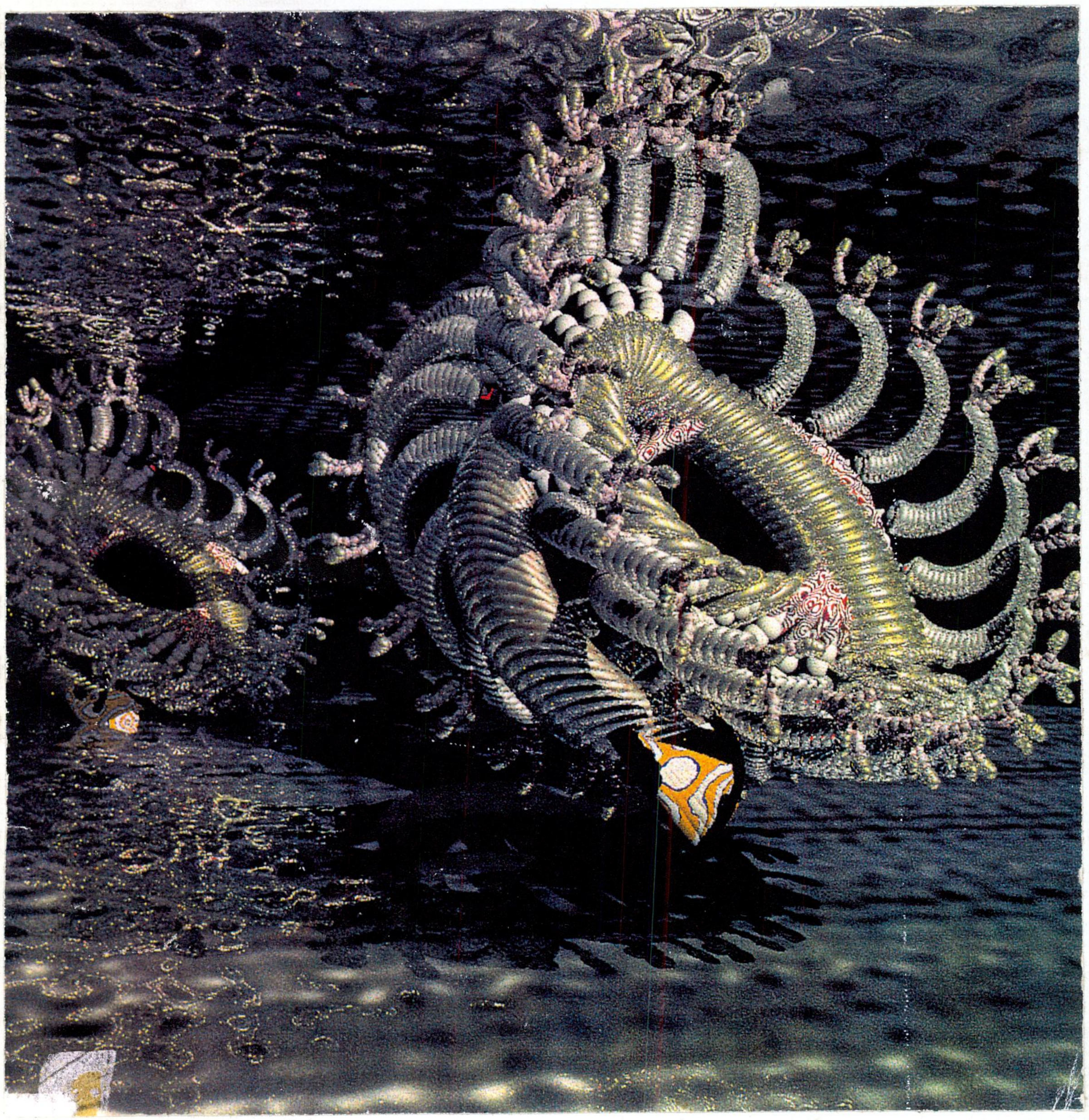
National College of Art & Design
Faculty of Design.
Department of Visual Communications.

Eden in Cyberspace –
The Computer Art of William Latham

by Michael McMullin.



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INTRODUCTION.

This study concerns itself with the notion of simulating natural forms through computer graphics for artistic ends. Specifically, I will be dealing with the work of William Latham.

The idea of using such an artificial means as a computer to help represent nature may seem contradictory at first. It has occupied many areas of research in the recent past, so by way of introduction to this thesis, I shall be devoting the first chapter to one such field – fractal geometry. Although this is essentially a scientific/mathematical idea, the images created through this technique are worthy of discussion.

To introduce William Latham's work, Chapter 2 will discuss the techniques he used before turning to computer graphics. These range from drawings to sculptures, but ultimately manual techniques such as these failed to realise his goals. This chapter should help explain why he moved on to work with computers.

Chapter 3 is simply to introduce the benefits offered by using computers to create images. This chapter will also provide an overview of the computer system Latham uses.

According to Latham, his work is based on the subjects of Art, Science, and Junk Culture. Chapter 4 will address these issues in relation to his work.

In order to bring the subject up to date, I shall discuss one of his more recent works in Chapter 5. This piece takes the form of an animated video, generated entirely by computer. Watching his creations in motion raises a number of questions, which will be addressed in due course.

Finally, I shall look at present technologies and contemporary computer artists in an attempt to evaluate future directions for his work. As computer graphics are such a new field, the technology and the techniques used are constantly changing. This situation is likely to continue for some time, so I feel such a discussion is not out of place. At the very least, it should expose some of the many shortcomings of computers at present.

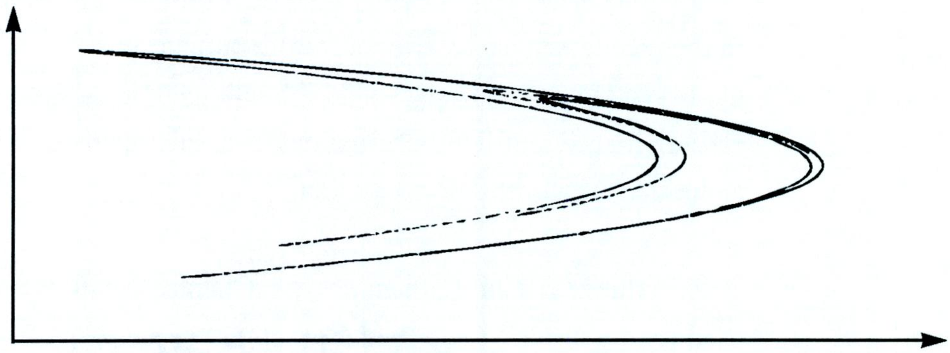


Figure 1.1: Strange Attractor.

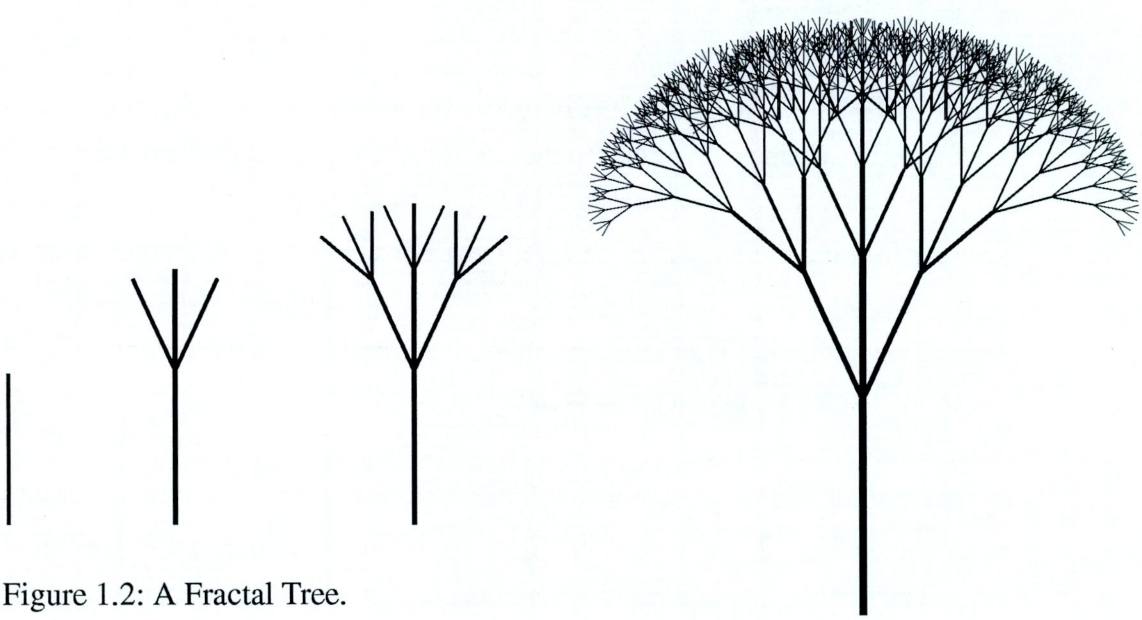


Figure 1.2: A Fractal Tree.

CHAPTER ONE:
CHAOS.

Sometimes it is a scientific discovery that inspires other areas of study, and art is not immune to this. In the Renaissance, for instance, it was discovered that perspective could be calculated accurately, and the results had a profound effect on painting. Nowadays, we are undergoing another cultural revolution dominated by the computer. When such machines began to produce images, they represented statistics and graphs. Within a short time, however, these graphs became more complex than anyone could have envisaged. Strangely, some of the images took on a unique aesthetic that shattered a previously held notion: that machines could not produce beautiful pictures. The most famous examples of such 'graphs' are known as fractals.

In simple terms, fractals are the visual representation of certain mathematical functions, usually achieved by the constant repetition of a simple process. It is almost a reversal of abstraction, because one begins with a simple key element, and exposes it to a simple change over and over, until it begins to form a complex shape.

Their original use was to help explain visually a scientific idea known as Chaos Theory. In a way, this can be seen as an attempt to examine natural occurrences, dealing with everything from the unpredictability of long-term weather forecasts, to the shapes of natural forms, such as rocks, clouds, plants, and even life itself. This theory draws a number of conclusions, the most surprising of which claims that there is an underlying order in all these 'random' events, but it is often too subtle to be detected.

A 'Strange Attractor' is the name given to one type of graph that illustrates the chaotic process (Figure 1.1). Without getting too involved in the mathematics of this example, we are presented with a graph of seemingly random events. Each axis can change independently of the other. One experimenter used the example of a leaking pipe. On one axis, he plotted the time between one drop and the next. On the other axis, he plotted the time interval between the next two drops, before repeating this process again and again. Not surprisingly, there appeared to be no order to the graph at first: points seemed to appear at random. Eventually, the points began to mark out a definite shape; a 'strange

attractor'. This 'strange attractor', which can also be calculated mathematically, is essentially a record of all the possible 'random' events in this particular system. What it shows is that there *is* an underlying order behind natural events. What it does *not* attempt to show is how to predict a future event; we only know that it will be one point on this graph, but which one is anybody's guess.

