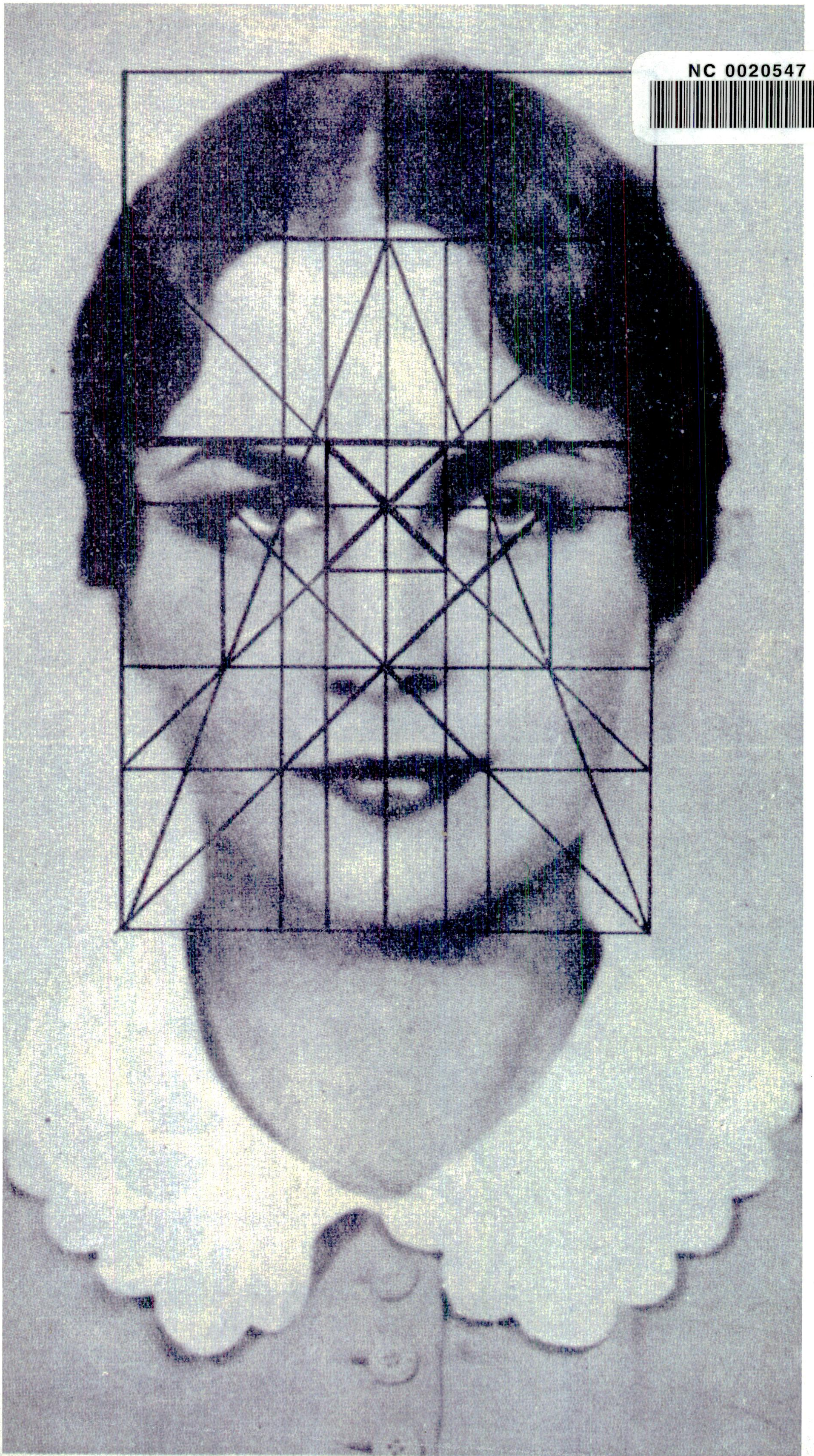

National College
of
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Fine Art Sculpture

BIOMORPHISM

by

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Introduction

Biomorphism is a vague Allusion to the forms of nature in art undergoes a generic metamorphism in response to the implications of recent scientific advance. The chief element in such a transformation is a new understanding for form described by the movement of historical biology beyond the confines of its Neo Darwinist foundations. The conclusions offered by the shifting paradigm are subsequently related to the implications of creation and control suggested by modern biological capabilities. A theory of form and of biological invention combine to outline the potential of generative art to which the up-dated term of biomorphism can now be applied. The transitions in the ensuing arguments are achieved through an understanding and assimilation of occasionally dense scientific material. The idea that art must enhance it's ability to feed off science is a significant element in the ensuing proposition so certain material that might be considered intimidating was nevertheless included.

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A Note on Truth and Progress

The certainty of truth is the key to power. Power over individuals, animals and forces, power to lift airplanes and drop bombs. Every society has a construct of truths which is essential to the stability of it's power structures - technological on one hand (truths which are unrefutable in the way that a 747 jumbo jet has never had an unconvinced passenger) and social on the other (truths which tell us something about the way we live. The historical and political). Challenge these truths successfully, and somebody must lose power, which hurts. So Marxism is the enemy of capitalism and best of all science is the enemy of religion. Thanks to science, we know that the things we believe and understand today, are obviously secure and certain in the same way that the last century convinced itself that maggots appearing in cheese was evidence of the spontaneous generation of life, or that the stars were twinkling lights of a distant land opposite ours on the inside of the globe. It gets worse the further back you go. But why have we not acquired an even vague distrust of certainty as a notion, in the light of the embarrassing lunacies of the past and in the face of frequent vascillations of the current party line? The reliability of truth in this day and age is a property of a favourite notion of ours this century and it is an enemy which crosses our path many times in the forthcoming arguments - it is the idea of progress.

Progress is a brilliant invention although inevitable - it can't have taken much to come up with a hierarchical ladder, since man has been so used to looking down at things all his life. But this is exactly what progress is. Our assumed ladder has a bottom, a top and plenty of rungs, but to pass from a lower to a higher rung you must have undergone some kind of improvement. This is odd in the sense that a man climbing a ladder doesn't have to wait for his brain to enlarge before he climbs the next rung. On the other hand, flying is a lot more reliable now than the broken bones approach at the start of the century, and modern audio digital technology definitely sounds better than analogue. Nothing it seems can stand in the way of progress. Problems arise when progression as a criterion is restricted by the exclusive application of linear progress (the ladder). Progress is a value judgement and is often misrepresented in this way. But can a model of lineartechnological progress be applied to humanity, art, economics and science as it consistently is? Of course it can - we're obviously better off than we were one century ago being then less knowledgeable, less humane, and less capable than we are today. But we were no less confident. People are often quite surprised to hear that their brain size is no different from that of Cro-Magnon?? man (the first humans, probably 150,000 years ago) and that recent research has shown that brain size far from progressing, is actually reducing in capacity. How have we achieved progressive technological advancement? The progression of technology is merely the inevitable result of extrapolating time caused by a technological effort which has remained constant from day on. The jump from 'the wheel' to 'the plane' has not come from increased ingenuity but from time itself. We have found more technologies by an even process of research no different 10,000 years ago as it is today.

Science itself is a hard progress to knobble given that we have already accepted that it's discoveries increase in complexity with time given that ingenuity and reason are constant. However, as we shall see, science does not phrase it's questions according to what was last answered, but according to a specific world view of the day. Thomas Kuhn, inventor of the paradigm writes;

> Scientific theories should be looked upon not as dealing with pure objective facts but rather as

systems of belief relating to a wider context: a frame of reference consisting of interlocking scientific social and even political ideas.

Milton, 1993, p193.

Science therefore does not form a heroical expedition of truth, progressively reaching higher levels of significance and certainty. History has taught us only too well that you cannot fix the horizon of truth - certainties are always displaced by the envelopment of a greater truth, so in a sense we can never be sure of our doctrines, until the whole truth is known. Can we ever reach the 'Omega point' envisaged by J.D. Barrow and Frank Tipler (mathematical physicists) where the human race knows and has done it all? If anything is certain it is that the truth is larger than our own imaginations, and current beliefs will always be at the mercy of later ones.

This day and age sees science controlled more and more by the power it creates - the same power which chose our more 'scientific' ancestors like the bone wielding hominid in Clarke/Kubrick's 2001, over their helpless retreating relatives. It is the same power which sees technological advance occur as a side effect of military research. I caution the reader to be aware of the fallibility of fact in the forth-coming presentation of the 'modern miracles' of biology and to remember that our construction of nature in the past and present has been inevitably artificial. To, attain any kind of objectivity and universality in an understanding of form, it will be necessary to blaze a trail in and out of dominant ideologies, supported by the greatest fringe minds when boundaries are crossed, and free from the distortions of orthodoxy when they are kept. Bear in mind also that the notion of linear progression is an unsuitable and inadequate model to unite change difference and time wherever it occurs. In the meantime we will discuss a theory which is itself the main root of our understanding of progress - the theory of evolution.

Rational Morphology and Darwinism

The early part of the 19th century saw the ravaging effects of science on the Bible, which by then was beginning to wear a thick skin. The last thing anyone wanted was a scientific theory of creation - a perfectly god one already existed, written by someone who ought to know having gone to the trouble of creating the world in the first place. Biblical scholars had previously translated creation into real-time as early as 1650 when Archbishop Ussher of Armagh after much scholarly deliberation decided that the earth was made in 4004 B.C. later amended to October 23rd 4004 B.C. at nine in the morning. This apparently left enough time for God to cram twenty million years of dinosaur fossils in the rock-beds to perplex the un-believers. But no one could pretend much longer and God was modernised in 1859 when Charles Darwin and Alfred Russell Wallace took on the power of the religious establishment with the theory of evolution through natural selection.

