

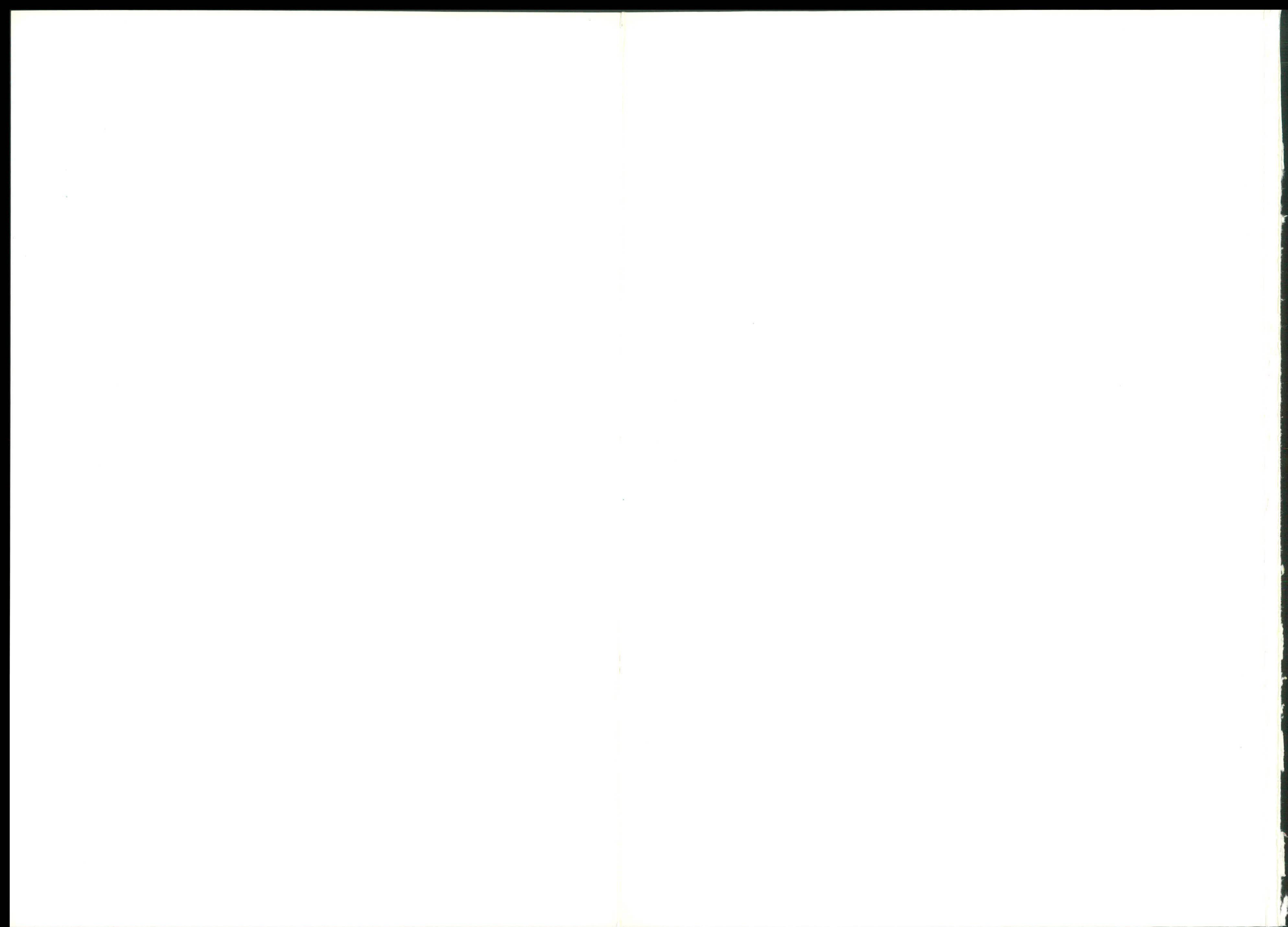
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Genesis

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Life
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the
information
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Genesis



**Life at the
end of the
information
age**

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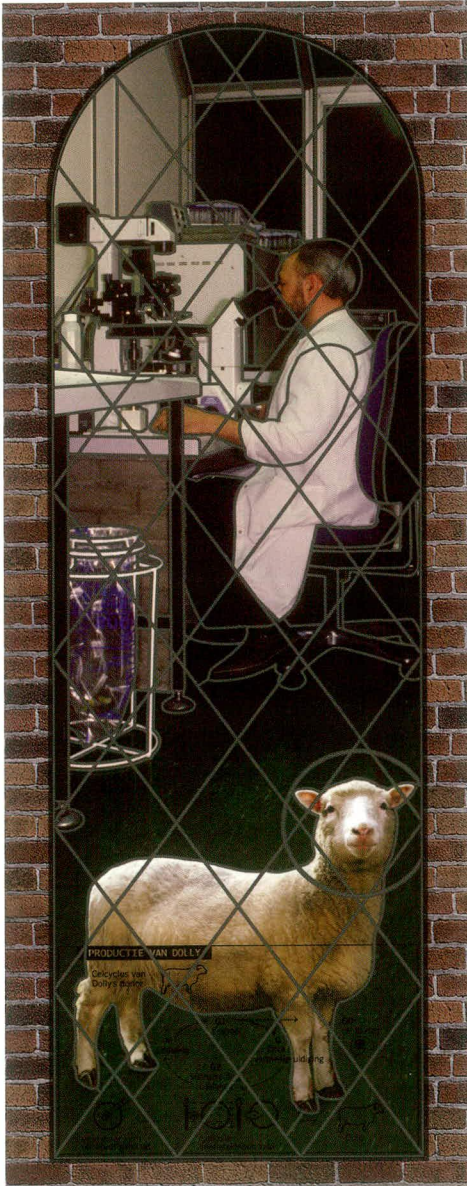
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Above:
Berend Strik and Hans van Houwelingen,
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Foreword