Strange Attractors have been found in many places, with much pioneering work being carried out in weather research by Edward Lorenz. The 'Mondo 2000' publication gives other examples that are more in touch with human emotions:

> *"Imagine that every morning on waking you assigned a number between 1 and 10 to your level of dread and a number between 1 and 10 to your current level of sexual desire. Each day's pair of numbers could be represented as a point on a little graph..." (Rucker, 1992, p. 37)*

The 'order' within these systems takes the form of a process that is applied repeatedly. However, according to Chaos Theory, natural forms are very sensitive. In other words, if the initial process that created a form is changed by even a negligible amount, this gets amplified immensely in subsequent repetitions. The result becomes totally unpredictable. The common analogy for this is the 'butterfly effect', which is used to explain the unpredictability of weather. It is argued that theoretically, this system (the weather) is so sensitive, that the air disturbance caused by a butterfly's wings can build into a storm on the other side of the world. (Gleick, 1987, p. 8)

Referring once more to the leaking pipe example, the experimenter found that if the water was leaking slowly, the time intervals tended to be orderly. After a certain speed, they became totally random. Chaos, therefore, is the barrier between order and disorder. It is the most interesting area in nature, because it contains random elements ('Where is the next point going to be?') and is yet quite orderly ('The next point will be on this attractor, somewhere.').

Fractals illustrate the ideas behind Chaos Theory. Rather than illustrating nature per se, they try to convey a sense of how it is constructed. Although many fractals are abstract shapes, some do actually resemble natural objects. A

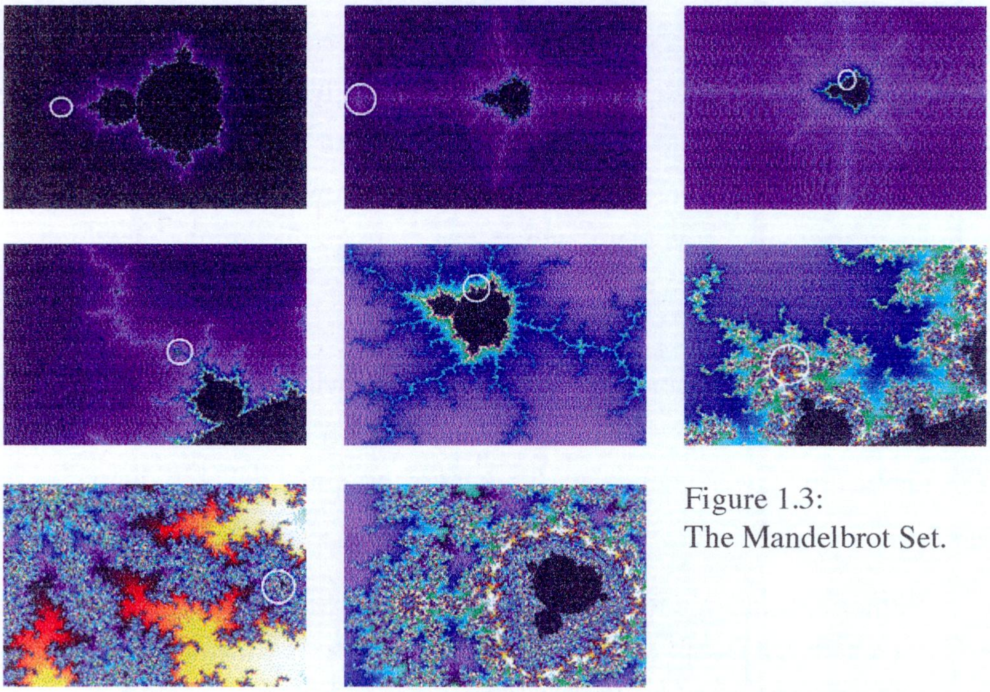


Figure 1.3:
The Mandelbrot Set.

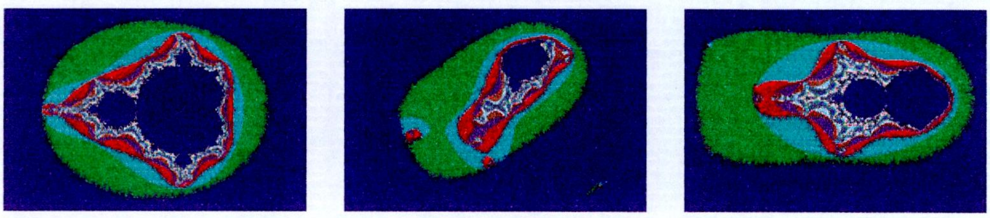


Figure 1.4:
Distorted Mandelbrot Sets.

tree is an easy example to illustrate, and can be done without the complex mathematics central to most fractals. There are many repetitions in this particular form; a branch often resembles a smaller tree, and a twig is just a smaller branch. Taking a simple tree shape, and repeating it onto itself ad infinitum produces a good, albeit geometrical version of a tree (Figure 1.2). If one looks at a real tree more closely, certain flaws appear with the model shown here, other than the rigid geometric feel to it. The silhouette of a branch in isolation does indeed resemble that of a tree, as does a twig. However, that is usually as far as the repetition goes before buds and leaves take over. It seems as though nature has a way of using a certain type of fractal up to a point, at which stage it changes to use something else. To simulate such an effect, perhaps human intervention could be used creatively to guide such processes. In the next chapter, I will be examining a hand-drawn system for creating forms, as developed by William Latham, that does just that.

As fractals go, this tree is quite simple, but it illustrates the basic characteristics of this type of image. For instance, no matter how closely one 'zooms in' on an area, there is always more detail to be found, although in this case the detail is always identical. Simple visual transformations such as this could be just as applicable to biological structures, such as blood vessels or lungs. However, the degree of repetition possible is very limited if rendered manually. Extensive mathematical repetition is only really practical using a computer, and this is where the range of such images become evident.

Benoit Mandelbrot, who first coined the term 'fractal', was one of the first to explore this field using computers. Rather than applying a simple visual transformation, as in the last example, he used a computer to apply a simple equation to each point on a plane, the result of which would determine the colour of the point. The equation was then re-applied over and over again to the results. There were two ways out of this loop. Firstly, a result would rush off to infinity; the number of times the equation was repeated before this happened determines the colour of the point. Secondly, the equation might never approach infinity, so after a predetermined number of repetitions, the computer moves on to another point. The larger the number of repetitions, the more accurate the end result will be. Figure 1.3 used 30,000 repetitions, a task that would have been beyond any manual means. The result of this process is the 'Mandelbrot Set', one of the most famous images in popular science. The best results are from magnification of the image, as illustrated in Figure 1.3.

Notice that the magnification involves the border around the large black pool. This is the chaotic region which produces the most interesting and beautiful results. The detail constantly changes, in contrast to the tree image, although the original image regularly reappears. (Gleick, 1987, pp. 227-228)

An important property of this image in regard to chaos theory is its sensitivity. Figure 1.4 illustrates a number of distorted sets. In each case, they began with the virtually identical mathematical equations, the differences being negligible. Like the butterfly in the weather system, these small differences magnified themselves with every subsequent repetition. I feel the results reflected this, for it produced very unpredictable images.

Are fractals art? The beauty of such pieces could be enough to warrant attention, but the lack of human intervention raises some questions. Kaleidoscope images are beautiful in a similar way, but they are generally regarded as attractive novelties – not art. Are fractals completely devoid of human input, or do they simply lack artistic intervention? They are obviously created by somebody, usually a mathematician. According to Dr. P. W. Atkins, "Fractal images are incomplete art, of course, since they are abstract and not culturally rooted" (Pickover, 1993, p. 79). However, our culture is extensively rooted in technology, so surely these images reflect that to some degree.

The arguments surrounding fractal 'art' can be applied to all computer art to some degree. If, for example, a piece of fractal generating software allowed the user to enter their own equations, does the resulting image have any worth? One has to ask when does conscious human effort end, and the technology take over. Therefore, when dealing with Latham's computer work, the role of the computer, and the role of the artist, must be clearly defined.

William Latham's work deals with evolving and breeding natural-looking forms, and his techniques bear many of the characteristics of fractals. For example, fractals begin with an equation. This equation could as easily be regarded as a seed for the image, or even a strand of DNA, appearing senseless in itself until it is subjected to the correct process. Also, evolving and mutating of an image can be done by altering the object at root-level; i.e. by making small adjustments to this initial equation, rather than to the image itself.

The main drawback with such images is the fact that they rely so heavily on mathematics, and numbers are often too abstract a subject to be applied visually. Looking back to the tree example, we can see that at least it grew out of a visual system more than a mathematical one. Despite the geometrical feel to it, we can learn from other fractal types that this need not be the case. Repetition can produce natural-looking forms, if harnessed correctly, and changing initial equations can control them. In a later chapter, I will be looking at the computer systems Latham uses to maximise artistic input.

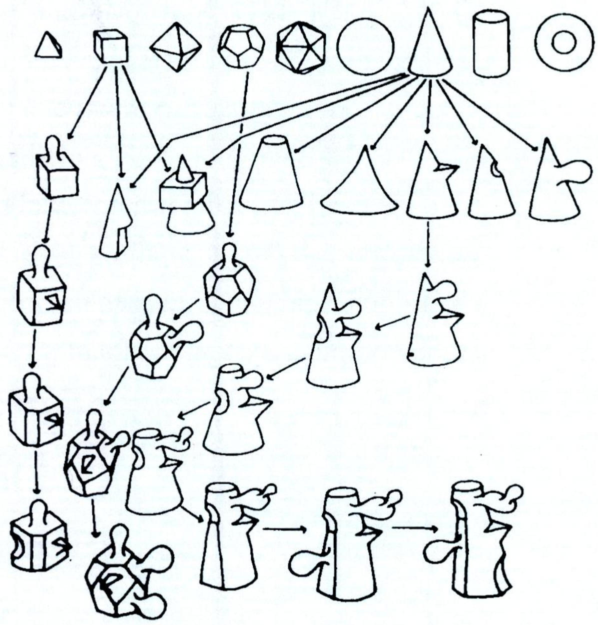


Figure 2.1: A Small Section of a FormSynth Tree.

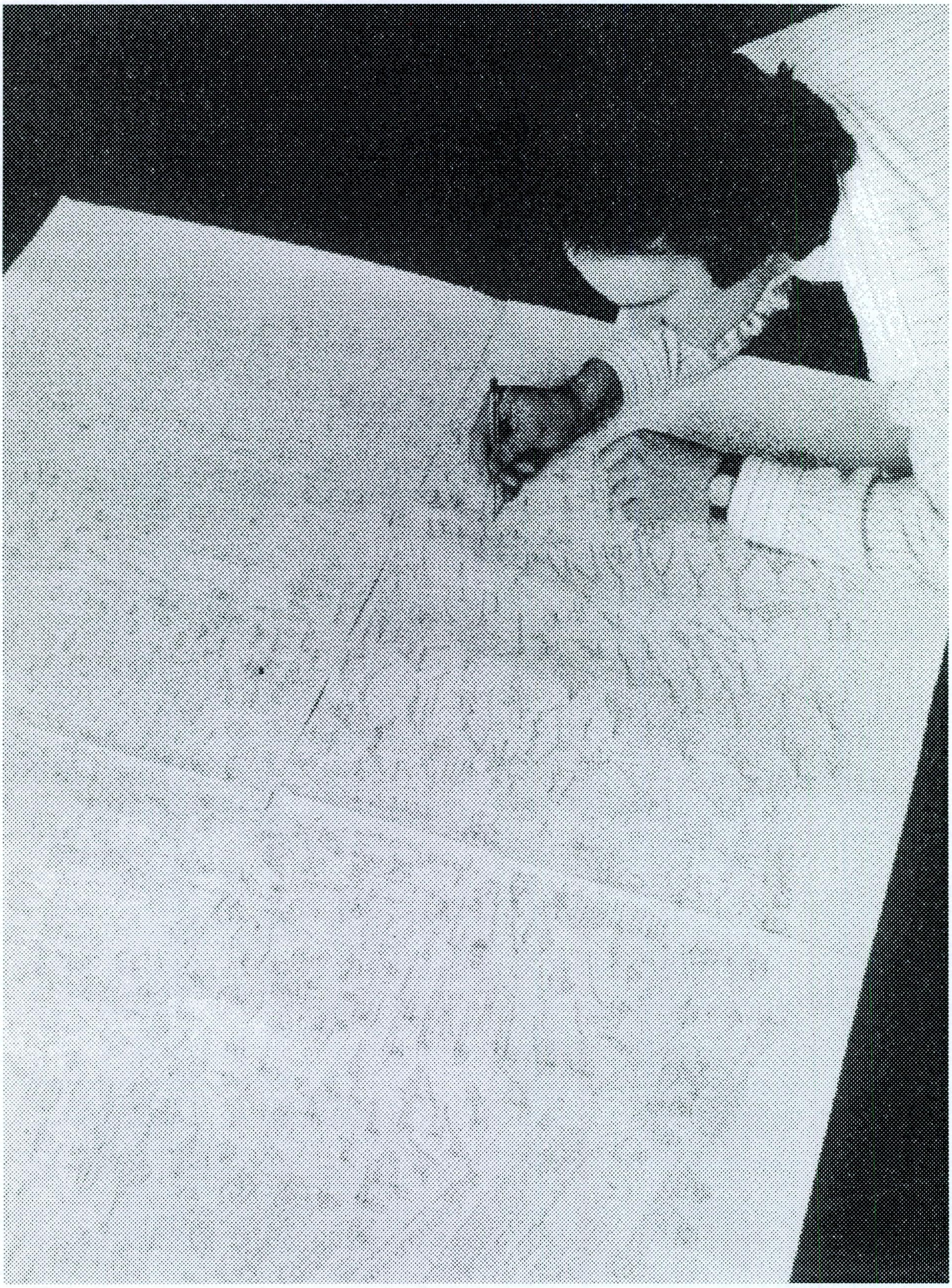
CHAPTER TWO:
FORMSYNTH.

