Art and science in Chaos

Contesting readings of scientific visualization

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INTRODUCTION

These days little is heard of the phenomenon called `Chaos Culture'. But by approximately 1987 a number of forms of cultural activity had taken shape around a popularized scientific concept called chaos theory or chaology, ranging from art shows and coffee-table books to acid house videos, T-shirts and comic books. By about 1990 it had already been superseded by new manifestations of technoculture, but while it lasted it provided an example of a moment in which a new scientific story found a cultural function due in large part to its easy appropriation by media technology. How did the mechanism operate by which this idea was introduced into wider society and became part of our mental furniture? It is best described as a cultural intervention into science or a scientific intervention into culture? And how far can we culturally critique this kind of mythologized scientific discourse before we have to engage in the rhetoric of physicists and mathematicians directly in order to justify our analysis?

The rise of computer graphics as an integral part of scientific practice coincides historically almost exactly with the emergence of chaos theory as a cultural force. In 1987 the National Science Foundation of the United States published a report which set a goal to provide every scientist and engineer with their own graphics workstation. This had the immediate effect of stimulating a new market for specialized computer software and hardware. At the same time, in scientific journals, TV documentaries and magazine articles, computer-generated imagery seemed to have become an indispensable means of communicating scientific research both within science and out into the non-scientific community. Chaos theory was able, through media, to become an icon, to become the image of a Lorenz attractor, a Mandelbrot set or a Henon map – chaos was able to become Chaos.

Computer imagery is used for different reasons by different kinds of scientific activity and in different disciplines. How imagery is used in research affects how theories and results are eventually disseminated and

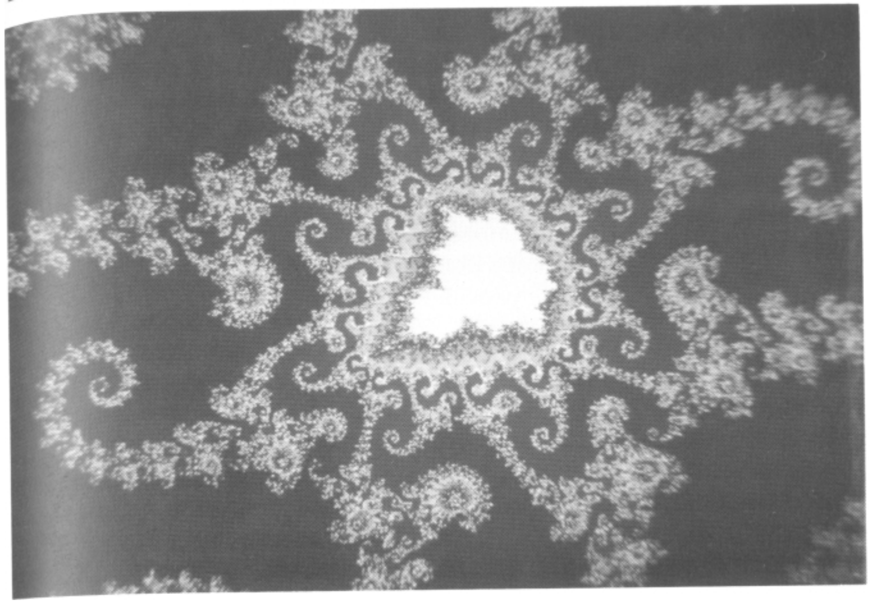

Figure 14.1 Fractal image, by Hugh Mallinder

therefore what the parameters of their cultural interpretation are. We may characterize the role of scientific visualization with respect to the representation of ideas in three main categories. The simplest category can be illustrated by astrophysicists who accumulate large amounts of data from radio telescopes which has to be represented in some accessible form prior to analysis. Rendering the various quantities (which are frequently non visual in themselves) graphically has proved to be a very convenient way to study subtle features in the data and also to communicate them to colleagues. This process is like building a visual analogue to the object under investigation.

In a slightly similar way visualization is used to present the data generated in simulation experiments. These experiments are usually conducted in order to test a theory about a phenomenon. A mathematical model of how the process is thought to work is constructed and a simulation is run to see what would happen. The results obtained are then compared to data collected about the actual phenomenon itself. An example would be an experimental model to show what happens when galaxies collide using a trial and error sampling, or *Monte Carlo* approach. Many different simulations of galaxy systems are run all with slightly different parameters to see which one most closely approximates the particular event being studied. The visualizations produced are more like pictures of the process of understanding something, or like visual thinking. Sometimes the simulations are of phenomena which do not necessarily exist. Physicists may conduct simulations of magnetic `monopoles' to see what kind of events they could be responsible for if they existed. This situation is more akin to the visualization of abstract ideas such as in theoretical physics or mathematics, ideas which may nonetheless be related to mathematical models of physical processes, such as in the case of complex dynamical systems and chaos theory. Pictures and animations of fractals and iterative mappings are certainly not *iconic* representations of otherwise familiar natural systems. They may provide the only tangible evidence of the mathematical object being studied. This gives visualization the function of creating the `object' of what may be pure research, it *objectifies* an idea to the extent that it can enter the general economy of signs as an image of itself. Scientific objects of knowledge are now in a form in which they can function through media without any additional information, finding a new life for themselves in the maelstrom of signs.

