Talk #2 Order Without Design

> Whenever Darwinism is the topic, the temperature rises, because more is at stake than just the empirical facts about how life on Earth evolved, or the correct logic of the theory that accounts for those facts. One of the precious things that is at stake is a vision of what it means to ask and answer, the question "Why?"
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> – Darwin's Dangerous Idea, Daniel Dennett (1995)

> The word 'change' has three meanings: These are the easy, the changing and the constant.
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> – Eight Lectures on the I Ching, H. Wilhelm

Thea: Let's pick up where we quit yesterday evening. You were saying that Newton's clock-work universe is obsolete and that something more interesting, and more receptive to life, is taking its place. My own sense is that people today are looking at three completely different worlds, not sure which one they are really living in. Most people (right up to and including the Vatican) can't take the Bible's Creation Story literally any more. The Newtonian world, as you say, is obsolete in advanced physics but still works well in ordinary life. And Darwin's story, that it all just happened through random variation and natural selection is scarcely credible to ordinary people, who fail to grasp why scientists find it so convincing.

Anyway, that's where I find myself against you. I don't believe that natural selection could have done the job alone. There must have been some intelligence, some creative intention guiding that process. And when you tell me, in the next breath, that learning and intelligence themselves are products of evolution, that sounds like pure confusion. If evolution is blind, then where does adaptive intelligence come in? How can you speak of intelligence and Darwinian evolution in the same breath?

Guy: Please be careful here. I'm not saying Darwin's natural selection did the job alone. I'm talking about self-organization – a larger concept – of which natural selection is just an important special case.

Thea: Well, I'll need some explanation of what you mean by self-organization. And before that: What does the word "evolution" actually mean? It seems to mean something more than simple change, but I'm not sure what.

Guy: That's an important point: Change can be random, or wholly unintelligible. But when we say a system is evolving, we imply a change process that is coherently patterned, self-driven and self-consistent. To speak of biological eco-spheres, human minds and our societies as evolving is to bring these three systemic levels under a common paradigm of self-driven, self-consistent, coherently patterned change.

Thea: Then I have to ask: What is the status of evolution in biology today? Is belief in evolution the same thing as Darwinism? And just how solidly established is it?

Guy: There's a fair amount of confusion around the concept of evolution, partly because Creationists are doing their best to generate as much confusion as possible, partly because there remain some genuine puzzles and controversies amongst biologists about the nature of evolution and its role in the shaping of life, and partly because the concept is increasingly applied outside of biology although there is much uncertainty on how to do this.

The point to grasp, I think, is that the word "evolution" refers both to a theory in biology and to a paradigm – a whole approach and mind-set – on the nature of change and the way that change is to be explained. As a testable scientific theory, neo-Darwinism proposes specific processes of change in the relative prevalence of the so-called "genes" – certain molecular structures on the chromosomes of inter-breeding plants and animals; and it uses these genetic changes to explain differences in the gross structure and behavior of organisms – to explain "the origin of species." This theory has been tested extensively and has stood up very well.

But as a paradigm, the idea of evolution suggests that we seek the explanation for any discovery of order or pattern in a natural system not by appeal to an external intelligence (as in Paley's famous watchmaker argument), but in the normal operation of the system itself. The paradigm of evolutionary change is compatible with any number of specific theories about the mechanism by which such change occurs – and with a variety of systems in which change can occur. The Darwinian paradigm can be invoked as an explanation for natural order wherever found.

Darwinian Biology

Thea: Well, let's start with biology. What is evolution's status in that field, as a specific theory?

Guy: In biology, the theory of evolution is about as solidly established as a theory can be – both by the (admittedly incomplete) fossil record and by laboratory experiment. Several areas of controversy remain, but there is general agreement amongst the scientists in this field that both micro-evolution (the changes over time within a species) and macro-evolution (the emergence of new species and classes) happen much as Darwin said they did – through a process of random variation and natural selection.

Thea: What areas of controversy? And why do you speak of "neo-Darwinism"?

Guy: Darwin's theory has been revised several times since its publication – mostly to take account of Mendelian inheritance and the discovery of "genes" (the molecular basis of inheritance), both of which were unknown to Darwin. Biologists speak of "neo-Darwinism" to remind themselves that these discoveries modify Darwin's picture a little.

