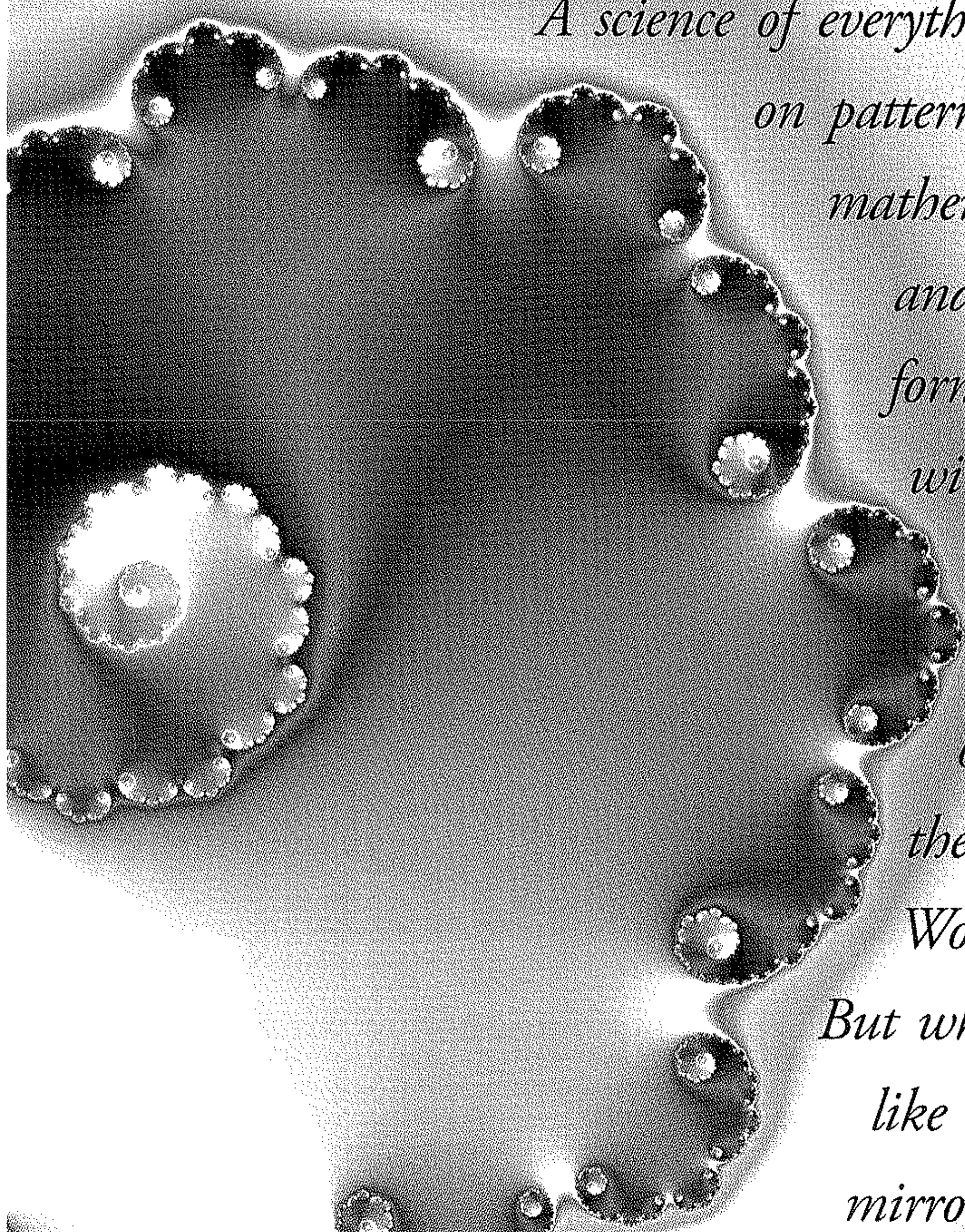
RHYMES AND REASONS

by Tyler Volk

A science of everything would focus on patterns—using grand mathematical schemes and convergences of form and function, with the possibility of illuminating both the wing of the hawk and the structure of the World Wide Web. But what will we look like reflected in this mirror?

