bonded.

The dark side of bonding social capital. High levels of bonding, can result in homogenization of norms and a drop in the explorative ability of group members, leading to a situation where the network members all think in the same way and may believe they are doing well while they are actually traveling unsustainable pathways. Organized crime groups and youth gangs are among groups exhibiting high levels of bonding, but low levels of long-term resilience. The rise of the Nazi party in Germany was accompanied by increases in standard measures of bonding social capital.[29] In Russia and China, blat and guanxi refer to a very intensive bonding social capital where participants can make virtually

[14] Aldridge and Halpern, 1998; Gittell and Vidal, 1998; LRDP, 2001; EFILWC, 2005
[15] Brown et al., 2002
[16] Vargas-Cetina, 2005
[17] Worstell, 1995
[18] Worstell, 2002
[19] Sarkar and Singh, 2006
[20] Flora and Flora, 1993; and Greenfield and Strickon, 1981
[21] Kenworthy, 1997
[22] Frank and Wellman, 1998
[23] Flap and Boxman, 2001
[24] Bian, 1998; Lin, 1999; Smart, 1993
[25] Burt, 1997, 1999
[26] Putnam, 2000
[27] Loewen, 1972
[28] Pieterse, 2003
[29] Satyanath et al., 2014. Bowling for fascism. http://www.anderson.ucla.edu/faculty/nico.v/Research/Bowling_for_Fascism.pdf

unlimited demands on each other leading to corruption and non-resilient allocation of resources.[30] Though, Crony capitalism including lobbying for support of commodity payments is a result of linking, bridging and bonding social capital which enables systems to expand at the expense of long term system resilience.

Necessary but not sufficient. Some contend that high levels of bonding social capital, when accompanied by high levels bridging and linking social capital will result in high levels of resilience.[31] The case studies and database analysis shown in this study indicate social capital is just one of the factors required for resilience. However, when such social capital is combined with the other factors we discuss, resilience is vastly enhanced.

In natural ecosystems and early theories[32], change toward more resilient systems is stimulated by crisis or disturbance. Natural systems don't change unless they have to. Human systems can change toward more resilient social ecological systems without a crisis, but often with a paradigm shift which is facilitated by linking, bridging and bonding social capital.[33] Carlisle chronicled a group of grain farmers, organized around a resilience perspective, who faced the same problems of drought and debt as their neighbors. However, this producer group embraced a more ecologically integrated approach. To experience this shift, producers needed a theory, not just a problem. The theory was supplied through their bridging and linking connections. Farmers re-oriented their focus from maximizing the exchange value of resources leaving the system to sustaining and renewing the value of resources remaining in the system (see Building Assets chapter). As shown in our case studies, the resilient farmers diversified their markets and built up their soil, water and processing assets.[34] Social capital, however, was just one of the components needed to engender resilience.

Some sustainability and resilience advocates contend that broadening participation is key to resilience. Though this is an admirable goal, much empirical research shows broadening participation can only result in increased resilience if other required factors are also present. In fact, broadening participation may bring in people who thwart resilience.[35]

Tempering connectivity with modularity. Too much connectivity (whether bridging and linking or other) can be a problem. Limited connectivity can sometimes boost the resilience of an ecosystem service by acting as a barrier to the spread of disturbances such as a forest fire. An overly connected system may reduce the probability of population survival when all populations are affected by the same disturbance, for instance a fire or disease. A social-ecological examples is the loss of electricity across the eastern USA and Canada in 2003, which affected some 50 million people, and occurred when local failures in a highly connected system eventually led to a total, systemic collapse.

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[30] Michailova, S, Worm, V 2003. Personal networking in Russia and China: Blat and Guanxi. European Management Journal, 21: 509-19.
[31] Frankenberger et al., ibid.
[32] Walker, J., and M. Cooper. 2011. Genealogies of resilience from systems ecology to the political economy of crisis adaptation. Security Dialogue 42(2):143–160. http://dx.doi.org/10.1177/0967010611399616
[33] Carlisle, L. 2014 Diversity, flexibility and the resilience effect. Ecology and Society 19:45.
[34] Carlisle, ibid.
[35] Reflecting the modular connectivity principle, participation must be limited. Some potential participants will undermine the process toward resilience. Ss in much of the path toward resilience, we must embrace contradictory approaches. However, most resilience researchers would stress the general principle of broadening participation for public consumption. See Stockholm Resilience Center, ibid.

