29

SUNDAY
13:30-14:30

Kyoto University Clock
Tower Centennial Hall

COMMEMORATIVE LECTURE II

Unity from Division: In Search of A Collective *Kokoro*

Protecting our environmental heritage in a global community, and achieving cooperation among all peoples

SIMON ASHER LEVIN
Ecologist; Professor, Princeton University
The 2005 Kyoto Prize Laureate in Basic Sciences

TWO CONFLICTING TENDENCIES can be seen throughout the biological world: individuality and collective behavior. Natural selection operates on adifferences among individuals, rewarding those who perform better. Nonetheless, even within this milieu, cooperation arises, and the repeated emergence of multicellularity is the most striking example. The same tendencies are played out at higher levels, as individuals cooperate in groups, which compete with other such groups. Most of our environmental and other challenges can be traced to such conflict, and to the unwillingness of individual agents to take account of the greater good. We need to take multicellularity to yet a higher level, and find the collective *Kokoro* that is the only hope for the preservation of the planet.

SPEAKER

SIMON ASHER LEVIN
Ecologist; Professor, Princeton University
The 2005 Kyoto Prize Laureate in Basic Sciences

Born in Baltimore, Maryland, U. S. A., in 1941. After receiving a doctorate in mathematics from University of Maryland, Simon Asher Levin held positions such as Professor of Ecology, Director of Ecosystems Research Center and of Center for Environmental Research at Cornell University; Professor of Biology and Director of Princeton Environmental Institute at Princeton University. At the moment, he serves as Director of Center for Biocomplexity at Princeton University. He established a new field of “spatial ecology” by using mathematical methods in which he specialized. His aim is to understand the complex biosphere comprehensively, difficult with traditional approaches that ignore the multi-level nature of systems. His work gives effective guidelines in environmental conservation, and is making a huge contribution to environmental science. Currently, he is interested in mechanisms sustaining marine biodiversity, battles between antibiotics and pathogens, and in the evolution of cooperation and social norms. He says that we are responsible for our future generations; and, with our limited resources, he wishes more and more people to realize the situation and act in ecological and ethical manners. Awards and prizes he received include the MacArthur Award from the Ecological Society of America, Okubo Lifetime Achievement Award from Japan Association for Mathematical Biology and the Society for Mathematical Biology, and the Dr. A. H. Heineken Prize for Environmental Sciences from the Royal Netherlands Academy of Arts and Sciences. In 2005, he received the Kyoto Prize in Basic Sciences from Inamori Foundation.

Unity from Division: In Search of A Collective *Kokoro*

Protecting our environmental heritage in a global community,
and achieving cooperation among all peoples

SIMON ASHER LEVIN

1.Natural Selection And Evolution: Bringing Order to the Biological World


fig. 1

The great biologist, Theodosius Dobzhansky (fig. 1), wrote that "Nothing makes sense in biology except in the light of evolution." Without question, the theory of evolution through natural selection is the fundamental organizing theme in biology, helping to explain the emergence of phenomenal complexity, the diversity of organisms, and how those organisms become arranged and interrelated in biological communities and ecosystems.

Natural selection is a force, much like gravity (or, in Wallace's (1858) terminology, "a centrifugal governor"). That we still do not understand all of the implications of natural selection, and its interactions with other influences, should be no more surprising than that we do not fully understand all of the implications of how gravity works in situations where diverse bodies exert interacting gravitational forces (fig. 2). In complex ecological communities, natural selection is operating at many levels simultaneously, and the consequences may be impossible to predict, and very sensitive to "frozen accidents."

As an explanatory tool, however, natural selection helps peel away the mysteries of the biological world. The explanatory power of natural selection is in its simplicity: It is little more than a filter, acting on random variation generated by chance events and secular changes in the physical and chemical environment (fig. 3). It is so effective that the basic principles have proved effective in the solution of mathematical optimization problems that are too difficult for explicit solution, and in the practical application to design problems as diverse as drugs and jet engines.