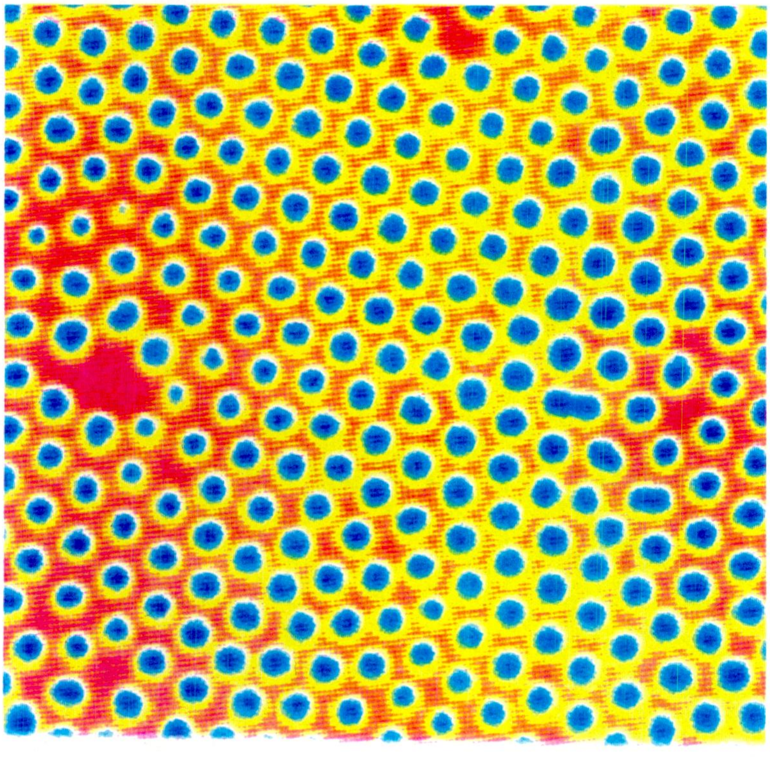
While the believers looked to Chameleon theologians to avoid disappointment, boxes were being filled and offices vacated on the other side of the fence. For just as evolution heralded the major restructuring of much of 19th century religious belief, it also spelled curtains for some of the prevailing scientific doctrines too. Perhaps the scientific community were shocked at how simple and obvious Darwin's idea was, and the comfort of their own indifference to the truth was highlighted by how complete and devastating a rebuttal it was. In any case, scientific beliefs that did not fit the Darwinist mould entirely, were identified with the unqualified fairy tales of the religious establishment, even though they had seemed perfectly right at the time. In fact more than a couple of things were overlooked in the rush to escape the embarrassment of former ideas. Before Darwin, scientists had dealt with the idea of fixed species (which God had brought into existence independently). The observed levels of complexity in organisms were accounted for by the Great Chain of Being or Scala Natura, which traced a hierarchy of sentience on earth from lowly algae (they haden't yet found bacteria or even viruses) right up to you know who. But that left no way to account for the widespread and astounding similarities between the various groups of animals. So pre-Darwinian biology sought ahistorical laws of form that would account for physical similarity through the existence of universal principles of organisation. These were the Rational Morphologists.

It was one of the greatest stars of the nineteenth century, Goethe himself, who coined the term 'Morphologie'. In probably his most successful foray into the scientific world, Goethe used the Greek word 'morph' meaning form, to describe his ideas about the shapes of our world. Form itself is better described as the organisation and formation of non-random elements. Morphology as it is used today pertains to the study of the structure and shape of living things only, somewhat synonymous with it's cousin anatomy, although not as preoccupied with detail and function. This was especially true of the Rational Morphologists who at the turn of the eighteenth century were searching for invariant form among like animals - anything that might betray a set of principals which would lead to a general theory of structure. They felt that a common mechanism did exist - a physically realised universal pattern which gave rise to otherwise diverse forms of life. Confronted by similarity, they saw regularity. Among it's champions were of course Goethe, the Frenchman Cuvier and the British Geoffrey St. Hillaire. It was Cuvier who studied the manifold morphologies of the fossil record in relation to current organisms, and was later credited with the founding of paleontheology, the study of fossils.

Geoffrey did pioneering work on vertebrate (all animals with backbones which excludes invertebrate insects, molluscs and worms) limbs, the pattern of which remains the same throughout the animal kingdom - five digits transformed into claws, legs, hoofs, paws, wings, etc. They sound quite impressive these rational morphologists, but unfortunately for the study of form, there was no place for them in Darwin's new order. Their discipline was motivated by the explanation for similarity in diversity which the Great Chain of Being conveniently lacked. It was this link to medieval understanding that was it's undoing in the face of Darwinism. But while the motivation for the study of form was a little dubious it didn't automatically invalidate the discipline in itself. In fact the questions which Cuvier and Geoffroy asked about their fossils and limbs are still valid today even in the face of the second reason which saw the extinction of the Rational Morphologist species over one hundred years ago; natural selection.

All Darwin did was to look at the homology (similarity in appearance) of organisms, just like the Rational Morphologists had done, and decide that they were all related. He saw the question of resemblance as being that of a Mother to her daughter, offspring to a parent. What we had therefore was a large family of species, and once you start thinking this way, everything else follows - the family must have a tree leading to singular common ancestors. Then he wondered if species were related, but different, how did this difference arise? Charles Darwin loved breeding pigeons, as man had been doing for quite a while, and he also travelled around the country fancying himself as an amateur livestock breeder. He could see the dramatic and deliberate changes wrought by breeding desired characteristics together. Here was a mechanism of gradual change within species that man had already grasped. The thing is, Darwin thought, could it be applied to the natural world where there was no one to do the selecting? The answer to this lay in what the desired characteristics in the wild would be. Man's cows needed to be docile and inert, so that they could be easily handled and exploited. Nature's cows on the other hand needed to be alert and aggressive to protect themselves from carnivorous predators. Any cow which wasn't talented in those areas was more likely to meet the grim cheetah than the grim reaper. The more able you were to escape the pressures and dangers of an environment, the longer you were likely to live. Any sort of increase in longevity would then mean more offspring through the larger amount of breeding seasons available to the long life cow. Survival itself meant deliberate selection. So no artificial farmer had to walk in and choose the dimmest cows and fattest bulls - a selection process already existed which was completely natural.

For the Rational Morphologists this was indeed bad news. The idea of fixed species was out of the window, to be replaced by gradual transformation. This metamorphosis along with survival and selection of the fittest amounted to an apocalyptic conclusion for the study of form - an animals' physical realisation was merely the incidental consequence of external constraints. No magical laws of form. No mystical organising principles. No hidden order or pattern hinting at dynamic and deliberate self organisation. It was just plan trial and error, or in the words of the unscrupulous French biologist Monod 'chance and necessity'. A brief lull in the proceedings arose when Darwin floundered over the exact mechanism for evolutionary change - what supplied the raw variety for selection to act in the first place? Darwin was only able to postulate that minor fluctuations of form within species were responsible, but he knew like everyone else that these were not radical enough to create new species in themselves. Towards the end of the 19th century, Darwin's theory had fallen into disrepute and the creationists and Rational Morphologists began to peak out of their meagre cracks. In 1900 three scientists independently discovered the pea breeding experiments of the unknown Augustinian monk Gregor Mendel who had died 20 years before. The mechanism which had eluded Darwin to his death was actually within his grasp just after he had written his theory. Darwin was fully exhumed as the new century began, gloriously propelled by the infant science of Mendelian genetics which had found mutation to be the source of variety within species. As the progress of genetics furiously expounded, the Neo Darwinist or synthetic theory was formed. Finally Darwinists could explain in detail how organic forms could be randomly altered to be conclusively shaped by the specific requirements of one environment. The universality of form had been struck an awesome blow. It's head has lain, twitching protests in the guillotine basket, unheard of and unthought of until now.



THE PROBLEM OF FORM

This brings us to the rather turbulent affairs of modern biology. Neo Darwinism is now the orthodoxy, the mutant progeny of it's marginalised creationist mother. While we have made a concerted leap towards optimising our ideas relating to the questions of our existence, Neo Darwinism reveals some discordant resemblances to it's predecessor. In the words of Saunders and Ho

> Explanation in terms of all powerful force of natural selection has come more and more to resemble explanation in Terms of the conscious design of the omnipotent creator.
>
> (Saunders 1984, p36)

We have it appears, come full circle. A virtual industry has arisen around the teachings, illustrations, accounts and more increasingly, defenses, of natural selection and random mutation, perhaps to the extent that truth has been sacrificed by those who profit most from certainty. (We can look to scientists here, and also to a structure so hungry for power that certainty is rewarded by funding - hence the pressure on scientists to publicise and endorse without sufficient testing, leading to a wide variety of misdemeanours such as Thalidomide and 'jam jar' fusion). Chief among the defenders of the faith in relation to the Darwinism is Richard Dawkins, Professor of Zoology at Oxford University and best selling author. His book "The Blind Watchmaker" is a patronising and zealously emotive defence of what can only be described as the author's beliefs. Dawkin's explanations are not without ingenuity, but the overall effect is unconvincing. I discuss specific examples later, but it is important now to see that from empirical evidence alone, no one is in any position at the moment to defend anything. The reason we suggest this and the reason that Neo Darwinism and it's authors-in-shining- armour are important in my discussion is that the theory has been dogged by a problem from the time of Darwin which threatens to fundamentally overhaul fixed elements in the current dogma. The ideas which collectively amount to post-Darwinism (Tenhaaf 1993) all radiate from the newly reemergent problem of form.

What is form? Form is an answer. It is a solution to a finite problem. We can therefore see that the study of form might deal with questions. If form is the reply, the question might be; "what is the physical constitution that must be assumed if a finite number of givens is to be realised". The constraints of this model are such that it suggests that form can never be abstract, in the sense that it always occurs as a result of some algoithm (computable function) or prerequisite. This certainly does not pose a problem for modern physics whose continuous trend Kaufmann notes has been to uncover ordered causations in behaviour which was previously understood as chaotic.

> Study of strongly disordered systems where many elementary units interact with one another in randomly chosen but specified ways, has already revealed strikingly ordered properties in apparently chaotic systems.
>
> Kaufmaun, 1993, P 664.

Modern biology, the kingdom of natural selection also finds no problems with the question/answer model and it doesn't have to rely on chaos theory to show why.