Pauline Terreehorst
Director Centraal Museum

The Centraal Museum is proud to present *Genesis*: life at the end of the information age. This is an extraordinary exhibition that opens up new territories for a classical art museum such as ours. In the twenty-first century museums need to rethink questions such as 'information', 'reduction' and the false dichotomy of 'art' versus 'science'. In *Genesis* 'information' is linked to computer technologies and genetics. We invited our guest curator, Emilie Gomart, to be our guide on this fascinating journey across numerous boundaries and into uncharted territory. She has not been afraid to engage in a fundamental discussion about the parallels between art and science. She challenges our fixed notions of the distinctions between these disciplines – a Romantic legacy – and introduces a generous acceptance of noise, chaos, disorder and the importance of context. She stresses the similarities between contemporary art and pioneering science, such as the role of the imagination. These themes have been brilliantly translated into three dimensions in the exhibition design by Inside Outside's Petra Blaisse and her team.

This exhibition and the events that surround it would not have been possible without the early support of Robert Zwijnenberg and Mirjam van Rijnsingen at the Art & Genomics Centre; the initial funding by Gijs van der Starre of NWO's Netherlands Genomics Initiative, was also crucial. The support of the Mondriaan Foundation, Prins Bernhard Cultuurfonds and VSB fonds gave the project an important moral boost. We have relied heavily upon Utrecht University for loans from its Museum and advice and assistance

in innumerable ways. I would like to extend my special thanks to the Hubrecht Laboratory.

Finally this exhibition would not have been possible without the groundbreaking work of Bruno Latour, whose ideas have influenced every aspect of the project. 'What is Life?' This is the question posed by all great works of art. In *Genesis* we reframe this question in an exciting context where art and science merge into something yet unknown.

Life at the end of the information age: Parallels of science and art

Emilie Gomart
Guest Curator Centraal Museum/
Lecturer (Philosophy) University
of Amsterdam

'The price of metaphor is eternal vigilance'
(Norbert Weiner)

*'The only myth is the myth of a science
without myth'*
(Michel Serres)

Metaphors influence how we perceive the world. It was only in the 1950s with the first computers, that scientists could say that the brain was a computer and DNA the program that controlled the development of the organism. *Genesis* focuses on the power of one metaphor, the 'information metaphor'. The 'information metaphor' shaped the 20th century. Everything, life itself, seemed to be based on 'information' - genes, bits, sequences of signs.

Genesis describes parallels between art and the life sciences. Art and science might seem miles apart and have different goals and different venues, they have both been influenced by the 'information metaphor'. In

the first part of this show, products of 'information' in art and science reveal their surprising resemblances. In the second, art and science struggle to overcome the limitations of this 'information metaphor'.

In this introductory essay, I would like to introduce three of these parallels between art and science to suggest the *range* of relations which might pertain between art and science. In the late 19th century and now again at the beginning of the 21st there has been much debate about 'the' relation between art and science. Following scholarship in art history, art has been described as figurative, suggestive, and also warm and human whereas science has been described as literal, unequivocal, cold and asocial. One opposition is supposed between art and science which also allows for a complementarity: science is useful to society for the technological progress it provides, art compensates for science's a-sociality by facilitating the introduction of science to a broad public and by suggesting the impact of science on society. One *a priori* relation is then posed between art and science - and this relation rests on fixed notions about what 'art' and 'science' are in essence and in general (Cf. Latour *Infra*). In this show and in this essay, I want to show not one relation between art and science but a series of relations, all different and changing. I begin by suggesting that the one relation most often posited - that science is literal and art figurative - is simply untrue. Metaphors - and the specific metaphor of information which is the focus of this show - have structured work both in art and in science. But above all, I want to avoid speaking of 'art' and 'science' in general. I focus on one metaphor and its multiple instantiations; I focus on one science - genetics between 1950 and today; and focus on a few artists who have explicitly engaged either with tools from

genetics or with scientific representations of life. I will not describe all the possible relations between these scientists and these artists in the show *Genesis* but focus on three important parallels.

██████████
'Shut up and code!' (graffiti in MIT computer lab 1960s)

██████████
The first example of a parallel between art and science - or more specifically, between certain geneticists and several artists occurred at the beginning of the Cold War, in the 1950s and 1960s. This parallel emerged around the idea of information. What is 'information'?