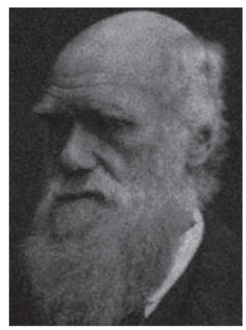
fig. 4

Charles Darwin (1809-1882, fig. 4) is, properly, recognized as the father of the theory of natural selection, although credit must be given as well to his friends, the geologist Charles Lyell (1797-1875), who influenced Darwin greatly, and Alfred Russel Wallace (1823-1913), who proposed his own theory of natural selection in 1858 and thereby induced Darwin to publish his works earlier than he would have otherwise.

Darwin, the naturalist on the five-year voyage of the HMS Beagle, captained by Robert FitzRoy, was able not only to draw pattern from his observations in diverse climes, but to infer process as well. The idea is a simple one: Chance variation (fig. 5) continually produces new variants, some of which are better suited in a changing

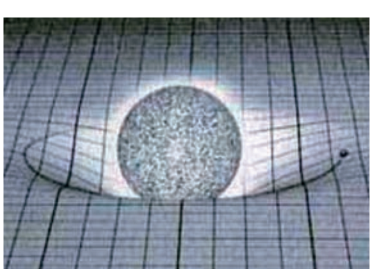
fig. 2

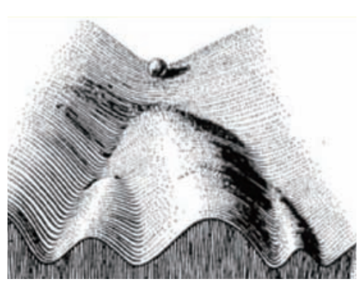
fig. 3


fig. 5

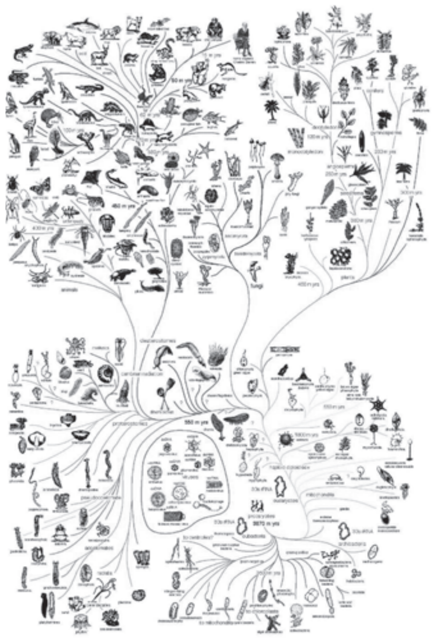

fig. 6

environment than the current common type, leaving more offspring to reproduce. Eventually, those types will replace the current type, only to be replaced themselves in the future. This is a never-ending tale, the inescapable consequence of the simple rule. Different conditions as well as initial evolutionary accidents produce different patterns, allowing the rich diversity of organisms we see today (fig. 6). But change is inevitable, and even the human species evolves, and will continue to evolve. Some changes in all species are minor, such as in hair or skin color; others affect susceptibility to disease and suitability to changing climatic conditions; and others are severe enough that new species arise.

Natural selection can be strong and lead to rapid evolutionary change, as in the evolution of bacteria to resist our antibiotics, or it can be weak and slow. But it is a patient mechanism; and hence, given enough time, even weak selection and slow change can give rise to fantastic diversity, and mystifying complexity. One of the keys to the evolution of complexity is cooperation among diverse types of organisms, which makes essential an understanding of how cooperation arises. As we will see in later sections, cooperation was a challenge for the classical theory, but recent and current research is peeling away the curtains that have obscured clarity.

2. Challenges for the Classical Theory

fig. 7

The theory of evolution through natural selection is, as already discussed, a powerful tool for explaining how change takes place, and how evolutionary improvement occurs. It is sometimes misconstrued as leading to perfection, and in its most naïve form might be thought to lead to a single best type. Indeed, notions that humans represent somehow the pinnacle of evolution seem to arise from such views. But if that were true, there would be no other species but ours, and somehow we would need to derive our nutrients from the sun itself, or from one another. Natural selection, in its simplest clothes, is, after all, a homogenizing process; so how does diversity arise in the first place, and how is it maintained?