We recall that form 'is a finite number of givens realised'. For Neo Darwinism, the number of givens is extremely finite. In fact there is only one: I am a Neo Darwinist algorithm. My question is 'what physical constitution must I assume in order to ensure my optimum success in reproduction'? That is all. No further specification is required. My form must serve any function which leads to the largest amount of children possible in my reproductive niche. This apparently narrow algorithm can only be final if the principle of random mutation is doggedly affirmed. It suggests a possibility space of virtually unlimited size on which natural selection can act, establishing the significance of this mechanism as the sole determinant. Under the Neo Darwinist synthesis this definition characterises form across a wide spectrum of diversity, from the first self replicating organic molecules to the forty-foot Brachiosaurus and furthermore to virtually any living thing that has ever existed or ever will on this or any other planet in the universe. We would be forgiven for inferring the presence of a universal. However, it would be unfair to suggest that Neo Darwinists believe that 'everything conceivable is possible' as Saunders, Milton and other opponents have suggested. Dawkins has already fortified such an easy breach of defense by altering the goal posts a little. He does pay some lip service to the ideas of non-random mutation through development, but also asserts;

> It is selection and only selection that directs evolution in directions which are non-random with respect to advantage.
>
> Dawkins 1989, p312

The idea of selection as the only direction giving factor in the evolution of complexity has not however performed well under alternative scrutinies. As such dissonance begins to resonate throughout the scientific community, the newly emergent paradigm which redefines core beliefs is also one which bridges the gap between a functional, diachronic theory of form and a structural synchronic thesis. We have discovered a parallel between a weakening Neo Darwinist synthesis with it's reproductive form algorithm and a reawakening of the structuralist concerns of the rational morphologists within the new paradigm. The 'new paradigm' has arisen through the attempt to integrate new scientific discoveries, poorly recognised by a Darwinist research programme into the current orthodoxy. Such broad discoveries have sketched a worrying picture of a hypothesis passed on the rich and creative interpretation of certain empirical evidence. In particular discoveries in the fields of genetics and biochemistry point to a radical new understanding of the structure and form of an organism and how they arise; Morphogenesis itself.

When the fields of genetics and molecular biology became established some fifty years ago, their advances saw the emergence of the reductionist trend. Biochemistry showed on paper how the vital reactions of protoplasm, the living substance of cells described as "vital pulsating vibrant and throbbing" could be described instead in terms of the purely physical. Genetics reduced an organism to a causal blueprint with the implication that if you had all the genes (genome) you could build an organism (Jurassic Park). This essentially meant the death of the organism as a concern-

> Organisms have disappeared as real entities from contemporary biology.
>
> Saunders and Ho. 1984, p221

Why have theories of organismic form begun to reemerge? Darwin was haunted by the problem of form, and the skeleton in the closet of Neo Darwinism to indeed a very real one. Throughout vertebrate bone structure can be observed several characteristics of distinctive similarity. Most obvious among these is the inherent pentadactylism (of five digits) in mammal limbs. If mutation is random and is selected according to function, why has nature maintained a visible ground plan despite varying necessity? - Why do we not see separate mechanisms for diverse functions? This is the problem of homology and even Darwin knew his answer was weak. Such similarity in an organism Darwin said, comes from inheritance and is a consequence of it's resemblance to it's forebears. This explanation is clearly insufficient to describe homology among different species. In fact if you say that a species inherits a particular resemblance from it's ancestors, then you are also saying that these ancestors inherited it from theirs and so on without explaining how such a trait arose. Pass the parcel Darwin-style does not explain how an initial pattern was established, or why it has prevailed. Such circularities are characteristic of a theory which is itself circular as Kaufmann has noted (survival of the fittest - once the fit have 'survived', the fittest of those must survive etc.). The other question relevant to the synthetic theory is 'if the possibility space of mutants is high, why do we see numerous morphologies constrained to invariance? If the phenotypic (physical organism) trends do not fit the model of genotypic (genetic basis) space as appearances suggest then the principle of such a model is blatantly refuted. Neo Darwinism derived it's explanations to account for the differences between organisms, but is unable to explain the appearance of some astonishing uniformities. The shift to the new paradigm occurs over this problem of likeness or homology and is therefore primarily concerned with form itself. Two contrasting models of 'genetic space' are proposed to explore the transitional and territory created by the shift and to explain the new insight of form, of which it is composed. Darwin's author in shining armour will begin.

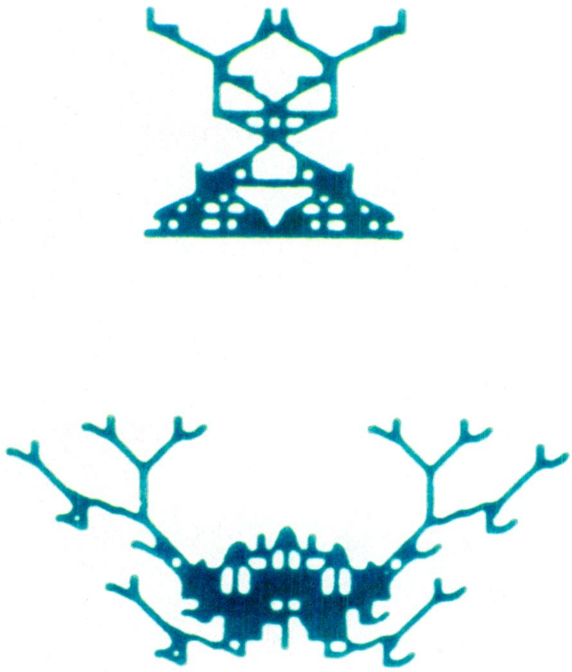


Figure One: The Lunar Lander and Tree Frog. (Dawkins)

Morphospace in Crisis

> Real animals are dotted around here and there among the hypothetical monsters, each perched in it's own unique place in genetic hyperspace.
>
> (Dawkins p73) 1989

The genetic hypervolume of Dawkins' imagining is no fairytale land of monsters and fanciful creatures, nor is it just a kind of tentative hypothesis. It is posited as a real mathematical space inferred by the notion of natural selection and random mutation. The genetic hypervolume is the concrete incarnation of Dawkin's fictitious and appropriately titled Biomorph land, a computer model which explores the power of cumulative selection on randomly mutated two dimensional algorithms. The computer takes a basic drawing rule and mutates one of it's sets of genetic instructions to produce assorted progeny which will then be selected for further 'breeding' by Dawkins himself. The criterion for selection was some kind of visual appeal or resemblance. So from basic tree shapes, Dawkins evolved various complex patterns combining hundreds of generations to produce the 'lunar lander' and the 'tree frog' (Figure one) and much more. This is indeed an exciting mechanism for evolving a variety of forms -a basic 'genetic' code can be altered sequentially to produce novel non-random form through cumulative selection. Because the model deals with limited and stable givens, in this case nine genes, one mutation per generation, each with an either plus or minus value, we can envisage the size of it's probability space. The probability space is the set of all biomorphs which other biomorphs could conceivably mutate into. In this model any biomorph could potentially assume the shape of all the others so the probability space is just the amount of different combinations of stable givens. Biomorph land then, is a multi-dimensional volume in which all possible combinations are represented, each biomorph surrounded by it's one mutant neighbours. The biomorphs therefore have definite spatial relationships to each other, distance representing genetic difference. Dawkins feels that this model is accurate enough to draw inferences as to the supremity of Neo Darwinism, even though he would assert;

> Embryonic development is far too elaborate a process to simulate realistically on a small computer.
>
> Dawkins, 1989, p57

Biomorph land it seems corresponds directly to the genetic hypervolume, and just as knowing the genetic code of any biomorph could enable you to locate it in biomorph land so too could we 'find' a dinosaur if we knew it's genetic recipe. We have arrived at the gates of Jurassic Park once more. To 'find' an animal in morphospace means to identify a pathway which will lead to it's discovery. The pathway is evolution, the steps are composed of one mutant neighbours and the discovery is the physical constitution of an animal unique to it's genes. Therefore, Dawkins can postulate that 'a complete reconstruction' of a dodo could be achieved from the selective breeding of pigeons, if only we knew how and had an extremely long span of time on our hands. Perhaps we would also need a leap of faith of similar length.

Chimpanzees are rather hairy, ugly animals whose simian resemblance to ourselves is not appreciated by many. Nevertheless their morphological divergence is huge, to the extent that we could say that very distant ancestors of the chimps might themselves have shared an ancestor with our distant ancestors. We could in all probability envisage our separation in the genetic hypervolume to be reassuringly large. This is not so. Studies of the genetic constitution of chimpanzees and humans in the seventies yielded the astonishing discovery that our genetic information is identical in all but a fraction of one for cent. (Saunders, 1984). Let the relationship of morphospace absorb the shockwave. The landscape of the genetic hypervolume is totally correlated in the sense that the distance between various phenotypes is proportional to their genetic variance or invariance. Neo Darwinism says that only the instructions within the genes are responsible for form, and since it is not possible for genes to evolve which don't relate to function (natural selection), then form is an indirect consequence of the functional genotype and is proportional. Thus if such ideas are correct we would expect to see divergent form of alternative phenotypes correspond to their genetic invariance. However organisms with divergent genotypes can have identical phenotypes while identical genotypes don't lead to corresponding phenotypes. Different species of rose have varying amounts of chromosomes, while they appear to be virtually identical. As we already know, ninety-nine percent of genetic information shared can produce organisms radically different to each other as anyone who owns a chimp will testify. The causal relationship between genotype and form is not a universal, and it's Neo Darwinist incarnation is shadowed in doubt.

Already there is crisis in morphospace. The "endless but orderly vista of morphological variety" (Dawkins. 1989. p66) inherent in the childishly mathematical model of biomorph land does not correspond to the complex diversity of it's analogue. For Dawkins these are grave tidings to be considered, as he uses the idea of fixed variance or distance to infer the validity of gradualism (the accumulation of minor changes contributing to altered morphologies over time). It is gradualism which suspends form in it's limbo of inertia. The levels of complexity and order in an organism can only be accounted for by the build up of tiny changes if random mutation is all that survival can select - large changes in morphology would be composed of many different elements which would be vanishingly unlikely to occur together randomly. We can see the strong suggestion that the probability space of the genetic hypervolume is uncorrelated. If the genetic distance in the landscape does not mirror the morphological, then the probability of each mutation in the gradualist chain is not equal as is necessary for the systematic build up of such a chain. One significant area where we see this correlation of morphological divergence with genetic also in action is the dreaded hotbed of 'names and nastiness' - phyletic taxonomy.

