The Chaos Revolution

A talk by Ralph Abraham
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I've been thinking about the sixties lately. Hardly a week goes by that I don't think about them, because there are some memories that aren't covered in the various books about that era -- memories of dreams that were unfulfilled. I had a dream...I dreamt that a major social transformation was happening. It did seem to be happening, and then it seemed like it didn't. Marilyn Ferguson wrote a book, *The Aquarian Conspiracy,* **which sold hundreds of thousands of copies and made a lot of money that she reinvested into the community, always in the direction of seeking that Aquarian transformation that somehow seemed to be postponed. So now we have a hippie in the White House who said when he moved in yesterday: "This is our time. Let's seize it."**

We probably all interpreted that our own way. I heard that he was a hippie in the sixties, living in London with his hair down to there, undoubtedly smoking grass and eating sunshine windowpanes and so on. He must be one of us. He's obviously one of us. Maybe everybody thought he must mean them when he said, "This is our time." It could be that the social transformation that was attempted in the sixties was just thirty years too early. Maybe we need sort of a trial balloon that charts the waters and the air currents etc., and then later on, there could be a conautical (?) form for a major social transformation. We have seen a few of them in history. Maybe they have a form, and the preconditions are all that's necessary for a renaissance. Maybe something exists now that didn't exist in the sixties.

Of course, this could be just more wishful thinking. We were wishful thinking before; we're the same folks that have been wishful thinking every year since birth, hoping for, not a gradual improvement, but some drastic miracle that really makes things better right away. In support of this wild fantasy, however, there is a kind of archeological evidence. There was an engineer named Sir Flinders Petrie, who was inspired by a kind of New Age rumor that said that the pyramids in Egypt weren't oriented.[?] He decided to go with England's top surveyor to check it out. He wasn't even an amateur archeologist, but when he got to the pyramid he fell in love with the whole Egyptian culture and spent his life digging up ancient Egypt.

He was the first Egyptologist. He dug down from the top to the bottom. Along the way, there were layers characterized by pottery styles, and philosophical concepts written on papyri in hieroglyphs. These concepts remained more or less constant for a certain distance in space, and therefore, time. And then suddenly, there'd be a major shift in style. It took years for each inch of digging down, sifting, classifying, and putting the stuff in bags. He did a pretty good job and invented a lot of the techniques of field archeology which are still used today, and when he got done, he had discovered eight distinct layers.

He believed that the sequence of social events in each of these eight transformations was the same, so he came forward with a kind of universal theory of social transformation: first comes mathematics, then science, then technology, then economic prosperity, then corruption of the rich, and then a

new cycle begins. The sequence he charted out was very convincing. Each sequence was separated by literally centuries of constancy followed by a sudden shift within less than a century. He tried to apply this theory elsewhere, in Eastern Europe and ancient Greece, and wrote a little book called *The Revolution of Civilizations.*

His theory is based on hard data of a sort that didn't exist before. Never had there been so much archeological information available before. When we consider that model for the present time, we see that a transformation in mathematics is happening, namely the Chaos Revolution, which didn't exist 30 years ago. The Chaos Revolution is as big a shift in the underpinnings of mathematics as ever happened before. According to the theory of Sir Flinders Petrie, who dug up ancient Egypt, this shift has to come first. So when we tried to bring in the Aquarian Age earlier, we had to fail. I don't know why, he doesn't know why. It's just a historical fact. So maybe we actually have the precondition for social transformation now that didn't exist before.

And now that we've got Bill, we should try it again. That should make us kind of curious about the Chaos Revolution. I mean, what is it? What is actually going on? Is there a sequence of paradigm shifts in the different realms that follow in a certain sequence? Chaos Theory, I mean the fundamental mathematical stuff, has existed for a century, but it's been locked up in a book that nobody ever studied until somehow it became visible to all and sundry through the computer graphic revolution, which is pretty recent. So now everybody can see it. It's on the cover of all the books, advertisements and billboards on mathematics, it's all over the place. One reason for that is that it's novel, and another that it's beautiful beyond belief. The images are beautiful...as beautiful as the Parthenon or the cathedral of Chartres.