As for the areas of controversy, these have to do mostly with the precise role of genes and the genetic code in relation to the living, metabolizing creature, with the relationship between natural selection and other forms of self-organization, with the precise meaning and role of ideas of "fitness" or "adaptation," and with the time-scale on which evolution occurred – whether gradual or "punctuated."[1] But there is no serious doubt that life on Earth is a genetic and ecological unity and not some number of

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1 On the theory of punctuated evolution, see *http://en.wikipedia.org/wiki/Punctuated_equilibrium* and *http://geowords.com/histbooknetscape/f28.htm*.

distinct and immutable species; that life arose on the planet about 3.5 billion years ago; and that species and whole orders of living creature evolved and are still evolving much as Darwin suggested.

Thea: What about the origin of life on Earth? Once there was life, evolution may have modified it continuously, as Darwin suggested, but how did life first arise?

Guy: There are several possibilities. It may have appeared spon-taneously through essentially Darwinian processes of self-organization (but here, the fact that self-organization means more than natural selection becomes important). Or, it may have been seeded onto the planet by spores floating through the inter-stellar void, or by garbage jettisoned from a space craft.[2] Probably, we'll never know for sure, though the discovery of an older, carbon-based life form, with a genetic code similar to ours, on a planet in our vicinity, would certainly tip the balance of probabilities. We can say: life is an infection that some planets catch. Our Earth may have caught it in several different ways.

Thea: So as you see it, the Creationists don't have much of a leg to stand on?

Guy: As I see it, they're standing on the Bible, and thumping as best they can. You can judge the level of intellectual integrity for yourself by visiting their Creation Science Home Page or the Institute for Creation Research.[3] But now remember that the broad concept of evolution extends far outside biology. The Darwinian paradigm has been applied, so far with varying success, at every level of organization in the natural universe from atoms and molecules to cultural traits.

Thea: And as a paradigm, I take it , you do not use the word "evolution" in its strict Darwinian sense?

science without skyhooks

Guy: The Darwinian paradigm is not a specific, falsifiable scientific theory, but rather a methodological commitment: namely, that complexity and adaptive fit have to be explained from the bottom up, not from the top down – with cranes, not skyhooks as Daniel Dennett put it neatly.[4]

Thea: Not being a construction engineer, I'll have to ask you to explain.

Guy: In building a skyscraper, the components – girders, wall panels, all the fixtures and materials – have to be lifted and maneuvered into place. In principle, this can be done in two ways: either from the ground up with some kind of crane, or by lowering from a helicopter, or a dirigible, or

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2 Though, obviously, these theories just push the problem back a step. How did that life originate?

3 At *http://emporium.turnpike.net/C/cs/* and *http://www.icr.org/* respectively.

4 In *Darwin's Dangerous Idea*.

(someday, perhaps) a satellite in earth-stationary orbit, with some kind of "skyhook." Now, the design of a living organism – or of anything else, for that matter – may be likened to the ascent of a peak in the abstract space of design possibilities, with higher peaks corresponding to more advantageous designs. Dennett's point is that this ascent must be accomplished with the equivalent of a ground-based crane because in Nature there are no skyhooks. An appeal to purpose or design cannot count as a scientific explanation. The order in any system has to be explained as an emergent feature of the system dynamics, not as an input from above.

Thea: I still don't get the metaphor.

Guy: A "skyhook" in Dennett's sense is a source of "Intelligent Design" – a god, for example. A "crane" is any process that recursively uses either trial-and-error, or capabilities developed through trial-and-error, to lift itself, as if by its own bootstraps. Darwinian evolution is a crane. The creation myths in Genesis and elsewhere are skyhooks.

Thea: So how could Dennett know there is no "skyhook" in the natural universe to bring order out of the chaos?

Guy: It's more a question of method than of Dennett's knowledge. Skyhook-type explanations only generate an infinite regress of further questions like "What moved God to create the universe?" and "Where did God come from anyway?" which are less amenable to inquiry than the question we started with. To avoid such regress, a scientific explanation of the natural universe and life cannot appeal to external purposes.

self-organization

Thea: But I still find it difficult to accept that life was created through random mutation and natural selection alone. I think that's the sticking point for most people.