A parallel can be found between the ideas of chaos and fractals and those of Latham. Both conclude that complex entities can be created through the repetition of simple processes. Inspired by biological forms and evolution, he tried to uncover the underlying systems used in nature for inspiration rather than using traditional artistic systems.

The system he uses for creating his images was developed long before he began using computers. Specifically, he developed a set of rules named 'FormSynth' to explore evolution and artificial life. He would begin with simple shapes (primitives) such as the cube, the sphere and the pyramid, and a number of simple rules, for example add, subtract, bulge and so on. These were integrated over and over to produce thousands of new forms, each based on the last, or a combination of a few. Latham compares this process to crystal growth. He could choose which forms to evolve, usually the ones that he considered to be the most aesthetically pleasing. The final product would be a large sheet of paper crammed with thousands of small forms, almost like a giant evolutionary family tree (Todd/Latham, 1992, p. 2). Any form could be traced back to simple shapes, regardless of how complex it had become. (Figure 2.1)

This 'tree' of unusual forms didn't have any definite end. The finished product was generally an enormous number of tiny drawings, showing some of the evolutionary concepts he was aiming for. Latham has often emphasised that he gives preference to the more beautiful forms, but unfortunately this is not always evident in this system. The sheer number of forms displayed can be overbearing, although it can also be said that much of the interest lies in searching for the different shapes.

Latham used this system to create drawings of forms from which he intended to create sculptures. Because of the complexity of a FormSynth tree, however, he could not reasonably build every single form. Even after deciding that he would only create a select few, he found that through his system, he had produced many forms that would be physically impossible to build. He says that the few forms he did build had to have a wide enough base, which did not



Latham working on a FormSynth Tree.

always mean he could choose the most interesting forms. Drawing appeared to have many more advantages over sculpture with regard to this system. Drawings could be produced rapidly, and yielded any form he could imagine. The disadvantage with drawings was the fact that although they were representative of three-dimensional shapes, they were in themselves only two-dimensional. For simple forms, this didn't really matter much. As they became more complex, one could only view the shapes from one angle, and this became a hindrance for both the artist and the viewer. Therefore, some elements of sculpture were appropriate in representing this system.

Clearly, FormSynth exposed some of the shortcomings of traditional media. One other obstacle was the limits imposed by both drawing and sculpture in terms of creating truly complex 'creatures'. To reach the level of detail found in even the simplest of living organisms required a much greater level of manipulation than was feasible by hand. According to Latham, he "wanted to continue working on the drawing instead of carrying out the mechanical execution of the sculptures." To do this, he began to look for more effective methods of rendering 'solid' forms, as manual methods were "creatively restricting." (Latham, 1988, p. 12).

The forms were only of secondary importance anyway – it was the system itself that was of most interest to him. Specifically, he placed most emphasis on the endless nature of a FormSynth tree, for despite the limited number of rules, there was an infinite number of forms for the artist to uncover. Taken as a whole, FormSynth questions the static nature of individual pieces. We live in a world that is constantly changing and evolving, and FormSynth illustrates this beautifully. This is why traditional sculptures proved inadequate for his needs – pieces in isolation from FormSynth make no sense. Latham describes the forms as "fruits off a tree" (McMullin, 1994). In themselves, they are strange and beautiful, but without the tree – the system – they are meaningless.

What Latham needed was a way to quickly create the many forms he drew in three-dimensions. Such a system had to be able to handle any shape, without having to consider physical constraints such as gravity. He found the computer to hold much potential for his needs. As I will discuss in the following chapter, there are many advantages to using a computer to apply a system such as his. As he became more involved with this technique, he used it to do more than just render the forms, but he actually used animation to evolve them

realistically. Before discussing these techniques, however, the next chapter will provide an overview of computer graphics.

CHAPTER THREE:
COMPUTER GRAPHICS.

The inadequacies of FormSynth led Latham to explore the realm of digital images. To understand why, we must firstly examine the capabilities of the computer. Chapter one introduced the notion of generating natural forms through computer graphics. This chapter will attempt to describe other computer graphics techniques that directly relate to those used by Latham.

Digital images share a number of characteristics. Most importantly, they are stored as electronic signals, which only become visible when connected to the appropriate hardware (eg. a monitor or printer). Such storage methods are extremely versatile, allowing unlimited duplication and manipulation. The final image is always a mosaic of small dots, called pixels, which combine to form a coherent image. It is how the computer assembles these pixels that often differentiates between different techniques. Essentially, there are two methods available.

The first method uses ‘bitmaps’. In other words, it stores the entire image as a grid of pixels, noting the colour of each individual point. This is somewhat akin to Seurat’s ‘pointillist’ work – an image being built up with tiny points of colour. Bearing in mind that a high quality print could contain literally millions of pixels, this puts tremendous strain on the computer. Despite this drawback, it does have many advantages. For instance, photographs can be digitised – converted electronically to a group of pixels – and stored as a bitmap. At this stage, the artist can alter the image by changing the colour of individual pixels. This is the basis of digital retouching.

The other method for creating computer images, and the method used by Latham, uses ‘vector graphics’. Rather than storing the characteristics of each and every pixel, the computer stores the characteristics of complete shapes. A straight line, for instance, is stored as the two end-points as opposed to each pixel comprising the line. The result of this method is that the computer has a better ‘understanding’ of a scene, knowing which pixels correspond to which elements. With a bitmap line, the computer cannot easily make a distinction between which points belong to the line, and which points fall outside it.

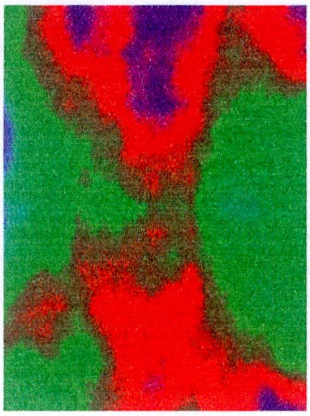


Figure 3.1.

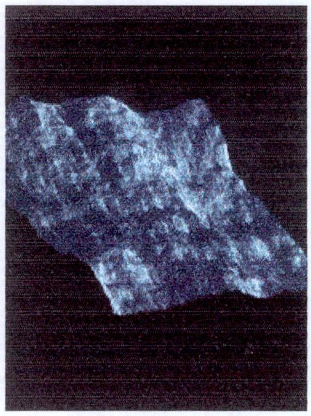


Figure 3.2.

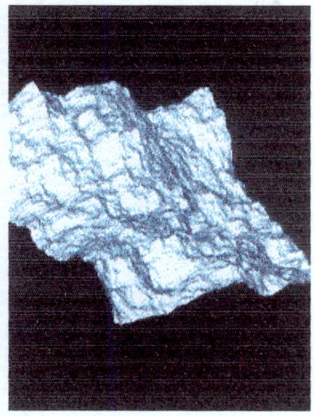


Figure 3.3.

Figure 3.4:
Ray-Traced objects.

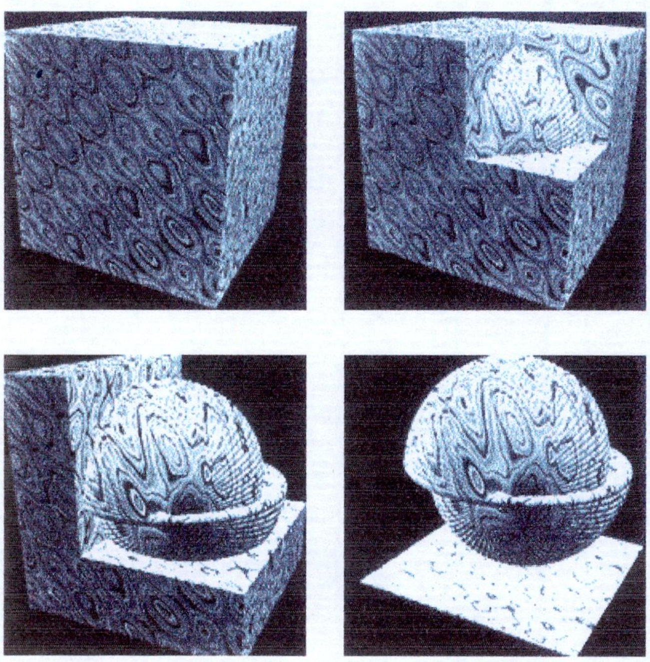


Figure 3.5.

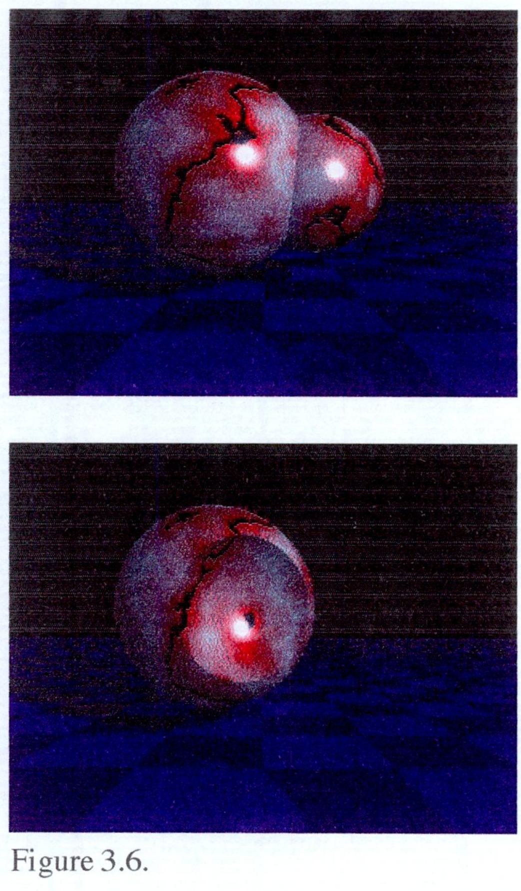


Figure 3.6.

