PART II

PATTERNS ACROSS NATURE:

A FRAMEWORK

INTRODUCTION TO PART II

One lesson of the story of the blind men and the elephant is that we are all trying to understand the same reality; a reality which is complex and multifaceted, but ultimately unified. The next question is; in what way is reality unified? What strands of unity link all that diversity? Actually, perhaps reality is too a word. What I am talking about here is the physical universe--nature; in the broadest sense. What patterns exist that link things in nature together? How can we, as blind men and women, see nature accurately? And if we see the parts of nature accurately, how can we link our perceptions into a unified whole? What connects the levels of nature described by physics, with the levels described by geology, biology, or perhaps (extending the idea of nature) even sociology? This will be the goal of the next few chapters- to identify some patterns broad enough to span a good deal of nature's breadth and depth, thus helping to tie it together intellectually.

Such unifying patterns are important to recognize because, while fields like physics and biology have a well-developed, more or less coherent body of concepts common to all their practitioners, there is no set of coherent, generally accepted concepts for describing how these fields connect to each other. Practically every university has a biology department, but I don't know of a single university with a "patterns across nature" department. There have been several attempts to form such a discipline, but they have never quite jelled. In the 1940's and 50's, *cybernetics* and *information theory* identified common patterns such as feedback, homeostasis, and information storage and retrieval; processes which are common in complex systems from organisms, to organizations, to nations. In the 60's and 70's, *general systems theory* identified additional common features, in systems at many levels of organization, and helped clarify how these levels fit together. *Catastrophe theory* helped clarify what makes systems stable and, as the name suggests, unstable. *Chaos theory***,** which hit the scene in the 80's**,** showed that systems across nature can be completely unpredictable, while uncovering strange kinds of order in that unpredictability. In the last 15 years or so, *complexity theory* has updated these earlier theories to understand the interplay between order and disorder in complex systems, helping explain how they adapt and organize themselves. Lately, there has been a growing interest in grand evolutionary narratives, linking systems in nature by their emergence in the history of the universe.

So far, none of these paradigms has been fully embraced by the scientific community as a way to connect the disciplines. One problem is that many of these fields have been overly hyped as the long-awaited unifying theory. When they didn't turn out to be quite that revolutionary, people forgot some of the real insights that they offered. Another problem has been that many scientists are mainly interested in their own discipline, not in unifying themes across disciplines. Many scientists, especially social scientists, are downright suspicious of any sweeping theory. These issues point to a limitation of any universal theory. Any theory capable of connecting diverse disciplines is likely to be quite sweeping and general, but a key aspect of every science is the particular facts and idiosyncracies– the things that are glossed over by the universal theory. Many scientists decide this means the general theories are useless. I think this is an overreaction. General theories are useful, even necessary, if we want to understand nature as a whole. They just aren't *sufficient*. They provide a birds-eye view of general patterns across disciplines, which is vital. But we still need to zoom down to see the particular insights and concepts of each field.

None of the general theories, so far, has ever folded all the sciences into one all-purpose framework that can explain everything. Perhaps none ever will. After all, the universe has a particular history that gives it all sorts of idiosyncratic features that simply have to be learned. For example, the theory of evolution can explain why mammals expanded and diversified after the dinosaurs became extinct, but it couldn't have predicted exactly how this would have unfolded. But universal explanation is not the only use of broad theories. Their real value may lie in helping us conceptualize how each field--each level of nature--is related to the others, without reducing them all to one idea.

My goal in the next few chapters is to weave together some insights from discipline-crossing theories like chaos, complexity, and universal evolution into a coherent framework that is useful for seeing broad patterns across nature. Think of it as a sort of conceptual ladder for climbing from field to field, level to level. The way I have woven things together is my own. It is not an established framework for connecting these ideas, because there is no such established framework. The ideas about harmony as unity in diversity are my own, as are most of the ideas in Chapter 7, where I try to combine several themes into a coherent system. These ideas are *not* intended as some grand new theory of the universe that will put all the scientists out of work. They are intended as a new way of combining ideas from several traditions into an easily understood framework that helps people imagine how nature works.

As I mentioned earlier, this is a vital use of science that is often overlooked: its ability to help us understand nature–not just topredict and control it, or base new technologies on its principles, but to understand it. And such understanding should not be just for scientists, but everyone who seeks it. When we recognize broad public understanding as a major goal, sweeping explanations become a necessity. But they are not enough. We also have to look at each science on its own terms, learning the basic concepts unique to each one. That will be the subject of Volume II, which gives more mainstream explanations of the sciences, based on a narrative of the evolving universe. Those who want to move on to the mainstream science may read Chapter 5, and then skip to Volume II. Afterward, if you want to look back at the framework presented in this section, please do so. I like to think it is a useful one.