Is it possible to construct cultural readings of scientific visualizations that can do justice to the scientific ideas that they are derived from, that are more than just an enigmatic confrontation with pretty pictures? Can we propose a meaningful new aesthetic which is informed by scientific literacy? Graphics is certainly used to communicate 'scientific meaning' in the sense of knowledge of the properties of a natural process or a model. If instead we use the term `scientific meaning' in the sense of an ideology or narrative then it also seems that the inherently media-accessible structure of electronic visualization has made it the chief way in which scientific stories can be experienced culturally. In the case of chaos theory this effect was reinforced by the way that imagery had become the main form of symbolic knowledge.

THINKING AND READING

In a 1990 issue of *Artforum* magazine the critic Vilem Flusser published a short article in his series 'Curies children' in which he tried to locate the new form of scientific imagery in relation to cultural artefacts (Flusser 1990). Here Flusser argues that imagery was the only way to express the subtleties of the new mathematical ideas such as fractal geometry, and that such concepts were not readily accessible by nor even appropriate to spoken language. Flusser is discussing these issues in the context of the early writings of the philosopher Wittgenstein, drawing attention to a passage in his *Tractatus Logico-Philosophicus* where he states 'It is true, that some things are unspeakable. These *show,* they are what is mystical' (Flusser's translation). Flusser then goes on to try to explain that just because concepts such as fractals can only adequately be communicated through pictures this does not mean that there is anything 'mystical' about them. What concerns us here though, is his argument that in order to understand what the pictures convey we have to understand the algorithms that generated them - `the mathematical and computer codes'.

Flusser distinguishes between two kinds of image now, `images of the world' and `images of thinking'. The first kind are the pictures we are most familiar with and are what Flusser seems to imply are pictures which are accessible to day-to-day modes of discourse like magazine photos and TV or which may be cultural artefacts like designs or paintings. The second type are products of non-cultural discourses like science and mathematics, their meanings are not found in the social situations of desires, personalities or conflicts, but in the world of mathematical objects and equations which have now advanced to such a level that with the study of fractal geometry and chaology that they can no longer be done justice by words alone.

But that is not all. It is not just the pictures themselves but the status of the mathematical models they give form to that are at issue here. `Does this fractal look like the Alps because the Alps too have a fractal structure, or because fractal images are able to simulate the structure of the Alps?' Such questions are meaningless, states Flusser. A fractal image does not mean a likeness of some part of the natural world, it simply 'means' the equation that generated it. Presumably to interpret the images without reference to their process of generation would indicate some kind of scientific mimesis lacking any explanatory power.

Flusser does not go on to describe how we can then go on to find out what the equation `means', we are left only with his appeal to look beyond the form of the image to the concepts behind it. In the absence of any clearer guidelines given in his article, his view of mathematics seems to be that we can find ample information of how a numerical image is to function semantically merely by studying its 'codes'. Mathematics then stands as a self-supporting edifice of interlinked concepts, techniques and expressions all functioning independently of any other mode of discourse. But this extremely pure view of mathematical practice will not do, and in any case many of the images that Flusser was talking about were produced by physicists and engineers out of an overriding interest in attempting to model the real world. A much more promising task would be to extend Flusser's strategy to ask the scientists concerned what they intend by their images and how they relate to their scientific work. In order to make an attempt at a truly comprehensive understanding of scientific concepts that are expressed In this imagery we first of all have to accept that the chief narrative of western physical science has been the construction of 'man' in dominant relation to 'nature', the control of his environment and exploitation of its resources, especially technologically – not just a word game played with mathematical tokens. For example, when people relied on pictures to 'show' what scientists meant, what happened in the case of Chaos?

Figure 14.2 Fractal mountainscape by Ken Musgrave, a collaborator of Mandelbrot’s at Yale University.

THE NEW CULTURE OF SCIENCE

The 1980s saw the increased availability of high resolution colour graphics in scientific research centres, and with it came the phenomenon of `scientific' forms of `art' almost completely autonomous of mainstream culture. The most well-known examples were Chaos Art and Fractal Art, forms which by the late 1980s had received widespread exposure in exhibitions and through the media. One of the first and most publicized of these manifestations was `Map Art', a travelling exhibition originating with the work of a group of mathematicians and physicists working at the University of Bremen. The researchers had been generating images of fractal Mandelbrot sets for their work on dynamical systems and some time after 1981 `the idea for an exhibition came up' (Peitgen and Richter 1985). They were invited by a bank in Bremen to exhibit their work to the public and to produce an illustrated catalogue. The success of this show lead quickly to two more by the end of 1984 and culminated with their work being added to the cultural programme of the Goethe Institute. But if Peitgen and Richter thought that all the art-going public were interested in were pretty pictures they were soon proved wrong; we thought that the aesthetic appeal of the pictures themselves would be sufficient. How naive we were.' Peitgen and Richter then went on to write essays for the catalogue in which they explained the scientific background behind their imagery and also began to promulgate some of the first ideas that would go on to form part of the scientific story of Chaos.

