The Future of the Mind

The New Mind's Eye

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Setting the Stage

What is the significance of being *The Symbolic Species*? What are the consequences of living in *The Interface Culture?* Should we be concerned that *The Singularity is Near*? What is it like to be *Alone Together*, or to be *Wired For Thought*? What does it really mean *When Machines Begin to Think?* What are the implications of *Supersizing The Mind?*[1]

While all of our senses are bombarded with information from our environment, the assault on vision is more intense than any other sense and our vision is supported by more of our neural resources than any other.

Visual information is intense. It encompasses both the specific and the general at the same time. It is both focused and comprehensive. But what if our intense visual absorption—all of those screens we live with and the application of computer-generated information to the mind—actually altered our evolution and led to the evolution of something new? What if these screens, these electronic visual adjuncts, were becoming an extension of the mind—not in the cyborg sense, but in the stream of our own perception? What if, for the first time ever, a species was not simply using the environment, but actually changing the environment in such a way that the environment would, in turn, change the species itself—stimulate the next step in its own evolution? Is that possible? What would it take? Sounds bizarre doesn't it?

For this to happen—for us to start shaping our own evolutionary future—would vision need to be capable of adapting in some manner to the increasing intensity of the information presented by cyber-driven visual displays? And how would the mind need to use this information? What would need to change to make a difference? But even then, how would all of this be translated into inherited characteristics, rather than being re-learnt by each generation in turn? Need it be? And if this were possible, how long would it take? Would the early stages be recognizable? Where would it show up first? In children? In what they learn? Or how they learn?

1 For all references like these, see the Bibliography.

Or how they use what they learn? Would there be discernible differences in how generations think? Would there be a leap in the ability of people to handle abstractions? Would metaphor change? What would be the differentiating characteristics? Perhaps more important, is this electronic visual stimulation simply the continuation of a longer term phenomenon that we have not hitherto perceived: the mind's use of externally stored and analyzed information? Could the changes progress beyond simple augmentation of the visual sense?

How can we explore these questions? What new perspective is needed? Traditionally, we have analyzed relationships as linear. Effect follows cause in predictable fashion. If only we can capture the sometimes elusive mathematics which describes the relationships, we will understand them and—the ultimate desire—control them! This long tradition of linear analysis and prediction has been reinforced by the introduction of the digital computer.

But what if that perspective is wrong? What are we missing with our egocentric, linear perspectives looking out from within our own neurosystems? Until recently we have simplified our analyses and understanding of ourselves by refusing to accept that we are part of everything around us. But, increasingly, we are finding the relationships of which we are a part to be nonlinear. Cause and effect are not so clear. Even nature refuses to follow our simple linear logic. We have various names to characterize these newly identified relationships: non-linear systems, chaos theory, network theory, complexity theory, and complex adaptive systems. These systems are all around us—in political, economic, biological, cosmological… and electronic settings. We ourselves are comprised of these non-linear systems, the most awesome of which is our brain.

I want to start by re-perceiving these questions in the context of complex adaptive systems—beginning with a brief survey of nature's relentless self-organizing. Complex adaptive systems, perhaps counter-intuitively, lurk behind the seemingly stable façade of everyday life and of life itself—from cells to consumers, from the weather to rush-hour traffic… and from vision to the mind. Yet, science is only now beginning to appreciate them.

There is an interesting phenomenon associated with these systems: emergent properties. These properties emerge from the interactions of the elements of a system and cannot be predicted from an analysis of either the elements or their interactions. Some in science have come to believe that the mind is an emergent property of the collective systems comprising the central nervous system. What of those participating systems outside of 'me'? Do they also participate in the emergence of mind? There are those in science who believe they do.