██████████ The idea of 'information' was the invention of computer engineers and mathematicians and their work marked the beginning of the Information Age. The effects of their idea of 'information' extended far beyond these two specialized fields. 'Information' was first used by engineers to solve technical problems of message transmission. It is a tool for answering engineering questions like 'How to 'translate' a message into a code which can be efficiently 'transmitted' and 'received'? 'Information' is not what we ordinarily mean by the term: it is not a 'news story' in the newspaper.

Information is a sequence of abstract signs, like morse code for the telegraph or bits (0s and 1s) for computer programming. The information metaphor is the use of this technical definition of information beyond the specific engineering problems it was initially meant for. The meaning of information was so important that famous designers like Charles and Ray Eames were asked to make short films like *The communication primer* to introduce it to large lay audiences.

██████████ 'Information' is an abstract

sequence of signs. When a message is fed into computers, it is translated into sequences of 0s and 1s. An electrical current passes through the machine and - following the coded instructions (0101001111) - opens and closes different switches or relays. 0 opens the switch, 1 closes it. Different sequences of 0s and 1s are the program that make the computer perform different operations.

██████████ The power of the idea of information was that it turned complex problems into simpler ones. Before 'information', engineers working on improving the transmission of signals had assumed that radio waves, computer voltages, telephone voices, television images each presented specific problems of communication.

██████████ The mathematician Claude Shannon simplified the problem: "The fundamental problem of communication is that of reproducing at one point a message selected at another point". The message was encoded into 'information' - a specific sequence of signs - emitted and received. And the difficult task of improving communications was turned into a single mathematical formula, with just a few terms:

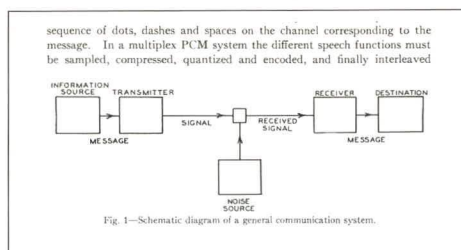


Fig. 1—Schematic diagram of a general communication system.

Once they had information theory, engineers could focus on the task: the efficiency of information transfer. They no longer had to take into account the diversity of the problems posed by the different media, TV,

██████████ **Above:**
C.E. Shannon, A Mathematical Theory of
Communication, July 1948. In: *The Bell System Technical
Journal*, Vol. XXVII, No.3

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radio, etc... Information had no longer anything to do with the physical entities of volt, voice or image. Information was abstract and extracted from its context.

■■■■■ This trick of abstracting and extracting information from its context had an immense impact on fields as seemingly diverse as linguistics, sociology, warfare, neurology, psychology, cybernetics, computer engineering, robotics, and art...

■■■■■ *"Suppose that you are given a problem to solve, I don't care what kind of problem, maybe it is a machine to design, or a physical theory to develop, or a mathematical theorem to prove or something of that kind. Probably a very powerful approach to this is to attempt to eliminate everything from the problem except the essentials... If you can bring this problem down into the main issues, you can see more clearly what you're trying to do and perhaps find a solution. Now in so doing you may have stripped away the problem you're after. You may have simplified it to a point that it doesn't even resemble the problem that you started with; but very often if you can solve this simple problem, you can add refinements to the solution of this until you get back to the solution of the one you started with."* (Shannon, 1953)

■■■■■ 'Cybernetics' is the name of this interdisciplinary drive born in the 1950s which studies everything as flows of information and communication. As John Tresch explains [See his article *Infra*], the very definition of 'information' was meant to allow for comparisons and analogies between fields: *"[Cybernetics] considers how messages are sent, received and obeyed at various points of any system – whether brain, body, computer, factory, or society. Using cybernetic terminology, all such systems can be considered as functionally analogous; since their systematic properties depend purely on relations of information, they*

may be treated as identical. Thus cybernetics treats machines and organisms in exactly the same way".

■■■■■ In the 1950s, biologists used the metaphor of information to understand Life. They too developed a 'cybernetic' vision of Life. Biologists had until the 1920s been lost in descriptions of all the particular forms of life. It had seemed to them that each species was a special case and that it was impossible to speak of Life in general. Suddenly 'information' allowed them to focus on finding just one thing: the code of Life, which like the 0s and 1s for computers, controlled operations in all species.

■■■■■ The power of the information metaphor was that it turned intractable problems into not only comparable ones – with other fields – but also simpler ones. As Fox Keller has explained in *The Century of the Gene*, information made for scientific questions which scientists could tackle.

■■■■■ Watson and Crick's discovery of the shape of DNA in 1953 suggested that biological information was inscribed in the DNA. DNA is shaped like a double helix, a twisted ladder. At the height of each rung in the ladder, there is one of four 'bases': adenine (abbreviated 'A'), cytosine ('C'), guanine ('G') and thymine ('T'). The four bases are assembled and combined differently to make up different sequences running along the spiral of the DNA molecule: ACTTGATTC ... This variable sequence reminded biologists of the varying sequences of 0s and 1s used in computer code 01000111.

■■■■■ This language of information and in particular of computer code is used to describe what genes do¹:

"A gene as we may say is a message, which can survive the death of the individual and can thus be received repeatedly by several

¹ Unless otherwise noted, all information and quotes on information and biology from the 1950s, are drawn from the works of Lilly Kay and Evelyn Fox Keller.

organisms of different generations”.