However, it's not just because these images are novel that people love them. It's because you've seen them, before you go to sleep. You also see them when you wake up, and then you can't remember them because they're not like anything else that can be remembered. There's no memory box to put them in. It's like one of those dreams that no matter how fast you try to write them down, they're already gone. Suddenly, the stuff of these dreams is on the wall. It's on the wallpaper, it's on the outside of the car, and it's on people's tattoos. Somebody told me yesterday they were looking for a good fractal image for a new tattoo. It's the externalization of the unconscious right onto the skin.

The first actual paradigm shift that you could blame on mathematics probably happened around 1973, just when people were giving up on the sixties. In 1973 I was already teaching Chaos Theory in Santa Cruz and had the wonderful good fortune to actually participate in, and be contacted about, the great news arriving in different fields. People would call me up and say, "I just got an idea, maybe you know something about it." They felt that they personally invented a new theory, Chaos Theory. "Is there really some literature about this?" they asked. This happens in one field after another, and each year it's a different field. I didn't go out of my way to find Sir Flinders Petrie's theory. I didn't even know about it at that time.

In 1973, it began with physics. And within a couple of years it had struck chemistry. I still remember the graduate students in chemistry who were so excited: that means you have this molecule, and this one, it's going to have a

chemical reaction in here with a laser, and you measure the energy, and the light comes out, and it doesn't repeat itself the way it's supposed to, and here's the data. It was actually an epiphany, a complete revelation, with the invisible diffusion from one field to another.

Whatever the underlying dynamic, the mechanism of Sir Flinders Petrie's observation may be, I have somehow experienced it in my dreams. It is very mysterious. The astronomers suddenly got excited about data from our solar system, they saw satellites, moons of different planets that roll and tumble. ..It took about ten years to get to the biological sciences. And then there were these really radical doctors who wondered about epilepsy, maybe the heartbeat, could it be...? These doctors would come to me feeling they were making a new discovery. Is there any mathematical proof for what I've discovered? they asked. They didn't realize that this had happened in astronomy, in chemistry, and in physics before that. They never read about it, there was no place to read about it. It came to them through some kind of diffusion in the intellectual field that's telepathic or something.

The social system is such a complex system, we don't really have the concepts for how it works. The doctors were afraid that if word that they were thinking in this way got out, they'd lose their funding, and their research depends on huge grants. Only a few people get these huge grants, and there is espionage and sabotage and all that stuff going on to protect their grant status. Sure enough, some of the leaders of this discovery did lose their funding because it was too radical for the funding agencies who send the grant proposals to the other scientists who hadn't yet experienced the paradigm shifts. What these leaders were saying seemed like insanity to the peer review people, who had to say no to the grant.

All these shifts, as we later saw, were permanent. They just took one, two, or three years to sweep over the entire field. It happened field by field. If it were just through diffusion in a large and complex system, it could happen in any order, but it seemed to pretty much follow the pattern of Sir Flinders Petrie's theory. In the biological sciences, for example, there were people in medicine who thought that a healthy state would be a steady state. They didn't even allow for periodic daily, seasonal, or annual variations. No indeed, it should be a steady state.

In a previous paradigm shift the biological scientists accepted oscillation, i.e., periodic variation, as a normal thing. That means biorhythm. And that means you have to acknowledge that there is some interrelation between an individual human being and the moon, which medical science didn't want to admit. Every human being knows this from direct experience, but science is sometimes divorced from experience. It needs a reconnection. So it started in medical science in 1983, then it swept through the biological sciences, reaching botany relatively late. Then suddenly, the social scientists became interested. First the social psychologists. Then a few years later, the psychiatrists. A scientist called me up from New York and said, "I'm going mad, I don't dare to speak about this to anyone else, but I want to know, could there be a mathematical justification for what I'm observing? I've noticed this with my patients and in practice, and you know, I feel like Galileo." He was the first domino in the domino effect in the field of psychotherapy. That was around '87 or '88.