Chapter 3

The Harmony of Nature?

DICHOTOMIES

LUMPERS VS. SPLITTERS

It has been said that the world can be divided into two types of people: lumpers and splitters. The lumpers find connections and group things together, and the splitters make distinctions and split things apart. But this distinction itself has a partisan flavor. It must have been made by one of the splitters, and the lumpers would certainly disagree with it. The fact is, both groups are partially right. Some of us lean toward lumping, and some toward splitting, but we all do both. We have to, because whether we should lump things together or split things apart depends on the situation. Sometimes we need to focus on forests, sometimes on trees.

Currently, I think our society is slanted toward splitting. We are big on dichotomies: liberal versus conservative; sacred versus profane; tastes great versus less filling. We think in eithers and ors, in oppositions of forces. And it's no wonder. Just look at an alert baby's expression as she surveys her world. Her reactions seem decidedly mixed- there is intense excitement, curiosity bordering on awe, a distinct touch of alarm. The youngster seems quite thunderstruck by the intensity of things; by the vibrancy and complexity of this new world in which she has arrived. So she does what we all did at that age, and begins the lifelong process of sorting things out, of arranging all the bloom and buzz into discrete, digestible categories.

We have to do this in order to make sense of all the sensations coming our way. And most of the time our categories and dichotomies serve us quite well. It's good to know the difference between doggies and kitties, friends and strangers, toilets and water fountains. But we can go too far, and let the boundaries become too hard and fast. We can forget that things don't always fall into neat divisions. Was the Chevy El Camino, for example, a car or a truck? Is a lamp an item of furniture or an electrical appliance? The truth is that the world often admits of degrees. What we see as a dichotomy may in fact be a continuum, and polar opposites may be complements. And there are no pure lumpers or splitters.

NATURAL VS. ARTIFICIAL

One of the most common dichotomies in the modern world is the difference between that which is natural and that which is artificial, or created by humans. We see the world of our creation- our cities, customs, and inventions, as very distinct from the "natural" world which we did not create. And different people prefer different worlds. Some see nature as harmonious and pure, and see the human world as unbalanced and corrupt. Others see nature as savage and disorderly, as a wilderness to be feared, or tamed by the march of human progress. The "fearsome wilderness" view has always been strong in Western culture, perhaps because of the Platonic and Judeo-Christian ideas that this world is profane, and that there is a more perfect one beyond. Periodically, though, it gets challenged by the other view.

In the last few decades, the “nature as harmony” view has been gaining currency. Lots of people think that nature has beauty and harmony, an implicit wisdom to which we should pay more attention. It’s not hard to see where this view comes from. Almost anyone thinks that a mountain stream, for example, is more beautiful than a sewage drain or a salvage yard. A meadow is a nicer place to look at than a parking deck. And the seemingly greater harmony of nature goes beyond simple appearances. Examples abound of the deep and intricate balance and complementarity to be seen in the natural world. Animals inhale oxygen and exhale carbon dioxide; plants do the reverse; and around it goes in an efficient, stable cycle. Examples also abound of the unintended folly of human actions. DDT seemed great until we realized it was wiping out birds. Australia is now knee deep in rabbits, toads, and camels because someone thought it would be a good idea to introduce them.

It’s no wonder, then, that people make the generalization that nature is balanced and pure, and that the human world is not. In some ways, it is obviously true. But the idea is usually based on gut feelings more than facts, so it tends to be both strongly held and vaguely formulated. The result is that people draw conflicting, often mutually exclusive conclusions from their intuitions about the “rightness” of nature. As we discussed in the last chapter, mutually exclusive conclusions mean that, if reality is in fact something more fundamental than a social construction, these conclusions cannot all be right. And of course, this matters, because people act on their false conclusions.