If we look at the differences between organisms with relation to the Neo Darwinism ideas of their decent we are indulging in the phyletic taxonomy. To Dawkins, "A good taxonomic tree is a family tree of evolutionary relationships". (Dawkins 1989. p261). To date, Neo Darwinists have not encountered problems finding the relationships that their understanding of evolution promises in the natural world. However, to those who are not actually seeking out such superficial evidence of descent, the relationships are less obvious. The issue here is the mechanisms used to study difference. If the 'death of the organism' is real and we can successfully substitute the genotype, patterns of descent can be obtained by studying genetic divergence. This is exactly what Neo Darwinist phyletic taxonomy does. The 'parsimony principle' (Dawkins) says that evolutionary relationships can be elucidated by comparing rates of neutral mutation which are thought be molecular constant. This is the process whereby a particular complex protein molecule undergoes superficial substitution, that is to say it's amino acid chain is slightly modified by mutation at a measurable rate. By comparing the differences and similarities the taxonomist can understand the nature of the distances between lineages and draw the conclusion that for instance a zebra's protein sequence is quite similar to that of a horse, but less similar to that of a giraffe. And sure enough, a zebra obviously approximates a horse more that it would a giraffe. But the implication of descent says that the zebra's morphological differences, mainly it's distinctive pattern, separate it significantly from an ordinary horse - the stripes must have evolved quite slowly, beginning a long time ago as their divergence from their ancestor is striking. However, suppose that it's pattern did not evolve slowly, through gradual random mutation and selective acceptance. Suppose that the jarring stripes of the zebra are a property or capability inherent in it's state. Imagine a mechanism belonging to the horse which could radically alter it's patterning through the acceptance of a minor genetic adjustment. The zebra's stripes in such a case would not be evidence of much difference. Just such a mechanism was discovered by mathematician Alan Turing (Kaufmann) and is symptomatic of an emergent science of complexity founded on the independent emergence of complex order in random states. In relation to Dawkin's model of morphospace it again demonstrates the reduced importance of the genes in generating the organism and further undermines the conceptual connection between the two. By taking developmental mechanisms into account, different zebras are seen to be more closely related to the horse than themselves. (D.K. Bennet, 1980, Saunders 1984). It is through an understanding of such mechanisms that taxonomic analysis has arisen independent of Neo Darwinism which introduces generative processes of ontogeny (development) as more accurate determinants than the genes.

It is by elucidating the dynamic nature of ontogeny as well that we can explain the other inadequacies of the genetic hypervolume model. Most glaringly obvious to all Biologists including Neo Darwinism in the mysterious implication of intermediates. We see that morphospace connects species of morphological variance with numerous intermediate stages forming a pathway through space. It is therefore a pre-requisite of Neo Darwinism that physical concrete evidence of species intermediates exists in the fossil record. Initially their gaping absence troubled Darwin greatly, but he felt confident of their eventual discovery as the science of paleonthology was merely in it's infancy. One hundred and fifty years on however, given advanced technologies and techniques, hugh resources and the efforts of the greatest minds in the field, nobody has found anything resembling a species intermediate in all the fossil beds of the planet. (Milton 1983, Tenhaaf, 1983). The smug smile of neo-Darwinist morphospace has, like the fossil record, got gaps in it's teeth.

Rugged Fitness Landscapes

Imagine morphospace now as a mantelpiece curiosity, reluctantly collecting dust in the background. While we have swum up river of the Neo Darwinist concept of morphology and the passage may have seemed somewhat treacherous, our aim in this domain is to show that the waters are more than a little murky with respect to form. In this respect, we need not travel any further and it is time to vacate the constraints of such a contrived volume. The territory which awaits is intriguing. We have seen the strong suggestion that many of the causes of biological form lie outside the genes. If this is so, then what does 'cause' form? And if the causation lies outside an organism's basic instructions then are we looking at universals common to all life forms. The universals which indeed suggest themselves have important implications for an understanding of organic form inherent in our own creative organisation of it, previously described by the term biomorphism. The identity of form slowly begins to crystallise. The next step in our search to decode organic form presents us with an alternative model of genotypic space. This 'rugged fitness landscape' describes the relationship between an organism's fitness and it's form with respect to the power of selection. It provides a convincing simulation of the achievement of complexity and order in biology and sets the background to the organization of form outside of the functions with which it has been so wrongly shackled.

It is time to venture back into imaginary deep space once more. Our guide in these realms is Stuart Kaufmann, eminent biomathematician whose magnum opus bible 'The Origins of Order' is one of the first biological studies to address the emerging 'science of complexity' begun through the study of chaos. His thinking about morphology centres around a hypothetical computer model called the NK rugged fitness landscape. This territory echoes some principles of Biomorph land, namely the representation of various genotypes by points in space but as we shall find the arrangement is a little more scenic. The space has a top and a bottom whose orientations reflect optimum fitness (upward) and random fitness (downward). It is composed of high jagged peaks, deep troughs and chasms as well as more undulating gentle topographies, and the immediate image which suggests itself is a mountainscape. Standing in the foothills, an organism is compelled to attain higher levels of fitness. Fitness is the measure of suitability that an organism's constitution provides in relation to the demands of it's lifestyle. The fittest animal is the fastest cheetah, or the longest-necked giraffe. Increasing levels of fitness are the inevitable result of 'selection of the fittest'. Higher fitness means moving to the next upward point on the landscape which represents a genotype identical to it's predecessor apart from it's acceptance of one beneficial mutation In terms of evolving populations, all of it's individuals 'hop' to the fitter point once the propagation of a beneficial mutation has occurred. The landscape is characterised by the varying gradients of different slopes - not all landscapes are the same. Varying gradients, or changes in the amount of height gained in a given distance arise as a result of specific fitness values inherent in the mutation rate - some mutants will be consistently fitter than others, leading to steeper climbs. These differences in the fitness values of available mutations is discovered to be a consequence of a small number of parameters, or governing conditions. Basically there are two of these - the number of elements in a system (N) and the number of interactions among these elements (K). N can be anything, from genes to organs just as the system could be genetic or morphological.

Let us imagine for our purposes that N is morphological. A high number of N is equivalent to a large number of parts in the system, hence a large value of N signifies a complex morphology. The relationship of N to K (the amount of interaction within the system) defines the territory of a fitness landscape that a population can envisage. For instance, if there is no interaction at all between the parts, the landscape is very simple. All the pathways to the best fitness lie on one plane of adaption. The computer calculates the values and creates 'Fujiyama', the simplest landscape attainable. This is because selection is totally free to chose the best trait in a given random range (mutation). Why should selection not be able to achieve the optimal trait? When one element is influenced by a number of others, it's own optimal choice will interfere with it's corrected elements in ways which are far from optimal. The optimal choice then for linked systems is the trait which effects all elements equally in a positive direction. The result is that an optimal trait may have to be totally abandoned in favour of consensus. The extreme end of this scale is a landscape in which each of the parts is connected to all the others, or N=K-1. This leads to extremely jagged landscapes, whose trait selection is totally unpredictable, and the corresponding topography is uncorrelated (the gradients are almost infinitely and randomly varied as opposed to the smooth slope of Fujiyama). The levels of the parameters N and K and their interactions have important implications for the degree of fitness that a form can achieve under natural selection.

The morphologies of the model perform well up to a point, but as either K or N increases either separately or in union, fitness tumbles and morphologies are constrained. Natural selection exhibits a complexity catastrophe. Growing complexities of K or N cause their fitness to be limited to isolated portions of the landscape for below their optimum achievements. When N=K-1 (interaction is total) the optimal solutions of form become lower and lower as N increases until eventually fitness stabilises at the average which would exist in the absence of selection. As Kaufuann describes:

> As systems with many parts increase both the number of parts and the richness of interaction among the parts, it is typical that the number of conflicting design constraints among the parts increases rapidly ..... No matter how strong selection may be adaptive processes cannot climb higher peaks.
>
> Kaufmann, 1993, p54.

A second complexity catastrophe operates when the K interactions are much lower. As N increases (the number of parts) their optimization is not constrained by K so the slope will rise steadily towards optimum fitness. Larger numbers of N however mean that the significance of a change in the value of one N (mutation) is greatly reduced. This lowers optimization as selection is too weak to influence the choice of trait. Morphologies slide ungracefully off their peaks as disorder increases as N does, and unselected drift mutation lowers the effectiveness of a form.

> A threshold is passed beyond which selection cannot hold a population of the locally fittest variant, errors accumulate and the population falls from rare optima towardless fit but more typical members of the ensemble.
>
> Kaufmann, 1993 p.96

The second complexity catastrophe seems to reduce form to potential chaos - random drift unchecked or fettered. However scientists have become increasingly astonished, peering into chaos - the dark turbulent heart of uncertainty, to discover the existence of a very 'strange' order - some very familiar unfamiliarity.

Self Organisation

> Strange attractors depict a system whose behaviour never repeats itself and is always unpredictable and yet, paradoxically always resembles itself and is infinitely recognizable'
>
> Briggs, 1992, P143.

The bizarre paradoxes of chaos theory have shed much light on an understanding of the complex process of morphogenesis. 'The Origins of Order' (Kaufmann) is best understood in the light of the chaotic mathematians jargon, and is liberally sprinkled with it's influence. Chaos theory was evolved with the capacity of computers, as increasing power was needed to bring the microscope down on chaotic systems, the space of complex numbers and non-linear equations. Chaos does not mean disorder, but is the boundary region between order and disorder. Order might be the rigidity of an ice cube, disorder would be the water in it's random liquid state and chaos then corresponds to the melting state. The developmental mechanisms of morphogenesis can be understood as chaotic systems. Such systems are deeply sensitive as a consequence of their holism, a property which the rugged fitness landscape describes as 'level of interaction' and the consequence of this interaction, positive feedback. As we have seen, when interaction is at it's highest, the landscape breaks down and becomes uncorrelated, the equivalent of chaos 'unpredictability'. Before the advent of chaos theory, it was thought that such supreme complexity must imply correspondingly complex regulatory mechanisms finely tuned if any sort of order or form is to be created. This incidently agrees with the Neo Darwinist idea of a delicately poised system composed of accumulated microvariation at a genetic level.

> High genetic precision would appear to be required to chose reliably between these many forms ../ reliable occurrence of an ordered

> morphology from a richly integrated developmental mechanism would require exquisite control of all the variables and parameters of the subsystems making up the integrated systems. [Kaufmann however disagrees] The suggestion is that [this] intuition is wrong.
>
> Kaufmann, 1993, p.637

This leads to the other way which biological systems mirror the chaotic through the characteristic of positive feedback.