Instead of taking the option of dryly describing chaos theory as a set of mathematical techniques Peitgen and Richter in fact went out of their way in *The Beauty of Fractals* to give the reader a dazzling collection of philosophical interpretations of the theory. Aided by a liberal use of graphs and diagrams, the two physicists expounded the intimate connections between dynamical systems, their mathematical modelling by chaos theory and their fractal properties; `it is hard to be clear on what part is actually fact and what part is insight suggested by the experimental results', the authors caution, before they go on to borrow some highly charged language to describe their conclusions.

Chaotic dynamics are usually presented in the literature in opposition to classical dynamics, in particular through the writings of the late eighteenth-century French mathematician Laplace, who is credited with giving one of the most concise statements of how scientists viewed how the world operated. His view is based on the idea that all physical systems, including large-scale phenomena like the weather, are dependent on the motions of the smallest particles that constitute them. If every part is subject to the same laws of motion as the others, then the dynamics of the entire system should be defined by accumulating the result of all its internal interactions. This idea led Laplace to boast that given the position and velocity of every particle in the universe he could predict in principle its future for the rest of time. Although there were obvious practical limitations to this approach, its implication was that every action was completely predetermined.

The main development that has happened to upset the classical determinism of Laplace is the growing realization that measuring the exact starting position or initial conditions of a system accurately enough to predict its behaviour has proved intractable. For example, in quantum mechanics the famous Heisenberg uncertainty principle stated in effect that it was impossible to gather enough information about some random processes such as radioactive decay to predict when it will disintegrate. On the scale of larger phenomena the situation is different but there is a similar outcome. In order to make predictions about a system we need to measure its starting conditions are accurately as possible. Of course we can never measure these with perfect accuracy, but we should be able to allow for this experimental error by assuming that a system that starts very near the position of the system that we are studying should end up reasonably near its projected future position. It is this assumption that proves to be incorrect for many processes because of their extreme sensitivity to changes in the initial starting conditions. Minute differences in the starting conditions of a system could be amplified very quickly over time until very shortly the whole system could end up in a completely different state. This is one of the basic properties of a chaotic system (Crutchfield *et al.* 1986).

When a process is entering a chaotic 'regime', its internal state, whether in terms of temperature or position, will start to change. First it will only loop perhaps between two different states, known as a cyclic attractor of period two, then as its mathematical parameters are altered more it will begin to enter double the number of states and the number of attractors will increase again. As it enters chaotic behaviour, it will start to fly off towards a large number of states without periodic regularity. Even so, the states it reaches, although unpredictable from its starting conditions, will be bounded to be within certain limits which can be visualized in 'state space' as being a particular shape, now called a chaotic or strange attractor. Sometimes this chaotic attractor can still be composed of one or more main centres of attraction which the system orbits around in an irregular pattern. The boundaries between these centres of attraction will typically have a fractal geometry.

This is the kind of research that Peitgen and Richter were involved in, the study of complex dynamics. By using computers to simulate the behaviour of systems using chaotic iterative functions, they were able to analyse their properties. But in the catalogue essays that they wrote to describe their research Peitgen and Richter chose to use a florid language that was more reminiscent of a social science. Here is how Peitgen and Richter describe the fractal boundaries of some strange attractors that they have witnessed on their computers. 'They all have in common the competition of several centres for the domination of a place . . . there is the unending filigreed entanglement and unceasing bargaining for even the smallest areas.... Occasionally, a third competitor profits from the dispute of two others . . . ' Really! The authors seems to have been spending too much time in the yuppie wine bars of the early 1980s. Later on we are introduced to some similar phenomena along with a shift in language that suggests the Polish Solidarity struggles of the same period: '[there are] isolated points which are not subject to its attractions. These are dissidents ... who don't want to belong.' We seem to have come a long waY from Flusser's assumptions about finding the meaning of an equation.