Not surprisingly, appeals to nature have been used to justify or attack just about every idea imaginable, with real effects on real people. Some people assume that herbal remedies are always safer and more effective than synthetic drugs, simply because they are natural. This is sometimes true, but it isn’t *necessarily* (or even usually) true. Arsenic, mercury, and hemlock, which are all quite natural, will all kill you quite dead, while synthetics like sulfa drugs have saved millions of lives. Social conservatives sometimes justify discrimination against gays on the grounds that homosexuality is “against nature”. Various forms of Social Darwinism, the idea that we should let the “fittest” in society rise to the top, and leave the unfit to their fate (because that is the way nature works) are still quite common. So, while there is no doubt that we can learn a lot from the natural world, it is crucial that we take this intuition and clarify exactly what it means, and what it does not. In this chapter, I will examine three questions: First, what does it mean to say that nature has harmony? Second, if nature does have it, then why? Third, why do we care? Why do humans appreciate harmony, wherever we find it?

THE ROMANTIC VS. THE SCIENTIFIC VIEW OF NATURE

> Sweet is the lore which Nature brings;
> Our meddling intellect
> Mis-shapes the beauteous forms of things:
> We Murder to Dissect.

-William Wordsworth

This book is mainly about the scientific idea of nature. Some people may find it strange to speak of harmony, creativity and beauty in connection with science. In fact, many don't connect the ideas of nature and science at all. They may have a deep appreciation of nature, and be be easily swept away by sunsets or birdsongs, and have no idea of the scientific explanations of these things. In fact, they may not want to know. Many see science as imposing a coldness and abstraction on nature's beauty. This is another persistent dichotomy in human thought. On one side are the romantics; the lovers of natural beauty who, like Wordsworth, believe that we do murder when we dissect. On the other side are the scientific types, those who appreciate natural processes most when they can take them apart and see how they work Who is right?

I think both are, partly. Science, at its best, can add to our appreciation of nature, showing us the spectacular subtlety of its underlying principles, and giving us explanations in addition to appearances. But science is not always at its best. When science over-reaches, proclaiming itself the only valid way of knowing, it does indeed "mishape the beauteous forms of things". It does so by flattening them, claiming that the basic laws, the causes and effects, the smallest pieces; are all that really matters. It is this face of science, with its vision of an orderly but sterile and mechanistic universe, that the romantics are reacting to, and I think that they are right to do so.

NEWTON'S SLEEP

"May God us keep, from single vision and Newton's sleep."
-William Blake

One reason for the conflict between the two camps is that science focuses exclusively on the objective, quantifiable aspects of nature. The nature that the romantics celebrate is a different thing. They are talking about nature as it appears to human perception (the nature-loving perception). So, what the romantics are talking about is a combination of nature as it exists "out there" with the way it appears to them. Part of what they are celebrating is their own consciousness. The clear sky seems blue because it scatters a certain wavelength of light, but the *experience* of that particular wavelength as blue is in our heads. Romantic types and scientific types are looking at two different parts of the elephant. The mistake is assuming that the parts are mutually exclusive. Scientists are mistaken if they declare that the objective part is all that is real. This is what William Blake was warning against. Consciousness and perceptions are real, in and of themselves. But romantics are mistaken if they decide that the quest to see nature objectively is unimportant or damaging. It is only damaging if it is assumed that what is objective is all that is real. And it has quite often been the romantics, not the scientists, who decided this is what the scientists are claiming. Sometimes it is Blake's sleep, not Newton's.

The inability to appreciate both views, or the idea that it is impossible to appreciate both views, is just small-mindedness. In fact, both the subjective and the objective views are necessary. Subjective experience is important, but unreliable. Scientists can point out when the subjective gut feelings are mistaken. But artists, romantics, and other subjectivist types can also point out when scientists are disregarding things that they shouldn't be. The key is to separate each point of view, and decide what each is for, and how they might be put together in a coherent whole which greater than either.

BEYOND THE CLOCKWORK UNIVERSE

Another point of contention between scientists and the romantics is the claim by some scientists that the universe is utterly mechanistic and deterministic, and thus, sterile and uncreative. To understand this view, it helps to look back at scientific history. Mechanism and determinism have their roots in philosophy, especially the philosophy of Rene Descartes. As we discussed in Chapter One, Descartes divided the world into separate realms of mind and matter. He claimed that mind was a transcendent thing; a link to the divine. As such, it was seen as totally separate from matter. Descartes saw matter as a simple, precise, and mindless machine, best understood by taking it apart and looking at its cogs and gears. This division was Descartes' attempt to reconcile science and religion--sort of a "good fences make good neighbors" approach. Mind was a spiritual matter; the subject of religion; while matter was the subject of science, with its newly developed tools of quantification and analysis.