Positive feedback is responsible for guitar and microphone screeches (Briggs), nuclear catastrophes, bacteria that outweigh the universe (Regis) and delightful peacock tails (Dawkins), and it is clear that this mechanism is far from positive in it's effects. The process is one of continuous iteration or repetition of a function with its previous result. In the case of the bacteria, the function is the ability of the system to copy itself - to double itself. This indeed sounds innocent enough, but if growth was unchecked by any constraint the results would be catastrophic. Eric Drexler, inventor of nanotechnology describes; "In less than a day they would weigh a ton, in less than two days they would outweigh the earth; in another four hours they would exceed the mass of the sun and all the planets combined (Regis, 1990, p.123). Chaotic systems create a mechanism whereby the tiniest random occurrence could become enormously amplified and propagate through the system, characterising it's unpredictability. Positive feedback occurs in many dimensions of the natural world, and Richard Dawkins even goes so far as to compare the arms race of human civilisation to co-evolving animal populations in the wild as relevant examples. We have already encountered pattern formation in the zebra's coat, whereby a simple mechanism was proposed which imparted stripes to the animal without also administering the time and taxonomic distance

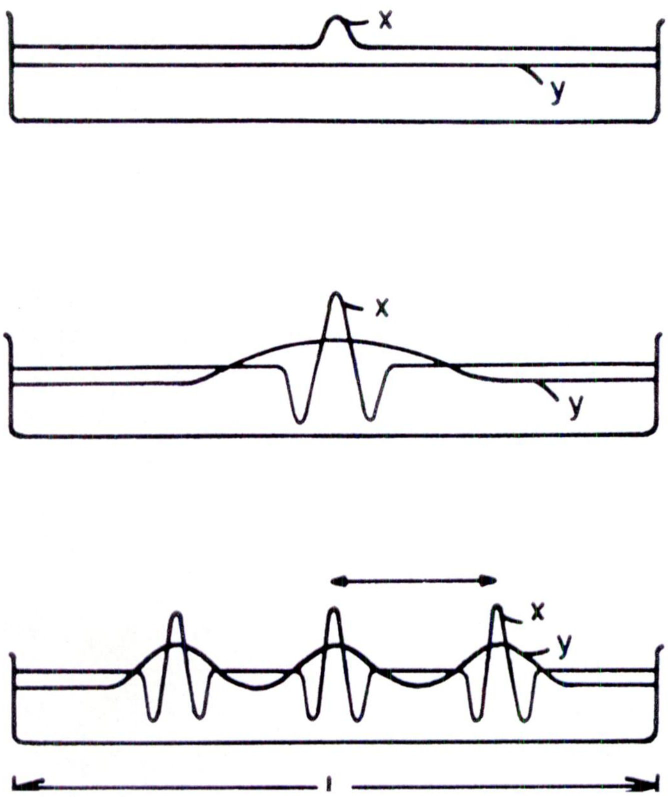


Figure Two: Reaction/Diffusion Mechanisms. (Kaufmann) required to explain the improbability. This was in fact positive feedback in action on a microscopic scale, where it was discovered by Alan Turing in 1952 (Kaufmann etc.).

A positive feedback process in biology is called autocatalysis. A simple autocatalytic sequence would be for instance the formation of a protein molecule which stimulates it's own proliferation. The molecule autocatalyses itself, causing an explosive rate of production to be set up - as numbers increase, individual molecules respond to the high increase of catalyst by increasing their own production which in turn creates a feedback loop which will cause an 'explosion' unless limited by an 'inhibitor'. Turing discovered that order arose as a result of diffusion. The reaction/diffusion mechanism consists of two chemicals X and Y at a relaxed and equal state. A tiny imperfection in X creates a small peak, triggered by it's autocatalytic function. However, X also catalyses it's own inhibiting chemical Y which begins to increase at this point. Y differs quicker than X however, and this inequality, Turing discovered, led to the establishment of a simply ordered pattern which would characterise the system. (Figure 2). The mechanism does not have to be understood to see that it has important implications for form. This system presents an organism with an order that is inherently probable - a simple mechanism that can generate a variety of forms, all a property of the tendency towards self-organisation in highly complex dynamic systems. Furthermore, the reaction/diffusion mechanism paved the way to the discovery of other tendencies of self-organization, among them many other mechano-chemical models similar in cause and effect to Turing's. Already we can see that generative processes of form exist which are a universal consequence of the tendency for chaos to exhibit order in specific circumstances.

Turing's model has been widely applied to a range of phenomena in the animal kingdom. The zebra we have already met is occasionally chased by a cheetah whose spots are also the result of reaction/diffusion, and we can see the constraints of it's order in Saunder's specification that no animal can have a spotted tail. Any animal can have spots blotches stripes or circles on it's skin, but spotted tails are strictly not allowed. The animal kingdom does indeed obey this rule along with many others and it is a concrete example of how form can operate within boundaries which are essentially oblivious to fitness. Kaufmann describes mechanochemical models which control segmentation of the embryo of the scientifically persecuted 'Fruit Fly' Drosophila.

> I have suggested that the monotonic and non-monotonic eigen function patterns of reaction/diffusion or other field equations might account for the positions sequences and symmetries of observed compartmental boundaries.
>
> Kaufmann, 1993, p629.

Other properties of self organization are exhibited by other systems. The 'molecular inter-connectedness' of the genome with all it's myriad genes gives rise to cell differentiation (or production of divergent cell types) spontaneously (Kaufmann). The process of dialogue between adjacent cells gives rise to the spontaneous spatial ordering of neighbouring cells. The regulation of a chemical gradient imports positional information to various tissues and causes spontaneous regeneration should the system be perturbed. The list is long but is possibly only the tip of the iceberg. The previous examples demonstrate how some shapes and patterns of animal form are inevitable, the distinctive signature of the process which produced them. Their ability to characterise form does depend on their performance, and while selection cannot chose the details of a mechanism, it can nevertheless preserve it. The criteria for performance however, just like those of generation, can lie outside the functions which selection creates.

All self ordering mechanisms have one thing is common - they generate a refined family of forms. Which member of the family will be born depends on the parameters of the system. By altering the parameters an organism can oscillate and explore the family of resemblances and capabilities. To ask what extent are these parameters fixed is to ask how powerful selection acting upon such universal mechanisms is, and how much of what we see is inevitable and how much is specific. The key point here is that some mechanism's are more dynamic than others. This is represented by the 'volumes of attraction' which describe how limited it's form will be. In dynamic systems of chaos, chaos theory has shown that while the results of a function can be totally random, this randomness has a tendency to occur in specific areas of possibility space more than others. Randomness in this context means that while it cannot be predicted where a point will occupy in a space, it can be shown that the points tend to occur within a specific distribution. The corresponding shape of attraction can be mapped and is called aptly 'a strange attractor'. (Briggs, 1992). Biological systems have strange attractors, although they may be called something different. (Kaufmann) The attractors lie within the space of variable conditions influencing a particular developmental mechanism. If the strange attractors are large, forms will be generated inside an unduly varying parameter space and hence would be extremely stable and convenient to produce. On the other hand, if the attractor is small or complex in anyway, parameters must be held in synchrony with the highly specific requirements of the mechanism. However, the action of the second complexity catastrophe (increasing number of parts weakens selection) tells us that selection is hard-pressed to hold populations around areas of high specificity. An adapting organism therefore would not be able to maintain such a mechanism, and genetic unselected drift would lead to severe instability and reduced fitness. Thus selection will tend to favour these mechanisms which are relatively easy to produce - the shapes and forms which in fact 'lie to hand' (Kaufmann).

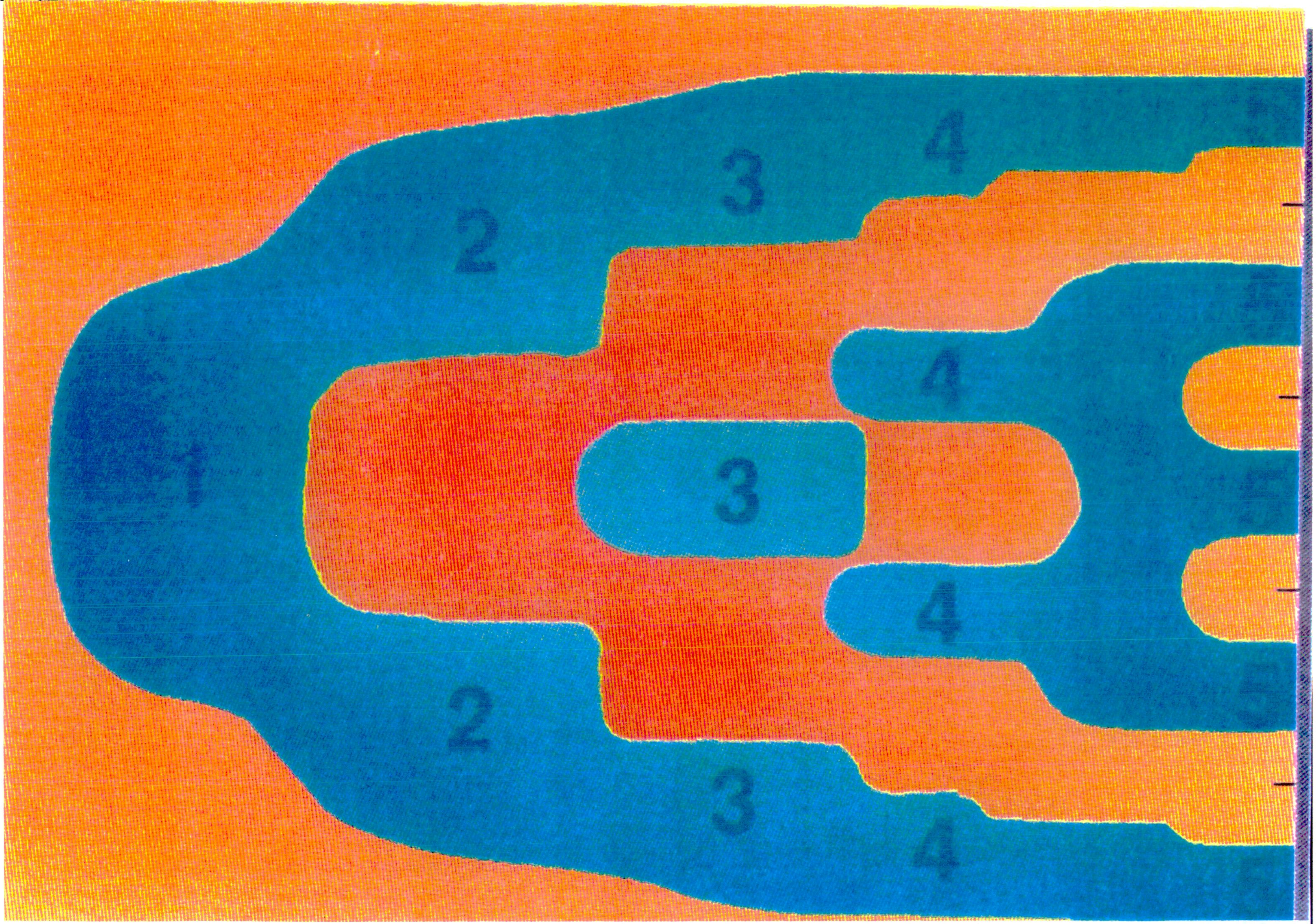


Figure Three. Sequential Limb patterning. (Maini, Jack Cohen)

