The Complexity of Diversity: Rethinking Gaps and Leveraging Differences

SUMMARY OF PRESENTATIONS

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University of Michigan, Palmer Commons

Note: The following notes were compiled by designated scribes at the conference and pulled together afterwards by editors at the NCID. Although this document endeavors to capture the essence of each expert's presentation, researchers should contact speakers and review their related publications to access these studies more fully.

Part 1
Diversity Within a Complex Adaptive System

Atoms interact to become cells, diverse cells become people, and diverse people become societies. The new sciences of complexity give us a way to understand these interactions.

Complex adaptive systems consist of “agents” that differ from one another and interact in space over time. The diverse parts may interact to produce “emergent phenomena”— higher order structures, patterns, and functions than might not have been predicted just by considering the parts that comprise them.

Agents learn various strategies to adapt to their local and global environments. Population pressures and the system filter out the less successful strategies. In a system that is robust, enough variety remains to withstand “shocks” to the system, allowing for continuing functioning or adaptation to new conditions.

Scholars of complex adaptive systems agree on the necessity of diversity for complexity. Complexity arises from accumulating, interacting, and adapting differences. For this reason, complex systems scholars see diversity as something to be encouraged and nurtured. They recognize, too, that they themselves are diverse agents, bringing different ways of framing questions and discipline-specific tools to understandings of diversity.

Complex Systems: An Introduction
Michael Cohen, University of Michigan

We can't control complexity, but we can work with it and potentially steer it in the general direction we want to go. We also can't eliminate complexity.

While there is no theory of complex systems, it does provide a framework to generate several fruitful questions about diversity:

- In a given context, what is the right balance between variety and uniformity?
- What should interact with what, and when?
- Which agents or strategies should be copied or destroyed (selected)?

Variation, interaction, and selection are key concepts in understanding complex systems. For the colloquium's exploration of diversity, variation is the most relevant concept, but interaction and selection are also important because those concepts lead to considerations of what one does with variety.

In a complex system, a population of agents and their strategies interact. The things that are of interest to researchers of complexity are the processes that create variation in types of agents and strategies, the patterns of interaction among agents, and processes of selection that influence which agents and strategies will become more frequent.

"Complexity" in a system is evident in feedback loops and difficulty in predicting outcomes. The relationships among the parts can be nonlinear—no simple one-to-one relationship, constantly increasing or decreasing over time. Here is an example of feedback: VHS gains a foothold in the market, which makes it advantageous for a new consumer to buy a VHS recorder, which makes VHS more popular.

Human tampering with complex ecosystems has lead to notable failures to predict outcomes. For example, when 24 rabbits were released onto Australian estate for hunting in 1859, no one predicted there would be 600 million rabbits in 1950.

Looking in more detail at the three important questions, the first focus is on variety. What is the right balance between variety and homogeneity? Diversity is not always beneficial; sometimes variety makes things worse.

Variety may have complex outcomes. Consider the composition of districts in the House of Representatives. In the 1950s there were many districts with a 50/50 voting split between Democrats and Republicans. Now, the distribution is bimodal; many districts are solidly Democratic or solidly Republican. This has two effects:

1. The House is more diverse, but the districts are more homogenous. This moves discourse from within districts, to within the house.
2. Large swings in public opinion used to have a large effect on the composition of the House because many districts would swing one way or the other. Now, large swings seldom have a large effect on the

composition of the house. There is a dampening of the amplification of public opinion to the representative body.

Another example where variety is employed is in open source software, such as the Linux operating system, where the code is available to all and anyone can change it. Using an army of 10,000 volunteers who don't necessarily know each other might seem to be a bad way to design something as complex as an operating system. But the "many eyeballs" approach to solving a problem is one that has been successful in producing a very stable system.

It is precisely this kind of problem —a complex one— that yields best to bottom-up solutions involving many diverse individuals.

The success of bottom-up approaches depends on a good selection system, and it highlights a related issue in problem solving. When is it best to explore, or try radically new and innovative solutions? And when is it best to exploit, or build off of previously successful solutions in small increments?

It is best to explore under the following conditions:

1. The problem is long-term or widespread.
2. There is fast feedback on variations tried. Problems like education and monetary policy are poor choices for exploration because there is an extraordinarily long lag between implementing a trial solution and seeing the outcome.
3. There is a low risk of catastrophe or looming disaster; you've got nothing to lose.

The second major concept for a complex system is interaction. Who should be interacting with whom and when? What is the right kind of interaction, and how much is too much interaction? For example, in efforts to model the spread of a disease, it matters who interacts with whom and how often. If you assume random interactions, you may get a radically different result than if you model interactions more realistically.