(H. Kalmus)

■■■■■
“DNA is a linear coded tape of instructions. The entire thread constitutes a ‘message’... The smallest unit is perhaps some flip-flop which can make a yes-no decision. If the result of this yes-no decision is evident in the grown organism, we can call this smallest message unit a gene”.

(Quastler and Dancoff, 1953)

■■■■■
“the hereditary properties of any organism could be characterized as a long number written in a four-digital system [(ACT or G)]. On the other hand, the enzymes, the composition of which must be completely determined by the [DNA] molecule are long peptide chains formed by about twenty different kinds of amino-acids, and can be considered as long ‘words’ based on a 20-letter alphabet. Thus the question arises about the way in which four digital numbers can be translated into such ‘words’”.

(K. Halmut)

■■■■■
It is also present in Watson and Crick’s classic *Nature* article presenting the structure of DNA in 1953:

“We have recently proposed a structure for the salt of [DNA] which, if correct, immediately suggests a mechanism for its self-duplication. ...

■■■■■ The chemical formula of [DNA] is well established. The molecule is a very long chain, the backbone of which consists of a regular alternation of sugar and phosphate groups. To each sugar is attached a nitrogenous base, which can be of four different types... two of the possible bases – adenine and guanine – are purines, and the other two – thymine and cytosine – are pyrimines...

■■■■■ The phosphate –sugar backbone of our model is completely regular, but any sequence of the pairs of bases can fit into the structure. It follows that in a long molecule many different permutations are possible, and it

therefore seems likely that the precise sequence of bases is the code which carries the genetical information. If the actual order of the bases on one of the pair were given, one could write down the exact order of the bases on the other one, because of specific pairing. Thus one chain is, as it were, the complement of the other, and it is this feature which suggests how the [DNA] molecule might duplicate itself.

■■■■■ Previous discussions of self-duplication have usually involved the concept of a template or mould. Either the template was supposed to copy itself directly or it was to produce a ‘negative’ which in its turn was to act as a template and produce the original ‘positive’ once again. In no case has it been explained in detail how it would do this in terms of molecules and atoms.

■■■■■ Now our model for [DNA] is in effect a pair of templates, each of which is complementary to each other. We imagine that prior to duplication the hydrogen bonds are broken and the two chains unwind and separate. Each chain then acts as a template for the formation onto itself of a new companion chain, so that eventually we will have two pairs of chains, where we only had one before. Moreover the sequence of the pair bases will have been duplicated exactly”.

■■■■■
For engineers, information was a linear sequence of 2 abstract signs, 0s and 1s. For geneticists biological information was a linear sequence made up of 4 ‘letters’ (C,T,G and A). Biologists suggested that each sequence of three bases (for example, ‘CCG’) might be a ‘code’ for one of the twenty amino acids constituting the proteins – important building blocks of the body. In this way, different genetic sequences coded for different traits (like blue eyes or dexterity). Parents transmitted these sequences to their children; there was always the chance that one of the letters in the sequence might ‘mutate’ causing

a change in the trait it had coded for. The different sequences of A, C, T, G's in DNA explained why species and even individuals were so different from each other.

Clearly, metaphors – and this metaphor of information – have had a huge impact on the birth of modern genetics. Science is far from literal: metaphors helped shape their work and turn it into something they could grasp and work at like a puzzle. The very idea of 'gene' and of how DNA 'replicates itself' has been shaped by cybernetic images of information transfer.

In the 1950s and early 1960s, scientists raced to find out which letter combination (C,T,G,A) corresponded to ('coded for') which amino acid. They had to 'crack the code' of Life! Crick and others founded the 'RNA tie club', an informal club where men speculated about the code over drinks and not in the lab. In the 1950s, biologists – and also physicists – tried to solve the mystery of the genetic code as they would have any other information puzzle: using mathematics, logic and... MANIAC, the largest US computer used to crack enemy codes at Los Alamos Scientific Laboratory.

"I am afraid that the problem of the genetic code cannot be solved without the help of an electronic computer!" (George Gamow, 1953)

So what does the biological information look like in the 1950s?

The DNA model made by Watson and Crick for its first public exhibition, the Brussels world fair in 1958, is a crystalline structure, symmetrical and regularly rhythmic. A lattice of balls red and blue, black and white. Simply, elegantly mathematical. A wonder of order. 'Information' was made by mathematicians

and the forms produced under its influence in the early fifties were evidently mathematical.

The discovery of the structure had involved X-ray photos of DNA and many 'wet' manipulations in the lab, yet the regularity of the structure seemed to authorize Crick and Watson – as well as other scientists in the next decade – to stay away from the lab, and try to solve problems in genetics with only logic and speculation. The order it seemed to demonstrate made life look like a mathematical puzzle which did not require the messy, tedious work of the lab, but flights of genius.

The rhythmic repetition of balls of four colors (referring to the four molecules abbreviated ACTG) reminded Watson and Crick of the permutations of abstract signs used in information input for a computer. In the 1950s, the input of computers was a long paper ribbon with punched with holes. Later punch cards were used. The holes in the ribbon or card corresponded to 0s and 1s, opening and closing relays in the computer. The rhythmic DNA model as a 2 meter tall punch card for the body?