The climatic and other conditions across the globe are highly variable (fig. 7), and on many different scales of variation, creating uncountable opportunities for specialization. Microorganisms are nimble and short-lived, and can take advantage of opportunities that we cannot even measure (fig. 8). The first organisms to evolve when Earth began were such simple microorganisms, probably under the surface of the earth, or in the oceans. Over billions of years, their cumulative effects produced increasing levels of oxygen in our atmosphere, and gradually led to the evolution of a greater diversity of organisms, with each layer of complexity building on what had already evolved.

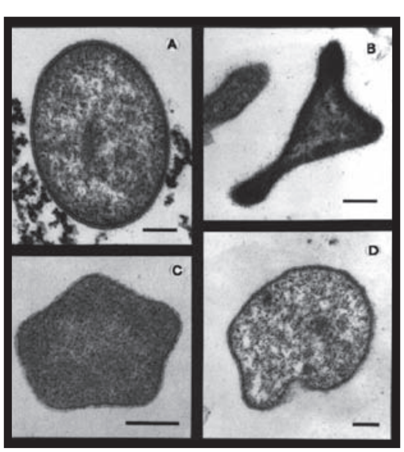

fig. 8

Organisms also became more and more complex, involving different kinds of cells with different basic functions. Humans, of course, are highly differentiated organisms, with specific tissues and organs for performing diverse tasks; but even bacteria have such specialized organelles and parts, such as the cells that serve as propellers to drive them through their fluid environments (fig. 9). Development of organs from groups of tissues is also widespread throughout the animal world, including even the lowly *platyhelminthes* worms. These are all particular examples of *multicellular* organisms, meaning organisms that have more than one cell, including cells differentiated for specific tasks.

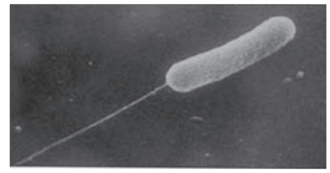

fig. 9

Cooperation and multicellularity. We are multicellular; and, of course, so are most organisms that we can see without a microscope. Multicellular organisms are the most complex in Nature, and how this complexity has arisen has provided another challenge for evolutionary theory. Some complexity arises by the familiar process of mutation or recombination, coupled with selection; however, this "cellularization" (*syncytial*) theory is unlikely to have given rise to much of the multicellularity that we see today. Some of the most complex changes have occurred when organisms have simply engulfed other organisms that could perform particular functions, and then made them part of a new whole. Lynn Margulis, for example, proposed that mitochondria, which are crucial parts of eukaryotic cells, arose by a process of endocytosis (ingestion) of aerobic bacteria (which require oxygen) by anaerobic bacteria (normally unable to live in oxygen-rich environments), creating a permanent partnership. Similarly, she proposed that chloroplasts, which allow plants and eukaryotic algae to photosynthesize, similarly arose when photosynthetic bacteria were ingested.

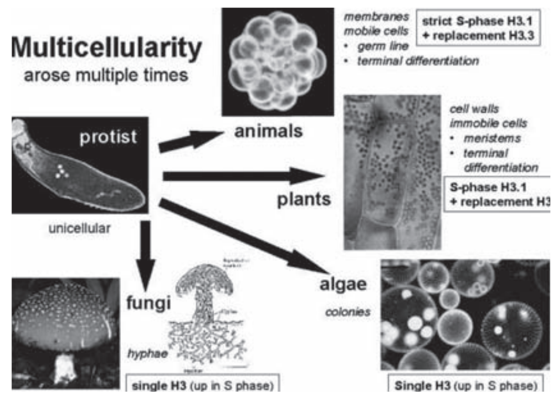

fig. 10

These examples of multicellularity arose (fig. 10), from an initial mutualism between different species. More generally, we know of many such examples of mutualism between species in which the individual reproductive identities have been maintained. Many sea anemones, for example, incorporate single-celled algae, which can photosynthesize and provide oxygen, glucose and other foods to the anemones. Fungi also form symbiotic associations, called lichens, with algae, so that they can derive the benefits of algal photosynthesis, and combine to produce food for the lichen.