In the language of complex adaptive systems, the mind is in the midst of a phase-shift. What does that mean? Economics gives us an example. In economic theory, there is a simple relationship between the price of a good and the demand for it. Over a wide range of values for price and demand, this relationship holds. But occasionally a redefining event occurs in the marketplace and the fundamental relationship changes. Following a disruptive change in supply—a new and different source of supply—there comes a shift in demand, accompanied by a shift to a new continuum. Manufacturing augmented crafts. Automobiles supplemented horses. Television augmented radio and movies. Wireless joined wire line. Each time there was a redefining event in the self-organization of the economic system, the relationships among the parts changed.

Such a redefining event occurred in the construct of the mind about 50,000–100,000 years ago. The mind self-reorganized! We see the consequences in the record left behind by our ancestors. Sophisticated art, lurking in caves, appears as if out of nowhere. Adornment of the person, of everyday apparel, increasingly sophisticated icons of worship, and even the decoration of everyday utensils—they all suddenly litter the archaeologist's landscape. This is a mind very unlike the one preceding it. We shall see just how different. The elements enabling the emergence of mind, operating on the eons-long time scale of nature are still shifting the mind to a new continuum. We are still within the swirl of change. Will we belong to the new continuum or the old? Are we still members of the *Homo sapiens* species today?

In order to understand where the mind will go, we must first understand how it came to be. That may not be easy since science begins from what our mind looks like today. It may also be unsettling to our notion of self, which we value so highly. Our species is egocentric. Science is filled with clues to the future of mind—books, papers, research—but, with few exceptions, they address mind only in the singular state of 'me,' and only in a linear fashion. "Me, Myself, and I" has been celebrated in song by everyone from Billy Holiday to Beyoncé to Sho Baraka. Yet we are not simply 'me,' we are part of families, groups, political and economic systems, cultures, and perhaps most importantly, systems of technologies. Today we are members of a web embracing not only all of us but the technology we create. We interact with one another and with technology at an increasingly frenetic pace. We have augmented the capabilities of our brains with enormous external capabilities. The external augmentation of our neural systems is not new. It began eons ago with perhaps something as simple as a pile of rocks, or a deliberately broken tree branch—external memories of locations, events, or direction. These processes of augmentation and interaction continue today. But does it stop simply with augmentation?

The future of the mind appears in three evolutionary trajectories operating through millennia: pattern recognition, vision, and post-birth development. They are inexorably changing who and what we are… changing the very nature of mind. They are independent, yet inextricably bound together.

In **Part One**, we explore the progressive increase in the ability of natural systems to recognize patterns, take action based on patterns, and use patterns in cognition. Our ability to compare different environmental disturbances—to observe patterns in the environment—enabled metaphor-based cognition. And increased sophistication in the acquisition and use of patterns led to the emergence of an integrated realm of subjectivity—the self.

In **Part Two**, we examine the power of vision to enrich the acquisition and evaluation of patterns, the extension of vision by synthetic augmentation, and the education of vision by post-birth development—both natural and cyberous.

Pattern recognition and vision arise from our biology. The ability to see and recognize patterns is contained in the genes passed down by our ancestors after interaction and adaptation with the environment. A special case of pattern recognition, metaphor, is of particular interest.

In **Part Three**, we learn to appreciate the profound implications of electronically augmented post-birth development to the self-organizing and functioning of neural systems. In post-birth development, knowledge and skills acquired by our ancestors, and today incubated by the technology in which we are immersed, are passed on to us within culture—within a system that transcends us individually. With the augmentation of synthetic systems, the cognitive power of metaphor is no longer constrained by neural capacity or by the experience of self.