Is there 'an art' influenced by information? I can cite a few examples, related differently to information – without speaking of art in general.

The molecular shape was in fashion at the festival of Britain in 1952, where 'crystalline patterns' advertised the elegance of science. The Atomium built for the Brussels fair in 1958 and the covers of books by Wiener's *Human use of human beings* or Quastler's *Information theory in Biology* all use regular patterns of balls and spokes to advertise both the shape of the smallest particles known to man and the cybernetic network-shape of an information society.

A first parallel can be found between on the one hand the engineers and

biologists fascinated by sequences of code and on the other artists interested in seriality. In some artists' case, this parallel was the product of reading Max Bense's or Abraham Moles' books on information theory in aesthetics. Just like engineers and biologists, several artists were interested in sequences. For engineers, 'Information' was a simple sequence of bits, 0s and 1s. In the 1950s, engineers did not care what was meant by the message. (It might be a truth or a lie, or the sound of a kiss). All they wanted was to evaluate the efficiency of a transmission. For example, what was the difference between the message sent and the message received? Did 00010010 become 00010100 in the transfer? Engineers created and compared series of abstract signs.

■■■■■ 00010010 00101001 01010100
10010101 00101010 10100101...

■■■■■ In parallel to engineers and mathematicians, several artists too – often in continuation of the constructivist interest in 'variants' – were interested in sequences. They called this 'seriality'. They made not one art object, but a series of abstract geometrical forms. Each form was simple and slightly different from the ones preceding and following it. In this art as well as in information engineering, what mattered was not content – meaning – but the differences in sequences of abstract signs.

■■■■■ Seriality imposed a rhythm and a regularity more often associated with science and logic than with art. This art aimed to produce works that were 'objective-neutral reflections of reality' (*'objectieve-neutrale weergave van de werkelijkheid'*).

■■■■■ In the United States, another group of artists developed in a slightly different parallel to Information theory. These artists included John Whitney, Lillian Schwartz and Stan Vanderbeek, and were the first to use computers to create similar

sequences of abstract forms. These artists cooperated with computer programs and used math to make art. As Whitney witnessed: *"The question for me was would I be able to draw a free-hand line and somehow get it into the computer as digits information so I could manipulate it? ... I was told that anything you can define mathematically you can do with a computer very easily. At first, I was horrified.... And yet I began to realize the great breadth of elegance in simple geometric graphics and the historic respect geometry has enjoyed as a graphic form"*. (John Whitney, 1970)

■■■■■ And Gene Youngblood – first and classic commentator of this new art – described Whitney's film *Permutations* in terms which seemed almost borrowed from engineers to describe permutations in sequences of code: *Circles, quadrants, multiplex forms of infinite variety and endless motion interact serially and cosmically until one is transported into a world of expanded consciousness that intuitively understands this new language. It's as though the very essence of the idea of permutations is expressed in this film, as though the word was no longer separate from fact.* (Gene Youngblood)

■■■■■ But for John Whitney – unlike other groups in Europe – neutral objectivity was not the aim. John Whitney aimed to create a new universal language of sound and image capable of expanding the mind of modern man. He used an M-5 anti-aircraft Gun Director as his first mechanical analog computer but said, *'This complex instrument of death now became a tool for producing benevolent and graphic designs'*. This is what distinguishes this second variant of this parallel between science and art.

■■■■■ The geneticists used the information metaphor to grasp that DNA transmitted information efficiently across

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Emilie Gomart

generations. Some artists understood cybernetics to suggest that *images* were also a kind of message and one which might be capable – better than words – to transmit efficiently and rapidly information to a viewer. Information theory fed into many studies of the communication of images in the 1950s and until today. Underlying many of them, as common dream:

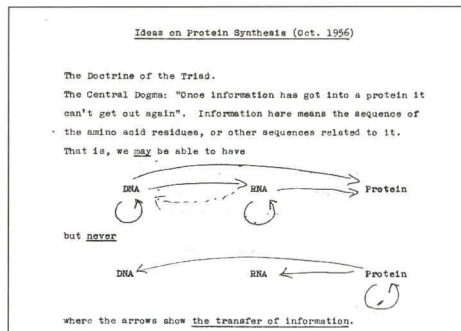
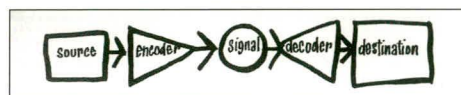
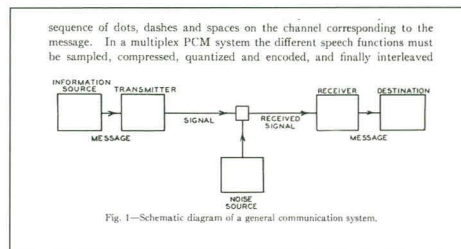
'It is the belief of those who work in cybernetic art that the computer will erase the difference between what we feel and what we see...'

(Gene Youngblood)

A dream of total efficiency of the communication of images can be traced – partially at least – to this cybernetic vision of information flows.

Both this art and the genetics of the 1950s thought of their work in terms of permutations of sequences and of the transmission of messages. But more striking than this was that both this art and this genetics believed in the total efficiency of the coded message – and both omit the same term in Shannon's original definition of communication: noise.