Now, economics is a social science that has an extensive mathematical department called mathematical economics. People desperately want to predict what the domestic or the international market, the trade or whatever, is going to do. The finance ministers of all these countries have to really get a handle on what's coming, or their boss - the president, the prime minister, the grand vizier - will be pushed out. Unlike the doctors, who not only take your temperature but also have to kind of estimate the pulse, they have all this numerical data to help them. Financial data comes already numericalized and is therefore accessible for mathematical treatment. It's not surprising that economics had an extensive mathematical development. So who would expect that among all the social sciences, economics would be the last to become interested? Just about two years ago, mathematical economics discovered chaos. They got very excited. "Does this mean that we can predict the stock market?"

To me, that was the most astonishing out-of-order element in the entire sequence, which still exactly fits the Flinders Petrie model. It should have come earlier if it was just ordinary diffusion. These mathematical economists are among the best mathematicians in any branch of applied mathematics. They're in tune with the latest developments. It seemed a coincidence that they were stuck on a paradigm that had been the leading thing just a few years earlier. You see, two decades earlier, they had fastened on differential topology, which was then the hottest frontier in mathematics. They got stuck on it and never moved an inch. It seems like a coincidence, but it conformed perfectly to a model of social transformation, making you wonder if there is something like the renaissance going on? That's a big shift, like the Aquarian conspiracy, and it's happening now instead of thirty years ago. Could it be that historians a century hence will actually call it the Chaos Revolution? That would be fantastic, but it would conform to Flinders Petrie's theory.

So who's calling me today? A year ago it was the literary critics. It had passed the sciences. Every science has been turned around. Bill Clinton has not called me, but I had a call from the United Nations. If Bill meant it when he said, "Now is our time. Let's seize it," then it's very unlikely that he could ignore this whole development. It's the biggest intellectual rocket booster engine around if you really want some leverage to solve a problem. It would be pretty optimistic to think that it could all come together into a self-conscious application of the latest all and everything, converging on the major problems of our own evolution.

The first field in the humanities affected was literary criticism. There are now three books about chaos and literature. Some novels have a story that is something like life. If you had a mathematical model for a story, you could try to apply it to life, like history itself. Herstory, story, which is what I've been talking about since the beginning, is having a kind of mathematical model for history itself -- for the whole story, including the sky, the solar system, the moon, the biosphere, the botanical and zoological species, human society, emergence of cities, major social transformations like the urban revolution, the renaissance, and so on. This past summer - the developments are always in the summer because that's when the professors go to the conferences - this past summer it was anthropology. And now we're arriving at philosophy.

Anthropology? Philosophy? How can you envision a paradigm shift in these fields that has anything to do with chaos and fractals? To take a particular part of philosophy, let's consider Greek philosphy. The Chaos concept existed in the Greek pantheon among gods and goddesses. They could have had, but didn't have, an explicitly chaotic model for the all and everything. But now we can't avoid it. If you think seriously about your spiritual experience, or your daily financial experience, or work, or your relationships and no matter what else, if you do your best to understand what's happening to you in any of these spheres, you'll use all the cognitive apparatus tricks and intellectual strategies we have in order to obtain the maximum understanding of whatever it is, and you certainly couldn't leave out this paradigm shift that has happened. Understanding is different now than it's been for at least 6,000 years, and it'll never be the same.

I'll attempt to give a step by step example. First let's consider an individual human psyche. This individual might have good thoughts and evil thoughts. Sometimes, if I'm really good, the evil thoughts will be unconscious, in the shadow. There could be a polarization in the psyche, in the mind, so that over here is the good, and over there is the bad. Now let us imagine - and this is in the category of the philosophical class of binaries, or dichotomies - good/evil polarized. All that is good, all this is evil, and in between is a clean line. That's the post-Chaos paradigm. The post-modern, or the Chaos paradigm, deconstructs that [WHAT?} using this fractal.