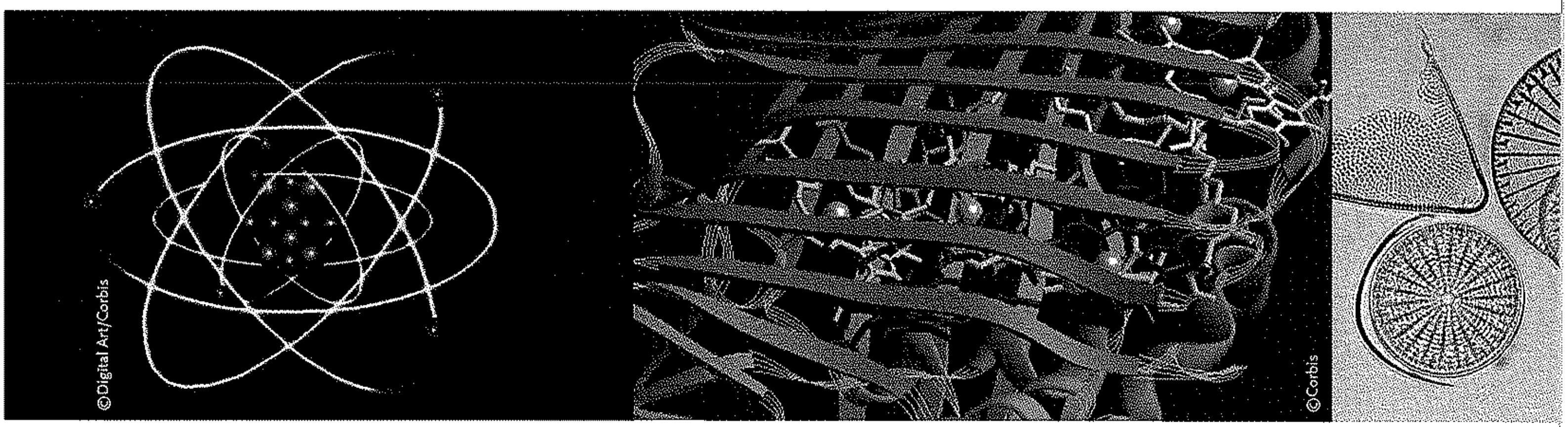


CITATION INFORMATION:
Tyler Volk. Rhymes and Reasons.
Science and Spirit, 2004, vol. 15, issue 5 (Sept/Oct), 44-50.

One day toward the end of summer, I hiked to a perch in the colorful canyon lands of southwestern New Mexico. Nature, in all her glory, was on full display, and I sat quietly, taking in the scenery and marveling at the deep beauty that surrounded me.

A great many very different elements helped to shape this experience—rocks, clouds, the plant and animal life. But everything around me revealed, often in subtle ways, one aspect in common: pattern. As I reflected on this, my quiet moment grew into a reverie I found perplexing, even disquieting.

> THERE EXISTS THE INTRIGUING POSSIBILITY THAT VERY DIFFERENT PHENOMENA MIGHT SHARE COMMON PATTERNS.


©Digital Art/Corbis
©Corbis

I am a scientist, and although I enjoy beautiful scenery like anyone else, I am trained to look beyond appearances for underlying patterns and their causes. What is science, in fact, if not the search for the underlying causes and dynamics that generate patterns? In practical terms, this quest takes place in arenas of things with similar features, which thereby establish the disciplines. Astronomers look into space for objects formed by gravity and starbursts. Geologists focus on crystalline rocks and heaving continents. Systems with DNA and proteins snare the minds of biologists.

But because all of these things possess *pattern*, there exists the intriguing possibility that very different phenomena might share common patterns. This speculation leads us to conceptualize a single gargantuan arena that includes, well, everything—and thus the possibility of a science of everything. This would prove ultimately satisfying to the insatiable human drive toward understanding. Insights gained from one field might be applied to another; perhaps the patterns of physics and biology could illuminate psychology, art, even politics.