Ironically, this attempt at reconciliation would lead to many of the divisions between science and other ways of knowing. Early scientists like Newton seized on Descartes' mechanistic, mathematically precise philosophy of nature, with spectacular results. According to the laws Newton discovered, one could look at the motion of an isolated moving object, plug some numbers into the appropriate equations, and predict its motion into the indefinite future. Before this new, precise sort of science people did not really appreciate the idea that nature obeys such precise laws. Moving objects were thought to simply fall into place based on their "innate tendencies". Light objects like clouds were thought to tend naturally upward, while heavy things like boulders tended downward. These tendencies weren't necessarily seen as hard and fast rules that under identical conditions produced identical results. It just didn't occur to early natural philosophers to frame things in such rigid mathematical terms, because they didn't think nature was that rigid.

But around Newton's time, when this view was beginning to change, the first good clocks and other precision instruments began to appear. (The new views and the new machines were of course related.) The rigidity and precision of Newton's laws reminded people of these new mechanical wonders. As has happened many times sense, they began to think of nature in terms of the technology of the day, resulting in a view of nature that has been called the "clockwork universe". In this view, the universe is like a great clock, with the stars and planets whirling with a motion as fixed and unchangeable as that of the gears in a clock. Whereas the early view of the universe had a great deal of slack in it, which was thought to be taken up by the direct intervention of spirits, fate, or God; this new view was utterly deterministic--every event seemed to be fixed utterly by previous events. Things like freedom and chance began to seem like naive illusions, and God's role for many intellectuals became that of a divine clockmaker, setting the universe in motion and then leaving it alone.

In the years after Newton, people became infatuated with this view of nature, thinking it was the dawn of a new era, when humans would learn to predict nature absolutely, and thus, control nature absolutely. One exemplar of this view was the mathematician and natural scientist Pierre Simon, the Marquise de LaPlace, a brilliant man who I will mention many times in this book. Laplace illustrated his deterministic view of nature by imagining an omniscient being which came to be called "LaPlace's Demon". LaPlace believed that if there were a being who could know the state of the universe at any instant with absolute precision, it could extrapolate, based on the laws of nature, and know everything about the universe at any time in the past or future. To LaPlace's demon, knowledge of everything that has ever happened, or ever will happen, is contained in the present, because the future is completely determined by the past.

The Laplacean dream of a perfectly orderly, deterministic universe stayed strong long after Laplace's time. Einstein, for example, fervently believed that the universe is entirely deterministic. He seemed to think that the universe is designed with a sort of perfect order, and that nothing in such a universe could be left to chance. In books written by scientists up until about the mid-1980s, it's quite common to find great enthusiasm with the possibilities of a deterministic universe. There is a sense that they are looking forward to a time when they will be able to see into the future, simply by collecting enough data. This spirit pervades Isaac Asimov's *Foundation* series of science fiction novels: in the story, a new society is founded at a distant outpost in space. One of the founders is a scientist who has found a way to predict the future course of the society. Before he dies, he records himself in a series of holograms, and appears to the leaders of the colony over the next few centuries, telling them what they should do to keep things going as planned.

People like Laplace, Einstein, and Asimov got so excited about the idea of a completely predictable universe because they were all people with a deep appreciation for order. What they found stunning is the great insight of early scientists like Newton- that the world is far more orderly and lawful than people had suspected. And this insight--that nature has precise, universal laws, and is at least partly predictable and understandable--is surely one of the great achievements of human thought. But the utter faith in a completely deterministic universe seems to have gone too far. While it was appealing to those with a preference for order and predictability, others found it horrifyingly rigid and sterile. In Laplace's universe there is no room for freedom or creativity- everything, and everyone, is simply going through the motions that were determined from the start, and there is nothing truly new under the sun.

As the 20th century has progressed, such extreme determinism has been moderated. The picture of nature now emerging is one which both scientists and artists can admire, because it is partly predictable and orderly, and partly unpredictable and creative. Several ideas in modern science suggest that unpredictability and randomness may be an integral part of the universe. Actually, the first blows to the Laplacean dream occurred in the 19th century, when scientists began to realize that the Earth and its inhabitants have changed over time. Newton and his peers would have assumed that the world was created all at once in more or less its current form. But the realizations of geologists that the Earth's landscape has changed; the undeniable fossils of extinct organisms; and ultimately, Darwin's theory of evolution by natural selection; suggested a world of inventiveness and creation.