Your model fractal is the beach. Here's the ocean, and there's the land, the sand, and seen from an airplane 30,000 feet above, there is a clean line in between. But then you walk out on the beach and you see that there are waves, and then a wave comes in and the beach looks like mostly water. There's water on top of the sand, there's water in the sand, it looks shimmery, it looks more like water than sand. And then the wave goes out. Pretty soon that water drains out of the sand and you can see a shiny line kind of receding back toward the water. The wave has already gone back to the ocean, and here's the shiny line going back after it. And what's left this side of the shiny line is more like sand than water, although it's still wet. If you walk across it, your footprint fills up with water. So it's some kind of mixture of land and water. When you look at just the water that's on the beach, it's like a continuous thing with holes in it, which are sand grains. And then you focus on the sand and it's this continuous thing, and that's the dirt. Then there's water, you know, little pockets of water with water droplets in it.

Looking at it that way, this is the model fractal. There is no clean line between the water and the land. Instead what you have is beach. That's a fractal. Now let's go back to good and evil. That's another fractal. Take a can of white paint and put in a drop of black ink, and then take the paddle and stir it. As seen from 30,000 feet above, it pretty soon looks grey. But when you really look, you see that there's only black and white, no grey. There's the black streak, it's very fine, and between the two black streaks is the white streak, it's very fine, and if you could stir it backwards again, you could, in principle, separate the white from the black. So after we see these fractals on every magazine and book cover and on the TV, you start thinking in that way. You say okay, the good and the evil in the mind must be stirred up like that, right? Which means that wherever you are, if your

thoughts are good, there's hardly a millimeter to travel before you hit an evil thought. It's not like the light and the shadow. It's all grey.

That's a fractal model of the psyche. That psychiatrists are trying to actually use this intrigues people. Take co-dependence; it's the kind of thing that has a lot of layers, and they're all different. Think of multiple personalities. I'm a multiple personality. I mean, sometimes I feel really great, and other times I'm just tired out. We all feel like kind of a crowd of people. You look in the mirror, and you've got this committee meeting going on. Now suppose that your different personalities are like fractals, that they're all stirred up together and it's really hard to stay in one. Maybe the healthiest situation is when they're all stirred up. You get like a millisecond of that one, and then there's this other one, and you have sort of an average personality coming out. That's a chaotic situation, a chaotic form, a frothy structure in the psyche, which may actually be a healthy one.

Someone who is really diagnosed as a multiple, however, will be Nancy for three days running and then John for about a month. That's like the paint before you stirred it up. It's not stirred up enough. It's not fractal enough to be healthy. You could think of the individual psyche like that. A society, a psychology of the collective conscious, or call it the will of the people or something, would be like a multiple personality, and maybe the influence of each person actually spreads out. Sometimes it goes down a narrow channel for a long way. After a telephone call,[?] our networks are spread out spiderweb style,[?] and the whole society is a mixture of people that's sort of like a fractal, a social fractal. This is still ordinary reality.

In Greek philosophy, we think about the soul. Somebody called me up from the UC Berkeley Extension, and said, "We've heard about you, maybe you'd like to give a workshop for us?" And I said, "What kind of thing are you interested in?" and they said, "Well, soul is selling really well this year." What's happening now may be another manifestation of Sir Flinders Petrie's theory. What's popular? What do you find in the lyrics of popular songs? It's kind of an indicator of a wave theory. There's a guy who predicts the stock market after studying the lyrics of popular songs, it's called the Elliot Wave.

If we wanted to go all the way with this, we'd have to think of the largest picture of all and everything. Let's take the Platonic model. It's such a good one that it must be a gnostic epiphany. The guy tripped and observed very carefully and brought back the actual experience, which then sort of conforms to our experience. It's hard to tell after the translators from Greek to English get done, but here's a version of Plato's cosmological model. The big one [GOD?] is some kind of formless thing, which is basically all will. It's like kind of a very compacted testosterone job. It just wants to create, it just wants to do stuff at all costs. That's called The One, and you can't even describe it. It's just like a point. It's like in Taoism, the Unkarma (?) kind of thing.