Form Realigned

So what does 'lie to hand' for the selective 'consumer'? The shopper in Morphospace who was promised an almost endless variety of forms to choose from was sharply disillusioned when it was discovered that a lot of the product ranges simply weren't stocked. Furthermore most of the shelves with individual ingredients were too high to reach, and our shopper had to settle for a limited range of packet mixes which were quick and easy to make but impossible to disguise. Rugged fitness landscapes as an environment for self organisation expose the morphospace shopper myth and show that selection cannot escape the stunted range and distinctive stamp of the different morphological brands from which it is compelled to choose. But as we have seen some brands are more dynamically stable than others. If the attractor volume in parameter space is large then the form or pattern can be achieved without the fine tuning that selection could fail to provide. This also means that 'small changes in state or parameters leads to small changes in morphology' (Kaufmann, 1993, p636). Minor fluctuations do not radically disturb the morphology but oscillate it between it's 'family of forms', becoming a positive force for adaptation to unstable environmental conditions. The forms which are easy to produce are also those which maintain their stability in the face of necessary adaptation. They are dynamic, and hence will be preserved in the programme of selection. A practical example of just such a dynamic form is our old friend, the mammal limb. Biomathematician Philip Maini altered Juring's model (Jack Cohen and Ian Stewart, 1993) to include simple embryonic pre-patterning and produced a convincing model of 1-2-3-4-5 limb sequencing (figure three). This basic mechanism would surely 'lie to hand' for our evolutionary shopper, and it's plan has been implemented and altered to produce hands, feet, hooves,

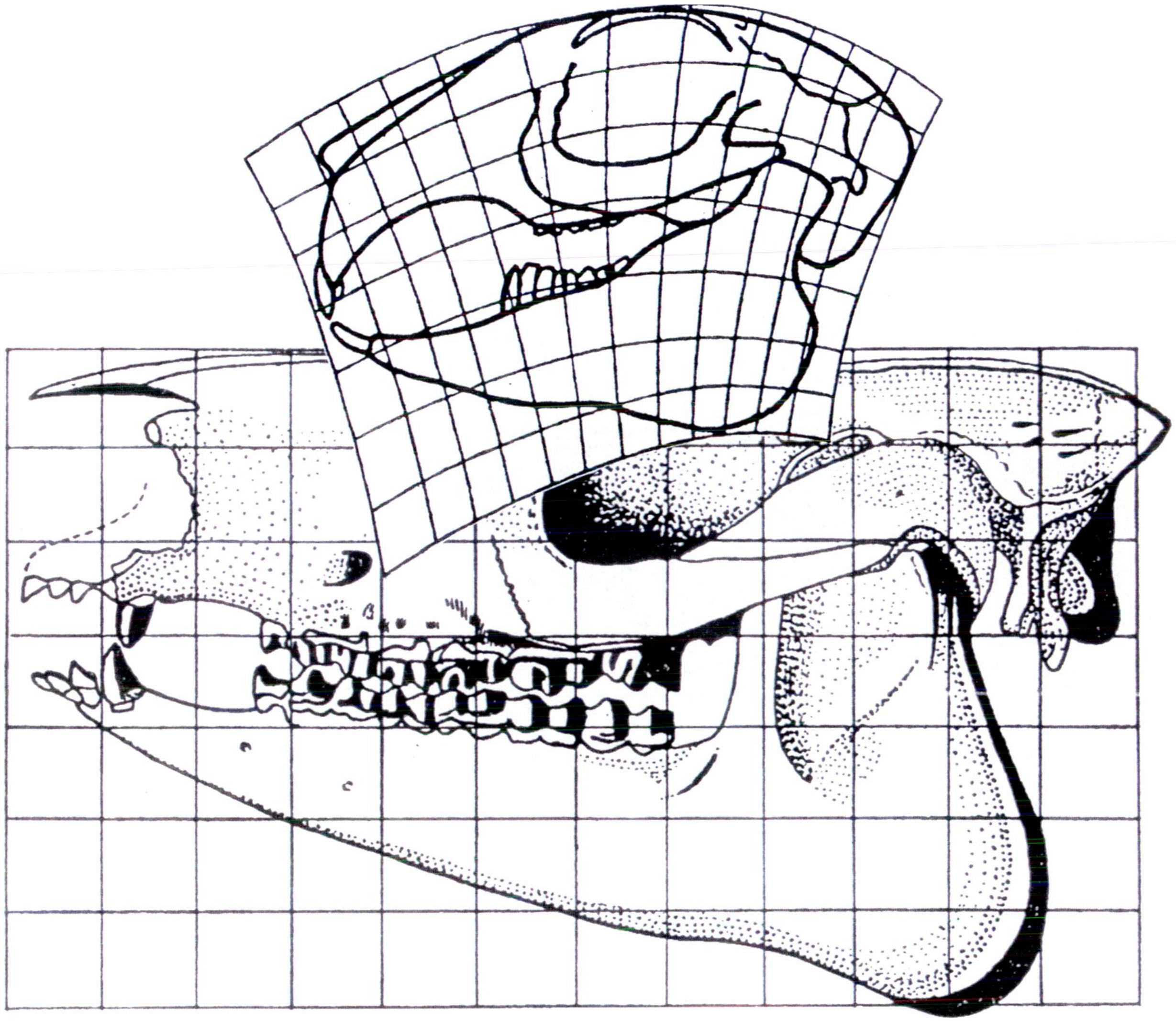
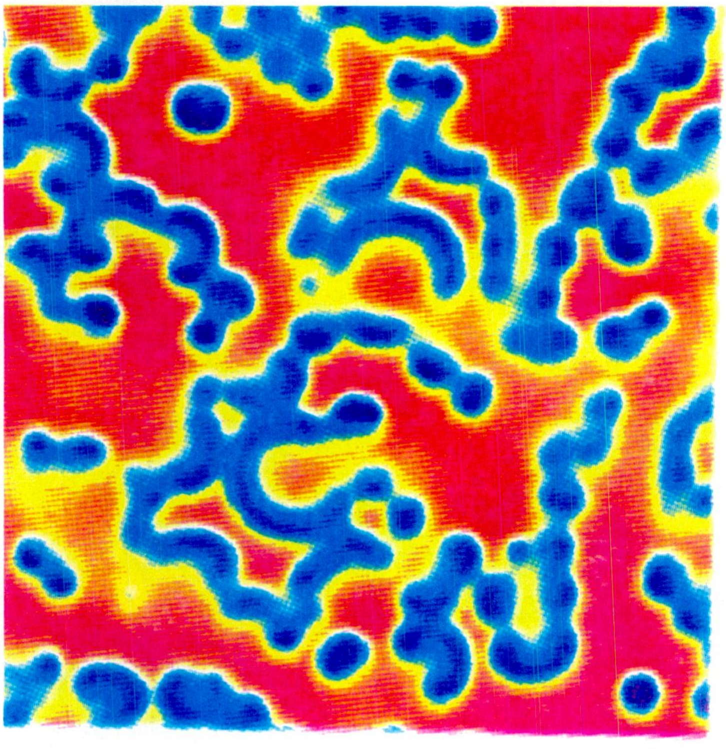


Figure Four. Co-ordinate Transformation. (Thompson) claws, paws and even wings. Finally we have a reasonable explanation of homology which has preoccupied biologists including Darwin and the rational morphologists for over two hundred years. It is homology which reflects the emergence of self organisation and the preservation of it's dynamic independent of the 'optimum reproductive success' of the Neo Darwinist form algorithm. This is the contribution of chaos to the identity of form. It is also the contribution of physics to biology, in particular that branch of physics which is 'beginning to discover ways in which very complex systems nevertheless exhibit remarkable order' (Kaufmann, 1993, p664). In this way Kaufmann continues a tradition begun by D'Arcy Thompson in 1917 with the most praised and revered book that modern morphology honours, 'On Growth and Form'. Thompson intuitively recognised that organic form could be described by the physics and maths of the period and he successfully applied such observations to a variety of phenomena. It was the study of form which lead Thompson to carelessly disregard Darwin's evolution in his efforts to explain the existence of order which appeared to operate outside selection. Kaufmann and his contemporaries Saunders, Ho and Goodwin have reinstated some of Thompson's conclusions through the recognition of the identity of form, suggested by the new physics. In this way the most famous of D'Arcy, Thompson's insights, the co-ordinate transformation and mapping together of divergent shapes through simple functions is united with the dynamic capability of the systems that Kaufmann discovered. The spatially transformed Cartesian net which metamorphoses the rhino skull into the rabbit (Figure 4) is an elegant example of the family of related forms which Kaufmann's mechanism predicts. The picture which emerges is a kind of inevitable archetypical form anticipated by the rational morphologists but characterised by those morphologies that can maintain their robust character in the face of adaptation and in spite of selection.



Biotechnology

A radical new understanding of organic form has momentous implications for biomorphism, the tendency towards biological form in art. However, it is difficult to relate a dramatic paradigmatic shift in science to the incarnation of biomorphism exemplified by Moore, Helpworth, Dali and Miro to whom the term has previously been applied. Regrettably the application has been synonymous with any kind of undulating curved irregular shape, and has seemed to imply some kind of natural mystic harmony with organic form. It is alarming to discover that the only reference that Henry Moore can make to the organic shapes of his work is to allude to his fondness for the shapes of pebbles discovered on a beach (Penrose etc.). Whatever it should encompass, the biomorphic blanket should not extend to shapes characterised by erosion, a rather coarse force compared to the inextricable and ordered lattices of chaos that time has constructed and crystallised into the function and form of a living state. Perhaps it can be understood that the blankly flowing curves of biomorphism were enough to characterise nature in the face of more mechanistic phenomena, notably the emerging industrial iconography of girded metal, chimneys and factories of the Industrial Revolution which made it's way into modernist abstraction (Constructivism minimalsim etc.). But how can we relate the curves of biomorphism to a post-modernist, post-industrial artificiality, whose machines approach biological complexity in both function and form. Biomorphism cannot exist as a mere polarity any more. It's own ill defined territory is under seige from it's opposite, and the artist whose intuitive curves are at the heart of nature is unaware that the heart of the cow in his picture is fashioned in plastic. The saddling up of physics has yielded awesome power as well as capabilities of a more delicate nature. Biologists Kaufmann laments suffer from physics - envy. The insecurity arises from the need of biologists to be over sensitive to the whispers which emanate from the corridors of physics in order to push forth their respective fields in the shadow of a more concrete domain. Kaufmann further adds that biologists should content themselves with 'middle-level theories'. This is indeed a sensible refrain as biology is a 'historical' science which must somehow describe life, itself a combination at the most complex level of all other branches of science. However, perhaps this humility is not appropriate to the stunning advances of modern biology as heralded by the advent of new technologies, which have transformed the flesh and bones of the human condition into a fantastical tabloid spectacle. Modern miracles suggest that biology is indeed reaching the bottom levels of the mysteries of life. In truth, physics has not matched the great bounds of the biotechnological revolution. In 1953 people were driving large cars around unaware that the molecular structure of DNA was about to be discovered. In 1994, people are still driving large cars around, but artificial insulin is pumping through their veins courtesy of a donor's heart and the lungs, liver and cornea are also new, while a plastic hip joint rotates slickly in the leg of a passenger who leaves to pick up some frozen embryonic children that are waiting in the freezer. The technology which characterises this century's is biological. 'Physics is dead as a model for organisation. Biology is the antecedent'. (Monde).