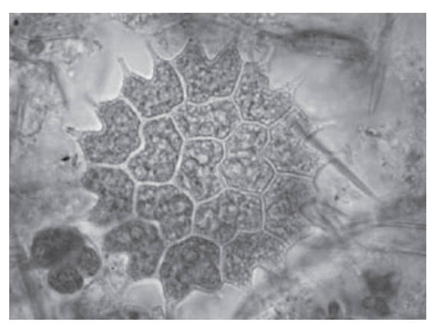

fig. 11

The most prevalent examples of the emergence of multicellularity, however, are probably explained neither by cellularization nor by interspecific mutualisms, but simply from cooperation among members of the same species. This is, for good reasons, termed the *colonial* theory, since it involves individuals "learning" first to live in colonies (fig. 11), before those colonies became integrated wholes over evolutionary time. Biologists have studied this phenomenon at levels from the lowly slime mold to the beehive, from the swarms of insects to schools of fish, from herds of bison and wildebeest to primate troops (fig. 12). In human societies, unfortunately, we are only in the early stages of the development of multicellularity (fig. 13). We cooperate in small groups, but often largely for the purpose of competition and combat with other groups. Unless and until we can learn to get beyond that, and to achieve a multicellular state of mind that encompasses all of humanity, our chances for global survival diminish. Achieving that universal *Kokoro* is the greatest hope for the human future.

3. The Emergence of Cooperation and Competition at Higher Levels of Organization

Cooperation is at the root of multicellularity, and cooperation is central to our addressing our common problems. Yet cooperation seems, at first blush, exactly the opposite of what natural selection — the survival of the fittest — is about. Yet we see cooperation, and indeed altruism, all about us in the animal kingdom. How does this apparent anomaly occur? How does cooperation arise in animal communities, and why does natural selection not only allow it, but even reinforce it?

In the haplodiploid insects — the bees, the ants, and the wasps — most females are sterile workers, giving up their own fitness for the good of the colony (fig. 14). Darwin was puzzled by these situations; in Chapter VIII of his famous *Origin of Species*, he wrote that this paradox "at first appeared to me insuperable, and actually fatal to the whole theory." But Darwin concluded that, although this was the "by far the most serious special difficulty that my theory has encountered," that natural selection could fully account for such extreme altruism, provided selection was operating at a higher level of organization — "the family." In this, he anticipated later solutions to the problem, but without care to the more specific genetic explanations that would come nearly a century later, and after much greater understanding of genetics was available. Darwin, not surprisingly, also recognized the relevance to the central theme of this paper, cooperation among humans: "We can see how useful their production may have been to a social community of ants, on the same principle that the division of labour is useful to civilised man." We will return to this theme shortly.

The great British biologist, J. B. S. Haldane, explained apparent altruism most succinctly, when he said "I'd lay down my life for two brothers or eight cousins." What he meant simply was that, since he shared half his genes with each brother, two brothers together would carry as many of his genes as did he himself. Similarly, since children share half their parents' genes, two first cousins share one-eighth of their genes with one another, so eight cousins are equivalent to two brothers, are equivalent to Haldane himself.

Nowhere is such altruistic behavior more widespread than in the haploidiploid insects. Why should that be? Haplodiploid means that males are haploid — they arise from unfertilized eggs, so only get the genes that their mothers contribute. Females are diploid — they get half their genes from their fathers, and half from their mothers. What that means is that full sisters will share all the genes that they get from their fathers, and half the genes that they get from their mothers; so, overall, they are related in 3/4 of their genes; compare that with the fact that Haldane's sister, Naomi Mitchison, would have shared only 1/2 of her genes with any sisters, or with J. B. S. himself. For a haplodiploid insect, then, there is even greater incentive to be altruistic. The late evolutionary biologist William D. Hamilton, who won the 1993 Kyoto Prize for his insights, worked out the esoteric mathematical details of this idea, called "kin selection."