The Platonic ideas are in what's called the "intelligible sphere." It's not a material thing; it doesn't have matter and energy and ordinary time and space. It has its own time and space, enough of it to contain all the forms, all the stories, all the 47 plots that comprise all plays. They're all there in this intelligible sphere. And then there's the sensible sphere, which is what we

call ordinary reality. So that's a kind of a three-part model right there. I have not mentioned the soul yet. Soul is something that fills up the sensible sphere, like the water on the beach. It extends a little bit outside the sensible sphere, like a corona around the sun, where it's reaching up from the sensible toward the intelligible sphere. It actually fills in the space between those spheres as a kind of elastic medium. And this elastic medium is called the soul, the cosmic soul, the world soul, the soul of the world, the animus mundi. It's not the main thing, it's not the ordinary thing. The cosmic quality according to Plato is the first time the idea came up in literature, although it must have a prehistory that we don't know, in Babylonia, Sumer or Egypt, Crete, Anatolia and so on. We don't know where this kind of model of the all and the everything was, before Plato. His is the clearest mathematical model of the all and everything.

I represented intellectual concepts in religion as gods and goddesses, but they aren't actually non-material anthropomorphic individuals, they're more like abstract concepts. There may be a different way of expressing the same thing, but this is the philosophical way. So the cosmic soul is this elastic medium within which it takes form, and it communicates between the spheres. And one thing that it is supposed to do is to create something, create a new thing. You need the idea from the intelligible sphere, it's sort of propagated through the cosmic soul. The cosmic soul was eventually identified with a goddess, Hecate, so it was Hecate who would do these things. Plato would say the cosmic soul took forms intermediate between the intelligible sphere and the sensible sphere, and propagated the idea, the model, the blueprint or something down, so that it incarnated in material form. Whether it was an object or a sequence of events, a story, or a prototype, the archetype would precipitate down like rain from the clouds, through the cosmic soul. That was the creative role. Eros is another manifestation of the cosmic soul. The individual soul is a ripped-off piece of the cosmic soul, and it's the job of the cosmic soul to take a piece of itself and attach it to a body. That's just one example of its creative process. It's all described in great detail in the Timmaeus.

Rocks also have a soul, a little individual soul, a piece of the cosmic soul that's ripped off as part of the creative process. In the morphogenesis of that rock, the beach and all the fractals of mathematics play a role. They have models in the intelligible sphere that precipitated through the cosmic soul. They are given individual soul form, which, like Rupert Sheldrake's morphogenetic field, help the creativity in the sensible sphere where you finally get energy and matter to incarnate the idea. This creative phenomenon connecting the individual soul to the cosmic soul was studied in the world of Platonic philosphy, especially in the Neoplatonists around the time of Christ. They imaged the descent of the individual soul as a process, descending through the cosmic soul. They visualized this piece of the soul as coming down into actual incarnation and gathering body -- not a material body but kind of like a shell around it. They called it the vehicle of the soul. It becomes more and more dense and more and more formed, and takes on more and more structure as it descends in the incarnation process. After your birth the incarnation is complete. The vehicle, though, is still lying around for your use if you want it. You can get in it and travel back toward the One, reaching maybe not all the way to the intelligible sphere, but almost all the way, depending on your skill in traveling.

The instructions for this trip are contained in Neoplatonic books, particularly the one by Iamblicus called *The Vehicle of the Soul*. This is just a little review of one part of philosophy that spanned about a thousand years, from Plato to Proclus (?), and it's not really forgotten. It was built into Christianity in the early Christian Gnostic movements. Changed beyond recognition but still with us are all the elements including angels and demons, which were invented around 200 A.D. as part of the process of understanding the specific mechanism for incarnation and specific ways for communicating ideas from the intelligible to the sensible and vice-versa. Now let's take this little bit of pre-Chaos philosophy and view it again after the paradigm shift of the Chaos Revolution reaches philosophy.