Just as high connectivity across a landscape can increase the risk for simultaneous exposure to a disturbance, well-connected actors with similar types of knowledge, and preferences for immediate gains rather than long-term resilience can lead to negative outcomes. Stock market and real estate bubbles can be some of the results.

Modularity helps contain disturbances by compartmentalizing social-ecological systems whereas over-connectivity can be associated with the collapse of systems. Modularity, the ability to close down connections, denying connectivity, prevents the collapse that unbridled connectivity permits. Modularity contains disturbances by separating social-ecological systems from each other, e.g. land management with prescribed fire that uses firebreaks to limit the spread of the fire. Similarly, quarantine mechanisms may restrict the spread of epidemics or invasive species.

Modularity, by preserving populations, assist in regeneration following disturbance. For example, where populations are too closely connected, severe disturbances to one population (such as oil spills, hurricanes, or disease) may affect all populations. However, where populations are separated in space, disturbances to some will not impact all, and unaffected populations may provide important regional sources of seed stock and other materials for recovery.

Modularity requires the ability to be independent. Systems must be able to survive with reduced external input in order to keep a disturbance outside. Farmers who can produce their own transplants won't get disease from transplants grown elsewhere. Creation of fertilizer on the farm rather than relying on outside suppliers is perhaps one of the most poignant examples of independence today. So much of agriculture relies on the total connectedness of farmer to purchaser, farmer to seed supplier, farmer to chemical company, farmer to….. With reliance on so many external system to uphold the farm, it becomes increasingly vulnerable, especially when required to enter restrictive contracts that often consider on farm assets as collateral. With increases in weather extremes and the fluctuation of water availability to many parts of the world it is increasingly likely that a crop failure could occur. This single failure, perhaps by no fault of the farmer, could spell the end of his career based on seizure of his assets. This is clearly an example of connectivity gone awry.

The relationship between connectivity and resilience is characterized by a threshold effect. Connectivity contributes to resilience up until a certain point at which a degree of modularity can prevent revolt in a system and a shift to an alternative stable state.

In other cases, openness of a social-ecological system might be the key to general resilience, e.g. seed dispersal as a key to recovery from large infrequent forest fires. Hence, there are a number of trade-offs between modularity and connectivity that is well understood for some social-ecological systems, but not for others.

Connectivity and redundancy. Successful networks support and stimulate each other. In resilient systems, this support of networks leads to what ecologists call redundancy. Redundancy builds out of networks. The resilient system is always using modular connectivity to build redundancy. A network of similar enterprises helps each other overcome constraints and disturbances which might destroy a farm or company of any system operating on its own. The redundancy chapter (Who's got your back?) explores this in more detail.

Feedback and connectivity in complex adaptive systems. Feedbacks are the two-way 'connectors' between variables that can either reinforce (positive feedback) or dampen (negative feedback) change. An example of reinforcing feedback is introduced grasses in Hawaii that catch fire easily, which promote further growth of the grasses and curb the growth of native shrub species. More grass leads to more fire which, in turn, leads to more grass. This becomes a loop and self-reinforcing feedback. An example of a dampening feedback is high body temperature causing the body to sweat leading to decreased body temperature.

In many situations negative feedback does not occur quickly enough to change a system before resilience is radically reduced. Imagine an ecosystem such as a freshwater lake that provides you with readily accessible drinking water. The quality of this water is linked to slowly changing variables such as the phosphorus concentration in the sediment, which is in turn linked to fertilizer runoff into the lake. These "slow variables" do not have tight, quick feedback to the farmers applying phosphate to their fields. Similarly, when we import goods from overseas, often we don't know how it was produced or the deleterious effects on social ecological systems from its production. This lack of tight feedback can result in change in the slow variables of pollution and worker degradation which stifle resilience.