Of course we are never free from the resonances of the language we choose to employ, and later on Peitgen and Richter come to some conclusions about the general meaning of this new scientific discipline which are relatively free of Thatcherite perceptions. The scientifically important property of non-linear chaotic systems is that once they enter a chaotic regime their progress cannot be predicted from their initial starting conditions without doing an explicit simulation. This places fundamental limits on the power of prediction (if a system is modelled as chaotic), but still gives us a way of studying such a system and perhaps finding other useful information about it. It is no longer sufficient to discover basic laws and understand how the world works "in principle". It becomes more and more important to figure out patterns through which these principles show themselves in reality.' These patterns are best appreciated when they are rendered in full colour computer graphics. They conclude, `It a deep truth to assert that our world is nonlinear and complex.... Yet physics and mathematics ... have successfully managed to ignore the obvious ... [and remember that] these sciences had a strong impact technology ...' A quotation from Robert M. May from 1976 lays down the challenge for these new paradigm makers;

> I would therefore urge that people be introduced to, say, [a nonlinear equation] early in their mathematical education. This equation can be studied phenomenologically by iterating it on a calculator.... Such study would greatly enrich the students' intuition about nonlinear systems . . . in the everyday world of politics and economics *we would all be better off* if more people realised that simple nonlinear systems do not necessarily possess simple dynamical properties. (italics added)

.. *we would all be better off.'* Through a succession of metaphors from market economics, oppositional politics, to the origins of life and creative insight, Peitgen and Richter's work abounds with readings of this object from pure mathematics. In spite of this passage and the earlier hint of some general influence on technological progress, the essay neglects to address how chaology is actually applied to the real world outside of the confines of pure maths. Exactly how we would all be better off apart from intellectually, or how this knowledge would relate to the experience of our daily lives is not clear. The implication is that at the same time there is some fairly major rethinking of the scientific world-view going on. But in the following years as chaology became public property the cultural appropriation of their work helped to tease out some answers.

Flusser had argued that concepts such as fractals cannot be `spoken of' as Wittgenstein had written but could be 'imagined' using computer graphics. Similarly Peitgen and Richter say that Julia and Fatou's early discovery of the self-similarity so important to fractal geometry was an idea so difficult to explain that it had to wait until Mandelbrot discovered a way to 'show' it. But Julia and Fatou also had to wait until Edward Lorenz found in 1963 that their work would have relevance to applications in fluid dynamics. Before that time scientists assumed that the equations to describe the behaviour of fluids would simply need to be extended to account for more and more oscillations as the fluid became more turbulent, but Lorenz discovered that under certain conditions the simplest basic equations would give rise to complex dynamics, to chaotic attractors. The rapidly changing state of the fluid resulted in what is described as a 'folding and stretching' in state space, a phenomenon which exhibits a fractal structure. Strictly speaking of course, this only means that the equations that model turbulence give rise to fractals, not that the fundamental structure of the fluid itself is fractal, but without some relevance to real world applications chaos theory and fractals would merely have become a mathematical curiosity like Julia and Fatou's original iteration theory, unable to find resonance in everyday life and certainly not becoming a `Chaos Culture'. As it was, Lorenz's ideas still had to wait many years before they were fully appreciated and widely applied. If Lorenz discovered the importance of Chaos as early as the beginning of the 1960s, why did we have to wait a further twenty-five years before we heard about it? Would it have made any difference if Lorenz had had good enough computer graphics to be able to make psychedelic patterns in time for the hippy revolution?

STORIES OF CHAOS

The mid 1980s saw the convergence of many factors that made it the right time for technology to impact on culture and to drag science along with it. Personal computers such as the Apple Mac had just become afford-able and easier to use and computer graphics had received enormous attention through its exposure in TV videographics and film special effects. Information technology was a business buzz word and commercial opportunities at the tail end of the era of `enterprise culture' provided the motivation for young designers and programmers to launch a series of ventures based loosely around the application of technology to the arts and entertainments. Acid house music and successors like hardcore and techno had a need for icons and imagery in their clubs that the catherinewheel spirals and `seahorse valleys' of the Mandelbrot set ideally suited. And this time, unlike the hippy festivals of the 1960s that had to import eastern religions and pagan mysticism to bolster their ideology, fractal graphics came complete with the scientific credentials of chaos theory, a secular doctrine more appropriate to an environment of streamlined competition and economic progress.

By 1988 youth magazines were publishing special issues on the phenomenon of `Chaos Culture'. By this time fractal graphics was appearing in music videos, in clubs, T-shirts, TV programmes and all kinds of popular books and magazines. Descriptions of the scientific theories behind Chaos took the form of anecdotal fictions like the famous `butterfly effect'. In this story the arbitrary sensitivity of chaotic systems to initial starting conditions is illustrated by imagining a butterfly flapping its wings in Australia thereby contributing to patterns of global wind turbulence that are amplified to the extent that it is responsible for a dust storm in Arizona (or a hurricane in New York, etc.).