Guy: But as I've been saying, you don't need to accept any such thing. Other processes of self-organization seem to be at work as well. It turns out that natural selection is not the only mechanism available to a Darwinian paradigm of explanation. We now know that systems can self-organize in other modes. Natural selection is only one of evolution's tricks.

Thea: That's interesting. What are the others?

Guy: I can tell you a few of them. There may be others – possibly, many others. A lot of work is being done in this field, and there is no knowing where it will go.[5]

A first mode, the oldest known, should be called Tao, or the yin/yang principle to honor the ancient Chinese who discovered it. (Indeed, the Chinese had the idea of a self-organizing system – which they called *zi-ran* – the "self-so" – a few thousand years before W. Ross Ashby coined the term

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5 A good overview of the concept of self-organization and its applications can be found at: *www.physicsdaily.com/physics/Self-organization*.

"self-organization" in 1947.) The yin/yang principle tells us that systems evolve toward a balance between centripetal and centrifugal forces, or between their processes of intake and outflow. The planets in their orbits would be one example. The metabolism of a human body would be another. The debits and credits of any business would be a third.

Thea: Why did it take so long to re-discover the "self-so" in the Western world?

Guy: That is an excellent question, for which I have no good answer. What's obvious is that the Western mind took a different direction, focusing more on the dynamics of physical systems than on organic growth.

Thea: Perhaps the very success of the Tao principle worked against a deep application of mathematics to the problems of mechanics.

Guy: Perhaps. Or perhaps the study of physics was not stimulated by a military interest in ballistics in China as was the case in medieval Europe. It's impossible to say. This result, like most, must have been suggested by many factors rather than caused by any one of them.

Another mode of self-organization: It's been known for a few centuries that many systems configure spontaneously to minimize one of their parameters. For example, soap films on a twisted loop of wire configure to minimize their surface area. Below a critical temperature, bars of iron (and other materials) spontaneously magnetize themselves because alignment of the magnetic fields of their particles represents a "least energy" configuration for the bar as a whole. The so-called "Bénard cells" which appear in a fluid heated evenly on a flat stove element are a third example. Indeed, the whole field of classical mechanics can be formulated on a principle of least action.

Thea: A principle of economy in Nature?

Guy: In effect, yes. It was originally conceived by a French astronomer and mathematician of the 18th century, Pierre-Louis de Maupertuis, who wrote that "Nature is thrifty in all its actions."

Thea: Like the good mother she is! Go on.

Guy: A third principle of self-organization, now known as teleonomy, might also be called "the lobster trap effect," as it has long been used for just that purpose. The trap is a simple box with bait inside and a funnel leading in, so that lobsters can easily find their way into the box but cannot easily find the small opening leading out. The general concept is that a change process can be one-way only, or overwhelmingly more probable in one direction than the other, so that random contributions from the outside produce a steady accumulation of order. In biology, this simple principle finds an amazing number of applications, and accounts for the seemingly purposeful development of living organisms. It ex-plains, for example why an acorn develops into an oak tree, if into anything at all – a central problem in biology since Aristotle, who conceived a kind of backward causality called teleology, to explain it.

Thea: It seems a kind of miracle that an acorn could grow into an oak, or woman's fertilized egg cell into a human baby. Without some kind of teleology, or "the will of God," it seems impossible.

Guy: That perception has been a stumbling block in biology. The notion of teleology was jokingly called the biologist's mistress because he couldn't live without her but didn't want to be seen in public with her. Now, under her new name and recognized as an entirely respectable mode of explanation, he is happily married to her.

Thea: I don't see what changed exactly. Except for two letters, what's the difference between "teleology" and "teleonomy"?

Guy: "Teleology" is a philosopher's term for nature's apparent purposefulness – the idea that an intention for the future can cause events in the present. We use it all the time to explain why we are doing things: I am talking now with an intention to explain this distinction to you. An imagined future state is conceived as causing my present action. How could that happen?

To explain mind as an effect of a brain's activity, part of the problem is to switch this arrow of causation. In science, it is felt, only causation from past to future can be allowed. That was why the biologist could not be seen using teleology "in public" – as an explanation of anything at all.