In the social domain, values and traditions can also be important slow variables. They can affect existing ecosystem services, for instance, through agricultural practices, such as when and how much fertilizer is used in the fields surrounding a lake. When these values and traditions change (e.g., through paradigm shifts to more ecological integration), slow variables eventually see the effect.

In most cases, dampening feedback helps to counteract disturbance and change so that the system recovers and keeps working in the same way, producing the same set of ecosystem services.

An example of this is the shift from clear to algae-dominated water in shallow lakes. Clear water shallow lakes usually have many rooted plants growing on the lake floor. These plants absorb phosphorous and nitrogen runoff from agricultural and urban development in the surrounding catchment and help to keep the water clear.

However, there is a limit to how much disturbance or change a system can be exposed to before they are overwhelmed. The system may then become configured in a different way. In the case of the lake, increasing agriculture in the surrounding area might result in phosphorous and nitrogen levels in the water that eventually exceed the absorptive capacity of the plants. Once this threshold is crossed, excess nutrients in the water lead to growth of free-floating algae. The algae in turn reduce light penetration, gradually leading to the death of the rooted vegetation and the loss of the dampening feedback they provided. Restoring a clear water regime usually requires repeated manual removal of algae, and the reduction of nutrient runoff to a level far lower than what it was before the regime shift occurred. Only then may the rooted plants re-establish themselves and help recreate a clear water regime.

Complex adaptive systems and feedback. The feedback loops discussed above are simplified. As discussed in earlier chapters, biological and social systems are self-organizing systems that adjust and reorganize in response to disturbance and change, such as floods, hurricanes, fires, invasive species, or immigration of species.

These complex adaptive systems are composed of complex adaptive systems which are continuously changing and adapting to the other systems they are in contact with. The key challenge in managing slow variables and feedback is identifying the slow variables and feedbacks that maintain the social-ecological regimes which produce desired ecosystem services. Since all systems are adapting and changing as complex adaptive systems, unforeseen consequences are ubiquitous. Intensive experience in the system is required to identify key feedback systems which must be enhanced to insure resilience.

Limiting fishing around coral reefs did not result in increase of fish which graze on plants competing with coral until researchers recognized that these fish were hatched and spent their youth away from the coral near shore. When these areas were protected, the abundance of herbivorous fish controlled competing plants and enabled resilience of the coral.[36]

Feedback and nonverbal communication. Feedback is a type of communication. In social ecological systems, communication between people is crucial. Lack of understanding of feedback from key stakeholders in a social ecological system can stymie efforts to increase resilience. Much communication is beyond words and those who don't read these nonverbal cues may be unable to facilitate resilience. The constant adaptation and change of complex adaptive systems means a misinterpretation of nonverbal behavior can destroy progress toward resilience. Individual differences in nonverbal communication skills have been quantified as emotional intelligence.[37] Most nonhuman communication is nonverbal and other organisms must be very adept at it to be resilient. Nonverbal skills and abilities are important in initiating and maintaining social interaction, developing interpersonal relationships, and managing impressions. Nonverbal skills and abilities are also linked to stress management. Most importantly, nonverbal skills can be learned and improved. For example, research on deception detection suggests that this decoding ability improves by providing feedback concerning performance and accuracy and with practice.[38]

The foundations of community resilience. Though controversial and outside the mainstream of evolutionary research, increasingly many contend that ecological communities are the units which survive extinction events and recover from them. [39] Charles Darwin described the sterility of certain castes of social insects, and more generally, the reproductive self-sacrifice such organisms represented, as "one special difficulty, which at first appeared to me insuperable, and actually fatal to my whole theory." In the 1960's, W.D. Hamilton proposed the theory of "kin selection," which offered a brilliantly simple explanation for such altruistic behavior. Hamilton recognized the importance of a measure he called inclusive fitness, which incorporates both the individual's personal reproduction (classical fitness) and its influence on the reproduction of collateral relatives. The essentials of kin selection and inclusive fitness are summarized according to a simple equation, called "Hamilton's Rule," which is expressed: $C/B < b$. "This says that the cost C (which is the loss in expected personal reproductive success through the self-sacrificing behavior) divided by the benefit B (the increase in the relatives' expected reproductive success) must be less than b, the probability that the relatives have the same allele," if the altruist gene is to survive natural selection.