When physicists discuss their seemingly interminable work-in-progress toward a theory of everything, they refer to deep unifying principles of quantum mechanics and gravity. But closer to what I have in mind are those findings—also often mathematically based—from discipline-crossing sciences with names like "complexity," "nonlinear dynamics," and "chaos theory." In these sciences, researchers use computer models to ask whether disparate systems—from the psychological webs of language to the swarms of molecules inside cells—have similar behaviors and explanations. The quest has not abated. In just the last few years, we have been treated to eye-opening discoveries in the geometry of networks and to mind-stretching books like *Emergence* by Stephen Johnson and *The Emergence of Everything* by Harold Morowitz.

In my book, *Metapatterns*, I describe a set of design principles that apply on multiple scales, from nature to mind. Examples are borders, binaries, and centers. These metapatterns are not rooted as much in mathematics as are, for example, the results from complexity theory. Thus there will probably be many approaches to finding rules that unify. How far will these explorations go? And what will we find out about the self when it is understood as a system or pattern?

At the very least, it is already clear that patterns exist that bring harmony to things that appear dissonant. In moving from the particular to the general, we glimpse, with Plato of old, something transcendent because unifying principles are in some sense outside and beyond any particular discipline.

Galileo's Admonition

As I sat that late afternoon, a low-angled sun cast golden light on the massive cliff bluffs. The minerals in these bluffs are rigid because atoms lock together into the state of matter we call "solid." I gazed up at the clouds. Their countless water droplets stay aloft because of energy released when vapor condenses from air; the resulting updrafts sculpt the white billows that slow dance across the sky.

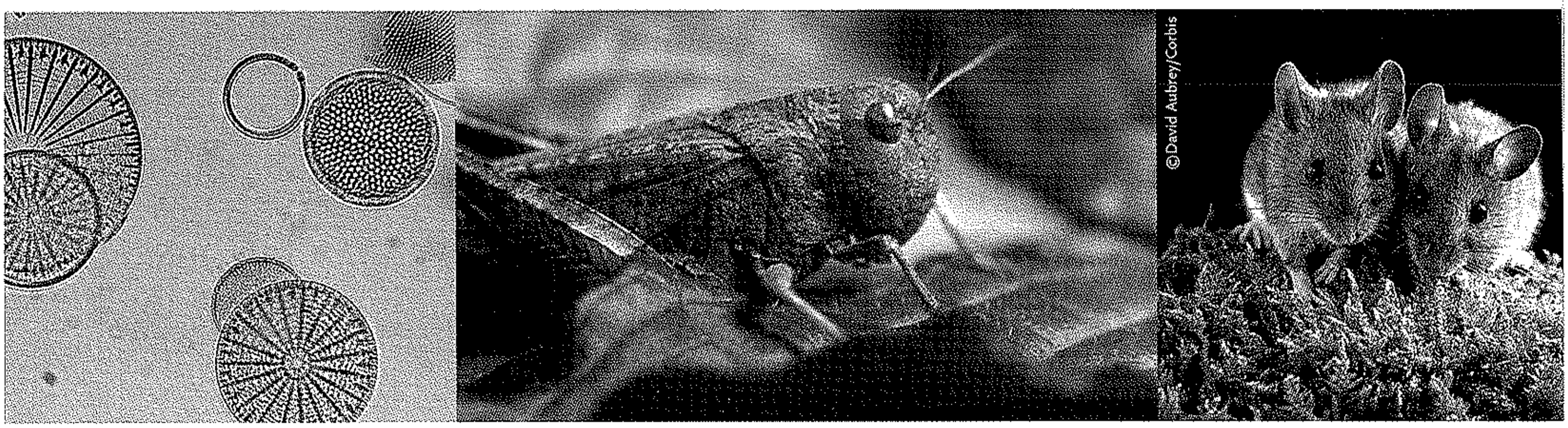
Both rocks and clouds share general patterns based on small parts in relationship via physical forces. These forces can be quantified because they occur in specific strengths. We express such relationships in tidy mathematical formulas, and thereby come to believe that we understand how it is that the physical patterns of nature come into being. The equations themselves have parts related to each other in quantitative ways, mirroring the actual quantitative relationships of systems in nature. The equation on our paper somehow models the physical reality.