In more popular debates we could find a multitude of quasi-mystical interpretations of chaos theory. Some of the most stereotypical were from

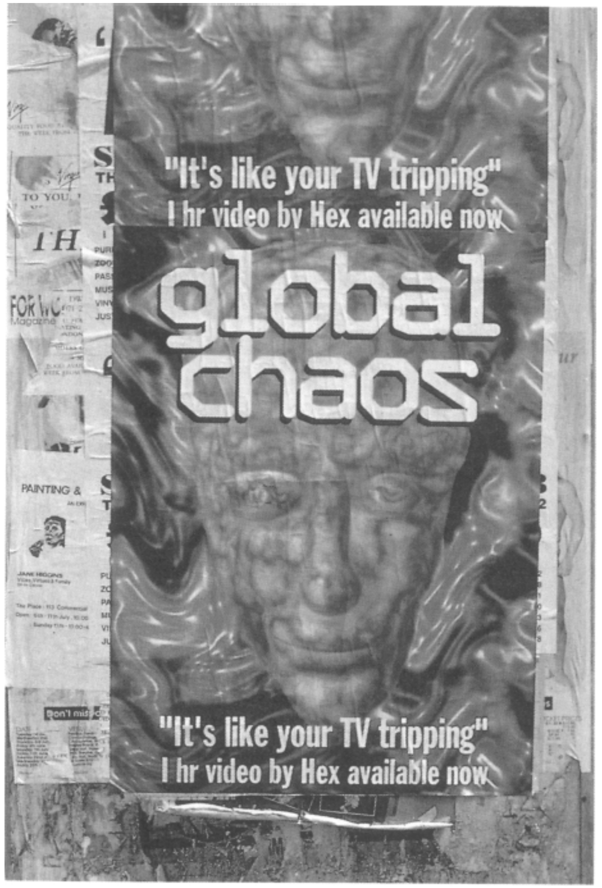

Figure 14.3 `Global Chaos', Poster, Hex Media, 1993

people like Fraser Clark, the editor of the *Encyclopaedia Psychedelica International.* In an article in *i-D* magazine entitled `Chaos Culture: the New Order?' (Anon 1988), Clark is described as festooning his publications with images of the Mandelbrot set `seeking to harmonise the 60's hippy and the 80's technoperson.' Clark himself is quoted as describing chaos theory as `unification science, interrelation science, whole science. It shows you that there is a connection between everything.' This attempt to elevate a set of mathematical tools that may be no more than an experimental technique to the level of a perennial philosophy is a method which may sound depressingly familiar to some. But later on in the article Clark is quoted as offering a second interpretation of Chaos which focuses more on its functionality, though still with a hint of transcendent teleology. `It teaches us to accept that there will be periods of turbulence in life, but then a pattern will emerge. It teaches us to accept that we can't always be in control and centred.'

This tendency for scientific theories to mutate almost automatically into New Age cults is resisted by some people whose opposing viewpoints have the effect of exposing some classic misconceptions in this debates. The comic book writer Alan Moore, at the time preparing a new work drawing on many of the themes of chaos theory states that,

> In a way Chaos and fractal maths gets rid of the need for a God. Previously people said that the unfathomable complexity of existence was the best argument for the existence of a creator. But Chaos and the Mandelbrot Set say that's not the case, that with one simple rule fed into a primordial mess, you can have an infinitely complex, perfect order emerging.
> (Moore quoted in *i-D* magazine 1988)

Comparing this to Fraser Clark's earlier statement we have an example of how a scientific model can be taken either as a sign of the power of science itself or as a description of or metaphor for the wonder of natural forces. It is purely a problem of ideology, both interpretations could be correct. Those scientists of the former persuasion were never put off their belief in physics by the 'complexity of existence' in the first place. Classical mechanics was considered perfectly adequate to describe natural phenomena, at least in principle (and it is foremost a matter of principle that we are concerned with). The turbulence in fluid-flow dynamics, for example, was seen as merely a further indication of how the laws of classical mechanics when applied to independent water oscillations would ultimately combine to give the appearance of random motion, just as Laplace would have argued. The fact it was not discovered that turbulent fluid flow is possible without considering it as the complicated interaction of separate oscillations was not discovered until Lorenz's work in the 1960s says more about the epistemological history of scientific ideas than it does about their truth value in relation to mysticism. In this sense scientific realism and mysticism are bedfellows – Fraser Clark can always claim that chaos theory has discovered something about the fundamental nature of the deity.

There are, then, several key features here that chaos theory is able to provide in order to be incorporated into a popular fiction. Through its subversion of determinism, Chaos is able to return a sense of mystery to otherwise dry and mechanistic accounts of the world. Nature is seen in a creative evolution, unexpectedly generating diversity. Through the plotting experience of a fractal on your computer, the ability to generate so much detail from so simple an equation can be regarded as a grotesque but compelling discovery. This active participation in the phenomenology of Chaos is often cited by scientific writers as a major advantage in the cultural colonization of the science. The inability to determine the outcome of a chaotic system from its starting conditions is also translated into evidence for the scientific possibility of free will. The apparently wide applicability of chaotic dynamics to models of physical systems, as well as inspiring models of everyday phenomena such as stock-market fluctuations and the froth on a cup of coffee, creates a rhetoric of chaos theory as the grand unifying theory, invisibly connecting all the strands that come together to form our multi-layered world.