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[36] Adam et al., ibid.
[37] Goleman, D. (1995). Emotional intelligence. Bantam.
[38] Riggio, R., 2006. Nonverbal skills and abilities. SAGE Handbook of Nonverbal Communication Ed. Manusov and Patterson. Sage.
[39] Though controversial and outside the mainstream of evolutionary research, increasingly many contend that ecological communities are the units which survive extinction events and recover from them. More detail is available at Roopnarine, P. and Angielczyk, 2015. Community stability and selective extinction during Earth's greatest mass extinction doi: http://dx.doi.org/10.1101/014688 .

If, for example, an individual had the choice of saving his own life or the lives of two sisters or eight cousins then the survival of the fittest theory should be indifferent about the choice as they will save the same number of genes. But on the other hand if I could save three sisters instead or nine of my cousins then the theory would favor the self-sacrificial act, "saving my kin rather than saving my skin!"

The idea of the "fittest" in Darwin's theory is the ability of an individual to survive and reproduce and therefore to pass on some of their genes. If a mother gives up her life for her offspring, the mother ceases to exist. But, from another point of view, the mother continues to live on in her child, genetically. Although the mother as an individual has not benefited from her altruism, half of her genetic code survives.

This new definition of fitness shifts the focus from individual fitness to family fitness, which takes into account the survival of an individual's relatives. Evolution is no longer seen simply to be a process of individual selection, but also one of family selection.

Certain small birds, robins, thrushes and titmice, for example, warn others of the approach of a hawk. They crouch low and emit a distinctive thin, reedy whistle. Although the warning call has acoustic properties that make its source difficult to locate in space, to whistle at all seems at the very least unselfish; the caller would be wiser not to betray its presence but rather to remain silent. The bonding connectivity underlying resilience is the foundation for resilience of communities.

Cooperation and altruism even in algae? The cooperation and even altruism found in tightly bonded human groups is found throughout Nature. Volvox is a green algae which lives in colonies of up to 50,000 cells. Volvox colonies have a division of labor. Most permanently renounce reproducing themselves to take on other jobs, such as moving the group around by swimming. A similar division occurs in most multi-cellular creatures: their cells are either "germ" cells—reproducers such as sperm and eggs—or "somatic" cells, all the others, which leave no heirs after the individual dies. This can be seen as a profound form of altruism. By not reproducing, somatic cells commit evolutionary suicide to benefit the group. Something similar also occurs in insect colonies, which often have sterile "worker" castes.

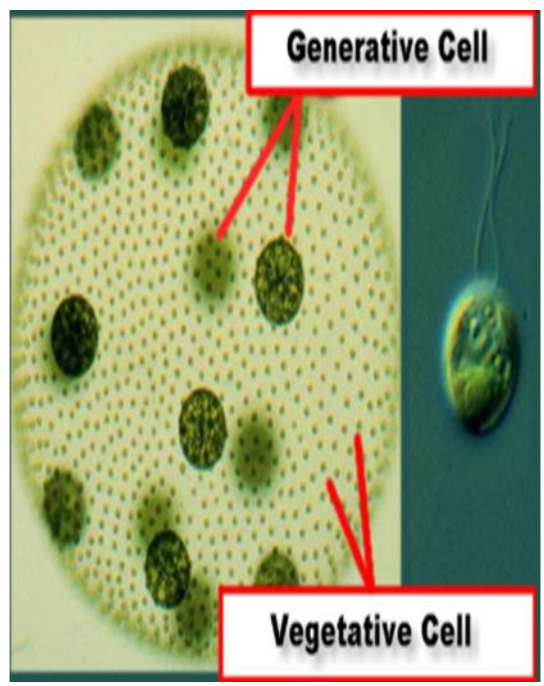

Figure 3. Vegetative cells of algae sacrifice themselves so generative cells have enough resources to reproduce.

In Volvox, biologists have found that a gene called RegA causes this "reproductive altruism." RegA suppresses cell growth. Because a cell must grow a certain amount to reproduce, RegA also ends its reproductive career. Both germ and somatic cells have the gene, but in germ cells it's inactive.