The mathematical models that articulate systems in nature are elegant and convey powerful, often startling, insights into Mother Nature's mysterious ways. We speak of mathematics as the Queen of the Sciences, believing that her understanding transcends all others. From simple lines of pencil on paper come equations orienting great stone pyramids or guiding rovers to Mars.

Today, mathematical formulas are embodied in computer chips and software—the telescopes of the science of complex emergence. Galileo's insight endures.

In *Emergence*, Stephen Johnson describes how computers simulate amoebas with the ability to form a colony—a superorganism—during reproduction. Such organized swarming and differentiation is similar to the ways cities grow during the self-organization of neighborhoods, another process that has been modeled via math.

The basic theme or underlying pattern in these examples is that of numerous simple parts in relationship to one another. The parts, whether amoebas or people, self-organize into larger-scale structures. Biologist Stuart Kaufmann, a pioneer in the theory of complexity, uses the metaphor of a scattered array of buttons, which are then connected by threads into a network. The simple rules that guide the connections give rise to structures of increasing complexity. Such networks of things and relations, fleshed out by the computer models, are the larger-


©David Aubrey/Corbis

In 1998, physicist Albert-László Barabási and his collaborators found the first "scale-free" system of real-life buttons and threads. It was in the World Wide Web.

Galileo, at the dawn of modern science, saw with unprecedented clarity the power of mathematics, and touted it as the very structure of nature:

"Philosophy is written in this grand book—I mean the universe—which stands continually open to our gaze, but it cannot be understood unless one first learns to comprehend the language and interprets the characters in which it is written. It is written in the language of mathematics, and its characters are triangles, circles, and other geometrical figures, without which it is humanly impossible to understand a single word of it; without these, one is wandering about in a dark labyrinth."

scale systems whose behaviors, it is hoped, imitate systems in nature.

Not long ago, a special new kind of network was discovered. Physicist Albert-László Barabási tells the story, in *Linked*, of how in 1998, he and collaborators found the first "scale-free" system of real-life buttons and threads. It was in the World Wide Web.

The fractals in an ordinary leaf are one familiar scale-free pattern. Its few big veins branch into numerous secondary veins, which branch into even more numerous ones at finer scales. In a pure scale-free pattern, the relationship between any two scales remains constant across all scales.

The scale-free aspect of the World Wide Web was seen by evaluating the numbers of links (threads) to individual sites (buttons). Most sites have just a few links to them. Some sites have lots of links. And a special few sites, such as Google, are linked by hundreds of thousands or millions of others. From a statistically large number of sites, Barabási's analysis revealed a relationship between links and sites, a mathematical formula holding true at different scales. Hence the Web is a scale-free pattern.

The discovery of the scale-free character of the Web showed scientists what such an odd creature looked like and made this type of network easier to spot in other far-flung settings. Sure enough, in a flurry of papers since then, the scale-free network has shown up in Internet routers, in cell metabolism's interacting molecules, in protein regulatory systems, in biotech companies with collaborative agreements, in sexual relations (at least in Sweden), and in Hollywood actors who appear together in films (see sidebar).

Galileo would be pleased. The discovery points up the power of mathematics to reveal unifying principles of pattern in the world, pattern that we simply would not have seen without the illumination provided by numbers. The repeated success of mathematics in the sciences can seduce us into thinking that all explanation is found in mathematics, that there is but one key that opens all the locks between true understanding and us. But is everything really mathematical? Do all the elements of a science of everything lie in the realm of number?

Emergence and Convergence

During my mountain reverie, a red-tailed hawk soared across the sky. The structural parts of this mighty bird, so elegantly functional, evolved as adaptations for survival—sharp eyes to see prey from afar, sharp beak and talons to grab it, and powerful wings to carry it off. The hawk's sweeping wings, masterfully crafted by nature, are flat because flatness affords a large surface area with which to impose forces upon the air for lift and flight. Human engineers craft the wings of a Boeing 747 in exactly the same way.