It is this narrative functioning of the scientific theory of chaos, and specifically its cultural manifestations in relation to postmodernism, that were the subject of an essay by film theorist Vivian Sobchack. Published in the November 1990 issue of *Artforum,* this article entitled 'A theory of every-thing: meditations on total chaos', can be seen as a touchstone of how Chaos theory was itself theorized in the mainstream of critical debate. Sobchack studied how Chaos had been represented in popular scientific works like Peitgen and Richter's catalogues and James Gleick's book (Gleick 1987) and makes cultural readings of the terms that it speaks in, like order, scale, subjectivity and randomness. In Sobchack's hands the specifically scientific aspects of the theory are subdued in preference of the framing of Chaos as a conceptual metaphor for postmodernism. Perhaps to provide a balance for the prevailing hysteria about fractal science at that time, Sobchack embarks on a particularly pessimistic description of Chaos as a cultural phenomenon displaying all the worst aspects of postmodern life.

A lot of the article is devoted to examinations of the aesthetics of fractal imagery that help to form its popular impressions. 'Libidinally driven by desire for control, this fetishised relationship with simulation is nowhere more visible than in the computer graphic models of "reality" ' (Sobchack 1990). Chaos is interpreted by Sobchack in terms of a kind of desire to combine the ability to impose scientific order on the world with a desire to transcend its physical limitations and attain a kind of digital freedom by entering a mathematical space of infinite fractal depths. The ability to generate fractal imagery at any scale allow them to be continually zoomed into, reminiscent of the film *Powers of Ten,* in which a camera zoom is constructed to travel from outer space right down to the size of an atom on the hand of a man fishing. Sobchack sees this scalelessness as a 'refusal to accommodate human bodily orientation' and finally a 'transcendence not only of physical ground but also of moral gravity'. This experience of exploring the endlessly subdividing tendrils and spirals takes on the quality of 'aimlessly fulfilling plural, random and nonlinear trajectories' and will 'dramatise the deceptive way in which postmodern culture's privileging of difference also trivialises it beyond value.' The 'difference' that is so important to some cultural theorists in terms of cultural identity is now worthless when it becomes a feature of this mathematical numberscape. In the end, Sobchack is driven to the adoption of such extreme language that she describes chaos theory's coupling of order and chaos as exhibiting 'both fascist yearnings and a dangerous relativism'.

Early on in her essay Sobchack makes a statement that 'chaos theory has little to do with the specificity of human embodiment and historical situation.' In a conclusion Sobchack writes:

> In postmodern culture as in chaos theory, the computer enframes the world by making it absolutely available and manageable. What emerges is not merely a computer graphic image but a philosophical picture of a 'world' deprived of meaning. That is, it makes no *existential* sense (author's italics).

It is only at the last two paragraphs of Sobchack's essay that she concedes that there is a positive 'existential' side of chaos theory. This is the side that teaches that organisms are always in a state of complex dynamic flux and that the relevant level of study is at the macro-phenomenon level instead of the elemental. For Sobchack this is most significant when Chaos is applied to the body. She quotes from a neurobiologist: `Everybody used to search for equilibrium, but now we understand that biological systems don't go to equilibrium until they die and cease to exist.' But if Sobchack has intended to play devil's advocate in this essay it is a role that has limited mileage. For what has got left behind in her account is a deeper engagement with the scientific practice that grounds chaos theory, and the perception of this practice as a resource from which the causes of the negative cultural readings that she fears can be challenged.

Chaology manages delicately to poise the need to control and to determine responsibility with the desire to retain creative freedom and subjective agency. Sobchack sees a danger in this, that when both modes of action are possible, one will be used as an excuse for not applying the other. The way to resolve such issues is not to reject Chaos as a conceptual red herring but to see this field of discourse as one of the new areas in which critical activity must take into account the methods of scientific practice.

VISIONS OF SCIENCE

In her 1991 book *Simians, Cyborgs and Women,* Donna Haraway published a series of essays written over the previous ten years in which she constructs an argument in favour of cultural theorists taking scientific research seriously in their need to create new ways of challenging social conditions.

What is not covered in Haraway's work, however, except perhaps in certain references to *National Geographic* photo features, is the impact of media technology in channelling scientific artefacts directly to the public in the form of electronic imagery. In many instances now we see how research imagery has been absorbed into culture without, or in spite of, any accompanying scientific text. Even in the classic media form of the television documentary, programme editors have frequently adopted the strategy of building an entire documentary item around a suitably photogenic piece of computer visualization. When graphics is used to publicize research in this way, how does this complicate the process of telling and critiquing scientific stories?

The more common way for scientific ideas to be mediated into popular culture has been through science fiction, but so far this does not seem to have happened in the case of chaos theory. The actual imagery of Chaos is unusual in that it invites discussion in parallel with the scientific theory that spawned it, sometimes in spite of it. This allows Vivian Sobchack to treat it as an aesthetic phenomenon.