Fractals can be considered an extreme form of vector graphics. Complex as they appear, the computer can 'understand' them because they are constructed mathematically. Figure 3.1 shows another fractal I created using Fractint software. It seems to resemble coloured clouds, but the computer can be instructed to interpret it differently. The Renaissance masters discovered that three-dimensional forms could be mathematically translated onto a two-dimensional plane, such as a canvas. Likewise, a three-dimensional scene can be calculated by a computer, and displayed on a two-dimensional screen. This fractal can be used in the translation. In this case, the computer regards the different colours as heights, much like an ordnance survey map. It constructs a three-dimensional landscape out of the fractal, and the user can specify where the lighting will be, what angle to view the shape from, and so on. Figure 3.2 shows a rocky mountain constructed from that fractal. It wasn't quite right, so I changed the position of the light source, and slightly altered the way the computer interpreted the colours. This produced the image in Figure 3.3. Ultimately, it is possible to create worlds in computer space to our own specifications. Although the examples shown here are essentially mathematical models, in reality the mathematics are hidden from the user, leaving the computer to handle all the difficult calculations.

FormSynth, the basis of the previous chapter, manipulates simple shapes. Because these shapes are very geometrical, they can be easily 'understood' by the computer. Because computer space gives artists total control over their working environment, it offered Latham the freedom he needed to apply his artistic system. Some of the shapes he created using FormSynth would have been difficult if not impossible to sculpt physically. In computer space, he does not have to apply gravity if it is a hindrance to the aesthetics of a piece, and likewise, a block of heavy-looking stone may be supported on the tip of a needle. In short, he could create any sculpture that his techniques produced, but they would have to occupy a virtual, as opposed to physical, space.

Virtual space has its own drawbacks. One cannot view virtual sculptures in the same way as traditional sculptures, by walking around them, or even touching them. Much research is taking place at present into improving interaction with computer space, notably in the field of virtual reality (to be discussed in a later chapter). For now, the most practical solution is to use the computer screen to act as a camera onto this virtual world. We must tell the computer where we want to look at, and it will obey. The advantage of all this is that we can view

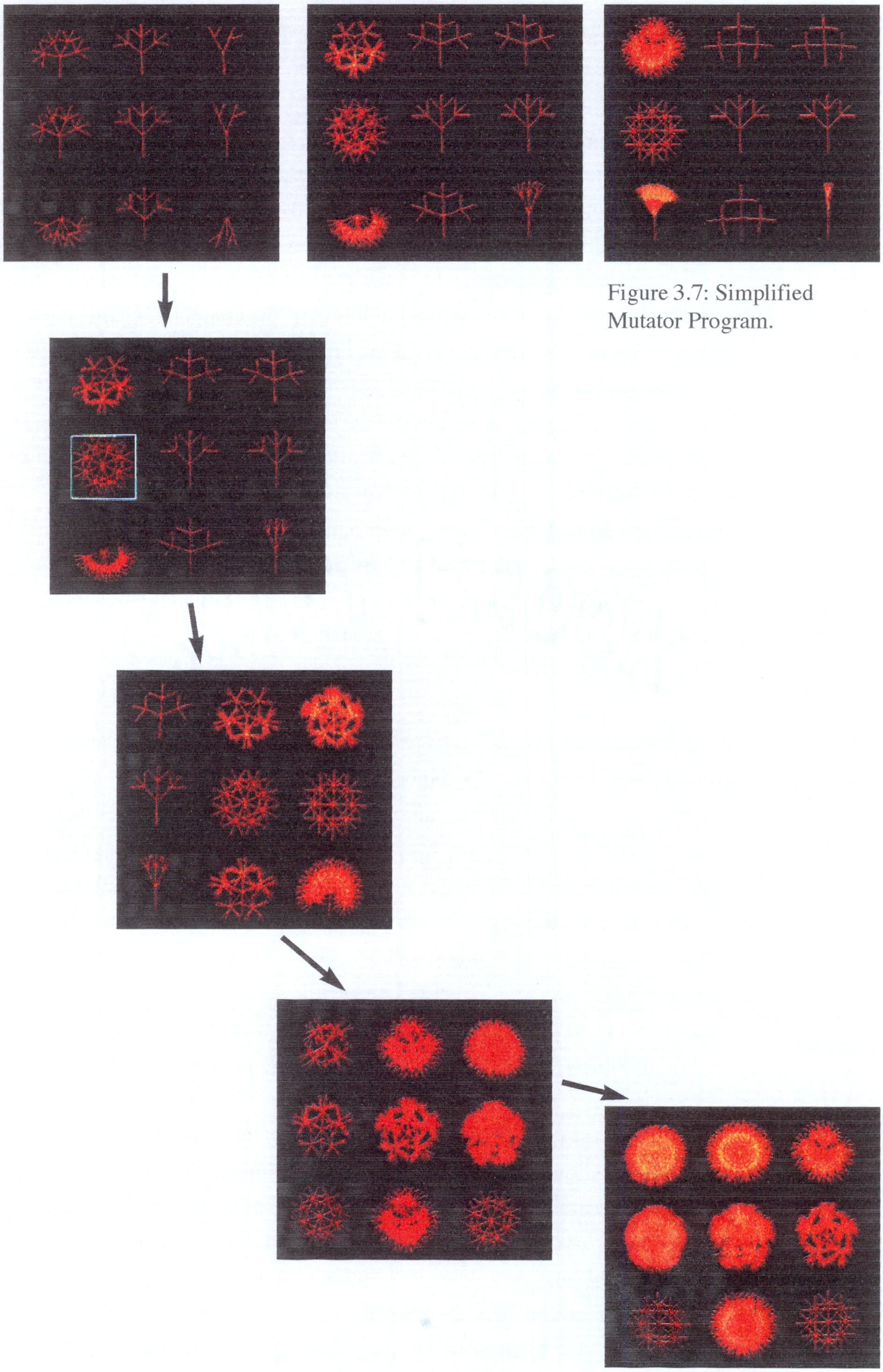


Figure 3.7: Simplified Mutator Program.

any object from literally any position, even from within the sculpture looking out.

Obviously, these sculptures are illusions. They certainly do not exist physically, and nor does the space they occupy. However, as graphics techniques become more advanced, the illusions become more convincing. A technique called ray-tracing allows accurate rendering of light, shade, reflections, and so on, with the result that computer images are often indistinguishable from photographs. Figure 3.4 shows an example of ray-tracing.

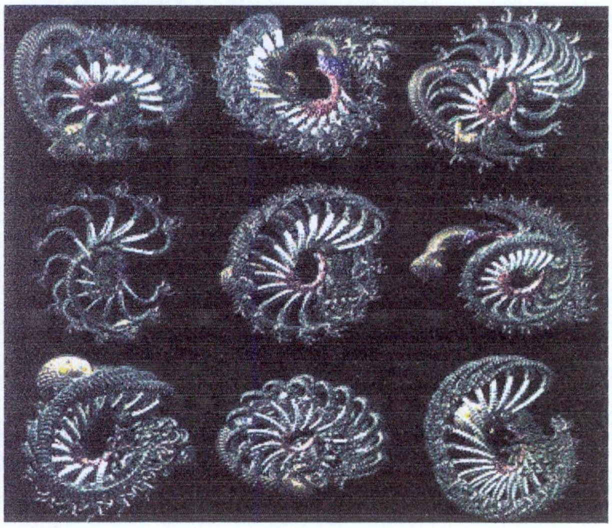
Latham's computer systems can create shapes that actually behave like real solid objects, if this is appropriate. This is ideal from a sculptor's point of view, for if the computer understands solid objects, it allows one to 'carve' into shapes. Figure 3.5 shows a piece Latham carved out of a virtual block of marble. His computer system goes further than that by allowing most of the FormSynth rules to be applied to a piece – addition, subtraction, and so on (Figure 3.6).

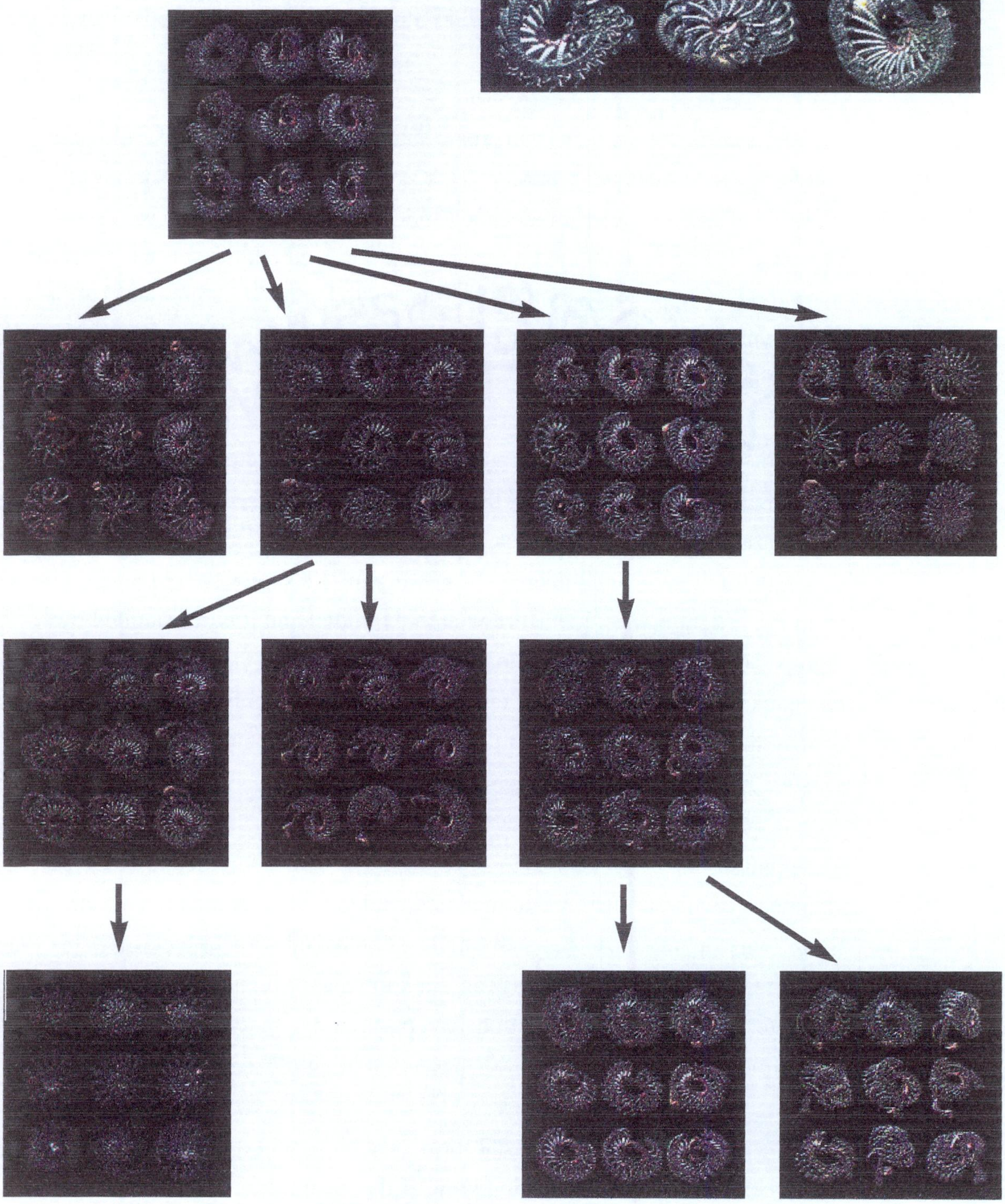
As each shape in a computer-generated scene is constructed from mathematical equations, to alter the shape one simply needs to alter a few parameters. To illustrate this idea, I developed a small piece of software to generate the 'tree' fractal in chapter one. Figure 3.7 shows some typical scenes from the program. The tree is drawn in the middle, and it is surrounded by eight variations that have some parameter changed. If a variation is preferred, one can choose that image, and eight variations of it will be rendered. One can control the amount of change in these variations from a subtle effect, to drastically different shapes.