Now with teleonomy, the lobster trap effect, this problem disappears. The lobster doesn't crawl into the trap because he wants to get caught. From one perspective, he crawls in because he wants the bait inside; but from another, he crawls in because his sense organs suggest to him that there is something good in that direction, and because his nervous system and musculature propel his body accordingly. In this latter perspective, there is nothing mysterious or scientifically disreputable. Indeed, you demonstrate a very common one-way effect every time you stir sugar into your coffee.

Entropy, the "second law of thermodynamics" about the one-way dissipation of heat, seemed to forbid self-organization; but without such one-way processes a real science of biology could not get started. A breakthrough came with the recognition that much of chemistry happens quite mechanically on this very simple lobster trap principle.

Thea: Yes, all right. I see the difference now. Please go on.

Guy: A fourth principle of self-organization, the so-called avalanche effect, governs the shape of snow slopes, sand piles, and similar situations in which stuff heaps up until it reaches a critical point of steepness. The slides which then occur are of varying size, following a power-law distribution in which small slides are very common while large ones are rare. The curious thing is that disease epidemics, shake outs in the economic marketplace and many other phenomena follow a similar distribution, and can be seen as instances of the same effect.

Thea: Why is that? They don't look much like avalanches.

Guy: At first sight, no. A similar dynamic seems to be at work, but the short answer right now is that no one knows, in general, why power-law distributions happen. They seem to occur in situations where there is free choice amongst many possibilities, but also a tendency towards agreement, however small and for whatever reason. The Internet is a fine example of such a situation, and the popularity of Web sites has a marked power law distribution. So does our preference for rock stars and other celebrities, which is why so many people seem to be famous just for being famous.

Thea: And getting richer because they're rich. Pareto's law of income distribution is well known in economics.

Guy: Yes. I deliberately avoided mentioning it. Pareto's law and Zipf's law of word distribution in linguistics were among the first power laws found. At that time, they were purely empirical findings. No one had any idea that they were instances of a more general phenomenon.

Thea: It's a sort of clustering effect isn't it? With the clusters likely to break down after they've reached a critical point? It sounds like a special case of that yin-yang book-keeping principle of balance between aggregating and dispersive forces.

Guy: Perhaps. But I don't think anyone really knows. All these effects of self-organization may be related on some deep level. We just don't fully understand them yet.

To continue: the last principle I need to tell you about is self-consistency – or self-similarity in its more general version. The idea is that a kind of dynamic stability is possible when a system changes in a cyclic or nearly cyclic way. One very simple way for a system to self-organize is to get itself in a loop. When this happens, we may see a tremendous amount of activity going nowhere. More interestingly, we may observe repetitive activity that gradually goes somewhere. Such a system may be stable insofar as it repeats itself; at the same time it may be unstable, or only loosely stable, insofar as small changes accumulate until some very large change results. The general form looks like a spiral: basically cyclic, but with a tendency to expand or contract.

Thea: Yes. You can see that spiral growth pattern on a head of cauliflower if you look carefully.

Guy: This principle of self-similarity explains it. For any growth process – of plant from seed, of chick from egg – today's growth always begins where yesterday's left off. Already Aristotle, writing around 350 B.C., had noticed this pattern of self-similar growth. In bio-chemistry, self-similar cycles of this kind are called autocatalytic loops, and thought to be the origin of life itself. More generally, they are called re-entrant, or autopoietic loops. Their ancient symbol is the Ourobouros – the serpent either swallowing or vomiting forth its own tail, depending on how you want to see it.

Thea: That sounds like life! Days succeeding days. Mothers giving birth to daughters who will in due course become mothers themselves.

Guy: That's it. The wheels goes round and round, and the car rolls forward. The days go round and round and a life goes forward. The seasons go round and round, and Nature rolls forward. "We're captives on the carousel of time," as Joni Mitchell sang.

Except that in the real world, the cycles do not precisely repeat. What we usually observe is not an exactly repeating loop, but a loosely stable loop that cycles around what is called a "strange attractor point" in a certain "basin of attraction." Each cycle begins from and is based upon the cycle that preceded it. Each cycle makes the next one possible, often serving as a kind of template for the next, which will not, however, be exactly the same.