However, one could believe in an evolving universe and be a strict determinist at the same time. Even if the universe looks different today than in the past, one could still hold that its future form was completely determined from the beginning. Laplace's demon could still observe the infant universe and foresee its future. In fact, Laplace himself suggested that the solar system had evolved, forming out of an original cloud of debris in space (he was basically right.) Today, even this sort of determinism seems questionable. In quantum mechanics, for example, the behavior of particles is probabilistic, not deterministic. One can say with confidence what a quantum particle is *likely* to do, but one cannot say what it *certainly* will do. Quantum mechanics has an element of unpredictability, even in principle.

Another blow to the Laplacian dream came from the theory of chaos. Chaos occurs in systems that are non-linear, which means that the effect of two variables on each other is not a straight line when graphed. Chaotic systems are unpredictable in detail, but they often fall into broadly predictable patterns called "attractors". In theory, chaotic behavior is completely deterministic. In other words, the future behavior of a chaotic system is entirely determined by its initial conditions. The reason that chaos is unpredictable is that very tiny differences in the initial conditions may become amplified into wild fluctuations in the behavior of entire system. This is the famous "butterfly effect"--the idea that the wind from a butterfly flapping its wings in Rio de Janeiro could eventually lead to a hurricane off the coast of Cuba.

Chaos theory demolishes the Laplacian ideal of a fully predictable universe (though not, in itself, that of a deterministic universe), because we can never know a system in complete detail, down to every last atom. There will always be details we miss which can drastically alter the evolution of a system. Even if we could completely specify the motions of every atom in a system we are trying to measure, chaos is still possible, because the system is still influenced by gravity and radiation from objects throughout the universe. The Newtonian belief that it is useful to think of a system as though it were disconnected from everything else breaks down in chaotic systems, because minute effects from distant objects can become magnified. Not only that, but if the influences that become amplified in chaotic systems are small enough, they reach the realm of quantum behavior, which seems to be truly non-deterministic. In fact, it may be that chaos sometimes amplifies the randomness in the quantum behavior of atoms into largescale systems, in effect throwing a wild card into the workings of otherwise deterministic processes.

Chaos may be related to a third blow to the hope for a fully predictable universe. This is the fact that there are some numbers in mathematics, and thus, inevitably, some processes in nature, that cannot be reduced to a mathematical description that is shorter than the number or process itself. This phenomenon is called *Algorithmic Incompressibility*. An *algorithm* is a set of procedures that can solve a problem in a finite number of steps. Examples include the rules of long division and computer programs for calculating interest rates. Things that are algorithmically incompressible cannot be reduced or "compressed" into an algorithm. The fastest way to predict the behavior of such a system is to watch it and see what it does. It could be that the entire universe is partly incompressible, which would mean that there are things which are absolutely unpredictable.

In short, the idea of a clockwork universe has become harder and harder to accept. We live in a changing, evolving universe; and we probably live in a (partially) non-deterministic and unpredictable universe. Nature is not the sterile clockwork that early scientists imagined. There is order and predictability, which is good. But there is also surprise and novelty, which is also good. Nature, like many of the things we appreciate most, is creative--constantly balancing novelty and order.

A CREATIVE COSMOS

HARMONY AND CREATIVITY: PRODUCT AND PROCESS

HARMONY

To examine the claim that nature has harmony, we first have to decide what, exactly, we mean by the word. Since the most common way of deciding what a word means is to look in a dictionary, let's start there. The *Oxford English Dictionary* lists 6 definitions. The last three concern music and literature, so I will focus on the first three, which concern the broader senses of harmony:

-Awaiting permission to quote dictionary definitions-

According to the *OED*, harmony is an old word that has maintained much the same form over the centuries. It comes from the Latin *harmonia*, and the Greek root *harmos*, which in the noun form means "joint", and as a verb, means "to fit together, arrange".

Looking at these definitions, it seems that harmony has two main components: 1. It involves combination, agreement, or arrangement of multiple, different parts. Multiple elements are required. One note can't be harmonious all by itself. 2. There is a sense that the parts are combined in a specific way; they are not just thrown together in a heap. In some sense the various parts fit together *well.*

Multiple, distinct parts; that fit together well--these two factors are the essence of harmony. Think of a piece of music that you consider harmonious. Both elements are present. First, there is a variety of different tones. Most people would not consider a repeated plinking of middle C terribly harmonious. We need multiple notes. However, harmony is more than just variety. A two year old at the piano has all sorts of notes at his disposal, but his composition would probably not be considered harmonious except by optimistic parents. The notes have to be arranged with some care and skill; they have to fit together well. Not just any outpouring of sounds will do. So, harmony is situation where a several distinct elements are combined in an orderly or effective way. Both parts are necessary. Sheer variety, the toddler at the piano, is not harmony. But neither is pure uniformity. Harmony is a state where a diverse set of elements are somehow unified. For the purposes of this book, harmony is defined in terms of these two complementary elements: *Unity in Diversity*.