The point of this program was to show a way in which parameters could be changed visually, as opposed to mathematically. It also seemed to suit the way FormSynth operated; shapes evolving in a controlled way. In fact, Lathams computer system uses a similar program known as 'Mutator' to simulate (un)natural selection and evolution. The program is obviously more advanced than mine, as is evident in Figure 3.8, but the principle is still the same.

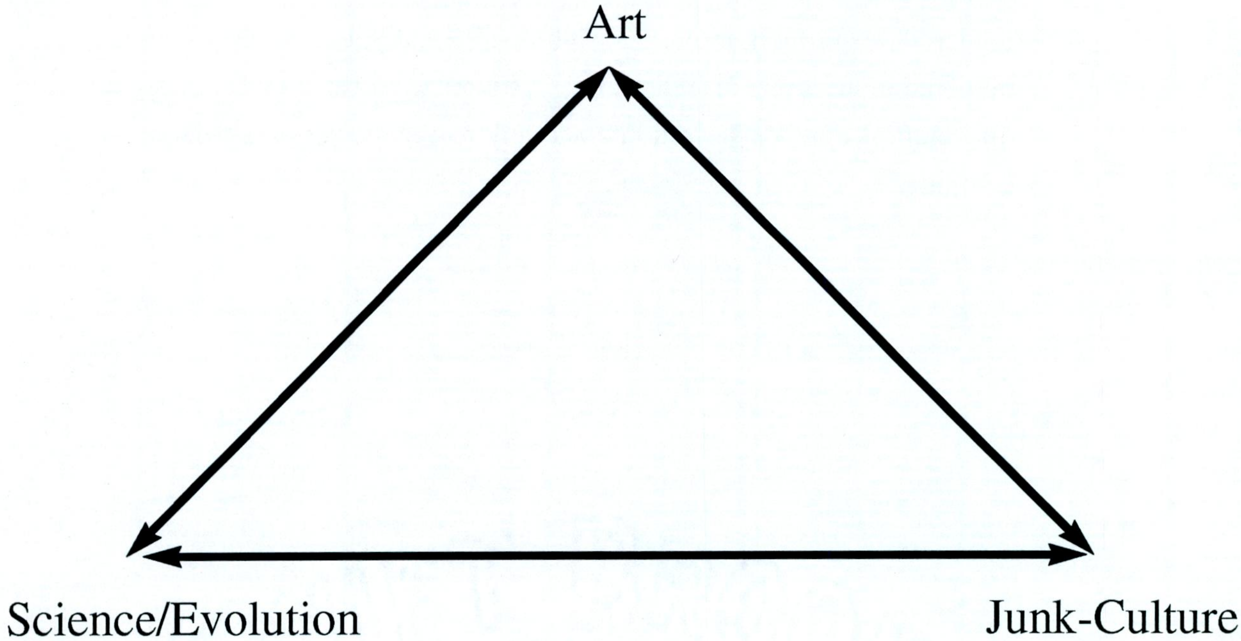
Once he has created and evolved a form, he can present it in any number of ways. He can select an interesting view of the 'sculpture', and create a print.

Figure 3.8: Mutator.





As I mentioned above, these can be nearly photographic in quality. Alternatively, he could get the computer to render a series of views, and output them to video, creating a computer animation. As the computer 'eye' can access anywhere in computer space, the results can be spectacular. This method can be taken one step further by evolving the forms as they are being rendered, resulting in moving sculptures. Recently, Latham has also become involved in multimedia technology. His work is stored on CDs as digital information, and is accessed interactively by the viewer on a personal computer.


Art
Science/Evolution
Junk-Culture

CHAPTER FOUR:
LATHAM'S WORK.

Figure 4.1 shows a triangle similar to one in Latham's studio. It represents the three main aspects of his work, and this chapter will discuss these elements. He mentions the fact that up to about a year ago, his work tended to dwell somewhere between 'Art' and 'Science/Evolution', but "nearer art". For a number of reasons, he began to explore mass-media ("junk culture") in more detail, thus completing the triangle.

To begin with, I would like to discuss his work in terms of art and science. It is appropriate to ask what direction his work takes : does he create animated sculptures (art), or does he explore artificial life (science/evolution)? Clearly his work has some aspects of both fields, so I shall attempt to give a brief description of each.

The word 'sculpture' has many connotations which are often steeped in tradition. When somebody such as Latham begins to redefine such notions, questions are naturally aroused as clear definitions become blurred. Sculpture is often thought of as 'static', although mechanically animated pieces are often accepted under the definition. The important point is that a piece of sculpture is a physical, three-dimensional piece, that can usually be walked around or touched. Latham's computer sculptures do not possess these qualities. They exist only as a computer program, or a print, or a video. Real physical examples of his work do not, and often cannot exist.

Artificial life is another term that could be applied to his work. His animations consist of seemingly natural 'creatures' that often display many of the characteristics of life – birth, death, reproduction and aging, to name a few. The structure of his pieces owes much to nature, as they appear to be organic. Having said that, his creations do not evolve independently of the artist. Latham is the creator of these creatures, and without his direction, they cannot exist. These pieces are comparable to puppets, brought to life for as long as the puppeteer controls them. He assumes the role of choreographer, and the movements of his pieces are filmed.

According to Latham, his work contains properties of both fields - he likes "to

pick and choose" between sculpture and artificial life (McMullin, 1994). Different pieces have different emphasis, but essentially the illusion of life is intended to be a stylised one. His early work, for instance, was developed on Mike Kings 'sculptor' program, and was primarily used to render some of the many forms created using FormSynth. Although he created some pieces that were virtually photographic in quality, the forms themselves were 'static', and could be considered to be virtual sculptures. More recently, he produced 'Biogenesis: Artificial Life in Computer Space', which will be described in more detail in the next chapter. The word 'sculpture' seems to be an inappropriate description for this video, and despite the above arguments dismissing the Artificial Life content of his work, it is hard to believe that these forms are not living.

'Evolutionism' is the term Latham gives to his work. Whether or not the final product is animated is irrelevant, but the system through which the forms are created is based on biological theories of life and evolution. That said, it is difficult to appreciate the full beauty of his work without seeing it in motion. Creating organic forms that move naturally is something that is probably beyond the scope of traditional sculpture, and it should not be disregarded if it creates an interesting new aesthetic along the way.

His work could also be seen as an artistic venture into genetic engineering. This is a field that has always been open to debate, from the inhuman Nazi experiments, to the controversial ethics of some fields of modern science. To experiment with genetic engineering for artistic purposes would be unacceptable if it were not confined to the sanctuary of computer space. The 'life' he creates is very unusual, however. On the one hand, it is immortal – digital information, if handled correctly can last forever; a true 'master race'. On the other hand, dependence on the artist is paramount. Like all art, from images to literature, it can outlive its creator, but only if the artist allows it. If a computer is switched off, the image may be considered to be 'dead'. Because of the reproductive qualities of digital images, however, destroying an older image may be difficult. It may have found its way onto many storage devices, either by itself (like a computer virus), or more likely, it could have been intentionally distributed to others. The more an image is distributed into the world of computer networks, the more impossible it becomes to destroy completely - there is always the chance it may turn up on another computer.

Different metaphors can be used to describe his work. Latham often uses that of a garden, where the gardener (artist) is free to cultivate the most pleasing forms ("like a gardener trying to grow the perfect rose" (Channel 4, 1993)

It is important at this stage to complete the triangle mentioned above by discussing "junk culture". One of the deciding factors in his decision to involve mass-media was a financial one. As he has been working for IBM for some time now at a research level, it was inevitable that sooner or later the corporation would begin to ask for commercially viable products. This attitude could have worked against Latham, but as it happened, he was able to use it to his advantage. He had often criticised the 'elitist' mentality found in the art world, and now he had the opportunity and the corporate backing to do something about it.

According to Latham, his campaign involved a number of steps, utilising existing media networks to his advantage. The easiest such network would have been television. Much of his work already involved video, so it was easy enough to broadcast his work. "Biogenesis", for instance, was broadcast on Channel Four in late 1993. This method had similar drawbacks to the videos he showed in exhibitions, although certainly they were more accessible now by the general public. However, they remained linear to the extent that one could only view what the artist created in the order that he created it. Surely the versatility of the computer would allow greater possibilities for viewer interaction.

Because the computer seems to be an indispensable tool in many areas of todays society, there now exist many new openings for Lathams work. Surprisingly, the artistic systems he uses, such as Mutator, have found uses in many seemingly unrelated fields, such as financial modelling (McMullin, 1994). In theory, fractals can illustrate social trends as well as visual entities. In this context, should we take Lathams' work at face value (organic-looking 'creatures'), or is it indicative of the wider scheme of todays society, irreversibly dependant on computer controlled networks?

Into this situation, Latham has released a new multimedia product, 'The Garden of Unearthly Delights'. Multimedia software generally integrates sound, graphics and video into one interactive unit, and is usually stored on CD-ROMs to be used on a personal computer. The key word in this

description is 'interactive' – Latham creates the forms, evolves them creatively, but hands the role of gardener over to the user of this software. The product is described as many things – a game, an experience – but he appears to be questioning the nature of similar products. Video games, for instance, can potentially exist in a near-limitless area of cyberspace, but often the worlds created are too limiting, involving pre-defined goals and a rigid set of rules and restrictions. Latham compares this situation to the 'Wizard of Oz' – a world where we are limited only by our imagination, yet where we insist on following the 'yellow brick road' (McMullin, 1994). He is not alone in this view. Eugene Provenzo conducts extensive research into this subject in his book 'Video Kids'. Although he talks of the negative influence of violence and sexism within these games, he speaks harshly of the confinements imposed by game designers. In conclusion he writes that for games to be of benefit, they must encourage creative gameplay, not single goal combat (Provenzo, 1991, pp 30-31). Latham's work is not a game as such, but it is comparable to a Japanese Garden - full of exquisite forms waiting to be discovered. The atmosphere is relaxed - "meditative", according to Latham, which is in keeping with many of his videos. The fact that the user can now decide how to view his work interactively means that the attraction of the piece is enhanced. I believe it is the interactive element of computer games that draws people away from the passive involvement with television. Perhaps Latham's work will cause a similar stir in the art world.

CHAPTER FIVE:

BIOGENESIS.

After FormSynth, the videos he produced were extremely limited. After all, the forms he created remained static; only the computer's 'eye' moved. He showed the variety of forms that could exist in cyberspace, but they still owed much to traditional sculpture. This was proving inadequate for his evolutionary themes, and he began to explore ways of breathing 'life' into his creations.

The computer system he used was developed further to allow the pieces he created to function as lifeforms in their own right. Instead of solely moving about a static sculpture, the technology made it possible to actually evolve these pieces, following his FormSynth system much more closely. Again, the viewer could not dictate what to view, but now the question of whether or not these items were sculptures any more has to be asked. Are sculptures born? Do they reproduce, or get old and die? These pieces certainly did, but did not seem to belong in our world. Were they valid lifeforms? They seemed to live, even if their life was controlled by the artist. Yet now the 'artist' had taken on other roles - choreographer, film director, where the forms he created were the actors. Undoubtedly, the animations he produced were unique in the realm of computer graphics.