Part Four explores the future of the mind produced by these three trajectories—pattern recognition, vision, and post-birth development. Are there limitations in the tendencies of change that we explore? Have we appropriately defined mind? We will explore these questions and suggest three futures of mind:

1. **Unknowable Mind.** Our minds are already engaged in activity about which we know only the consequences, if that. We don't know how insights, ahaas! and that language so essential to science itself—metaphor—come about. We are also increasingly exposed to cyberous translations of phenomena beyond human experience—the real unknowable. What is next as the augmentation of technology becomes ever more intense? What *is* mind when technology, about which we are seldom fully aware, participates in the emergence of mind? What does it mean to me to have a mind that is more unknowable than that of my ancestors?
2. **Absentee Mind**. Is it valid to identify as ours, all of those remote memories we can now access with a movement of the cursor or the swipe of a finger? Is it valid to constrain our definition of mind to only those systems of flesh within us? Einstein once said "Never memorize what you can look up in books." Indeed, why encumber the flesh with what can be done collaboratively with silicon or in the Cloud? Remote, absentee participants in mind are increasing. What will that mean to me?
3. **Transcendent Mind.** Is mind still singular? Was it ever, or was that simply a convenient way of evading the messy complexity of the systems of which we are a part? Don't we observe emergence in societies, in cultures, in technology? Is it really useful to pretend that what we so jealously guard as our own, our self, would be the same without the participation of the systems in which we interact as elements? Where does 'self' fit in all of this? What will it mean to me to participate in a collective mind—a mind that transcends me?

As we follow the three trajectories of pattern recognition, vision, and post-birth development through time we will come face-to-face with a profound fact. Mind may be important to us, but it is not important to the self-organizing of nature. It is simply a consequence**.**

There isn't space to present detailed, complete arguments in support of each idea explored here. Instead, I present the ideas, re-perceived, in a framework designed to explore the evolution of the mind in such a way as to reveal potential for the future of the mind. I present ideas from several disciplines and numerous individuals. Only a few sources are referenced in the text. More are suggested in the section of additional reading at the end of each chapter. Many sources, helpful but more linear in approach, are included in the bibliography.

CHAPTER 1

Complexity and Environment

I begin this book with an overview of complexity theory because I believe the mind to be an emergent property of complex adaptive systems: our nervous systems together with those systems of our environment. How can that be?

Have you ever stepped in dog vomit? No, not the consequence of Fido's indiscretions, but the slime mold you may find scuffing through old leaves. Known within its community of friends as *Fuligo septica*, like many slime molds, the cells of this species are independent, but may get together for a walk through the leaves, and certainly for dinner. They may just as likely degenerate into their own diaspora, going their own way. When they do get together they look and move like a gigantic ameba. But if you step in one it's just as disgusting as your dog's indiscretion! So why am I starting this book talking about dog vomit? Because *Fuligo septica* is a beautiful illustration of a complex adaptive system.

The weather is another example of a complex adaptive system. In 1987, James Gleick's book *Chaos: Making a New Science* was published. It caused a sensation among ordinary readers interested in science. It splashed all over best-seller lists and was widely reviewed. It brought to the public a glimpse of the weirdness that supports everyday life and life itself. Gleick explained how Lorenz, a climatologist, first brought us face-to-face with the phenomenon of complexity theory through his study of the weather. Gleick quotes Douglas Hofstadter as saying, "It turns out that an eerie type of chaos can lurk just behind a façade of order—and yet, deep inside the chaos lurks an even eerier type of order."

It seems that dog vomit and the weather have something in common. They are both complex adaptive systems. Complex adaptive systems also underlie the three trajectories provoking the future of the mind: the processes of pattern recognition, vision, and post-birth development. It is no exaggeration to say that if evolution is the process of change, then complex adaptive systems are the means of the process.

Earth has passed through numerous periods from the Precambrian to the present including the most celebrated of all—the Jurassic with its fearsome dinosaurs. Countless species have come and gone. Today, there are millions of species, all with their own way of making a living. On the eons-long time scale of evolution, nature seems to reorganize the players every so often. Within the processes of nature, there seems to be an urge to reorganize. There is no outer direction for this organization. It is best described as self-organization. It is this relentless process of self-organizing that lurks behind the three trajectories that I am discussing and behind the future of the mind.