Kin selection certainly provides insight into why individuals help their kin, but cooperative behavior is much more widespread in animal societies. The simplest explanation for such behavior is called "reciprocal altruism (fig. 15)," in which individuals engage in altruistic acts in the expectation that the favor will be returned at some time in the future. We are, of course, very familiar with such behavior in human societies, and reinforce it by forming friendship bonds, or other such groupings. But very similar behavior can occur even when individuals interact more diffusively within larger groups, as long as there is a reasonable expectation that the beneficiaries will exhibit similar altruistic tendencies. The difficulty is that, as groups get large, that expectation goes down. Groups split into smaller groups in which reciprocal altruism can be maintained , and these groups may then interact competitively and aggressively with other groups.

As our societies have grown larger, the simplest forms of reciprocal altruism have broken down. Over our history, in culture after culture, small tribal groups, held together by reciprocal altruism, have realized that there are benefits to be gained by banding together with other such tribal groups, often in order to compete with yet other such larger groups. At this level, though, reciprocal altruism is not enough, and common rules have had to be agreed upon, together with punishments for violating those rules, often called "social norms." Those rule systems have become formalized as laws and customs, holding together societies and religions. Recent experiments have shown that, over millennia of cultural evolution, individuals have internalized such rules, as well as the willingness to punish defectors, even at cost to the punisher. In the case of religions, the threat of punishment can be especially effective, because it is reserved for a future time, after death, making it impossible to judge whether it really will be imposed.

Social norms can play highly beneficial roles within our societies, prohibiting socially damaging behaviors like theft, adultery and murder, and encouraging respect for our environment. But social norms equally can be damaging, leading to the maintenance of discriminatory caste systems, or leading to overconsumption and the exploitation of environmental resources (fig. 16). My Princeton colleague, Kwame Anthony Appiah, in his book *The Ethics of Identity*, confronts this dilemma by asking, "Is culture a good?" A search for a common *Kokoro* is a search for values and social norms that involve mutual respect, as well as respect for our diverse pasts and common future.

A second challenge, to which I return in the last section, is that groups with common interests and common norms often owe their existence to the fact that these coalitions provide advantages in competition with other groups. Once those external threats disappear, the groups have less reason to exist, and are likely to fragment and turn to internal conflict. Our challenge is to find ways to maintain cooperation in the common good even without the mechanism of competition and conflict with other groups.


fig. 12


fig. 13

4. The Global Commons

Recent years have seen a growing awareness of the deteriorating state of our environment. Our consumptive patterns have led to a toxification of our environment, accelerated climate change, and depleted biodiversity and other natural resources; growing conflicts between peoples are in no small way linked to these changes. Though we are the cause, we stand as observers, seemingly powerless to reverse the effects of our own actions. Why?

The problem is that we live in a Global Commons, in which we bear neither the full costs, nor the full benefits, of our actions. We feel individually only marginally responsible for the world's problems, and that our own sacrifices will do little to improve the situation. Economic markets, counted on by many to resolve problems of shortages, do not work effectively because they ignore the social costs, the externalities.


fig. 14

When we lived in small groups, and when our effects were regionally limited, this was less of a problem. Reciprocal altruism had a chance to work, even without the stimulus of intertribal conflict. As groups became larger, however, globalization increased, and our problems assumed larger and even global scales, their solutions faded further into the distance. Intra-group cooperation remained strong, and nationalism increased; but conflicts among nations made matters worse.


fig. 15


fig. 16

Even in small societies, problems of the commons require work to resolve. In 1832-3, William Forster Lloyd, an Oxford political economist, puzzled about the stunted status of cattle on common pasture areas in England: "Why are the cattle on a common so puny and stunted? Why is the common itself so bare-worn, and cropped so differently from the adjoining inclosures?" The answer, he concluded, was in a microcosm of the problems we face today. As Garrett Hardin explained Lloyd's arguments more than a century later, the commons environment creates a conflict in which there is benefit to the individual to overexploit, but cost to society. "Therein is the tragedy. Each man is locked into a system that compels him to increase his herd without limit — in a world that is limited. Ruin is the destination toward which all men rush, each pursuing his own best interest in a society that believes

fig. 17

"Each man is locked into a system that compels him to increase his herd without limit — in a world that is limited. Ruin is the destination toward which all men rush, each pursuing his own best interest in a society that believes in the freedom of the commons. Freedom in a commons brings ruin to all."