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Top:

C.E. Shannon, A Mathematical Theory of Communication. July 1948. In: *The Bell System Technical Journal*, Vol. XXVII, No. 3

Middle:

This is Tomorrow, 1965. Catalogue of the exhibition at the Whitechapel Gallery, designed by E. Wright.

Bottom:

Crick, Francis. *Ideas on Protein Synthesis* (October 1956) Original Repository: Wellcome Library for the History and Understanding of Medicine. Francis Harry Compton Crick Paper

These three sketches translate for different audiences Shannon's original sketch. The first is Shannon's; the second is Francis Crick's sketch for the 'Central Dogma of genetics'; The third is *This is Tomorrow*, the famous 1956 Whitechapel art show prepared by the Independent Group. (I will go into the 'Central Dogma' below). Here suffice it to note that Shannon's sketch – and theory – had placed much emphasis on the 'noise' which deforms the message as it is transferred from its source to its receiver. But in Crick's sketch and in *This is Tomorrow's* sketch, 'noise' has disappeared.

For these artists and geneticists, communication could be an even simpler affair than Shannon had even intended to make it: if the message was well encoded – in 0s and 1s or A, C, T, Gs – transfer would go all right. Shannon on the other hand had been obsessed how even such a well encoded message might be deformed by the bad quality of channels of transmission, poor emitters or receivers, etc... This simpler interpretation of information then is a first parallel between this art and this science in the 1950s. In the show, the huge, slow, rigid, fixed program 1950s computers – lent by the University of Amsterdam and by TNO – help to situate in time this simplistic version of information theory.

A second parallel between art and genetics concerns Crick's 1957 'Central Dogma' of genetics, the tools and images it spawned and how these were and – still are – used by different artists.

In the early 1950s, DNA was described as the carrier of biological 'information'. As the decade rolled on, Francis Crick formulated – with only a touch of irony – the 'Central

Dogma' of genetics: '*DNA makes RNA makes proteins and proteins make us!*'. Crick meant to say that information flowed in *one* direction from the gene to the body, and this direction could not be reversed: DNA causes us to be who we are, but the cell that houses DNA, the body, the environment could not cause changes in the gene. Once again, in plain English: according to the Central Dogma of genetics, the genes directed and controlled the development of the organism. Genes ruled. The organism was under orders from the genes. '*It's all in the genes!*' Critics called this 'genetic determinism'.

"They are in you and me; they created us, body and mind; and their preservation is the ultimate rationale for our existence. They have come a long way, those replicators. Now they go by the name of genes, and we are their survival machines. We are survival machines, robot vehicles, blindly programmed to preserve the selfish molecules known as genes".
(Richard Dawkins)

In the Central Dogma, what you are today, was in your genes from the start. The genetic sequence (of C, T, G, A's) was the plan; the adult organism is its faithful implementation. Results always matched the initial blueprint. (Or to use Watson and Crick's image for DNA, the gene contains the 'template' and the organism need only reproduce it – copy it – in 3 dimensions). The crucial aspect of this dogma was that it acted dogmatically on the organism: you cannot argue with the plan, only slavishly carry it out. The plan could not be creatively interpreted. Development was not a creative process – according to Dogma.

This Dogma had effects on re-conceptualising evolution. If development did not allow for change, how did new species evolve? There had to be room for creativity somewhere. Novelty emerged not in the lifetime of one organism but over millions of

years. Chance and natural selection allowed variation to occur over long periods of time. Evolution was creative – producing previously inexistent species – whereas development could only repeat what the genes had instructed them to do. Biologists represented both evolution and development mathematically and simulated them on computers. Genetic algorithms simulate these processes.

■■■■■ ‘Genetic art’ appropriates this evolutionary software to create forms that evolve in an unpredictable manner. Sommerer and Mignonneau, Karl Sims and Driessens and Verstappen all use versions of this evolutionary computing. In this sense, you could say that the Central Dogma has had via this software its effect on art. But intriguingly this effect has been the opposite of dogmatic: it has allowed for installations to focus on interactions. Viewers can ‘mutate’ forms as they develop, for example. Even if these interactions are carefully circumscribed, the viewer becomes capable of actively and concretely intervening in the creative process usually reserved for the artist.

■■■■■ *“Computers are creative because they give variety to a form: they distribute form – defining measurements in established mathematical boundaries by means of random generators”.* (Georg Nees, 1969)

■■■■■ Another way of conceiving this ‘parallel’ between genetic art and genetic Dogma is to situate them both within a longer tradition – intertwining art, science and architecture for centuries- where form is the product of mathematics. D’Arcy Thompson’s studies of biological forms is one early 20th century example. A more recent example is Przemyslaw Prusinkiewicz’s *Algorhythmic Beauty of Plants*.

■■■■■ *“For the harmony of the world is made manifest in Form and Number, and the heart and soul and all poetry of Natural Philosophy are embodied in the concept of mathematical beauty.”* (D’Arcy Thompson, 1917)

■■■■■ The Central Dogma of genetics is also the topic of Eduardo Kac’s installation *Genesis*. The exact relation between this work of art and genetics however might be more complicated than it seems at first sight.