Twenty-five years after Gleick's *Chaos*, there is as yet no comprehensive theory of these complex systems. But like the elephant partially explored and described by the blind men, these systems have been described in various ways by different scientific disciplines: non-linear systems, chaos theory, complex adaptive systems, network systems, and emergent systems are some of the perspectives given to them. I will use the term 'complex adaptive system' because adaptation is important to this story. For the sake of brevity, I will abbreviate the term to CAS (with CASs as its plural).

But be warned! CASs can seem counter-intuitive if not incongruous. We have an innate confidence in the regulated processes of life—cause and effect flow everywhere. Perhaps, as Douglas Hofstadter suggested, CASs are a little unsettling. Rudderless, without direction or objective—except for an unceasing urge to reshape themselves, to self-organize and self-organize and self-organize... ad infinitum. Yet, they are where this story begins. CASs are all around us. They *are* us and they *are* the environment. They adapt to change in their environment while becoming the changing environment of other CASs. They are a fundamental part of this story and the future of the mind.

CASs are distinct from systems that are only complicated. I may cut the grass with a lawn mower—a relatively complicated machine of numerous interconnected, interacting systems and parts, including starter, fuel, ignition, exhaust, propulsion, cutting, and grass handling. No matter what the conditions or the weather—hot or cold, snow or rain, or the terrain—smooth, flat, or filled with gullies—the machine will attempt to cut. No matter what is encountered—grass or weeds, bricks or twigs, flowers or garden hose—the lawn mower will do the same thing. It will attempt to cut whatever I put in its path. The lawn mower just sits there through rain, snow, heat, or cold, unless I move it. It does not adapt to change in its environment. But the grass, also complicated in nature, is a self-organizing system. It changes with no outside or centralized direction. It adapts to the stimulation of seasonal change. Grass withers in the face of dryness to preserve its future, grows with nutrients, reproduces, and goes dormant in the cold, saving itself for recovery in the warmth. Over eons of time, grass has adapted to changing environments.

The lawn mower is complicated. The grass is a complex adaptive system.

So why are we interested in CASs? These systems can be found at the cellular level and every other level all the way up to ourselves... and beyond! They are hierarchical. What do I mean by that? We normally think of hierarchies as levels of cooperation or collaboration within an organization like a church, or a firm, or an educational institution. In the case of CASs, the hierarchies come about through an interesting aspect of their organization. A CAS, once formed, is then available to be used as an element in the formation of a higher-order CAS. These higher-order levels can carry on without limit. Thus we have cells organized into systems into organs into people. We have individuals organizing into consumers or producers, groups into markets, markets into economies. They are all around us! And we need to understand a few things about this CAS phenomenon before proceeding.

So what makes up these systems? How do they work? If they are not fully understood by science, how can they be useful? There are several known aspects of these phenomena that are of interest to us.

- They are comprised of independent, basic elements—ranging from cells to consumers to galaxies.
- These elements self-organize in response to changes in the environment.
- The self-organizations balance between stability and chaos—on the edge of chaos.
- They only self-organize into possibilities adjacent to their initial conditions.
- They harbor an unpredictable property: emergence.

It is in this property of emergence that we will find the future of the mind.

The Basic Elements

All CASs are comprised of building blocks, independent elements interacting with one another for the benefit of the whole. You scratch my back and I'll scratch yours? Well, it is not quite that simple. Together, the interacting elements are better able to interact with their environment—better than any individual element could do on its own, *and* they collaboratively develop a capability for manipulating that environment for the good of the CAS and for the good of each of the elements. Even so, CASs are not necessarily optimal. Typically, they are just good enough, good enough to persist, good enough to survive, and good enough to multiply. I will explore this characteristic of CASs throughout the book.

The basic elements comprising a CAS need not be identical so long as they relate on a common basis. This characteristic of the element is illustrated by the object-oriented construct used in computer programming, where objects belong to a substitutable class no matter what their other characteristics, *so long as they retain the characteristics of the class*. They may differ in size, scale, or properties. So long as they relate with the same 'language,' function together in a common interest and maintain their integrity, the elements may be of any mix. They need not be 'living,' or mineral, or even sentient, (though they may be all of these and more). The elements comprising economies and societies—both CASs—demonstrate this aspect of the elements of CASs. CASs can include many disparate elements—even other CASs.