The individual soul in relation to the cosmic soul is a fractal relationship, just as the individual psyche or mind, in relationship to the community is a fractal relationship. Our tentacles reach everywhere. The interface between two individuals, or between one individual and the whole group, is very extended. It's like a spiderweb kind of wild fractal. Like the water and the beach. So the relationship between the individual soul and the cosmic soul is like the stirred paint, like the water in the sand on the beach, and the relationship between the intelligible sphere and the sensible sphere is also not a clean division with a simple gap which can be filled with this cosmic soul, but rather a fractal relationship, a chaotic relationship between the ideas and the manifestations. The cosmic soul, then, is filling that gap, which is no longer a simple gap, but a fractal gap. The cosmic soul would be more like the water in the beach.

I'm suggesting this as a model to try out, if, for example, you had a visual experience of your own soul in relationship to the cosmic soul. If it didn't look exactly like Plato's model or some other model found in a religion or in a spiritual practice -- if you don't have any place to put the experience, you kind of lose it. But if you have the idea of fractal models, and if your experience fits that model, then suddenly you have a place to put it. That means that those experiences could somehow be remembered, like dreams that look like fractal landscapes. It's easier to remember if you have the intellectual concept of a fractal landscape. If this model suits direct experience better, there could develop an accumulating consensus about the spiritual experience, which then could return to kind of a central role in the life of the community. That would be interesting, because then you could see that, in the context of your own experience, mathematics could actually have an effect on the evolution and the future of our species in the biosphere and on planet Earth. Such a return to spiritual awareness would be empowered by a mathematical idea, which is, after all, mathematicals[?].

In the neo-pythagorean era which followed immediately after Plato, they called the forms in the cosmic soul mathematicals. Mathematics was actually a synonym for the cosmic soul, thought of as this elastic medium in between. So, to return to the beginning of this talk, it's kind of a Platonic support for the Flinders Petrie theory. Pythagoras worshipped number above all. Mathematics as a spiritual discipline was the top priority for Pythagoras. The people in the Pythagorean communities wore white, and they didn't wear wool. They had amazing similarities to hippies. They were vegetarians. You could almost say that the hippies were unconscious imitators of the Pythagorean community at Protona, but in those communities you had to study mathematics for five years before you could even begin spiritual practice.

I'm not suggesting the worship of fractal geometry or chaotic dynamics, but I do think that somehow it's very liberating. The experience of the people in these different scientific disciplines reflects that. They felt liberated when they could actually remember what they had observed. They could record it. They could report it without losing their grant, because somehow the allowable had increased.

It would be amazing if popular culture followed a mathematical development. It would be understandable, though, in a time of a maximum paradigm shift, because that's when orthodox scientists reject new discoveries. There are a lot of people who hate dogma. They might be spiritually inclined and even go to church on a regular basis, but they certainly hate being told exactly what to think. When the church rejected Copernicus, for example, or put Galileo in jail, or when the church burned Giordano Bruno at the stake Easter Sunday in the year 1600, a lot of people were annoyed. In such times of heretical persecution you could expect a popular movement for the underdog, and today the underdog is the Chaos theorist in whatever field, because the old guard are still trying to support the old paradigm.

You see, everything around us is chaotic. The carpet is chaotic. It tried to be a regular pattern, but it couldn't quite make it to mathematical perfection. The paint on the wall has undulations. These are fractals. Nature has chaos and fractals everywhere. If you filter them out because of what you've been taught in school, you're not really seeing anything when you look at nature. The Chaos Revolution is rewarding. It's liberating. It empowers you. It empowers you to see what you actually see so you can register what you see. Then you can remember it and deal with it. It's more real. Science has been very dishonest.