Now, we set out to decide whether, and in what way, nature has harmony. If we think of harmony as unity in diversity, then nature is obviously bubbling over with harmony. There is unity to be seen everywhere in all the enormous diversity in the natural world. There are around 1.4 million *known* species of organism on earth, and many biologists think that we have identified no more than ten percent of the species out there. Now that's diversity. But unity is everywhere too. Think of all the common features in living things. Every member of every species is made of cells. These cells are all made of the same organic molecules, which in turn are all based on the same kinds of atoms. That is one kind of unity- -we are all made of the same stuff; united in our similar parts.

But there are other kinds of unity. There is unity in the other direction, in the form of wholes. Each organism is itself a unified thing; a system of hundreds of different types of cells, tissues and organs, all working together to form an oak tree, a mouse, or a human child. Unity goes upward and downward. And yes, it also goes across, linking separate structures. I have already mentioned the cycle that alternates carbon dioxide and oxygen between plants and animals. This is just one of the many examples of the intricate fit between different things in nature. Another example is that some kinds of fungi and algae, life forms from two different *kingdoms* of life, have inter-adapted to form a hybrid organism, lichens. Algae provide nutrition through photosynthesis, and the lichens provide a home for the algae.

But don't get me wrong. I don't mean to claim that nature is always a peaceable kingdom of cooperation and inter-adaptation. Cheetahs and antelope, and ants and anteaters are also inter-adapted, but in a rather more antagonistic sense- that of predator and prey. Cheetahs are adapted to eat antelope, and antelope are adapted not to be eaten by cheetahs. They are working at cross purposes. In fact, even the two members of the lichen partnership struggle over nutrients. Take another look at the three definitions of harmony above. The first and third definitions describe nature quite well. The second definition, which emphasizes peacefulness, does not necessarily apply. Nature's harmony is not without strife.

Still, if we define harmony as unity in diversity, it is obvious that nature is packed with the stuff; so much so that this definition by itself is almost useless. Nature has several different kinds of harmony. So far, we have established what harmony is, in its broadest sense, and that it can indeed be found in the natural world. Obviously, we are going to have to get more specific about the kinds of harmony in nature, the lessons we can learn from it, and where we fit into it. I think the best way to look deeper into the harmony of nature is to begin by looking at the process of creation by which it is formed.

CREATIVITY

Harmony and beauty seem to be closely related. A beautiful painting or piece of music tends to be one which strikes us as harmonious. The diversity of colors or tones is combined into a coherent unity. The various parts fit together well, and we like it. This may be why many of us find the natural world more pleasing than the artificial (if disharmony actually is less common in the natural than in the human world). But it is worth asking: why do we care? Why do we find harmony beautiful, and discord ugly? Let's leave aside for now the fact that different folks find harmony in different places. The fact remains that people have a deep, gut level response to what they find harmonious, whether it is Monet, mathematical economics, or the Sex Pistols. The question is, why is the response there?

I believe the answer has to do with the nature of creativity. Creativity is the process by which harmony is made. I think that this process, in its basic form, is universal, in the broadest sense. It occurs throughout the physical universe as well as the biological world. It also occurs in products of the human mind. Symphonies and dramas, inventions and jokes, are produced by a process very similar to that which produced stars, mountains, and trees. This, in part, is why we appreciate harmony and creativity. The hallmark of human beings is flexibility- we, more than any other species, make our living by being creative; by finding new ways to do things. The capacity for innovation is one of our biggest biological advantages. Because of this, evolution has ensured that we enjoy being creative, and that we appreciate creativity and its product- harmony- when we see it. Nature was being creative long before we humans were around. The fact that we appreciate the resulting harmonies underlines the fact that our mental and cultural styles of creation are an extension of nature's broader process of creation. Now let's take a closer look at what creativity is, and how it works, wherever it is found.

WHAT IS CREATIVITY?

Two friends of mine went to a convention once in Dallas, Texas. They had decided to go on short notice, so they were driving through the night to attend the opening talks the next morning. At around 2:00 A.M., it started to rain. They turned on the windshield wipers, but they just swept back and forth twice and stopped. They were miles from the nearest town, where no mechanics or parts stores would be open anyway, and they needed to keep driving to make it on time. It was raining too hard to see, so they pulled over to try to think of a way to fix the wipers. After a few minutes, they had the solution. They both took the shoelaces out of their shoes and tied them together to make two long strings. Then they ran the strings out of each window, and tied them to the wiper blades. With that, they were on the road again, pulling back and forth on the strings to power the wiper blades.