The interfaces among elements determine the manner of exchange—the modality of interaction among the elements in a system. In an economy it may be currency; in a brain, dopamine. This modality both supports and constrains the relationship of the elements and contributes to the simplicity of the relationships. These interfaces support feedback for two-way interaction and exchange. The most familiar example of this modality constraint is our senses. We smell odors, not light.

These interactions can be seemingly chaotic. Elements may participate in multiple CASs simultaneously. It's like belonging to a poker club, a bridge club, and a pinochle club… on the same night, in the same room, at adjacent tables. Elements need only adhere to the protocol of each of the CASs in which they participate. This property is evident in economies where individuals can be manufacturing workers, service providers, consumers, or facilitators of the interaction of others. Multiple roles are also apparent in societies, and in the central nervous system. Disintegration, or perhaps disengagement, occurs when participation in a CAS leads to conflict among the functions of the elements. We see this in bankruptcies, corporate buyouts, revolutions, mental disturbances, and the ultimate cellular disengagement—death.

There's more. Since any element in an environment is eligible to participate in a CAS, the CASs *themselves* participate in relationships with other CASs, self-organizing into an endless potential of layers or hierarchies. In higher order systems within hierarchies, the interfaces may extend deep into the systems and be comprised of other CASs. The hierarchies of interaction can be limitless—important to the future of the mind.

A World of Elements Responding to Change

These systems are all around us. They nurture us. They shape us. They comprise us.

CASs are opportunistic, adapting to change and to stimulation from without. Each CAS functions in the context of its own environment. It is subject to the influence of that environment and self-organizes in response to changes in that environment—but on its own terms. The availability of new or changed elements, the disappearance or modification of elements by the environment, all represent opportunities or threats stimulating self-organization.

Since CASs self-organize as elements of the environment, comprised of elements of the environment, and in response to disturbances in the environment, this self-organization reflects the environment. Self-organizations are consequences of stimulation by the environment; they are an integral *part* of the environment. The current state of a CAS reflects the culmination of all previous self-organizations, all previous responses to the environment. The structure of the CAS represents its response to the environment.

As a CAS changes in response to stimulation or opportunities, it also becomes the changed environment encountered by other CASs. It *is* the environment to other CASs. The relationships and patterns of self-organized systems change as the environmental circumstances do, and environmental circumstances change even as CASs do. In every sense, the self-organizations of CASs reflect their environment and are part of the environment of other CASs. They co-evolve.

Self-organization at one level of a hierarchy may or may not cause reorganization in other levels of the hierarchy, depending on whether or not the elements in other levels change. We see this in economies and societies. There may be changes within a business, or an industry, or a new set of laws to cope with societal changes, yet the economy—or the societal relationship—persists.

Living on the Edge

Chaos is a term encountered in the study of CASs. Complex adaptive systems encompass both stability and change. They exist at the transition between orderly systems with stability and those that are chaotic in behavior. They truly skirt the edge between stability and chaos. CASs are restless, seemingly without discipline. But there are limits to this restlessness.

CASs are governed by their own emergent rules. The rules for each arise from within and are used by the elements participating for the benefit of the CAS as a whole and the individual elements comprising it. Yet CASs need integrity. When an environmental influence provokes change that is not within the scope of the existing system, the system disintegrates. Poof goes the CAS! The independent elements are then freed into the environment, available for new self-organizations, new CASs. The assets, competitive advantages, skilled workers, trade secrets of commercial organizations in bankruptcy, are dispersed to other organizations capable of using them in their systems. Mergers and acquisitions often 'spin off' unwanted or unusable functions. The chemicals in the cellular makeup of our bodies return to the environment in death.