Chaos theory provides a new way of looking. I call it chaoscopy. It requires having a fairly hefty computer and appropriate software. You can put the data in and it makes a picture on the screen that is hard to see without this chaoscope, revealing the order within the chaos. Looking at, for instance, stock market data, if we want to predict the stock market two weeks from today so we can make a bunch of money and retire, then the chaoscope gives you a picture of a form that's intrinsic in the data. You can't see it directly in the data. It doesn't predict anything well enough to bet on, but it gives you an understandable picture. People try to teach [who?] how to predict the stock market by giving them jelly beans when they get it right. What they actually do, I think, is mostly to develop their own chaoscope. They sort of rediscover this chaoscopic trick that comes from the Chaos theory. It's sort of a cheap way to get a new science, training a computer with jelly beans. It's an area where you make fantastic gains with a chaoscope.

Let's say you take EEG data from a number of electrons on the scalp. You'll get a very crude view of a biological neural net, which has been compared to hanging a microphone from a balloon over Beijing to try to learn Chinese. So when this really bad data of a biological neural net is subjected to chaoscopy, you can see that it has an unbelievably simple model. It's been said that this kind of EEG data is sixth-dimensional, and that human thought is somehow basically approximately six-dimensional. That's a pretty low dimension when you think of these zillions of neurons pretty much going on their own independent trips, communicating very loosely, and coming up with a coherent self-organized behavior that has so much overall order that it

behaves like a six-dimensional dynamical system. I'd say that's astonishing. That's a new development, a discovery of biology made with chaos theory. It organizes itself really simply, otherwise we couldn't exist. If it becomes too complex, the person is ill. And if it's too simple, you're also ill. For example in epileptic seizures, the dimension of the EEG activity actually decreases to four or so. That's a new way of diagnosing epilepsy.

Music and Chaos is another thing that's happening today, along with philosophy and the cosmic soul. People try to compose music with chaotic dynamical systems by essentially playing a dripping faucet into a synthesizer or something. That's not too interesting, but over the last five years or so, more and more sophisticated connections between musical apparatus and chaotic systems are being explored. Composers seem to be people who rapidly understand mathematics and engineering and all that. They very quickly press things into service with total competence. The popular songs and their lyrics are some of the most interesting views of cultural evolution.

We did a rave recently in the Cathedral of Saint John the Divine in New York, the largest Gothic cathedral in the world, with a fairly serious supercomputer that was loaned to us by the computer company for this purpose. The connection between the picture and the music was, I would say, semiautomatic -- that is, there's an algorithm that connects the picture to the sound through a whole series of computers in a network, but the algorithm itself has parameters which could be manipulated by the performer according to composed scores and some improvisation. It was performed by three people, sort of a trio, with two of us preoccupied primarily with the picture, and one busy with the connection between the picture and the synthesizers. The acoustics in that cathedral are pretty astounding. It's an eight-second echo from one end to the other. Inside, the cathedral is two acres long. It was quite an awesome experience. I was thinking of the 1960s when the local rock group was playing and there was a light show with petrie dishes with colored ink and a projector. Those forms definitely went with the music in a way that meant something.

Nowadays there are also a lot of light shows, especially on MTV and on those sports broadcasts on the weekend. They have very fancy computer graphics and video displays, but only some of them really use mathematics. Well, that's my line so maybe I have a bias, but I think that mathematics provides the possibility of a much more intimate connection between picture and music. It's much more meaningful in terms of our primary experience than just general artistic graphics when triangles are moving around in time with the music, particularly the images that are created with fractal geometry and chaotic dynamics. Mathematics has been pretty well destroyed by schools. It's a serious evolutionary dead end, especially if you think there could be any possible validity to Flinders Petrie's theory. If mathematics is a dead end, we're in a dead end.

What happened with mathematics is that people somehow forgot that it takes multiple representations to understand the mathematical idea. The picture is not enough. The symbols are not enough. The numbers are not enough. You have to juggle these three cognitive strategies simultaneously in order to transmit a mathematical idea. In school, maybe in the sixth, seventh or eighth grade, they finally tell you a mathematical idea in symbolic form, which absolutely can't be understood that way. Maybe a few people get through

the filter by telepathy, but almost everyone is turned back. The teacher says, let x represent a natural number. The pictures and the numbers aren't there, only the symbols. It's impossible to understand this idea. Then they tell you you're stupid and put you back a grade. This happens to everybody. Can everybody be that dumb? It just really doesn't make sense. The people who got through the filter by some trick or other became the teachers, and then they taught their students who became the teachers. There was a cultural diffusion into an evolutionary dead end, where mathematics actually died. It's already dead. There were some heretics who managed to keep it just barely alive.