A third area of inquiry is selection. Which types of agents and strategies should be copied or encouraged? The game of chess is a helpful example. You can't see to the end of the game, so you use appropriate indicators instead. You learn over time what strategies work well, select those, and let others fall by the wayside.

A pitfall in selection is misattributing group success to the individual. One player's extraordinary success may have more to do with the group composition than his individual attributes.

A complex systems framework suggests new questions for organizational designers, such as how to manage variation as in “exploration versus exploitation,” how to find high-leverage points of intervention in interaction patterns, and how to thoughtfully orchestrate selection of both the agents in the organization and strategies they use in interactions.

The harder it is to predict the outcomes, the more useful the complex system framework becomes.

Diversity in Complex Systems

Scott Page, University of Michigan

Diversity offers the promise of different perspectives or ways of thinking about how things work. This is important because some problems that are easy to solve in one way may be difficult or impossible to solve when approached another way. As a rule, diverse perspectives create more ways of looking at the problem and therefore more solutions.

Diversity vs. Ability: A Test

Suppose you set up some artificial problem-solving agents, with different sets of tools, and rank their ability to solve a particular problem. You might think of this as their “IQ.” Now suppose you create two groups: one group with only those who rated high on the IQ scale, and one group with some morons in it. You have them solve problems. On some problems, the diverse group performs better than the high-ability group.

This phenomenon can be explained by diversity. People who are good at solving a particular problem (or set of problems) will often have the same tools. The moron in this example happened to have some different tools, which were helpful when combined with those of his group members. Although a diverse group is not always better, under certain conditions it is.

A toolbox analogy helps address the question of why some disciplines in the academy seem to value diversity more than other disciplines do. Think of people as a collection of tools, rather than an IQ value. This approach makes ranking difficult. Suppose we consider person A to be more highly ranked than person B if B's tools are a subset of A's. If tools are randomly possessed, then the chance of such a subset occurring is extremely small.

However, when tools are ordered, that is, on a ladder of increasing difficulty (first you learn to speak your language, then read a second language, then speak it brokenly, then speak it fluently, etc;), then the chance of one set of tools being a subset of another is 1. If we suppose multiple ladders — a math ladder, an intuition ladder, a verbal communication ladder, and so forth— then the probability is somewhere in between.

We segregate ourselves within the academy. In those disciplines where there is really only one ladder (math, physics, economics), people have a tendency to believe that individuals can be easily ranked. But in disciplines with many ladders (English, history, philosophy), there is a tendency to believe that people can't be ranked. Those in the many-ladder disciplines tend to value diversity more than those in the single-ladder disciplines. Interdisciplinarians see all of the ladders, so they are also more likely to value diversity.

Diversity: A Weapon of Mass Construction

Norman Johnson, Los Alamos National Labs

Self-organizing collectives can achieve higher performance and robustness than systems structured by “rule books” of optimal procedures. Collective synergy among a diverse group of agents is what is important. People may start out in different places, with different goals, but they join together temporarily in order to advance all of their causes. As each person independently pursues his or her goals, the paths to achieving those goals overlap, and the synergy of their work provides the solution.

Ants solve difficult problems, such as finding the shortest distance between their nest and food, collectively. No one ant takes the "best" path, but in aggregate they do. This collective solution only works if there is a diverse group of ants. There is no one agent that was “fittest.” Unlike natural selection, it is not a competition. Success depends upon the synergy of the group.

This collective synergy contrasts with Cohen’s perspectives on the role of diversity in a complex system. There, individual performance benefits the whole through the process of selection, which enables diverse collectives to perform better and avoid being misled by misinformation. Performance from synergistic diversity has a “sweet spot.” In the case of such synergy, a collective may function in three ways: 1) A collective may select a strategy at the individual level. 2) A few members may be selected but the others are eliminated. 3) It may achieve performance but at the expense of some members of the collective.

Finally, a system may use optimization where all operate from the same “rule book.” Optimization sacrifices robustness for performance. When there is a change in conditions, the “rule book” may no longer work, and there may be no agents using alternative strategies that work under the new conditions. An "optimized system,” in which every agent uses the same rules, can be less robust. It may also be less efficient. If all ants take the same shortest path, then they may slow the entire system down. If the system is perturbed, the old way of doing things may no longer be optimal. If methods are institutionalized, and there are no individuals exploring deviations from the institutionalized path, over time, with many perturbations, you may end up with an archaic system that is no longer optimal at all.

Diversity in a collective is bounded by individual performance and diversity. Competition, optimization, and stress can all reduce diversity and performance. Under stress, individuals in a collective may copy each other's strategies, leading to a reduction in diversity and performance. Cooperation is a form of exclusion. There is a trade-off between cooperation and diversity.