Through her privileging of the 'existential' applications of chaology, which in effect means its function in biology and the life sciences, Sobchack rejects Chaos imagery as displaying postmodern vertigo and decentring of the subject. But these fractal designs have also been theorized by scientists in terms of boundaries between the individual areas, these areas being the centres of strange attraction. The boundaries between the centres have fractal geometries, in that instead of having the properties of clear and definite demarcations, they subdivide endlessly into the infinite details of spirals and eddies. In one of these `mappings' described by Peitgen and Richter, the boundaries between three areas of attraction divide the plane up so finely that mathematically every single point shares a boundary with all three areas. 'Wherever two regions are about to form a boundary (yellow and blue, for example), the third region (grey) establishes a chain of outposts ... they in turn are surrounded by chains of islands in a structure which is repeated down to infinitely small dimensions' (Peitgen and Richter 1985). There are other examples of mappings that split the plane between four or however many centres. This does not seem to be an illustration of the `death of the subject' theorized through Baudrillard's 'fractal subject' but its recasting as a network of infinitely subtle connections emanating from a single node.

Interestingly enough, some artists and writers see it as their duty to publicize scientific theories that they see as important for the good of their fellow citizens. Alan Moore, the comic book writer already quoted from *i-D* magazine above, talks further about his plan for a comic book series called *Big Numbers.* Describing it as 'a 12-part 500-page representative view of a small English town at the end of the 20th century', Moore says that the aim is a 'search for a fractal view of society', through a depiction of 'the turbulence that occurs in all levels of life . . . and the hidden order which underpins life's apparent randomness'. Moore sees this project as a way for the theory of Chaos to reach the mainstream through the imagery of popular culture.

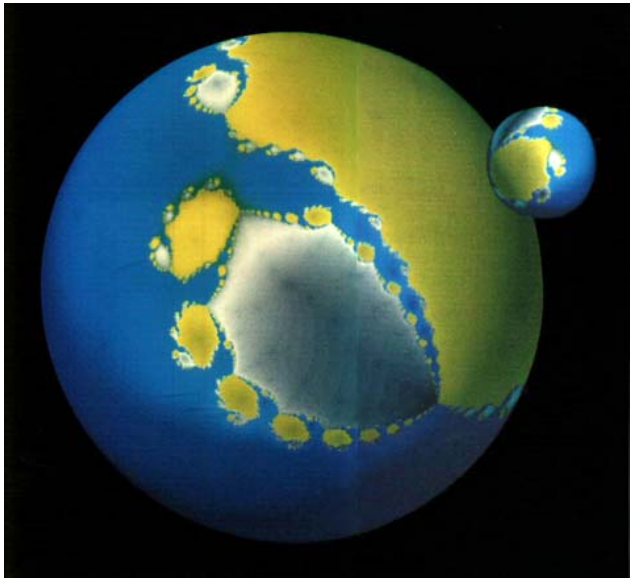

Figure 14.4 The ‘Fractal Subject', from Peitgen and Richter 1985.

> Let's face it, the majority of people don't make maths text books their staple reading – and the school system acts as a kind of aversion therapy. ... Perhaps the only chance Chaos and fractals have of being understood by a wider audience is through art, literature, music and comics.
>
> (Moore, *i-D,* 1988)

But though Moore hoped to get permission from Benoit Mandelbrot to use the image of the fractal that bears his name on the front cover, it seemed that Mandelbrot himself, while personally sympathetic to the project, was reluctant to allow this to go ahead on the grounds that a further popularization of his theories would fuel the criticism from other scientists that his work was lacking in serious intent. We seem to have reached a situation in which cultural producers can adopt scientific theories to validate a body of work, but then that very popularization discredits it in sections of the scientific community.

A POETICS OF KNOWLEDGE

There are some organizations that have built their reputations on what we might call the transferal of scientific visualization into projects of an artistic nature. $(art)^n$ is the name of a well-known group that also works out of the Electronic Visualisation Laboratory at the University of Illinois. It consists of various artists and scientists who collaborate on producing artworks usually in the form of photographic and holographic installations. In their voluminous publicity they describe their work as `painstakingly constructed models carefully loaded with references to specific art-historical figures.' What this usually consists of is combining an image illustrating some scientific subject with an image taken from a well-known cultural genre of some kind. A typical example of this approach of throwing science and art together in the hope that something worthwhile will emerge is "`Apollo at Sunset". Visualisation of the Rhomboy Homotopy, a four dimensional (up-down, left-right, front-back, and another, variable axis) object, juxtaposed with an image from nature'. Perhaps their most ambitious attempt to force some relation with human experience was a six-panel holographic installation called `Messiah' which consisted of `A visualisation of the AIDS virus, based on scientific data available in 1987. Most of the structure portrayed is still accurate by 1990 standards. . . . In the background of each panel is a CATSCAN of a person named Messiah who died of AIDS'. It is $(art)^n$'s declared intention that this work should be one of the chief means of publicizing the discipline of scientific visualization through its participation in cultural events: `[The work of $(art)^n$] represents collaborations by scientists and artists who want to communicate their love of the often complex mathematical beauty of nature.' If we take this kind of talk too seriously we begin to slide into the position where we think that science can prove that nature is beautiful.