To trace RegA's ancestry, researchers hunted for genes similar to RegA in a one-celled creature, Chlamydomonas reinhardtii, believed to be closely related to Volvox's single-celled ancestor. The most similar DNA sequence they identified was one called Crsc13. It also suppresses cell growth, they found, but apparently for a different reason—to help the cell through lean times.

C. reinhardtii, like plants, conducts photosynthesis: it uses light energy to build sugars needed to live. In darkness, the researchers found, Crsc13 goes into action. Since photosynthesis can't occur in the dark, the gene blocks the assembly of chloroplasts, tiny compartments where photosynthesis occurs. Crsc13 thus prevents "unnecessary investment" in temporarily useless activities, saving resources for more essential work.

In Volvox, evolution apparently co-opted the gene for the grander goal of cellular cooperation. This transformation may have required no change in the gene itself; all that needed to change was the way it was activated and inactivated. Every organism has this ability to switch genes on and off. It's often accomplished by coating the relevant DNA with specialized molecules blocking its use.

In evolutionary terms, there may be no fundamental difference between altruism in Volvox and the generosity that inspires people to give, say, to charity. Both might ultimately stem from similar mechanisms. Any gene that allows someone to delay gratification for future benefits, might be co-opted by evolution to shift those benefits to others instead. Variable or stressful environments may encourage this process according to the authors of the study. Periodic hardship frequently spurs the evolution of survival mechanisms that involve suppressing biological activities, like Crsc13. [40] In tough times, people often come together; so do many smaller organisms.

Resilience and cooperation. In humans and apes, cooperative behavior extends beyond the family. While hanging laundry, researchers "accidentally" dropped a clothespin out of reach. Stretch as he might, he couldn't grab it. He even cried out, "My pin!" A young chimpanzee sitting nearby picked up on the distress and retrieved the clothespin.

Since the chimp received no reward, or even a "thank you," this experiment indicates chimps can be altruistic, a quality many scientists thought only humans possessed. Researchers performed the same experiment with human infants and found them equally helpful. Interestingly, if researchers threw the pin deliberately, neither chimps nor humans would pick it up. They only retrieved it if they could infer that Warneken needed it to complete his task. The researchers went on to investigate more complicated tasks, such as retrieving an object from a box with a flap. Children and chimpanzees are both willing to help, but they appear to differ in their ability to interpret the other's need for help in different situations. When the scientists accidentally dropped a spoon inside, and pretended they did not know about the flap, the children helped retrieve it. They only did this if they believed the spoon had not been dropped deliberately.

The tasks were repeated with three young chimpanzees that had been raised in captivity. The chimps did not help in more complex tasks such as the box experiment, but did assist the human looking after them in simple tasks such as reaching for a lost object. While infants helped on a variety of tasks, the chimps weren't as willing to help with some of the more difficult chores.

[40] Nedelcu, A. and Michod, R., 2006. The evolutionary origin of an altruistic gene. Molecular Biology and Evolution, 23: 1460-1464.

Situations were set up in which an adult did things like hold out a basket in which the infant was asked to place a toy. After the infant complied, in the test for role reversal, the adult placed the basket within the infant's reach and held up the toy herself. All 18 month olds and even some of the 12-month-olds spontaneously held out the basket for the adult while at the same time looking to her face, presumably in anticipation of her placing the toy inside. Chimps never do this. [41]

Altruism as an innate instinct has limits in application. Rhesus monkeys were given a lever which dispensed food but at the same time as dispensing food, it gave the monkey in the next cage an electrical shock. The monkeys with access to the 'shocking' food levers would not pull the lever, foregoing food for many days, rather than give the monkey next door a shock. However, the monkey was less likely to refrain from pulling the lever if another species of animal (a rabbit for example) was being shocked. Scientists deduced that the monkeys were more altruistic toward animals of their own species rather than animals of different species