Flat shapes that enhance surface area are metapatterns, mathematical to the extent that all three-dimensional shapes have inherent ratios of surface to internal volume. Such innate properties can be discovered and used by evolution when those properties confer an advantage in survival and reproduction. Thus evolution has prompted the wings of bats and butterflies, as well as those of birds, to converge; they are not exactly alike, of course, but they do share the overriding feature of flatness.

THE REPEATED SUCCESS OF MATHEMATICS IN THE SCIENCES CAN SEDUCE US INTO THINKING THAT IT IS THE ONE KEY THAT OPENS ALL THE LOCKS BETWEEN TRUE UNDERSTANDING AND US.

©Bettmann/Corbis

This *convergence* is crucial in biology. In *Life's Solution*, British paleontologist Simon Conway Morris leads us on an encyclopedic tour of the ways evolution has created similar solutions in independent places. Separate evolutionary pathways often converge on the same point. The two long teeth protruding fiercely from the mouth of a saber-toothed cat are mirrored in the independently evolved pair of dental sabers of a large marsupial mammal in South America (both creatures are now extinct). Plants in the deserts of Arizona and Kenya sport similar adaptations in the form of thick stems with accordion-like ribs, able to close up during drought in order to cover the stem's air pores, thus preventing water loss. This design, too, was independently evolved.

Convergence occurs in life cycles as well, evidenced by the number of animals programmed to die soon after sex. When winged mayflies emerge from their aquatic nymph stages, for example, their bodies carry death sentences. After nuptial flights and mating, the mayflies die because they have neither mouthparts nor digestive tracts. Pacific salmon show the same pattern. As they return to the freshwaters of their birth, their bodies go into overdrive for the upstream swim, and because of floods of hormones within, they are literally burned out after reaching the upper watersheds and mating. They die afterward.

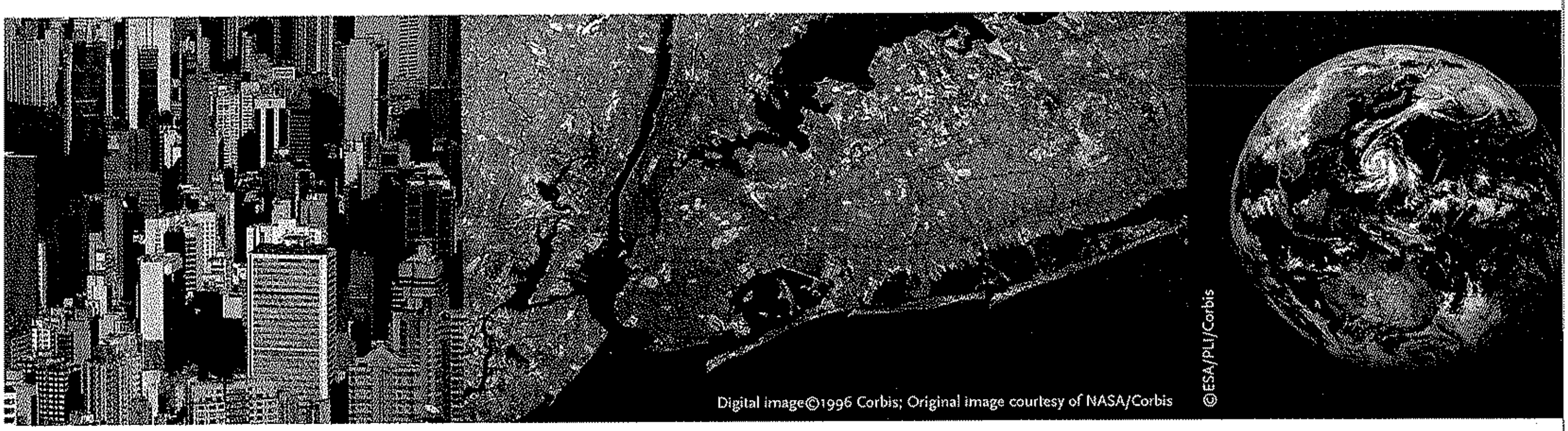
For both salmon and mayflies, a vigorous single round of mating is more valuable to the persistence of the species than a long life. So their short lives have a common structure—a convergence.