This section will deal with an overview of how he puts together such a piece, taking the example of his short film, 'Biogenesis: Artificial Life in Computer Space'. Already the suggestion is there that he considers his creations to be alive to some degree. One critic once observed: "the organic geometry of William Latham's computer sculptures is often curiously marine-like" (Phelps, 1988, p. 10). This is especially evident in this piece: the forms we are presented with seem to float weightlessly in space in a very natural manner, reminiscent of sea-anemones in their motions. Latham himself compares the forms in this piece to coral, especially regarding the way they 'grow'.

The first form we are shown appears to be constructed from artificial materials; some of its tentacles, for instance, seem to be made from clay. This is especially interesting given the title of the piece. 'Biogenesis' refers to the concept that all life is created from living organisms. Here we have 'creatures' that behave very naturally, yet seem to be purposefully showing their

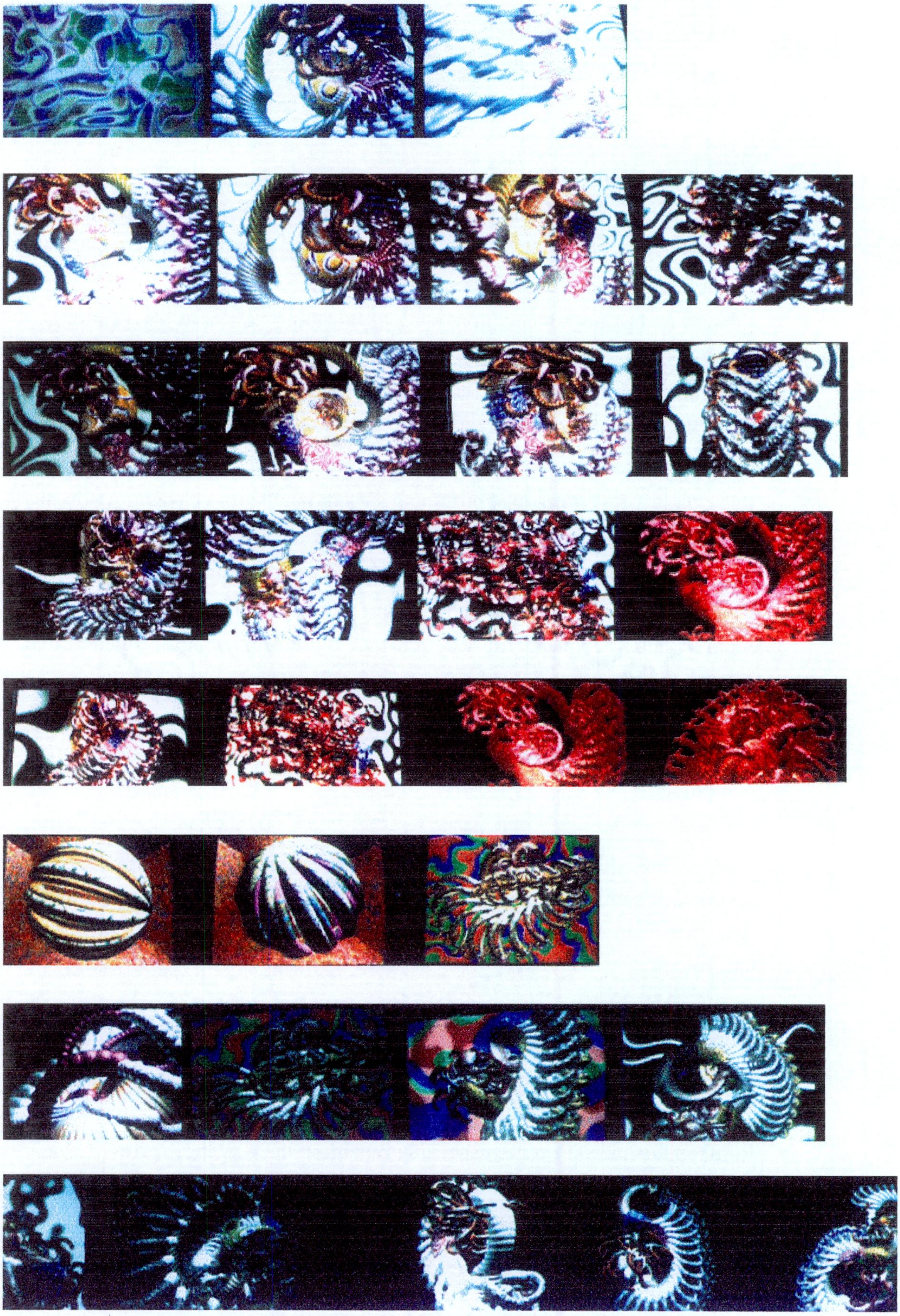


Figure 5.1: Biogenesis – Artificial Life in Computer Space.

artificiality. To me, this is questioning the idea of what life is. For centuries, sculptors have looked beyond inanimate materials, and shown that they can produce a life of their own. Latham's work goes one stage further by taking advantage of the fact that, to a computer, a piece of marble is no different to a living organism. Therefore, materials that we consider to be lifeless, actually form the very basis of life in his world. In fact, he had been using such ideas for some time, as mentioned in the previous chapter, but until he showed his creations in motion, this concept could not be appreciated in full.

The movements of this creature are so natural, that one becomes unaware of some of the more unnatural events in the video. To maintain the graceful nature of the piece, when one part of the creature collides with another, Latham allows it to pass straight through as though there were no obstacles in its path. Of course, this would be impossible in our world, but Latham sees no reason to restrict the beauty of his creations through mere physical laws.

After introducing us to this creature, our view becomes obscured by a red, 'rippling' effect, something like drops of blood in water, reinforcing the comparisons to sea creatures. For a brief moment, the effect is to allow us to view this form in a near monochrome light. 'Flash Art' critic Rupert Martin has this to say about his work: "The shiny surfaces of the forms are camouflaged by a kind of coloured marbling which is extremely artificial, and the most successful images end up being the most monochrome." (Martin, 1989, p. 122) Without the distraction of coloured surfaces, it begins to resemble a lobster, or at least a more 'plausible' lifeform in terms of what we would expect in our own world. However, I feel that Martins' views are very conventional when presented with this work, almost as though he is resistant to change: "One misses the interaction with the real, resistant, often intractable materials which has, until recently, comprised the activity of sculpture." (Martin, 1989, p. 122).

Next we are introduced to an egg-like form. This shape doesn't change much in terms of structure, but it demonstrates the superficiality of surface colours and textures. While it rotates in one direction, its 'skin' constantly moves in another, changing between a spectrum of colours. Unlike the first creature, this form almost appears to occupy a definite space. Although it floats freely, the background suggests that it is in some way constrained.

Figure 5.2: *Grown Form*, Latham 1989.

After a few more 'ripple' effects, the original creature is shown again. This time, however, it appears to be in a state of change. Its surface texture is behaving in a similar manner to the egg, suggesting to me that the egg represented a 'cocooning' stage in its development. What emerges is a similar form, only it is predominantly white, creating an angel-like effect when it fans out.

I feel that the purpose of the film is similar to that of an aquarium or zoo. We are invited to view his creatures candidly, watching how they live and grow. Although themes of rebirth and metamorphosis are evident in this piece, he has created other films which show different aspects of these creatures' existence. For instance, in 'Mutations', he actually shows how his creatures give birth, and as the film progresses, they grow old and die.

Artificial Life is a field that is open to much debate. Up to now, the word 'life' applied to carbon-based lifeforms, only because this was the only type of life available to us. When presented with a different type of life, are we qualified to recognise it? (Gerbel & Weibel, 1993, p. 124) Regarding Latham's video work, there are a number of flaws. The computer gives one a chance to interact with virtual worlds, but in Lathams case, this interaction is limited to the artist, not the viewer. We cannot explore his 'lifeforms' in any way other than the way he presents them to us. He has since gone some way to solve this problem, however, by getting involved with multimedia software, as discussed in the previous chapter.

His forms do not appear to have any artificial intelligence as yet. If we consider his pieces as films, however, then this can be overlooked; his creatures can be considered actors, and as such need not demonstrate their own thinking. The level of detail found in his creations would have to be sacrificed anyway in order to give way to these concepts, and this would detract from the beauty and uniqueness of his forms. Alternatively, his work could be depicting non-intelligent life, for example plants (Figure 5.2). Because they suggest organic forms without actually reproducing known lifeforms, there is a certain ambiguity in his work.

According to Latham, he attempts to stylise the concept of life in his work. He claims the title of this piece is ironic: he presents us with non-living forms that appear to be alive. The DNA inherent in real living organisms is replaced by

numbers in a computer program. The resulting illusion questions the common perceptions of life and reality, comparing them to the alternative reality offered in a computer program.

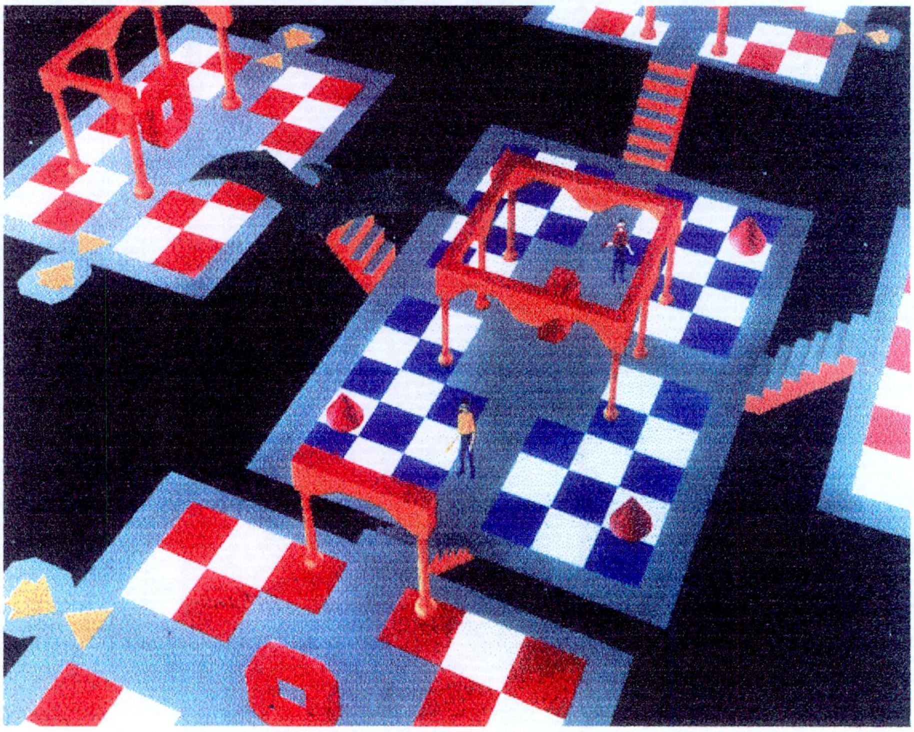


Figure 6.1: *Dactyl Nightmare*, a Virtual Reality game.

CHAPTER SIX:

THE FUTURE.

Virtual Reality (VR) is the name given to a new state-of-the-art human/computer interface. The user wears a special headset that contains two small computer monitors, one for each eye, that show two slightly different views of a scene. This is known as stereoscopic vision; we perceive depth in this way, and this illusion has been used in many forms for years. With VR, the viewer is looking at a computer-generated scene, and when one moves their head (which results in the headset moving) the computer calculates what the new view should be. The effect is that the viewer is totally emersed in computer space. More complex set-ups include sensors, such as gloves, which allow the user to interact with these new worlds. This is a vast improvement on common human/computer interfaces, although the technology does not come without its limitations, mainly expense. What potential does this medium hold for artists? Basically, it should allow the viewer to experience the world that the artist chooses to use. After all, what is the point in creating a piece in three dimensions, and forcing the spectator to view it on a flat screen?