Is this the case on a larger scale within human society as we care for our own species more than those around us? Much has been written on the emotional and physical disconnect of humanity from other species, manifesting in animal abuse, overt pollution and degradation of whole ecosystems and general disregard for the long, or short, term health and well-being of species other than our own. It is then a paradigm shift on a larger scale to move towards a more encompassing altruism that embraces our own species as well as others? Farmers of the past and present have seen the soil they tend as a kind of kin, the animals they care for as valuable beyond their monetary gain and the seeds they sow as their own kind of family deserving of care and attention through the growing season. In the working with nature chapter we discuss this more fully, though it's important to realize here the value of integrating our compassion, empathy and subsequent altruism with the earths many ecosystems, species and habitats. It is the recognition of this irrefutable connection that can help us to respond to large scale pollution and habitat destruction with the commitment and energy necessary to the scale of the issues at hand.

Size of group and size of brain. Social intelligence hypothesis posits that complex cognition and enlarged 'executive brains' evolved in response to challenges that are associated with social complexity, The number of social group members a primate can track appears to be limited by the volume of the neocortex region of their brain. This suggests that there is a species-specific index of the social group size, computable from the species' mean neocortex volume. There is a correlation between brain size, particularly the newer frontal lobes, and the size of the social group an animal lives in. This rule works for our primate lineage and, it turns out, also for hyenas: those with the simplest social systems have the tiniest frontal cortices.

The spotted hyena, which lives in the most complex societies, has far and away the largest frontal cortex. The brown and striped hyenas, with intermediate social systems, have intermediate brains. It appears that primates are not unique in the complexity of their social lives. Holekamp and colleagues, who have found an array of complex social behaviors in spotted hyenas that are as complex as those of baboons. The groups are comprised of 60 to 80 individuals who all know each other individually. There are alliances, rivalries, and social hierarchies headed by an alpha female.

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[41] Warneken F, Tomasello M (2006) Altruistic helping in human infants and young chimpanzees. Science 311: 1301-1303.

Using a regression equation on data for 38 primate genera, Dunbar predicted a human "mean group size" of 148 (casually rounded to 150 and today called the Dunbar number).[42] Dunbar then compared this prediction with observable group sizes for humans. Beginning with the assumption that the current mean size of the human neocortex had developed about 250,000 years ago, i.e., during the Pleistocene, Dunbar searched the anthropological and ethnographical literature for census-like group size information for various hunter-gatherer societies, the closest existing approximations to how anthropology reconstructs the Pleistocene societies. Dunbar noted that the groups fell into three categories — small, medium and large, equivalent to bands, cultural lineage groups and tribes — with respective size ranges of 30-50, 100-200 and 500-2500 members each.

Dunbar's surveys of village and tribe sizes also appeared to approximate this predicted value, including 150 as the estimated size of a neolithic farming village; 150 as the splitting point of Hutterite settlements; 200 as the upper bound on the number of academics in a discipline's sub-specialization; 150 as the basic unit size of professional armies in Roman antiquity and in modern times since the 16th century.

Capacity for cooperation requires social learning. However, the large brain of humans does not develop unless it is nurtured in the group. The human brain begins forming very early in prenatal life (just three weeks after conception) and does not complete its growth until adolescence. The brain is far more impressionable (neuroscientists use the term plastic) in early life than in maturity. This plasticity has both a positive and a negative side. On the positive side, it means that young children's brains are more open to learning and enriching influences. On the negative side, it also means that young children's brains are more vulnerable to developmental problems should their environment prove especially impoverished or un-nurturing.

Just as newborn babies are born with a set of very useful instincts for surviving and orienting to their new environment, parents are equally programmed to love and respond to our babies' cues. Most adults (and children) find infants irresistible, and instinctively want to nurture and protect them. It is certainly no accident that the affection most parents feel towards their babies and the kind of attention we most want to shower them with—touching, holding, comforting, rocking, singing and talking to—provide precisely the best kind of stimulation for their growing brains. Because brain development is so heavily dependent on early experience, most babies will receive the right kind of nurturing from their earliest days, through our loving urges and parenting instincts.