Luckily, the rain stopped soon, so they could stop their manual windshield wiping they wore their arms out. The shoelace trick was no long term solution, but it was an excellent example of creative problem solving. As such, it offers some insight about what distinguishes a creative solution from a more mundane one. If my friends had been driving during the day, with a less pressing deadline, they could have simply waited for the rain to stop, driven to the nearest town, and had the wiper motor replaced. That certainly would be more orthodox, but it would not have made such a good story, because wouldn't be very creative. The shoestring solution is a creative one because it is original. Novelty and originality are absolutely central to creativity. When the Earl of Sandwich allegedly put a slice of meat between two pieces of bread for the first time, he was being creative. But when I made myself a sandwich for lunch today, I didn't stop to admire my ingenuity. The sandwich has become old news. In order for something to be considered creative, it has to be new. It was only creative the first time around. But there is more to creativity than novelty. A creative idea, invention, or work also has to be *appropriate*. That is, it has to be effective in the domain for which it is intended. My friends could have stopped the car and begun performing CPR on their wiper motor. That would certainly be original, but it couldn't be considered creative, because it wouldn't work.

So, to be creative is to find a new, as well as effective, way of doing things. This is a broad definition, because it applies across many activities: The scientists who make breakthroughs are usually the ones who can look at things in novel ways, but their theories still have to make sense. A good metaphor also combines novelty and appropriateness. It compares very different things, in a way that works, thus drawing a new and apt connection. Comparing the sun to a ball of fire is not creative; it's been done to death. Comparing the setting sun over a battlefield to a *Red Badge of Courage*, as Stephen Crane did in his novel of the American civil war, is creative, and it is one reason that the book is famous. Nature is full of this kind of creativity--of novel forms that are still effective. Here's an example. In the winter, weasels turn white, except for the very tip of their tail, which is black. This sounds counterproductive, because they can't blend into the snow as well with the black spot. But strangely enough, the spot is a great defense against hawks. When a hawk sees a weasel running across a field, it goes for the black spot, perhaps thinking it is a mouse. The weasel usually loses a little black fur rather than its life. Who would have thought of that? It is a simple and original defense, but it works.

THE CREATIVE PROCESS

Now that we have discussed what creativity is, let's take a look at how it works. A good example of the creative process is a brainstorming session. Imagine a group of advertising professionals trying to come up with a good slogan for Acme potato mashers. First, everyone writes down all the ideas that pop into their heads, without stopping to worry about whether they make any sense. Next, everyone reads their ideas to the rest of the group, and the group decides which ones have promise and disregards the others. After this narrowing and cross-fertilization of thought, everyone goes back to writing down ideas. But this time around, the ideas will be more refined, because many of them will be variations on the best ideas from the last round. Now, everyone reads their new ideas, and the best ones are retained again. This process can be repeated several times, until the group closes in on a set of refined, promising slogans. This process has two main steps: Throw out wild suggestions, then keep the good ones (repeat). Now, if creativity is the generation of original but appropriate ideas or innovations, it is easy to see how this process is effective at generating creativity. There is an originality phase- the freewheeling generation of ideas- followed by a test of appropriateness or effectiveness, where all but the best ideas are discarded. Over time, these steps alternate to produce novel, but effective, ideas.

Some thinkers, especially Karl Popper, whom we met in the last chapter, and the psychologist Donald Campbell, have suggested that this two-step process is universal. It occurs whenever new forms or ideas are being created, whether it takes place in an individual's mind or in the development of new species. Campbell had an excellent phrase for this process: "variation and selective retention". (Actually, he said "blind variation" to emphasize the idea that the variation stage is often random, or at least unstructured. However, since human creativity is often goal oriented, I prefer to think of it as unconstrained variation[1]).

Obviously, the idea of purely random variation followed by selective retention calls to mind biological evolution. There is variation within a species, usually caused by random mutations. This is the originality phase, where new, untested forms appear. Then there is selective retention. Only a small percentage of mutations are beneficial, which in biological terms means that they help an organism survive and reproduce more effectively. Most new forms are discarded because they are unhelpful. But sometimes mutations are useful, and allow an organism to survive and reproduce better than others. This is the selective retention phase. These mutations are retained, because the gene that carries them gets passed on. The life-forms

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[1] Both Popper and Campbell seemed to consider this process to be absolutely universal, underlying every kind of creation, and that it always strongly resembled biological evolution. I don't think the process is quite so precise or universal. But it is very common, and tremendously powerful.

we see around us today are a result of this process. They represent the accumulation of characteristics that have stood the test of time.