Figure 6.1 shows a scene from a virtual reality arcade game called ‘Dactyl Nightmare’, running on the Virtuality System in numerous arcades. The detail is obviously too sparse for Lathams’ requirements, being restricted to very simple primitives. However, according to Jon Waldern of Virtuality Entertainment Systems, realistic graphics should be available “around the middle of next year [1995]”. Although the hardware will undoubtedly be expensive, the possibilities go beyond entertainment. In Latham’s case, the technology could be used to create a ‘Virtual Gallery’, for instance. Such a ‘place’ would be free from the restrictions imposed by a physical gallery. This would allow Latham’s work to be presented with total control over the scale and conditions of such space. FormSynth uncovered some of the limitations of traditional sculpture, and his computer animations expanded the advantages offered by still computer images. The added depth that virtual reality brings would give yet another dimension to his pieces, and perhaps it would expose the shortcomings of his animations. With each advance in technology comes an advance in our sensory expectations.

Latham has been discussing the possibility of a VR project for some time now.

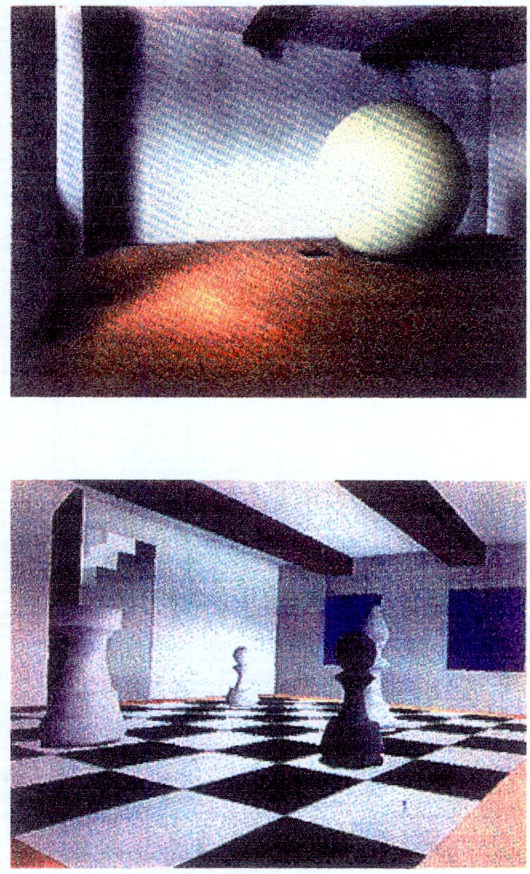


Figure 6.2: Virtual Environments.

This project is known as SAFARI, and will be an artificial world containing his creations. However, the role of 'gardener' will be replaced by that of 'hunter'. He envisages a situation where several people can enter his computer space at any one time, each with their own aesthetic judgment. Each will hunt a form, but instead of shoot-to-kill, one would decide how to improve the creature. This results in an artistic hunting trip. The idea of group artistic interaction is essentially pushing the idea of his multimedia project one step further.

In reality, such technology is a long way off. The realistic graphics due to hit virtual reality will still use simpler techniques than Latham's. For instance, the simple primitives used today will have textures mapped onto them, and more light sourcing will be used. Figure 6.2 shows an example of what to expect. Although the quality seems quite good, in fact there are only a handful of basic shapes being used. With Latham's creations, each piece may contain hundreds of primitives, and the light sourcing is much more advanced. With virtual reality, rendering speed must be kept to a maximum, so light intensities are taken at a few key points on each object, and averaged out. As mentioned in a previous chapter, Latham utilises a technique called 'Ray Tracing', where each beam of light is calculated from the viewers position, to any 'object' it touches. This allows for advanced effects such as mirrored surfaces, or refraction through glass and water. The disadvantage with this technique is that an object takes too long to render. On a fast home-computer, 'ordinary' light sourcing can be achieved in near-real-time, but one ray-traced scene may take hours. The technology Latham utilises can bring this time down to a few seconds, but this is still far too long for real-time animation, let alone virtual reality. After all, to produce a true VR effect, each image has to be rendered twice from slightly different angles, and projected to each eye to produce a stereoscopic effect.

A more modest adaptation is 'Artificial Reality'. This is similar in concept to VR, but it uses relatively simple hardware. Like Lathams' current work, the computer screen acts as a window onto a virtual world, but in this case the viewer controls the course of the computer 'camera'. Again, this is difficult to implement in real-time. The trade-off between complex images and smooth movement would inevitably result in a compromise: either detailed images moving at very slow frame rates, or smoothly moving graphics that are too primitive to resemble nature.

The concept of computer networks – computers hooked up to each other usually by phone lines – offers potential to Lathams' goals. If artificial reality became a viable option, the SAFARI project could take place in a non-immersive computer space. The main advantages are that it utilises an existing network, and it is far more accessible to a mass-market. Latham would be reinforcing his commitment to "junk culture".

Joseph Bates, a computer scientist at Carnegie Melon University, showed that it is possible to create computer 'personalties'. His cartoon-like graphics depict four 'blobs', one of which is controlled by the user. Each of these creatures have different personalities, and as such they each react differently to user interaction, as well as to each other. Their movements are quite restricted, but they manage to convey a sense of communication by distorting their bodies. Again to achieve this level of intelligence, visual detail has been sacrificed. It would be interesting to allow this kind of interaction with Lathams' forms, when processing power becomes efficient enough.

'Polyworld', created by Larry Yaedger of Apple Computers, is another attempt at creating artificial life and intelligence. However, it differs from Bates' work because the creatures are left to develop independently of user intervention. He cites a number of criteria for life: "reproduction, a form of self-representation, a metabolism, interaction with the environment, interdependence of parts, stability under perturbations, and the ability to evolve."(Gerbel & Weibel, 1993, p.126) All of these are evident to some degree in Latham's work, but unfortunately they are all simulated by the artist. Forms may reproduce and evolve, but they are merely puppets controlled by Latham. In Polyworld, the forms actually 'think' for themselves (a basic neural network has been provided), they can 'see' their environment (a simulated visual perception function), and they have the ability to 'learn'.

The theme of Polyworld is survival. Several 'species' have been included, as have food and barriers. Again, the physical appearance of this world is simple. What is interesting about this world is that behaviours usually begin to emerge among the species. For instance, one creature might fight another in order to kill it, thus providing itself with food. Mating behaviours have also been observed in this world.

Yaedger has asked the fundamental question regarding Polyworld, namely is it alive? It seems to satisfy many of the criteria for life, but like Latham's work, I feel that he is leaving the subject open to question. This is a central issue, because at face value, cyberspace appears to allow anything to happen. But allowing life to be created? This has always been a controversial topic, although before computers, this argument has been largely restricted to genetic engineering. The work of Latham comments on such topics by engineering his own life. Confined to cyberspace, it is difficult to criticise from a moral viewpoint. However, if future technology progresses in any way similar to how I have described (which, of course, it may not), the world may have to concede that artificial life is as valid as any biological lifeform. As we progress down this road, we will probably accumulate an increasing number of moral questions. For every advance made in science, there may be an artist such as Latham to comment on it, which means that perhaps his work has only just begun. One article in a recent 'Edge' magazine featured a fictional piece where a not-so-distant future computer armed with artificial intelligence was taken to court over allegations it made. It decided to represent itself...(Jarratt, February 1994, p. 13).

CONCLUSION.

The work of William Latham is inspired by a number of fields. Current scientific theories on life and nature are integrated with artistic and sculptural systems to produce what he calls 'Evolutionism'. It was mentioned in Chapter One that the most interesting area of the Mandelbrot Set was the immediate 'border' of the shape, the area between order and chaos, for it contained the most intricate and unexpected detail. Likewise, Latham's work is a series of fringes between life and the non-living, art and science, high and low culture, the physical and the virtual, the process and the result.

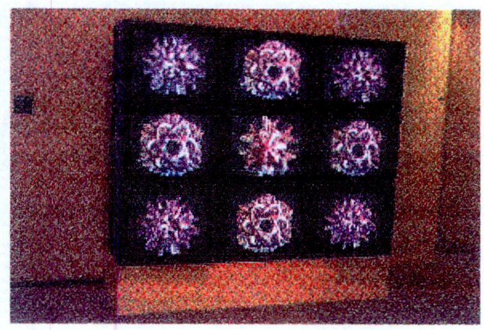
Is it art? Imagemaking on a computer does have advantages. For instance, an image can be manipulated to any extreme, and because it is stored as a series of electronic signals, it is virtually immune from damage or decay. But it can be argued that such an image loses its value as a work of art. This argument stems from the idea that a work of art is a 'precious' entity in its own right, but a computer image is always exposed to change and easy reproduction. A digital image can be reproduced indefinitely, and by its very nature, the last copy will be identical in every respect to the original. How can such an image have worth? To me, the answer depends on our preconceptions of what art should achieve. Obviously, there is no single answer to this, as different artists have different aims. However, similar arguments have been applied to other pieces of technology on their introduction - Gutenberg's printing press, and more recently, the advent of photography, have both been questioned. Both these techniques turned laborious manual processes into relatively simple mechanical processes, and were dismissed by some groups until it became obvious that they offered more possibilities for expression, rather than posing a threat to established methodology. For instance, it was pointed out that natural forms could be described mathematically using fractals, in much the same way that the Renaissance masters used mathematics to explain perspective. In both cases, the job of the artist was to use these techniques creatively, rather than applying strict formulae. Like all new techniques, questions are raised. The introduction of oil paint allowed painters to correct mistakes in their work, and made it easy to paint over guidelines - essential when working with perspective. Likewise, the computer offers advantages to artists, allowing them to incorporate new techniques into their work - such as fractal geometry - that would be difficult to implement otherwise. "Until artists can imagine a means

of using a given technology, so that the look of their identity, based in style, can come through . . . they're not going to embrace it."(Dery, 1993, p. 75). In Latham's case, his technique (FormSynth) utilised the technology well, so he was not simply using an expensive hi-tech canvas – he exploited the unique strengths of a new medium. In Chapter Two, the inadequecies of traditional means with regard to Latham's needs were discussed.

Throughout the history of imagemaking, the value of the 'original' work has always been given priority. Few reproductions existed, and in general, these were manually rendered, "usually branded as a forgery" (Benjamin, 1969, p. 220). This negative view made art inaccessible to most, although often the technology wasn't adequate for anything other than manual reproduction. This affected different art forms in different ways – a piece of architecture, for example, could be appreciated by more people than a painting at any one time. Different printing techniques began to bring images to the masses, but it was photography that posed the first serious threat to convention. For the first time, a medium existed that was more accurate than the human eye, and could be reproduced indefinitely. When dealing with photography, the concept of the original no longer holds true, as any print made can be considered original. The idea of producing a reproducible image now existed alongside the more traditional notion of reproducing an already produced image. Both have their merits, but nowadays it has become important for many images to be made available to the masses. This is achieved through film, magazines, or any number of mass media. (Benjamin, 1969, pp. 217-253) Digital images have been introduced to society in many forms in recent years, and are providing the basis for a new revolution. A digital image could begin as a photograph, a drawing, or it might be rendered entirely within the computer. What distinguishes it is that every image can be manipulated to any degree, and with a press of a button, the original image can be recalled. The same argument regarding originality still holds true, as each image can be endlessly reproduced. Now the concept of being endlessly altered comes into question. It certainly changes traditional views on the worth of an image if the image itself is open to any amount of change.