Such biological convergences are similar to scale-free networks in that a pattern occurs across different systems that emerged independently. But the reasons for the repeated patterns differ. For instance, some evolved, some did not. A science of everything will have to accommodate very different categories of causes.

realm can be no exception. Psychology examines patterns that should be subject to logic that exists beyond specific instances.

As the science of pattern rolls on, illuminating so much with mathematics, I can begin to see myself as essentially mathematical. This is a bit disturbing, implying that the self is an algorithm, churning away at high levels of abstraction, the way the word processor of my computer is a high-level operation with sub-levels and sub-sub-sub-sub-levels of programming within it. These are nested, all the way down to the ultimate simplicity of binary code, the ultimately reduced world of ones and zeros. Is the self similar? Are we a nested series of levels, all the way down to the firings of the brain's neurons?

If so, are particular levels more important than others? Traditionally, science succeeds in explaining upper levels by lower levels. Thus, to understand the cells inside the hawk's body, we must know about the forces of atomic bonding within the enzymes of those cells. But cells, in turn, also determine their molecules and atoms because cells serve as contexts into



Digital image©1996 Corbis; Original image courtesy of NASA/Corbis

©ESA/PLI/Corbis

More intriguing is this question: Is mathematics the exclusive key to the principles of a science of everything? The scale-free networks are clearly mathematical. So are the flatness of wings and perhaps the sharpness of saber teeth. But unlike the scale-free networks, which were only found by sophisticated mathematics, the properties of wings and teeth can be described with simple words and pictures. Their pattern does not seem to be purely mathematical, especially because functional applications are in play. So we must be wary about too swiftly concluding that nature creates everything mathematically. Instead, nature seems to have different ways of embodying what we can tentatively call *ideas*.

Patterns of the Self

As I sat contemplating the patterns of cliffs, clouds, and hawks in New Mexico, I eventually came to myself. Like everything arrayed before me, I, too, am a pattern. A body, of course, but also a mind—a complex system of ideas. If the science of everything truly includes everything, then the psychological

I, TOO, AM A PATTERN. A BODY, OF COURSE, BUT ALSO A MIND—A COMPLEX SYSTEM OF IDEAS.

which molecular structures must arrange themselves in particular ways. The loop of explanation goes both up and down.

These concepts have not been worked out adequately enough to give us a set of general principles for a science of everything. We can say that patterns occur as different modalities on various levels. The levels and modalities will eventually need to be categorized, understood, and put together into the proposed new science of everything.

The self, for example, is an upper-level psychological pattern that uses language as one crucial modality. Language allows us to deal with conceptual patterns, which we do every day in abundance. In contrast, we also express ideas graphically, surrounding ourselves with the icons of advertising and the news and entertainment of print and television. The practice of science itself depends on three modalities: mathematics, language, and images, all evident in its technical papers filled with equations, words, and graphs.

Mark Twain wrote, "History does not repeat itself, but it does rhyme." If he had quipped "nature" or "universe" instead of "history," he could have been pointing to a science of patterns. The discoveries of these rhymes—and their reasons—point to different modalities.

The science of everything will not be a single equation or a small set of equations. Reality is too complex. The different nested levels—in computer code, in psychology, in biology—require different kinds of descriptions, different logics. But for me, the real reason for the quest is to help us soar like the hawk.

As the hawk's wings evolved to fit the air, so too do we personally grow to fit how we understand the world to be. Perhaps there are different modalities, or logics, for forming patterns. It is likely that we, as the most mysterious of patterns that seek to understand other patterns, are true mixtures of these logics. When we discover and internalize knowledge, we become what we discover.

By studying such patterns at all scales and reflecting on their meaning, a new, comprehensive science just might be possible. This was the conviction that emerged in that moment of reverie, as I sat among the glowing cliffs, glorious clouds, and the formidable hawk; as the pattern that is me pondered the patterns that were not me.