This brings us to autopoiesis. Autopoiesis, defined by Maturana and Varela, is the process of becoming. According to Maturana and Varela, autopoietic systems literally pull themselves up by their bootstraps and are continually self-producing. The only product of their organization is themselves and there is no distinction between the producer and the product. Sound crazy? Well, as we used to say, "you are one." This process, and every CAS, is constrained both by past structures—by the history of previous self-organizations—and by the need to maintain ongoing structural integrity from moment to moment. Otherwise there is an end to becoming. Stability—no change—is death. Chaos is the collapse of system integrity—also death. Self-organizations and reorganizations that take place within a system while maintaining the integrity of that system operate at the edge of chaos and are said to have the property of autopoiesis: becoming is a process without an end.

This can have unexpected consequences. On the one hand, CASs can have the attributes of both stability and chaos. Well, maybe not simultaneously, but almost. On the other hand, tracing the path of a CAS through history might give the impression that it is seeking a direction—an objective—when it is simply following the path of least resistance through a series of opportunistic self-organizations, moving from one set of environmental conditions to another, and to another, and to another.

These systems can also spontaneously self-organize into sub-systems—into a division of labor. If we consider that these systems are constantly seeking new possibilities at all levels of a hierarchy, these self-organizations into sub-systems are simply moves into adjacent possibilities.

Initial Conditions, Adjacent Possibilities, and Adaptation

What are initial conditions and adjacent possibilities? Initial conditions are just what they say they are. They are the conditions before a change takes place—in whatever. After a change, the new conditions become the initial conditions for the next change. As a CAS self-organizes repeatedly, new initial conditions will arise repeatedly. Change can take place only into adjacent possibilities. They are possible only because they are one step away, adjacent to the initial conditions.

Imagine you are standing on a busy street corner with a traffic light, walk-wait signs, numerous pedestrians, and lots of traffic. Those are your initial conditions. That's where you are. You can obey the traffic signals, walk into the traffic, or walk in another direction. You can bump into or avoid the pedestrians, or dodge the cars and jay-walk. Or you can just stand there. Those are your adjacent possibilities. That's what you can do given where you are. Whatever you do, that becomes your new set of initial conditions for your next move: a move into a set of adjacent possibilities surrounding your new set of initial conditions.

The possibilities adjacent to the current state further limit the self-organizing options available to any CAS, substantially reducing the operation of randomness.

Another aspect of CASs is of particular interest. There is no going back. A CAS self-organizing into an adjacent possibility then resides in that new possibility with its own initial conditions for the next self-organization: the residual structure of the self-organization constitutes the beginnings for the next one. The adjacent possibilities presented from that vantage point do not include the previous state. If I cross the street, I am no longer on the same corner. If I remain on the corner, the traffic conditions will have changed. My adjacent possibilities will have changed. Been there, done that! The environment has moved on. That street corner has a completely different set of opportunities once a choice is made—or not. Traffic and pedestrians change. The signals change. The interaction of all the participants is at a different point. The opportunities are different. The previous state is not within reach. As a consequence, the sequence of initial conditions and adjacent possibilities traversed by self-organizations may not lead to an optimal organization. Suboptimal self-organizations are more likely than optimal ones. An illustration of this characteristic is the man standing among several hills. He is simply told to walk uphill. What are the chances of his reaching the highest peak among all the hills? Once he starts up a low rising hill, there is no turning back… just walk uphill.

Surprisingly, a hierarchy of simple *if-then* rules can lead to complex behavior. An example given early in the study of CASs in biology cited the operation of bacteria. *If* bacteria encounter an increasing flow of glucose, *then* they move toward it. In a noted software program, 'Boids', three simple rules lead to behavior emulating the practice of birds when they flock together. In a hierarchy of decisions, *if-then* rules can be very powerful. As these systems constantly self-organize in response to environmental disturbances, they are adapting to those disturbances.