In many such systems, like your cauliflower, a small residue or "gain" accumulates in the successive repetitions, so that the trajectory is not a closed loop but a spiral as we were saying. The system may experience small perturbations making it still more irregular. As the result of an unusually large disturbance, or eventually, after enough repetitions, the system may undergo what we observe as drastic, qualitative change of state, crossing a pass into a different basin. Providing only that some of these basins of attraction are easier to get in to, and/or harder to get out of than others, a kind of evolution may result. The system will tend toward and linger in some basins more than others. As Bateson put it, "Longer lasting patterns last longer than patterns which last not so long." So understood, evolution is no more than a tautology – a necessity of logic.

Thea: A tautology? Is that all the Darwinian paradigm amounts to?

Guy: There must be more to it, because we still need to explain why one pattern lasts longer or turns up more frequently than others – why it becomes the direction toward which evolution is tending.

There is so much we still don't know about self-organization, but here are seven known ways for order to appear spontaneously: the balance of yin and yang, collection and dispersion; the principle of least action; the lobster trap effect; the power law that "the more you have the more you will get"; the principle of self-similarity; and natural selection itself.

Thea: But what is self-organization anyway? It's not a force like gravity or electro-magnetism. It's not a law of Nature. What is it?

Guy: It's our name for something odd that happens when the conditions are right: a spontaneous appearance of unlikely-looking patterns that the laws of Nature not only permit, but can make over-whelmingly probable. Though it may be that these "laws" themselves evolved through cosmic self-organization.[6]

Thea: And the phenomenon called "Life" is just an oddity of this sort? Full of sound and fury, signifying nothing?

Guy: Signifying precisely itself. Wasn't that always the chief attribute of God? The Self-So; the "I Am That Am"? From one perspec-tive, this science doesn't abolish God, but recognizes him at last, and begins to show how he works.

the Baldwin effect

Thea: But doesn't life have any say in its own future? Can a regime of

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6 On this possibility see Lee Smolin's book, *The Life of the Cosmos*.

self-organization, have purpose in any sense at all?

Guy: At least one strand of ecoDarwinian thought suggests there may indeed be such a sense: In 1896, the psychologist James Mark Baldwin pointed out that learned or imitated behaviors could lead a creature to persist in some environment for which it was organically ill-adapted. Whatever bodily or behavioral plasticity the creature possessed could be exploited to cope with this strenuous environment; and some of these adaptive efforts might be successful. In time, selection pressure might increase the required plasticity to make individual adaptation easier, or might lead to genetic changes favoring the adaptive trait as a population norm. A plant growing in a shady place might come to have more chlorophyll in its leaves than a twin growing in a sunny place. A proto-seal hunting around and in the water could learn to swim and hold its breath in this way. We know in fact that a human living at high altitude becomes acclimatized to the thinner air by making more red blood cells, as a man who walks barefoot grows callouses on his feet.

As one consequence of these *personal* adaptations, there will be selection pressure to make such changes more effectively and efficiently. In time, the composition of the gene pool will shift as individuals who can adapt more thoroughly or readily leave more offspring than those who adapt less well. What started as a physiological adaptation of individuals gets taken up into the genotype, making the species as a whole better adapted to this lifestyle – or, in time, even creating a new species. In effect, the creature's acquired lifestyle, its learned way of coping with its habitat, shapes the selection criteria that shape its reproductive prospects.

Per this Baldwin effect, as it is called, the individuals of a species colonize an ecological niche by responding to its suggestions, and then by modifying their own bodies to respond better, through whatever organic plasticity they possess. Then, as an interbreeding population, they evolve to fill the niche as the selection pressures (that they themselves selected) shift the genetic heritage of their progeny.

In a sense, then, Lamarck was right all along, though not in the way he thought. The giraffe's neck *did* get longer from this animal's efforts to eat the leaves on trees. This did not happen because the effort or habit of stretching upward was communicated to the giraffe's genetic material. It happened because a longer neck carried reproductive advantage for individual proto-giraffes that (for whatever reason) preferred browsing in the trees to foraging on the ground. In the same way, once certain anthropoid apes began to use sticks and stones and other found objects as weapons and tools, imitating and communicating with each other as they did so, they placed a strong selection pressure upon themselves to learn such skills quickly and well.

Thea: So there is a sort of indirect purposefulness in the evolutionary process after all.