What we seem to have here is a situation in which the work of scientists when expressed in imagery can only be culturally appreciated in terms of aesthetics, or at the very most on the level of science as itself an aesthetic practice. Science itself is then presented as a practice dealing in a realm of pure knowledge where social interactions and daily practice become discounted. Is it possible to construct cultural readings from scientific visualizations, perhaps not from the examples here, that are informed by social and political relations? Although since Peitgen and Richter's heyday, pictures from fractal geometry and chaos theory have become tediously repetitious, their banal graphics inspired more ideological fervour than any we have seen praised since. And what of other kinds of scientific visualizations seemingly excluded from these cultural debates – how would the simulation of the ozone layer be seen in a computer art competition? Surely we can conceive of work that addresses the public meaning of scientific issues through a language of algorithmic imagery. Such a practice would be a poetics of knowledge, or of objectivity.

An interesting example of the role of imagery in modern scientific polemics is documented in an issue of the newsletter of the National Center for Supercomputing Application at the University of Illinois which describes how computer graphics was used in a study of the effect of forest fires on different ecosystems (Robinson 1990). In contrast to earlier views that forest fires were to be prevented at all costs, ecologists had now discovered that fire was a necessary part of the evolution of the forest. Fire benefits the forest by decomposing fallen plant material, opens up the forest canopy to increase sunlight for new seedlings and ensures a wider range of tree species. Although most forest fires are small scale, the evidence also shows that even quite cataclysmic fires are necessary for forest ecology. The scientists had to find a way to use these studies to reverse the publicity that had been promulgated for years: `How to convince the public — and policy-makers — that forest fires should not always be suppressed.' The solution was to construct a series of computer animations that showed simulations of forest growth under the effect of different fire-control policies. Using an array of computing, specialist graphics and video resources, and expertise the equal of any commercial production house, a tape was produced with the help of ecologist David Kovacic who had had previous experience using visualisation: `with the possibility of a national audience, Kovacic enlisted the help of Bob Patterson, postproduction supervisor of NCSA's media services ... to create a professional quality videotape for communicating the complex facts about forest succession.' What the study shows is not so much the importance of visualization in the process of scientific research itself, but its crucial role in the entry of that research into the greater scientific community and into public discourse.

Chaos imagery demonstrates through its brilliant renderings our lack of understanding and misconceptions about our own scientific creations. They show man's `strangeness to himself' or, as Donna Haraway puts it, that science is a trick played on man by the coyote of nature. It took the power of computer simulations in embodying strict determinism to realize that simple casual systems did not ensure predictability and simply related structures — this was not what determinism really `meant'. Determinism still works contingently, and chaos science is therefore fundamentally different and fundamentally the same. We can now see that science made assumptions about the implications of its own work that now seem mythical. What has changed is more an effect of perception. That new scientific perception is exercised metaphorically and literally through visualization. If fractals had been discovered by artists or if Julia and Fatou's iteration theory had not found wider applications then they would have remained an aesthetic curiosity. It is only their place as objects of knowledge that gives chaotic imagery their full meaning scientifically, and as we have seen, culturally.

When visualization tries to appropriate `content' by assuming a ready-made artistic genre or by restricting the matter to a straight visual decoration, it can lose the significance of its wider scientific and social references. In different fields of human activity like the arts and sciences, the same words, images and rituals can have different meanings. When these different texts are passed between these fields their meanings will inevitably change, like a poetry. The challenge is if we can make these changes lead us to new insights and knowledge. If computers and visualization can create these connections between different disciplines and their means of perception then perhaps they will result in a new cultural practice, a `poetics of knowledge'.

I would like to try to give a couple of examples of this hypothetical practice, a practice that as yet probably does not exist. Earlier, I drew attention to the work of the scientists Peitgen and Richter who made such an effort to explain the significance of their pictures of dynamical systems through a series of books, exhibitions and courses. Their approach was to elucidate notions like determinism, complexity and creativity, and give a new scientific perspective to old concepts. Another very different example might be David Blair's film *Wax: or the Discovery of Television Amongst the Bees,* which by comparison is more like a flight simulator on acid. This latter is like a work of science fiction which weaves a complex narrative between intelligent systems, natural and computerized, and political and psychological boundaries. But if we put these two enterprises at opposites ends of a spectrum which defines this `poetics of knowledge', we might be able to form an idea of a kind of work which could fit in the middle and it is this task which I would like to leave as a challenge for the future.

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