Suddenly, a rescue, a miracle: computer graphics. Mathematics becomes visible to everyone. Not only to mathematical specialists who escaped a filter through some kind of mental trip that allowed them to visualize. You just give them the symbols, and because of a weird gift, the picture just pops onto their mental screen. So they have it when nobody else does. They can see. For a century, mathematics has been done by these people who could see when nobody else could see. It was very lonely being a mathematician just a few years ago. You couldn't tell your friends what you were doing. You couldn't show it, you couldn't share it. But now suddenly we have computer graphics. We can show everybody exactly what we see. This is a very revolutionary thing.

If a rapid, catastrophic social transformation is essential for our survival and that of the biosphere, then we have to have one, and that requires that mathematics somehow be alive. The computer revolution makes further evolution possible, and therefore, we may have a future instead of not having one. If that is true, the computer revolution will eventually be remembered primarily because mathematics was made visible. Computers made it possible to keep track of your bank accounts, communications, and all the other stuff that computers do. This is very, very important in a mundane way, but the most evolutionary thing it did was to render mathematics visible, taking it out of the hands of specialists who are somehow culturally dead although very gifted in mathematics, and reviving the educational system with little programs that you can take home and run on the personal supercomputer in your toaster. You can suddenly see that you've been swindled in school, and the education continues outside of school. It's like playing music. We don't learn music in school. We go to musicians to learn how to play.

Some people say that the evolution of chaos theory in the last thirty years is largely due to the ability of computers to visualize and manipulate the data. Well, it certainly got a boost because of computers. But a lot of the things that were discovered were already known in some arcane corner of literature. For example, the famous Feigenbaum series, which is a big deal in Jim Glick's popular book on chaos theory *The Making of a New Science.* **An entire chapter is devoted to the great wonder that Mitchell Feigenbaum was able to discover the numerical property of this chaotic setup with a hand calculator. That's pretty fantastic. With a Macintosh, it's easy. But with a hand calculator, it's tough. He did it, and that's great. However, people eventually found out that it was known to Murberg (?) in 1958. Murberg discovered it without a hand calculator! The computer graphics that make mathematics visible are having a belated but revolutionary effect on mathematics itself. Many mathematicians don't want to look at a computer. They'll do anything to avoid it, but sooner or later they'll see computer graphics somewhere and get**

curious again about their own subject. Hermann Hesse's novel, *Das Glasperlenspiel,* is kind of a precognitive dream of what's happening now. The mathematical models we have now are a much richer set of models than we've ever had before, and they are the moves of Hesse's Glassbead Game. That book is a favorite of all mathematicians because it says, "You're important. You really know some great secret stuff. The world can't get on without you."

Like every math graduate student, I was given that book early on. I was very impressed and worried by the fact that at the end, Joseph Macht goes out from Castalia and drowns. That was sort of a warning to me, not to go out too far, and I haven't. There are frequently big paradigm shifts. Even more frequently, there are medium paradigm shifts. And there are little paradigm shifts practically all the time. There is no linear cultural progress. Evolution itself is a fractal. But the one we're going through now is even a bigger than the one in the Renaissance. It's bigger than the Troubadours. It's bigger than the Gothic cathedrals. It's bigger than Plato. I would say that this is the biggest one since we lost the goddess and got the patriarchy. Six thousand years. We're recovering from 6,000 years of oppression. Maybe that's just wishful thinking. It's a bigger fantasy than the Aquarian Conspiracy, because the Aquarian Age, you know, will last only something like 2500 years because the cosmic year is only 28,000 years long. So all right. I'm dreaming.