Beyond basic development, other stimulation is crucial for developing brain complexity: infants and children who are conversed with, read to, and otherwise engaged in lots of verbal interaction show somewhat more advanced linguistic skills than children who are not as verbally engaged by their caregivers. Because language is fundamental to most of the rest of cognitive development, this simple action—talking and listening to your child—is one of the best ways to make the most of his or her critical brain-building years.

The critical period for learning how to discriminate phonemes in language and process facial emotions is less than 3 years. (A phoneme is the smallest distinct unit of language, such as the "m" of "mat" and the

[42] Dunbar, R., 1992. Neocortex size as a constraint on group size in primates. Journal of Human Evolution, 22: 469–493; Dunbar, R., 1998. The social brain hypothesis. Evolutionary Anthropology, 6: 178–190.

“b” of “bat” in English.) At the beginning of life, babies can hear phonemes from all languages; by year 1, they can only hear phonemes from their own language. By 6-12 months, babies prefer social stimuli (faces, voices, and people) to objects. If the child doesn’t gain experience during this time, or enjoy interacting verbally or nonverbally with others, that can affect his or her social skills later. Basic social skills are acquired early in life that provide the building blocks for more complex social abilities later.[43]

The Bucharest Early Intervention Project allocated a group of two year old children randomly, so that some remained in institutions while others were placed in foster care. Several rounds of studies have been done on these children, who are now in their late teens. Comparing the images of the brains of the children at the ages of two and eight, those who spent their childhoods in orphanages had significantly less developed white matter in at least four parts of the brain. Unsurprisingly, brain regions responsible for emotion are particularly heavily affected, but so are those associated with maintaining attention, executive function and even sensory processing. At the age of eight, children who had once been in the orphanage but were then placed in foster care fell between the other two groups in the state of their white matter. The researchers concluded that their brains more closely resembled those of the children raised by their parents.[44]

It takes a family—and a village and a tribe. Increasingly research in many fields shows that the connections which result in resilience are built on interactions in the family and the group around the family (village, tribe, etc.). Evolutionarily, the unit of selection is not the individual, but the population—or tribe, if you will. No long term resilience is possible without community. The lone individual creating the most ecologically sound farm will see it perish when he leaves. Not only is community required for resilience, man was built for community.

Measuring the modular connectivity factor of resilience. If you wonder how you rank on this factor of resilience, answer the following questions:

1. Do you share labor or equipment with neighbors?
2. Do you market with neighbors?
3. Are you a member of any cooperative?
    a. Marketing cooperative
    b. Input supply cooperative
4. Do you use several marketing venues?
5. Are you a regular internet user?
6. Are you dependent on a single market outlet?
7. Do you buy from several suppliers?
8. Do you hire others to do your planting and harvest?
9. Do you generate any of your inputs on your farm?
10. If necessary, could you replace some inputs with inputs produced on-farm?

The farmer ranking high on connectivity and modularity will answer yes to all but 6 and 8. The last three address modularity specifically.