—Garrett Hardin

fig. 18

in the freedom of the commons. Freedom in a commons brings ruin to all." Hardin called this the "Tragedy of the Commons"(fig. 17).

Lloyd's insights caused a sea change in Hardin's thinking, in which he realized that the conventional economic thinking fell short of providing solutions. "With Adam Smith's work as a model, I had assumed that the sum of separate ego-serving decisions would be the best possible one for the population as a whole. But presently I discovered that I agreed much more with William Forster Lloyd's conclusions: Citing what happened to pasturelands left open to many herds of cattle, Lloyd pointed out that, with a resource available to all, the greediest herdsmen would gain — for a while. But mutual ruin was just around the corner. As demand grew in step with population (while supply remained fixed), a time would come when the herdsmen... would be trapped by their own competitive impulses. The unmanaged commons would be ruined by overgrazing; competitive individualism would be helpless to prevent the social disaster.

So must it also be, I realized, with growing human populations when there is a limit to available resources. ...It was so in Lloyd's day; it is even more so today.

These are the challenges we still face today, but they are greater and more compelling than ever before. These are the challenges that require that we find a collective *Kokoro*, built on cooperation and common purpose.

5. Achieving Cooperation at the Highest Levels: A Search for A Collective *Kokoro,* and for the Preservation of the Planet

Cooperation is widespread in the animal kingdom, especially in human societies. Bacteria signal one another, and exchange mutual favors. Amoebae organize themselves into slime molds, insects into swarms, birds into flocks, fish into schools, ungulates into herds. Primates have the most highly developed social organizations of unrelated individuals, relying on highly developed cultural practices to maintain the integrity of those societies.

But the tribes and societies and cultures we build become devices for conflict among groups, and too often it is that conflict and competition that strengthens the membership bonds. When groups come together, it is often because there is a common enemy. How can we get beyond this in achieving the survival of our species, and of our planet?

We must recognize that we have a common enemy, and that enemy is the extinction that awaits us if we do not change our ways. It is war and pollution, it is biodiversity loss and climate change (fig. 18), it is all the things that threaten the quality of our life, as well as our survival. The sooner we recognize this common threat, the sooner we can achieve the cooperation that will bond us all together.

Societies become locked into patterns of behavior

— social norms — that are curiously resistant to change over long periods of time, sometimes centuries; but, just as mysteriously, those patterns of behavior can collapse suddenly, giving rise to sudden change in collective behavior. A famous example involves the practice of foot binding in China, but changes also occur rapidly in patterns of dress, in attitudes towards smoking, and with regard to the role of women in many societies. These transitions are driven by contagious behaviors, as individuals imitate other individuals; but certain individuals occupy positions of key influence, and can trigger such shifts in behavior. This is true not only in human societies, but in almost all animal groupings. The phenomenon has been observed in experimental situations, as well as in theoretical models that explore the relationship between leaders and followers. The remarkable insight is that a very small number of leaders can cause shifts in behaviors of large groups of individuals, and lead them to coordinate their behaviors. Like a collection of self-stimulating pendulums, they easily become synchronized in their actions, a powerful collective force rather than a random collection without communality. This perhaps should not surprise us based on our understanding of human groups. The problem is that those few individuals can as easily lead in bad directions as in good; the models do not discriminate. Our challenge thus is to find the leaders who can take us down the good paths. There are those that argue that we cannot hope to achieve the necessary changes in our societies without laws and punishments imposed from the top down. That may or may not be true, but those top-down constraints will be difficult or impossible to impose if they do not reflect popular movements that lay the groundwork for them. Changing social norms creates the milieu in which bold leadership is possible; it is where we must begin.

We are *Karada* (fig.19), and we are *Kokoro* (fig.20). Modern society involves a conflict between the two, between satisfying our short-term hungers, and our longer-term spirits. *Kokoro* is our heart. *Kokoro* is our mind. *Kokoro* is our spirit. The only path to survival is a path to a collective *Kokoro.*

fig. 19

fig. 20