Guy: Yes, though the idea of purpose in Nature rightly makes scientists nervous. It's better to put it this way: To some extent, any creature selects the selection criteria that act upon itself and its offspring by the life it leads and the life-games it plays – the strategies it uses to survive and reproduce. In

Stuart Kauffman's language,[7] change occurs at "the edge of the possible," as random perturbations cause a system (in this case, an entire species with its gene-pool) to bump around in its design space of possibilities, expanding to occupy every niche where expansion is possible. The process is Darwinian, as it's a Darwinian mechanism that selects genetic winners. Yet at the same time it appears intelligent and purposeful to the extent that individual creatures choose from available options in their efforts to survive and reproduce.

Thea: So the system's random exploration and exploitation of its current habitat could be said to simulate purpose – give an appearance of purpose – while being as blind as Darwin said. I'm not sure if that makes the scientific vision less bleak or more so.

Guy: Speaking for myself, I like the idea that in exploring the edges of its life-world, a creature makes suggestions for the future of its kind, whether its venture succeeds or fails. It's a pleasing thought for me that the games that I and my fellows elect to play set the criteria of our success as biological players? No creature is entirely blind. Each is trying to pass its genes with such equipment (including mental equipment) as it can bring to the job. If you want a glimmer of intelligence behind evolution, that is best I can offer.

Thea: I don't know what I make of this "Baldwin effect." I'll have to think about it.

Guy: The Baldwin effect has one other feature worth noting here. As we'll see later,[8] in one version it applies as much to cultural evolution as to the biological kind. And with a similar result: Selection criteria that shape the evolution of cultural patterns are themselves shaped by the protagonists' intentions, and by the games they elect to play.

Thea: So what? Why is this worth noting?

Guy: Because our purpose in these talks is to explore the significance and implications of the ecoDarwinian paradigm for Mind and the works of Mind – not just for the origin of species, but for psychology and the social sciences. We're going to think of brain development, learning and cultural change as modes of evolution. As we do this, you will constantly be asking, where is the intelligence coordinating and driving these changes? And my reply, in every case, will be that the intelligence you are seeking arises spontaneously within the system itself – as a phenomenon of self-organization, not of intelligent design.

ecology and evolution

Thea: I'll give you this: Your ecoDarwinian paradigm is not nearly as simple – or simplistic – as most people think. It seems that the more you look at the whole idea of evolution, the more slippery it gets.

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7 See *At Home in the Universe* and *Investigations*, Stuart Kauffman.

8 In Talk #11.

Guy: Yes. Jacques Monod once remarked, "A curious aspect of the theory of evolution is that everybody thinks he understands it." From one perspective, each type of creature (or, more precisely, the population of that type) adapts to its environment, in accord somehow with the means by which it is already attempting to thrive and reproduce. From another perspective, the natural environment itself keeps changing, and dragging the evolution of individual species in its train.

Thea: And is this how the concept of ecology comes into it? I don't think you've explained that yet. How is an "ecology" different from a population of interacting species and creatures?

Guy: In the same way that any whole is different from the parts that make it up – as an alternative perspective on the same thing, with emergent features added. The population view is a local perspective emphasizing interactions and relationships between distinct groups and individuals. The ecological view is a systemic, contextual perspective emphasizing the contributions and constraints of a whole on its constituent parts.

Thea: Just the opposite of the liberal, individualistic perspective of classical capitalism. This is interesting: Where the original theory of natural selection encouraged an ideology of "Social Darwinism," the concept of ecology points in just the opposite direction to an idea that everything is ultimately dependent on everything else. But according to you these ideas are inseparable.

Guy: Indeed they are. Everything changes in an orderly way, beginning as what it already is – what it has become to-date: That is evolution. Everything that exists does so as a self-consistent whole, with its parts mutually dependent on one another for their continued functioning: That is ecology. Since everything we know of changes but, at the same time, continues (for a while) to be itself, evolution and ecology are just two sides of the same process – twin aspects of existence, so to speak.

Thea: All right. But what is an ecology exactly? It's a term that everyone uses – but always in a vague, touchy-feely way, without really knowing what they're talking about. Now you seem to be saying that everything, even the mind is a kind of ecology. So what, exactly, do you mean?

Guy: You could define an "ecology" as an open system of inter-acting components, loosely balanced and co-evolving on the edge of chaos.