We have seen that the elucidation of biological mechanisms has shown that the definite and often indefinite universal of physical states underlie it's mysteries. Our increasing bio-literacy which has arisen through the effort to understand and master those mechanisms, has astounding implications. Life is inherently inevitable. It is driven by self perpetuation, the core of all it's functions, processes and forms, the heart of it's evolutionary struggle. This programme arose either by chance operating on a limited probability space, or through the kind spontaneous generation that dead chaotic systems exhibit today. All biology since the dawn of life has served this function to create a diversity of invention which describes the success of it's self-propulsion on a global scale. However, the monstrous and profound toolbox of nature has fallen into different hands of late, and biology has seen it's mechanisms turned to an alien motivation. Man has transcended 'the meat' (Gibson 1984) to organise the phenomena of his own inception according to his own convenience. Humans can now organise the mechanisms which self perpetuation discovered and evolved, with their own intelligence. The blindness of the explosive slide from inanimate to animate can now be given a new vision.

It can now been seen how problematic a relationship there is between science and certainty. In particular, the inconsistencies of Neo Darwinism show that if truth is in question so perhaps are precious reputations. It is encouraging to note that the new paradigm is a gloriously open-ended theory and as such is the ultimate environment for debate. The linear progress model was found to have been inadequate in it's service as a value judgement to society as well as to the Darwinist theory of evolution from which it probably arose. The introduction of the little known Rational Morphologists established the first theory of form and it's aim as relevant concerns for discussion but then was forcefully overlooked by the introduction of Darwin and his conception of form. However it has been shown that these ideas, which have inhibited the recognition of the identity of form, are more than vaguely theoretical and dangerously unproven. The shift to the new paradigm from the old occurs around the question of form and the problem of homology, and two models of genetical space are discussed to show exactly how this shift occurs. The morphospace model has shown that it cannot account for observed form, and that form is not completely random. Alternatively the Rugged fitness model proved that selection cannot account for complex form, and created the conceptual environment in which self organization could emerge and characterise.

Natural Causes

The previous chapters have contained a glimpse of what has been referred to as the inevitability of life and form. The inevitability of form is characterised by the inability of selection to avoid the patterns and shapes of self organization. Their emergence in the absence of any suppressive agent is unavoidable and is what we would expect to see in any alternative pathways of a recapitulated biological program. Form also subscribes to the inherent inevitability of life. The many proposed models of the genesis of biological order (Kaufmann, Dawkins, Goodwin etc.) all describe a limited probability within which life has arisen. Life on earth began when complex organic molecules developed the ability to make copies of themselves. This tiny event which could have occurred simultaneously around the sterile globe or in one microscopic crevice, set in motion a chain of events that could not be dissolved or arrested. The very first generation of a copy molecule was the spark which ignited the explosion of life, which had lain dormant for hundreds of millennia as a potentiality in the physical and chemical states of the planet. This tiny event chaos teaches us was possibly less accidental than was previously thought (Briggs 1992, p40). Self organisation occurs spontaneously, as in some cases does function (Saunders and Ho 1984). It is not therefore considered unlikely or accidental that a seed molecule could have arisen out of such a vast cauldron of primeval soup. Once it had the positive feedback which earlier described the bacterial catastrophe of progressive doubling applies, and oversees the rapid proliferation of replicating molecules. Selection does not compel a creature to evolve a certain way, nor is it a discerning or sentient quality controller which nudges life towards higher fitness. It is merely the name given to the evident result of replication-improvements to the process will 'carry' and outgrow the less efficient predecessors. Selection appears to occur, but it's results are most profoundly inevitable.

Life itself is a discovery of a very basic programme. The panopoly of physical processes organised into complexity and consciousness are potentialities realised and enslaved by the only possible non intelligent mechanism for perpetuation. However, to what extent are we, the product of this biological perpetuation able to express a logic which lives outside it? The explosion of consciousness which accounts for this very page exhibits much intelligence and creativity in understanding and relating to the world. But surely the motivation for such efforts is firmly located inside of the evolutionary impetus, arising as it has from the need to master and control new environments and engender the social structure essential for group survival. Intelligence and creativity would after all not have evolved unless they benefitted or contributed to survival. Certainly the practical applications of our mastery of biology, which has led to the establishment of Medicine, is consistent with the criteria for selection and survival, so in this alone we have not transcended the blind cycle to which we are chained. Transcendence can only come about through the domination of those processes which selection has discovered and their organisation on a level abstracted from the function which they serve. Only in this way will man generate a significance which will live beyond his death. Art will take it's place among the profound objects of nature. This transcendence can be described as creation and the reorganisation of biological phenomena which it implies can be achieved through biomorphism. the elemental, pure creation of biomorphism does require some essentials. The occurrence of motivation outside of survival, a fluency of the biological medium, an ability to de code and reduce biological form and the existence of universals of form which maintain an integrity beyond their composite organisation. Through the study of morphology, this is exactly what we have found.

To accept a place on the board of life means submitting to the violent struggle for the right to play. The degegrations are endless - homicide, genocide, infanticide, armed robbery, kidnapping, assault and rape and all perfectly within the law. Nature just doesn't care. But what is not within the law? Death is a particularly unpleasant imposition on humans who are passionately immersed in the struggle to achieve an autonomous existence safe from the slings and arrows of nature's 'outrageous fortune'. All of us who feel we are sanitised and protected from the vascillations of selective drive and environmental fluctuations are regrettably compelled to die of what we call 'natural causes'. Readers will be surprised to learn that hundreds of people are at present living outside this law. The freezing and subsequent reanimation of a beagle leading to a 'fully functional dog' (Regis 1990, Mondo 2000) led to the foundation of cryonics and commercial suspension. Clients of cryonic suspension are so convinced by man's emerging ability to tinker with himself that they invest up to $200,000 each in complex freezing processes (suspension in liquid nitrogen at $-186^{o}C$) in the belief that man can arrest the process of death. The theory for this is sound enough. Death has evolved out of the necessity of our ancestors, and in the absence of such necessity we could just devolve the process and live forever. The 'necessity' is defined on one hand by the fact that life after breeding can have no selective advantage, and on the other death after breeding is advantageous as it makes way for the all important offspring. Sexual maturity is followed by the activation of an autodestruct mechanism which carries all animals to their grave. While humans cannot at present arrest the process, it has nevertheless been brought in for questioning and the results are encouraging. Perhaps just like Bond, cutting the right wire will stop the countdown.

With respect to the requirements of creative biomorphism, the program to cheat death is a valiant and hubristic attempt to transcend and escape the limitations which life poses to intelligence. Here is a concrete example of the tools of biology being reorganised under unprecedented motivation blatantly exclusive of evolutionary thrust. The very audacity to envisage an existence abstracted from the primeval programming from which it originally sprung is evidence of the inadequacy of nature to contain the aspirations of intelligent life. The destiny of man can thus be located beyond the banks of the river of life, and his capacity to alter nature and his need to do so have enabled him to escape the perpetual flow of evolution. The application of the question of mortality to modern biological practice yields a state of mind which exists beyond the inevitability of life.

What does our understanding of the inevitability of form tell us about the viability of a newly conceived biomorphism? Firstly, we have found that form can be decoded independently of the necessities and functions of an organism. The relevant example here would be Saunders discussion of butterfly mimicry (Saunders 1989). The viceroy mimics the ill-tasting monarch as a result of a pattern oscillation from it's own family resemblance to that of the monarch. The independence of these patterns to selection and function is seen in the remarkable discovery of an exact likeness to the monarch pattern in a butterfly which lives on the other side of the world, and who therefore could not gain from the imitation of the markings of an unpopular prey. Thus the pattern phenomenon must be considered independently of the

selected traits and functions which constitute the butterfly. Our concern here is that the significance of form is preserved in the absence of the organisational impetus of the organism.

Secondly, the explanation for the 'problem of form', homology, consists of the discovery of families of forms. or archetypes which underlie the numerical patterns of an animal. These universals on one hand re-iterate the conclusion that form can be separated from the organism. On the other, they describe specific shapes and sequences from which a biology can be constructed again independent of functional necessity. The programme for decoding organic form has suggested an inevitability that will characterise biologically, outside the inevitability of life.

The capability of modern biology, lithified by every passing research day, holds the key that will unlock the real potential for creation hidden inside a human intelligence. The implications of ultimate control do not have to be monstrous as in Michael Crichton's and Stephen Spielberg's in Jurassic Park. The vicious dinosaurs which prowled the pathetic fences of their own themepark were the genetic reconstruction of ancient Jurassic DNA extracted from a mosquito trapped in amber. They were genetic spectres, science fictional occupants of the public space where genetic engineering has released the unknown and uncontrollable Tyrannosaurus Frankenstein. But already within Jurassic Park is an implicit biomorphism. It is inherent not in the book or the story but in it's visual depiction. the main task of production was to bring the great dinosaurs to the screen. The detailed and up to date research of Crichton, the author, was augmented by scientific data describing in detail how the animals would look and move. The appearance of the dinosaurs was based on the anticipation of their structure pattern and personality, achieved through an analysis of the fossil inheritance. The principles of homology made it possible to describe these ancient animals in terms of the more modern providing a sinister familiarity of the dinosaurs to extant creatures. The universal results of mechano-chemical models meant that modern skin patterns could be applied with a good deal of accuracy to prehistoric skins. In short a great deal of morphological knowledge was used in the painstaking reconstructions. The resulting mechanized or animated forms looked frighteningly real, the result X perhaps of their relocation to the central territories which all reptiles at different points in their morphologies cross. The glinting green eyes of shark-like ferocity met ours through the cinema screen as well as through the reconciled gap of the millions of years of drift which separated us from such creatures. After such a long time, cinema goers were dismayed to discover that not much had changed, and that lurking behind the prevalent archetypes on screen and in nature lies the separate spectre of survival.