■■■■■ In a dark room four images are projected, one on each wall. A small ultra violet lamp stands on a pedestal in the center shining down at a Petri dish of fluorescent bacteria. The projections on the walls are clear and immediately recognizable: on one wall, a sentence from *Genesis*: “*Let man have dominion over every living thing...*”; on another wall, the letters of the sentence are translated into Morse code; on a third, the Morse code’s points, lines, spaces and dashes are translated (according to a code invented by the artist) into the letters A,C,T, G. We are told – by the artist via explanations on a computer screen – that this sequence serves as a recipe to produce a strand of DNA which is physically produced with standard lab techniques and ‘inserted’ into bacteria fluorescent under UV light. The bacteria mutate under the light, grow, multiply and die in a Petri dish in the middle of the room. As the bacteria are transformed, we are told again, the sequence of code is affected and in turn affects the lines of Morse code, and the lines of the biblical words.

■■■■■ Kac makes bacteria from code, and in turn rewrites the code by mutating bacteria. The artist lightheartedly ‘plays God’ as he works on codes to create new genes and new living organisms. But he also encourages us to reflect on the implications of

the causal link between codes and life and to feel the chill that this idea that 'you are your (genetic) code' cannot fail to provoke in us.

Kac's installation – referring to the causality of genes – evokes the 'Central Dogma' of genetics defined by Francis Crick in 1957. The relation between this installation and genetics seems straightforward then: this is art representing and critiquing science. It is an example of that relation between art and science which art history has taught us to expect: art will introduce science, because art is ethical and social and asocial science needs introductions to society... Or is it so simple?

The science in Kac's installation is a very peculiar one. Kac did not target just any definition of genes: he targets a 1957 definition of genes which since then has been the focus of powerful criticism as much outside as within the field of genetics. Many Nobel Prizes since the 1960s have been awarded to scientists who *contradicted* this Dogma. No scientist today would seriously say that genes 'cause' you.

So why does Kac target the Dogma? The Dogma is an idea which has immense 'communication' power. Each image in the installation (strings of genetic or Morse code, the sentence from the Bible, the image of bacteria in a dish) is immediately recognizable to a western individual just like a street sign is immediately recognizable to a car driver. Further, if it has lost its credibility in scientific circles, the Dogma is still used today to communicate with the lay public and in grant requests because, PR experts say, it is so much clearer – immediately understandable – than any other contemporary version of what genes do (Cf. Nik Brown *Infra*). Kac himself is no stranger to PR techniques – his work on Alba, the green fluorescent rabbit is just one example.

Upon closer look, Kac's installation has more to do with these

powerful PR techniques – distantly echoing the totally efficient images which 1950s cybernetic artists like Whitney had dreamt of. Perhaps one could even go a step further and say that in Kac's *Genesis*, the communication theory of images matches the communication theory of the genes: he uses images that are immediately understandable to communicate the idea that genes act immediately on the organism. Unequivocal images are chosen to represent an unequivocal, irrevocable process. Kac's installation has less to do with the content of science, than with issues of communication with images. There is a relation between genetics and this installation, but the link is indirect and passes not through contemporary genetics but through Gene Youngblood and the digital art influenced by the (information) ideal of immediately understandable images.

A third and final parallel between art and science can be found in their attempts to overcome the simplistic definition of information theory. In contrast to the geneticists and artists of the 1950s they re-introduce 'noise' in the equation and return to original interpretations of cybernetics. Actually, this suggests that to overcome the limits of 'information', many artists and scientists re-interpret 'information' rather than radically reject it. They offer new metaphors... but these are still metaphors of information. Have we finished with the Information Age? Nothing is less certain.

When in 1957 Francis Crick defined the Central Dogma he was influenced by a simplistic version of information theory. DNA did not interact with the cell. Information was sent efficiently, unassisted and almost immediately from the sender to the receiver. This view can also be critiqued

from the point of view of information theory - and in particular a branch called 'cybernetics'. In communicating a message, there is always 'noise': the message always gets slightly deformed by interference. You have to carefully repair and re-create the message many times over so that it can reach its destination. Norbert Wiener, founder of cybernetics, develops an alternative metaphor to the image of information as an abstract code-drawing on the Greek origin of 'cybernetics' (*kybernetes*) which means the 'helmsman' of a ship. As John Tresch explains (see *Infra*):

"Steering a boat is not a matter of simply holding a rudder pointed in a fixed direction. Instead it requires constant adjustments to its position, depending on cues given by different sensory input (about sea currents, winds and distance to destination). Cybernetics stresses that keeping a fixed direction requires constant modifications in response to information gathered from the surrounding milieu." (John Tresch)

The helmsman metaphor suggests that in order to reach its destination a message is not simply encoded and sent. It must also be constantly adjusted: this adjustment requires input from the external world. This input is called 'feedback'. A biology influenced by this 'helmsman' metaphor of information focuses not only on the genes but on the feedback mechanisms established between DNA, the cell, and their milieu. This is called 'systems biology' - explicitly inspired by Wiener's cybernetics. Scientific works by Astrid Visser (See *Infra*) and Erik Manders on visualizing 'genetic networks' and other cell mechanisms offer a glimpse of the complexity of these processes.