Thea: That doesn't help much. What awful jargon!

Guy: It's not that bad. Let's take it step by step:

1) An ecology is a system of interacting components: in other words, it is made up of parts that inter-communicate and influence each other.

2) It is an open system, existing as an on-going, re-entrant process within some larger world with which it exchanges energy, material and information – or suggestions, as I prefer to say.

3) It co-evolves: the system is understood through the Darwinian paradigm of self-organization – through processes of auto-poiesis, random variation, natural selection, and so forth. Each kind within it changes adaptively and, in doing so, shifts the selection criteria that affect other kinds. Strictly speaking, it is the whole system that evolves (or co-evolves) – not the individual kinds.

4) It is loosely balanced: the system cycles within a certain "basin of attraction" until some disturbance or accumulated change kicks it into a different basin.

5) It sustains itself on the edge of chaos: it is neither too disorganized to function coherently nor too rigid to change and adapt. In a chaotic regime the system's components behave unpredictably. In an ordered regime its components are locked into a structure which cannot change. "Edge of chaos" is the critical region in which orderly change – therefore adaptation – is possible.

Briefly then, an ecology is a loosely stable, open system. It sustains itself by drawing energy and raw materials from its environment; and it is fairly stable but not completely so. It sustains itself (in a broad sense) even as it changes and adapts.

Thea: That phrase "edge of chaos" does sound like the world we're living in. Not a comfortable place to be!

Guy: Well, my impression is that our world today is in real danger of tipping over into chaos itself. Edge of chaos is where we should be: a fluid region between totalitarian rigidity and complete disorder. "Edge of chaos" corresponds to ordinary water in its liquid state – where interesting patterns – vortices, waves and laminar flows – are possible. Ice is the rigid state of crystalline structure. Steam is the state of chaos, where only statistical regularities are found.

Thea: So "edge of chaos" is not really an edge. It's the region where fairly durable patterns are possible.

Guy: That's right. It's a regime or "phase" (as the physicists call it) in which random change and stable structure coexist. Only in this region will life and mind be possible.

Thea: But in common usage, ecology is just a word for the inter-relationship of plants and animals in the earth's biosphere. You're pushing the concept much further, aren't you? You're making it completely abstract.

Guy: The plants and animals on this planet are just one example of an ecology. A nation's economy, as Adam Smith pointed out,[9] can be considered as an ecology of self-interested business firms and private individuals. The human body, or any other creature's can be considered as an ecology of cells. In

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[9] In *The Wealth of Nations*, Adam Smith, (1776).

due course, I'll show you that an individual's mind too can be thought of as a kind of ecology – as can organizations, cultures, and whole societies. That is what Bateson was driving at when he spoke of the "ecology of mind." He was using much more than a pleasant metaphor. He meant that cognition – for living creatures, human individuals and whole societies – fits the definition literally. Each mind is a pattern of physiological and social activity; and these patterns co-evolve with one another and self-organize as they do so: Viewed in this way, mind appears to be a vast open system of inter-acting fragments, loosely balanced and co-evolving on the edge of chaos.

mind as an ecoDarwinian process

Thea: That would mean we don't really think our thoughts at all. Rather our thoughts are just patterns in the brain, co-evolving according to their own necessities?

Guy: And according to the inputs they receive. That's right. We can't think our thoughts in the same strict sense that we move our limbs because we are our thoughts. There is no locus of desire and attention apart from our thoughts. If anything, our thoughts think us!

Thea: Are you saying that thoughts are determined? Predictable?

Guy: Causally determined – yes, more or less, depending on how exactly that concept is defined.[10] The patterns of influence in a brain are so complex as to make causality almost meaningless. Predictable – no. Much less so than the weather – too unstable, too complex, with too many variables.

Thea: But thoughts comprise an ecology, according to you; and therefore co-evolve in a self-organizing, Darwinian way, affording some degree of cognitive order?

Guy: Yes. That's what I'm saying. We can think of ourselves as suggestion ecologies in which new suggestions are understood, evaluated and either taken up or rejected through a filtering structure of old suggestions. Let's save this for another evening, though.

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[10] See Daniel Dennett's discussions of free will in *Elbow Room*, and *Freedom Evolves*.