Generative Art

The animals of Jurassic Park are convincing beyond the illusion of the screen. From the stampeding herd of bipedal dinosaurs and the open plains on the park to the breathtaking appearance of the Tyrannosaurus Rex during a freak weather storm, no hints are entertained that we are in fact looking at a simulation. The scientists engineers and model makers wrought totally plausible creatures from the jigsaw pieces of bone which survived the human-dinosaur interval. Through our knowledge of behaviour and morphology, the creators of Jurassic Park constructed temples from a garbled blueprint. And yet this is what the fictional scientists of the story are supposed to have achieved, by interpreting the DNA sequences of sucked dinosaur blood. The results of both methods are convergent. If scientists had actually cloned dinosaurs, and they were up on the screen, they would not have looked much different to what was achieved by invention. In this case, invention if it is well enough informed, can constitute reality. The simulated dinosaurs of Jurassic Park are in many ways as valid as the real ones, and the truths and understandings on which they are based qualify them for a place in nature. The specifics to which such invention was turned (the co-ordination of the movements and behaviour to the emotional and physical expectations of the story) constitute the extra dimension required to denote creation. We can say that the simulations constitute creation because the power of scientific penetration was realised (simulation) and used (imagination). An extra dimension was added to the dinosaurs by the generation of their behaviour to serve the impact of the story, and composites of profound reality were made to dance outside of their own inevitability. Creation makes the puppet dance to our own tune.

The animation biology of Jurassic Park is an example of modern Biomorphism. Previous attempts to burrow a biological language of universals were ineffective due to a limited interest in morphology which was itself somewhat arbitrary. The emergence of the New Paradigm has brought with it an awareness of form, aspects of which have been catalogued in fore running chapters. The key to characterising biological form lies here, and artists must grasp the opportunity presented by such knowledge regardless of how unfamiliar the territory is. The power of biology arising in this century from the fundamentals of physics has led to a transcendence of the condition we have inherited, from the newly proclaimed mortality challenge to the more senseless alterations of environment and body. The power of art to transcend the inherency of our physicality lies in creation. All artists perhaps organise the perceived truths of reality (simulation) into new structures (imagination). The role in perceiving and relating to reality has always been a highly individual and subjective pursuit and is enacted by both science and art alike. However, the loose ephemeral intuitions that art has yielded are increasingly overshadowed by the concrete elucidation of science. The aesthetic order discovered in art yielded the equations of the golden selection which science can now use to describe art and life alike (M.Ghyka, 1946 also see cover). The discovery of fractural geometry by Benoit Mandelkrot in the sixties and seventies mirrored the iterative patterns of art, but produced figures infinitely more complex. We appear to have reached a bifurcation point where the revelations of art have been overcome by the creative potential of recent scientific advancement, and the unavoidable implication is that for art to branch forwards it's generative capability must be addressed.

Generative art is art which lives. Without simulation and imagination, the trinkets and resemblances which man

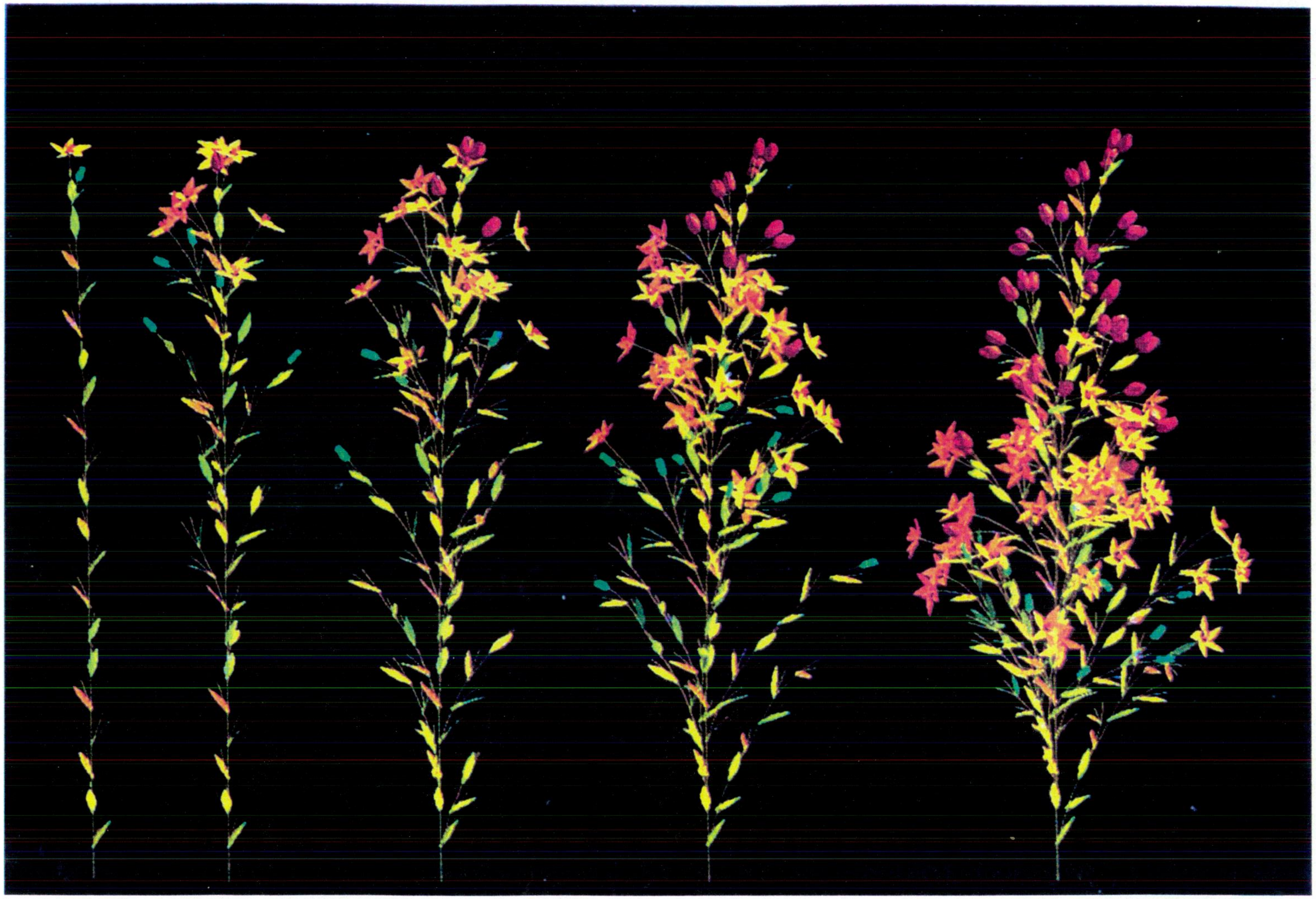


Figure Five. Growth Simulation. (Prusinkiewicz, Briggs) leaves behind are lifeless in his absence, like a fossilised footprint, the mere evidence of his passing. In medieval times art provided a way of relating to the world, the eye of the painter capturing or simulating the world around him and his imagination organised this field subjectively. However the imagination tended to describe the world around itself as well, in the absence of a more concrete understanding. The result was absolute subjectively, and on that art died with it's people. We surely can never hope to understand the meaning of a work located in a time where a pitch black reality was illuminated with the flickering lights of man's imaginings. Now that we are in an age where the light sources are much brighter and more reliable, our simulations can be beyond the superficial to the inevitable. Such art implies a crossover to science and it's abilities but there is not reason to suggest why such interdisciplinary activity would no be highly productive. Already, the analogues exist.

Przemyslaw Prusinkiewicz of Calgary University has been able to generate imitations of specific botanical forms. (Briggs, 1992, p.86). Figure five shows the simulated development of the planet mycelis muralus. The resulting flowers have the bland aesthetic of birthday cards, and would not seem to be the most significant artist statement. They do however have great significance in the fact that the flowers were not observed but created. The appearance of nature was not imitated but it's more profound generative processes instead. Peter Oppenheimer a scientist who works in computer graphics maintains that his work has "evolved from science into art" (Briggs, 1992, p.91) in trying to present "a fiction that is like the fact". The 'fiction' for artist George Gessert is the living imagery selected for in genetic art. He points out that genetic folk art has been happening for centuries with the selective breeding for consciousness altering drugs "Conscious selection involved intellectual, emotional and spiritual awareness" (Gessert, 1993, p.270). Gessert's own genetic art however consists of large numbers of potted plants occupying a gallery space. Because of the difficulties of attaining access to facilities, and the skills required, genetic art is obviously still in it's infancy.

Vast areas of potential creation have been opened up by the sciences, and the boundaries between art and science are quickly dissolving. To what extent the artist can participate in the technologies involved has yet to be seen. The implications of an ultimate knowledge of form do not stop at simulating dinosaurs though. The more we know and understand about how natural form arises, the close we can get to the ideal of generative creation. This horizon has only recently appeared, and theories of form and morphology are only just hatching. As the goals of artificial intelligence and artificial life are approached, it can also be seen that properties of artificial form are within reach of the artist. Generative art can be realised through a willingness to accept the legacy of power that science's certainties yield and to implement the legacy of our intelligence through the things we make, ultimately leading to the creation of art that will live forever.

Conclusion

The study of morphology has taught us many things. In general we have seen that biological form has a specific identity demonstrated by it's performance outside the Neo Darwinist straight-jacket. We have also studied the success of the reductionist aspirations of biological science where the levels of understanding reached in morphology and otherwise have imparted powers which challenge the inherency of our condition. The hubristic and bizarre attitudes to mortality, which have arisen within science, locate our desire to operate on a level outside of that created for us by evolution. Generative art has been identified as an inevitable direction in which such needs and capabilities could be developed. Specifically, the discovery of self organisation inherent in the frameworks of chaos and morphogenesis has suggested the presence of a universal order in a range of complex systems. The interaction of natural selection and self organization has yielded archetypical universals of form which assert themselves regardless of the greedy motivations which they serve. We have therefore identified the potential of form to be abstracted from the structures within which it has been developed. Modern biomorphism is biology and ingenuity, simulation and imagination - the aspiration to ultimate creativity. Generative art is characterised by modern biology's ability to penetrate and control and art's ability to transcend the purpose which has driven our development up to this point. Through generative art, man steps outside himself and into the footsteps of creation, the God he imagined.

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