Now, it can be argued that biological evolution is simply a special case of a broader process, and that Darwin was just the first to see the power of combining variation and selective retention. If fact, once we recognize the basic process, it shows up everywhere. A more general version has taken place in the physical universe, where objects have been retained based on their *stability*, a more general criterion than biological fitness. Hundreds of different subatomic particles, for example, can be created in laboratories, but most of them decay quickly. Many of these exotic particles were present shortly after the Big Bang, but today there are only a few. The reason is that only the ones that are stable are still around. We are made of that small set of particles which are long-lasting.

If we jump up to the more familiar world of human culture, we see variation and selective retention everywhere. If you look at the history of most inventions, they evolve over time in a way that is quite reminiscent of biological evolution (though not identical). Early automobiles, for example, came in an amazing variety of styles, including three-wheeled cars and steam-powered cars. This was an initial stage of variation. Then selection came into play- people bought the cars that worked best (or the ones that were marketed more cleverly). After some trial and error, the gasoline-powered, four-wheeled style emerged as the most effective form. Over the years, this style became a foundation for other innovations that people found useful, such as headlights, hardtops, and inflatable tires.

As we shift focus from the physical universe, to the biological world, to human culture, we see the process of variation and selective retention at all levels. Of course, while the process is the same in its broadest sense, the details differ markedly: As the physical universe evolved, the basis for selective retention was generally simple stability--stars and galaxies are common assemblages of matter in the universe because they are stable forms, and are therefore still around. In the biological world, the basis for retention is reproductive fitness. In the cultural world, however, innovations may be favored for all sorts of reasons- efficiency, profitability, aesthetics, good marketing, and so on. As an illustration of the different selection pressures in nature and culture, think about the difference between wolves and their domestic descendants, dogs. Wolves have been shaped to meet one basic requirement- reproductive fitness in their environment. The result is that wolves are all biologically very similar. With dogs, though, we have replaced natural selection with artificial selection. Dogs have been bred for dozens of different cultural purposes; including hunting, fighting, racing, guarding, and simple companionship. Consequently, dogs come in all shapes and sizes. Like us, they are a reflection of culture as well as biology. But while cultural selection is more variable than biological selection, the general process of creation is similar in each case.

THE CREATION OF HARMONY

In earlier sections I mentioned that harmony is commonly a *product* of the *process* of creativity, a process I have argued is universal. Now I want to clarify this relationship. So far, we have defined what creativity is and how it works: creativity is a combination of newness and effectiveness, often produced by a two-step process of unconstrained variation followed by selective retention of what works. We have also defined harmony, as unity and diversity. So how do harmony and creativity relate to each other?

Roughly speaking, diversity is created by variation, while unity is maintained by selective retention. It's helpful to look at this in terms of the passage of time. Creativity happens over time, alternating between generating new forms and testing them. As time goes on, there are more and more new things that still, in some sense, work. If a new form is retained it is because it somehow fits into its environment. Whether it is a gene causing better eyesight or the addition of headlights to a car, each new innovation must find a niche or it will fall by the wayside. At any one time, then, most things in the universe (those which are in causal contact) fit together in some sense. As time goes on and variation continues, there is an ever greater diversity of forms that still fit together. This is how the process of creativity produces harmony. At any one time, there is a great deal of harmony in the world. Variation provides an ever increasing diversity, and selection ensures at least a partial unity.

Now, where does this put us? We have discussed what creativity and harmony are, and how one leads to the other. We have discussed the fact that nature does have harmony, because it has evolved through a creative process that has generated diversity and ensured unity. Now we need to delve a little deeper. At the beginning of this chapter we discussed the common intuition that the natural world is more harmonious than the artificial, human world. But so far, we have only discussed the similarities between the two worlds. Creativity operates in a very similar way in nature and in human minds and cultures. If this is true, each of these realms must show some degree of harmony. I believe that they do. But I also believe that the harmony in nature is deeper, and that we can learn great deal from it. So, we need to decide exactly how the human world differs from the natural world. To do this, we need to look more closely at the kinds of harmony that appear in nature, so that we can see which we should emulate, and which we should not. But first, we need to delve more deeply into nature's patterns of creation.