Computer graphics go against the objectivity of photography. People trust photography to be true (although this is not always the case). Digital images can be made to look photographic, yet can be greatly altered, so they are untrustworthy. Therefore people can be made to believe in images that are

Figure 7.1: Exhibition Pieces.



false. This argument forms part of the intrigue regarding the work of William Latham. His exhibitions comprise cibachrome prints, and sometimes an animated video (Figure 7.1). Dealing with the prints first, they appear to be photographs of sculptures, so immediately one wonders why the sculptures themselves are not displayed. However, they often show inconsistencies with our own world, for example gravity appears to be different, and materials that possess certain qualities in reality appear to have different characteristics in these images. The reason why these pieces are not on display is the fact that these sculptures don't actually exist, except in the memory of a computer. This becomes more obvious when the animations are viewed. The computer guides the viewer around the sculpture, and into areas that would be totally inaccessible when dealing with traditional sculptural techniques. This can cause more confusion, as the scale of the piece becomes more ambiguous. Although no indication of scale is given, they must be a considerable size if a camera can fly through every crevice (and surely such a piece is beyond the scope of one person.) Of course, this is just an illusion inherent in the medium, but none of his pieces are obvious optical illusions, so the confusion is heightened. More recently his animated work has developed new characteristics, specifically the sculptures themselves have become animated, as opposed to the camera being the only moving element. The forms he creates find their inspiration in nature, so the fact that they are animated suggests that he may be attempting to create artificial life. However, just as many of his 'sculptures' would be impossible to create in the real world, he emphasises that nature is just a starting point : few of his creations could really exist in our gravitational field. Chapter Three dealt with some of the possibilities of computer graphics:

> *"The fine arts have shown what a human being is able to do. The computer-generated art will show what a human being is able to understand." (Leopoldseder, 1990, p 58)*

As mentioned previously, Latham clearly encourages the priority of mass culture over high arts. This is a central issue for Postmodernism. Modernist thought concluded, among other things, that the artist could be an objective observer. Postmodernism dismisses this idea by pointing out that we are all an intrinsic part of this world – *not* a separate entity. By separating oneself from the world, as is the case in modernist high-culture, one cannot effectively comment on society, to society. Mass-culture, on the other hand, is accessible to all, and forms an integral part of our experience. To comment on mass-

culture, or to use it as a medium, is to comment on our world and our experiences.

The idea of junk-culture, introduced in Chapter Four, implies that end results are disposable. In Latham's case, it is the process (experience?) that is most important. His 'sculptures' last only the length of a video, and often they wither away and 'die' before the end is reached. No single form is precious; if it were, it would remain unchanged. Through the media, we are often exposed to a stylised impression of life and society. Often it is difficult to differentiate between what is real and fantasy. Whether or not this is a positive attribute is irrelevent – what matters is that this situation provides a perfect environment for Latham's work. Sometimes we feel that we are looking at something 'real', but we are also aware that we are looking at a contrived image. On one level, therefore, his work is commenting on truth and objectivity within the media by presenting us with a fabricated reality. He presents us with non-living forms that appear to live, using mass-culture to present us with art.

However, the technology goes further. In the home environment, video games have taken the world by storm, going further than television by adding an interactive element. By and large, these games are played by one person at a time (although multi-player games are quite common, the fascination often lies with the fact that they can be played alone, man vs. machine, in a virtual environment.) "...They represent microworlds complete unto themselves. The images they present are easy to fall in love with, often narcissistic in nature, allowing the player to function within a self-selected and artificial microworld" (Provenzo,1991, p. 38). It appears as though computer graphics, through its versatility, is giving us the chance to create, explore and compete in man made worlds that exist solely in the memory of a computer. The technology exists to allow us to interact with images, as opposed to passively viewing them, and with artificial intelligence, some of these images can respond to our actions. From this point of view, digital images, and by extension Latham's work, do not necessarily pose a threat to traditional techniques, but rather give us a chance to explore new possibilities.

Chapter Five looked at an example of his video work, 'Biogenesis'. One of the main questions traised at that point was what constituted life in computer space. In reality, the work of Latham is non-living, but it doesn't appear so. We are presented with images composed of electronic signals. The difference

between one image and the next is just the colour of the pixels – the 'substance' of the 'materials' is identical, whether it resembles marble, glass, or even living flesh. What the computer *can* comprehend is the position of one form in relation to another, which means that on a basic level, it can understand the construction of a virtual world. This raises questions regarding the reality of the space presented to us. Perhaps when 'intelligent' lifeforms, like those discussed in chapter six, become a standard feature of Latham's work, the distinction between the living and non-living will become sufficiently blurred to raise more questions.

Roget's Thesaurus quotes Michelangelo's description of art as "a shadow of divine perfection". This attitude is evident in both Classical and Renaissance sculpture, when artists presented us with perfectly proportioned human figures. Latham chooses not to represent existing perfection, but rather to take the divine role of creating his own.

APPENDIX:

In Chapter Three, I introduced a simple computer program of my own to illustrate Lathams' Mutator system. This section includes a listing of the source code of that program for the benefit of those who may wish to explore this technique further. It was developed using Microsoft QBasic, which is available on most IBM-compatible Personal Computers, but it should be easily translated to other platforms with little alteration. It is structured in such a way that those familiar with languages such as C/C++ should also be able to adapt it. Please feel free to experiment with the given code.

The Listing:

```
REM *** MUTATE! Version 1.0 ***
REM ***Runs under MS-QBasic ***
REM * Developed: December 1993*

DECLARE SUB branch (nobr!, linlen!, lnbr!, x2!, y2!,
ang1!, brang!)
DECLARE SUB tree (x!, y!, inlen!, brang!, nobr!,
lnbr!)

CONST PI = 3.141593
CONST pi180 = 3.141593 / 180

inlen = 35
brang = 45
nobr = 3
lnbr = 80
mutation = 5

SCREEN 12
CLS

8 INPUT "EntER mutation RatE ", mutation

10 CLS
x = 280: y = 250
CALL tree(x, y, inlen, brang, nobr, lnbr)

nobr1 = nobr
brang1 = brang
x = 150: y = 120
IF nobr1 > (1 + mutation) THEN nobr1 = nobr1 -
mutation
brang1 = brang1 + (5 * mutation)
IF brang1 > 360 THEN brang1 = brang1 - 360
```

```
CALL tree(x, y, inlen, brang1, nobr1, lnbr)
brang2 = brang
x = 280: y = 120
brang2 = brang2 + (5 * mutation)
IF brang2 > 360 THEN brang2 = brang2 - 360
CALL tree(x, y, inlen, brang2, nobr, lnbr)

nobr3 = nobr
brang3 = brang
x = 410: y = 120
nobr3 = nobr3 + mutation
brang3 = brang3 + (5 * mutation)
IF brang3 > 360 THEN brang3 = brang3 - 360
CALL tree(x, y, inlen, brang3, nobr3, lnbr)

nobr4 = nobr
x = 150: y = 250
IF nobr4 > (1 + mutation) THEN nobr4 = nobr4 -
mutation
CALL tree(x, y, inlen, brang, nobr4, lnbr)

nobr5 = nobr
brang5 = brang
x = 410: y = 250
nobr5 = nobr5 + mutation
CALL tree(x, y, inlen, brang, nobr5, lnbr)

nobr6 = nobr
brang6 = brang
x = 150: y = 380
IF nobr6 > (1 + mutation) THEN nobr6 = nobr6 -
mutation
brang6 = brang6 - (5 * mutation)
IF brang6 < 360 THEN brang6 = brang6 + 360
CALL tree(x, y, inlen, brang6, nobr6, lnbr)

brang7 = brang
x = 280: y = 380
brang7 = brang7 - -(5 * mutation)
IF brang7 < 360 THEN brang7 = brang7 + 360
CALL tree(x, y, inlen, brang7, nobr, lnbr)

nobr8 = nobr
brang8 = brang
x = 410: y = 380
nobr8 = nobr8 + mutation
brang8 = brang8 - (5 * mutation)
IF brang8 < 360 THEN brang8 = brang8 + 360
```

```
CALL tree(x, y, inlen, brang8, nobr8, lnbr)
50 a$ = INKEY$: IF a$ = "" THEN GOTO 50

IF a$ <> CHR$(27) THEN GOTO 60
END

60 IF a$ = "7" THEN brang = brang1: nobr = nobr1: GOTO
10
IF a$ = "8" THEN brang = brang2: GOTO 10
IF a$ = "9" THEN brang = brang3: nobr = nobr3: GOTO 10
IF a$ = "4" THEN nobr = nobr4: GOTO 10
IF a$ = "6" THEN nobr = nobr5: GOTO 10
IF a$ = "1" THEN brang = brang6: nobr = nobr6: GOTO 10
IF a$ = "2" THEN brang = brang7: GOTO 10
IF a$ = "3" THEN brang = brang8: nobr = nobr8: GOTO 10
IF a$ = "m" OR a$ = "M" THEN GOTO 8
IF a$ = "l" OR a$ = "L" THEN GOTO 70

GOTO 50

70 CLS
x = 320: y = 350: inlen = 150
CALL tree(x, y, inlen, brang, nobr, lnbr)
75 a$ = INKEY$: IF a$ = "" THEN GOTO 75
inlen = 35
GOTO 10


REM *** SUBROUTINE TO DRAW BRANCHES ***

SUB branch (nobr, linlen, lnbr, x2, y2, ang1, brang)

linlen = INT((linlen * lnbr) / 100)
ang3 = ang1 + brang
FOR second = 1 TO nobr

ang4 = 90 - ang3
refang = linlen: REM actually linlen/ SIN(90 * (PI /
180)) ;sin90=1
y3 = y2 - (refang * SIN(ang4 * pi180))
x3 = x2 - (refang * SIN(ang3 * pi180))

LINE (x2, y2)-(x3, y3), 12
ang3 = ang3 - brang

NEXT second

END SUB
```

```
REM *** SUBROUTINE TO DRAW ENTIRE TREE ***

SUB tree (x, y, inlen, brang, nobr, lnbr)
x1 = x
y1 = y - inlen
LINE (x, y)-(x1, y1), 12

totang = (nobr - 1) * brang

ang1 = totang / 2
FOR i = 1 TO nobr
linlen = INT((inlen * lnbr) / 100)
ang2 = 90 - ang1
refang = linlen: REM *** actually linlen/ SIN(90 * (PI
/ 180)) ;sin90=1
y2 = y1 - (refang * SIN(ang2 * pi180))
x2 = x1 - (refang * SIN(ang1 * pi180))

LINE (x1, y1)-(x2, y2), 12
CALL branch(nobr, linlen, lnbr, x2, y2, ang1, brang)
ang1 = ang1 - brang
NEXT i

END SUB


REM *** END OF LISTING ***
```

Notes:

• Many versions of BASIC require that one uses line numbers. If this is the case, be sure to work around the few line numbers that are included in this listing.

• C/C++ users may want to note that the code between the `SUB/END SUB` commands is the BASIC equivilent of functions – *ie* . this program would require the functions `TREE()` and `BRANCH()`. The remainder of the code is part of the `MAIN()` function. Also note that you will need to `#include` the appropriate graphics libraries to draw lines, etc.

• Two other options have been provided within the program – pressing 'L' displays an enlarged version of the selected image, while 'M' allows you to enter a new 'mutation-rate'. Higher mutation-rates produce more unpredictable results.

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