Diversity can lead to synergy when collectives have:

- Common goals
- Common identity
- Common worldview (agreement on options), but with different preferences or goals

Otherwise, diversity can lead to competition and conflict.

Identity is an emergent property of the collective due to a common environment with problems in common. Identity can be defined as "If someone does something to someone in your group, it is as if they did it to you." Once the identity is formed, the commonality is no longer needed, and the identity of the group may survive despite changing circumstances.

In a more complex world, it is more likely that individuals will belong to multiple groups, and which group they identify with will depend on the situation. Conflict may be reduced by appealing to a secondary identity--for example, bringing Palestinian and Israeli women together to reduce conflict between the groups, appealing to their common identities as women rather than their differing political identities.

Emergent collective problem solving is missing in evolutionary theories, as well as social theories.

Biodiversity

John Vandermeer and Ivette Perfecto, University of Michigan

In the 1970s, ecologists helped popularize the idea of diversity as a positive thing—"the more diverse, the more stable the ecosystem." However, a more complex picture of the role of diversity has emerged over the decades of research since. This presentation centers on biodiversity, drawing upon ecosystems research. It does not imply any conclusions for human diversity.

Ecologists divide ecosystems into niches occupied by individual species adapted to those conditions. Fundamental niches are those where a species is able to live. Realized niches are where they live once all inter-species interactions are worked out. The concept of "competitive exclusion" holds that no two species may occupy the same niche. More precisely: if competition is too extreme, then one species must be eliminated.

Selection against those who live in a place where individuals compete for resources leads to the narrowing of niches to eliminate competition. But then another species can come in and take advantage of the niche opened by the narrowed distributions of the other species. However, there is a mathematical limit to how many species can be packed into a system.

Following the "spider web hypothesis"—more connections makes a web more stable—biologists used to think that having more species leads to greater ecosystem stability. But that is contrary to species packing. In fact, as more species are added, there is more overlap between niches, which leads to greater instability. All other things being equal, more species leads to greater instability.

Ecologists have revised their concept of stability. It used to be thought of as a fixed point, either stable or unstable. Now ecologists recognize that it can also be limit cycles--stable patterns of population fluctuations.

Diversity, rather than just emerging from the bottom up, may also be controlled from above. In a mowed field, there is greater diversity than in an unmowed field because the mowing cuts down the fastest-growing plants that would otherwise overrun the area and gives more species a chance to grow.

Likewise, it is possible for a predator to control diversity from above. The predators usually prey on one species. The rise and fall of the predator and prey populations are linked. Occasionally predators prey on another species. Think of the ecosystems as large collections of linked population changes. This leads to extremely complex behavior that you wouldn't see if you looked at each species in isolation.

For example, consider three species with overlapping niches, and three predators that occasionally prey on the wrong species. The population dynamics of species 1 and 3 (the ones that don't share a niche) track each other very closely. Species 2, which competes with both other species for resources, would have normally been driven out. It remains because it takes advantage of the times when species 1 and 3 have low population density because of predation.

So why we do we want biodiversity? Diversity seems desirable. Ants offered bundles of twigs will choose the bundle made up of a variety of types of twigs over bundles composed of only one tree type.

But what good is biodiversity? Why do we want to maintain it? There are many functions of ecosystems — productivity, decomposition, nutrient cycling, pest control and others —so measuring how well an ecosystem "functions" can be difficult to define, which is why most studies focus on agricultural systems where measuring function is measuring productivity.

The question is usually framed as the following: does increased biodiversity lead to increased productivity? Most studies indicate that an ecosystem's loss of diversity leads to reduced productivity, but the debate is in separating out the sampling effects. Diverse communities may just have larger plants, and thus productivity may not be a result of diversity per se. In managed ecosystems, such as coffee plantations or rice paddies, researchers show benefits to species diversity.

Researchers convinced farmers in China to use both disease-resistant and non-disease-resistant varieties of rice in their paddies. There were significant declines in disease in plots planted with more than one variety compared to monocultures.

Perfecto's research on coffee plantations also points to benefits from diversity. Take two types of coffee plantations: ones with low diversity of shade plants and ones with high diversity of shade plants. There is a higher diversity of bird species in the high diversity systems. Birds prey on herbivore insect pupae. Researchers simulated a pest outbreak by netting some trees to prevent the birds from reaching the insects. They wanted to see whether the birds in diverse plantations have more of an effect on the insects than those in the less diverse plantations. In the low-diversity plantations, birds have no effect on pest levels. In high-diversity plantations, birds had a significant effect on insect populations.

In managed ecosystems, then, there are measurable benefits to greater diversity.