This same characteristic is evident in the operation of the human central nervous system. The brain is composed of a multitude of sub-systems operating in almost limitless relationships and hierarchies, each subject to the influence of its own environment—including the body and other parts of the brain.

Emergence

Of particular note—and of some mystery—is the fact that these systems have an unpredictable property that emerges from the connections and interactions of the elements in the relationship. It is as if the relationship reaches a critical mass, and—boom—a phase transition occurs. Something emerges that is qualitatively different from the sum of the parts. This emergent property is not predictable from an examination of the individual elements, nor of the connections among those elements.

Consider the movement of automobiles in an urban area. The elements interacting are the individual automobiles, the rules are manifested in the signage and signaling, and in the actions of the drivers. An examination of the elements alone would not disclose the property that emerges from the system—traffic, sometimes stable sometimes chaotic. It is this property of emergence that is most important to the future of the mind.

Today, many basic elements available for self-organization are created by ourselves—the very systems self-organizing. These elements are as primitive as generation-specific adornment and as sophisticated as online social media and search engines. These elements are systems in themselves, with their own environmental stimulation and self-organization—systems we are creating. While it is unusual for a species to create an environment that then brings about subsequent change in that species, it is not new. Beavers build dams to create lakes for their homes. Corals build reefs for their footing. What is new is that the elements influencing the change are not just material. They are cyberous: machine-oriented, electronic in nature. Underlying them are the multiple dimensions of the Internet and the continuing connectivity of ever more sophisticated mobile devices. We are always in touch. Most importantly, these electronic elements are complementary to the three eons-long paths of adjacent possibilities that I mentioned earlier. These three sets of possibilities are still being explored by the CAS that is made up of us humans: pattern recognition, vision, and post-birth development. These three 'trajectories' in evolution need some exploration before examining the future of the mind and the contribution these forces make to that future.

Suggested Additional Reading for Chapter 1

For an introduction to complexity theory and how it has been revealed by several different disciplines, see Mitchell Waldrop's *Complexity: the Emerging Science at the Edge of Order and Chaos*, and Melanie Mitchell's *Complexity: a Guided Tour* which provides a current overview of complexity theory. John Holland in *Hidden Order: How Adaptation Builds Complexity*; and Stuart Kauffman in *At Home in the Universe: the Search for the Laws of Self-organization and Complexity* provide a more in-depth exploration of complexity theory. Terrance Deacon, in

Incomplete Nature: How Mind emerged from Matter, reviews the evolution of the concept of emergence. In *The Emergence of Everything*: *How the World Became Complex*, Harold Morowitz examines emergence in 28 levels from the primordial to urbanization.

Niche Construction: the Neglected Process in Evolution, by John Odling-Smee *et al* presents environmental modification by species as a complementing force to adaptation and selection by the environment, and discusses feedback in evolution. Humberto Maturana, in an essay entitled *Biology of Cognition* in the book *Autopoiesis and Cognition: The Realization of the Living,* by Humberto Maturana and Francisco Varela, provides a window onto self-organizing CASs as both biological unities and as simple elements in an environment of interacting systems. Humberto Maturana and Francisco Varela in *The Tree of Knowledge*, provide a basis for the cohesiveness of these systems—autopoiesis. Len Fisher, in *The Perfect Swarm: The Science of Complexity in Everyday Lif*e, explores group adaptation in the context of complex adaptive systems.

Emergence: Contemporary Readings in Philosophy and Science, edited by Mark Bedau and Paul Humphreys, provides a discussion of emergence from various philosophical and scientific sources. Three perspectives of emergence are provided by John Holland's *Emergence: From Chaos to Order*; Steven Johnson's *Emergence: The Connected Lives of Ants, Brains, Cities and Software*; and *The* 'Mind of The Swarm,' a short article by Erica Klarreich in the November 25, 2006 issue of *Science News*. James Gleick's popular book of a few years past, *Chaos: Making a New Science*, provides an appropriate visual introduction to complexity theory and the property of emergence.