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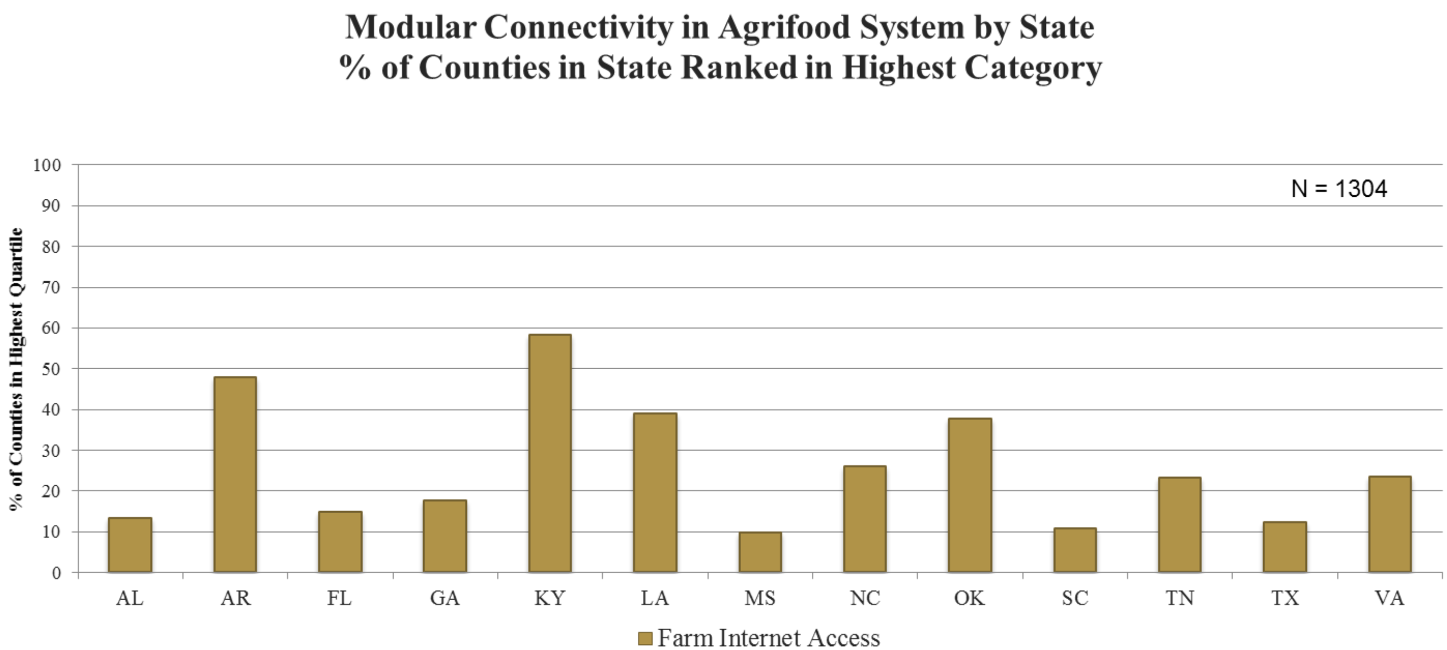
[43] http://www.edpsycinteractive.org/papers/socdev.pdf

[44] http://www.iflscience.com/brain/neglect-childhood-leaves-marks-brain

Secondary databases to measure modular connectivity in the 13 Southern States. At this point in our study of resilience in the 13 Southern states, we have found only one variable related to connectivity with a county-level data base. Results per state are presented in the following chart. See Appendix for methods.



Sources: 2012 Census of Agriculture; extra calculations by the University of Mississippi Center for Population Studies. Scores based on standardized score rankings on: % of farm operations with Internet access. Analysis based on 1304 counties.

Summary. Our ability to connect to one another and our surroundings has been the stalwart of building tribes, villages and communities all the way up to our truly remarkable world networks and enterprises. The fact that as we bond together, combining our collective knowledge and strengths we can effect larger, better and more efficient changes in our surroundings.

It is also true that through our connections we have created remarkably destructive patterns throughout our cultural development. War, tyranny, and exploitation of resources and people are all examples of tasks that require the support of a community.

How, then, can we leverage connectivity in a way that is less destructive to our natural environment, supports our ability to work effectively and communicates the needs of the present to our communities and our world? A monumental task to be sure, but one worth considering on a local, regional scale.

Each of us lives in a unique microcosm of people, abilities and resources that are unlike our neighbors that provide us with an opportunity to reach out for help while also offering something in return. It is this reciprocity that can develop into strong, dependable networks that are resilient, lasting through challenges on both ends.

When challenges arise we must consider our ability to be modular, independent; retracting our connection to a system that is diseased or failing. Whether your farm or business has a hard year, or if the supply chain has a fallout it is through our ability to plan for secession that we create resilience on a farm, or independent business scale. Bearing in mind alternate markets and opportunities that may become more relevant as time passes and your business necessarily changes.

It is this recognition that things *will* change that permeates and guides resilient systems to new life and greater capacity. Recognition that markets will ebb and flow, customer demands will shift, torrential rainfall or drought can wipe out your signature crop. All these things provide you with an opportunity to change, shift and reorganize your resources into a new strategy.

To make these changes fluidly we must be fluid, and well connected. Independent, yet *inter*dependent. Trusting and trustworthy to do your part in absorbing the inevitable shocks so inherent to all living systems.

A unit, connected to the greater system.