Further, computer technologies are also displayed - like the 'portable cave' - which allow three dimensional viewing of molecules. These

suggest how computers do not necessarily abusively reduce the body but can also be crucial tools in grasping the complexity of the body. Actually, without computers and their use in bioinformatics, there would be no image of complexity in biology today.

This helmsman metaphor of information has also indirectly transformed how one makes computers. The biological interpretation of information has - it could then be said - transformed the field from which information originated. Explicitly drawing on recent developments in systems biology, 'Artificial Life' experts - following Rodney Brooks and Luc Steels in the 1990s - designed robots as feedback systems. In the traditional view, the computer/robot is provided with an explicit model of the world. The computer would then make decisions based on this information. The more information about the world was put into the computer, the more intelligent it was supposed to be.

In contrast, Luc Steels in the 1990s designed robots that used relatively little internal programs to model the environment. For instance, there is no programming in the robot about what kind of surface the robot is moving on - all the information is received as feedback from the robot's sensors. The information is not fixed inside the program but produced in the interactions between robot and environment. In evolution, Rodney Brooks had argued, there were insects before there were thinking humans. Therefore, AI should first learn to design robots that react and interact with their environment as well as insects before they try to design robots that reason and speak like humans. Recently, Steels has begun working on robots which combine insect and human-like qualities: they learn to move and they learn to speak (Cf. Luc Steels *Infra*).

For the show *Genesis*, we

invited artists Adam Lowe (from the collective Factum Arte), Mark Dion, and Kathleen Rogers to react to this final twist in the evolution of the information metaphor in art and science. Striking installations have been produced. I will describe only two.

A first installation involves a huge bronze sculpture of a popcorn kernel standing next to a DNA portrait, both by Marc Quinn and in the background a film produced by Factum Arte. In the recent exhibition about Quinn's work at the Groninger Museum (29 April - 27 August 2006) the Popcorn sculpture and the DNA portrait had been juxtaposed without the film. In the Groningen introductory text, the process of making a sculpture from a scan of the original had been likened to the development of an organism based on its genetic blueprint. It was claimed to be an unproblematic unfolding of a pre-fixed form. The Groningen display referred implicitly to the Central Dogma of genetics- the chilling 1957 idea that 'genes cause us'.

In the Utrecht installation for *Genesis*, Adam Lowe at Factum Arte had teamed up with Marc Quinn to offer a metaphorical counter-argument to the Central Dogma. The final form – the Pop Corn sculpture – is not simply the slavish implementation of instructions and blueprints engraved in stone at the beginning of the process. The film made by Factum Arte lasts 20 minutes and in that time the original shape of the original pop corn does not determine or direct all the other interventions. Quinn's hand selects a kernel among many others in the pan which 'popped' them. Then an avalanche of techniques – lasers, gasses, acids, sounds, computers, and also – to a small degree – human intervention all intervene in the shaping of the final sculpture. Importantly, these interventions do not just faithfully

implement the blueprint of the first pop corn. They each *re-create* the original and in the process they also transform it. They each leave their own trace on the final shape. They each add information to the original information of the pop corn chosen by Quinn.

In systems biology, biological information is not in the original coded sequence: DNA sequences interact with other DNA sequences and cellular mechanisms to produce molecular agents which in turn determine the rate of expression of other sequences. In Factum Arte's film it is clear, in parallel to this biological idea, that the original pop corn shape does not determine the final sculpture's shape. Many other interventions are combined and added: it is from these interactions that the final form emerges.

Factum Arte's attentiveness to transformations has been developed over many projects involving the digital reproduction of monuments such the Dama de Elche or the tomb of Thutmose III. (These reproduction projects will in 2007 be the focus of an exhibition *Facsimile* co-curated by Adam Lowe and Bruno Latour at the Fondazione Cini in Venice - programmed to travel to the Utrecht Centraal Museum). Through this experience with reproduction, Factum Arte came to conceive of the result (or 'copy') as richer than the original. He insists on the 'mediations and transformations' that occur during a reproduction process – terms developed by philosopher Bruno Latour for describing science. For Factum Arte, the ideal of simply and efficiently 'copying' an object became as problematic as the (simple version of) information theory where a message is sent and received without noise. Rather than try to limit and banish noise, and strive to make 'exact copies' – artists like Adam Lowe – in parallel to systems biologists and AI experts

like Luc Steels – embrace noise as a source of added information. If noise cannot be avoided, reproduction and communication can be re-conceived as ‘mediated’ activities where the result is not determined in advance.

[REDACTED] The contrast with the genetic Dogma is clear: Watson had described DNA translation and transcription as a process of copying.

[REDACTED]
“Previous discussions of self duplication have usually involved the concept of a template or mould. Either the template was supposed to copy itself directly or it was to produce a ‘negative’ which in turn was to act as a template and produce the original ‘positive’ once again... Now our model of DNA is in effect a pair of templates...” (Watson and Crick, 1953)

[REDACTED]
For Factum Arte, reproduction is not copying. And the work of making the sculpture is not a routine implementation but a true act of creation – though creativity here has changed meaning: it is not the work of a unique genius artist but that of a helmsman navigating the choppy sea.

[REDACTED] Mark Dion’s installation also foregrounds issues of replication and creation. He reproduced to the smallest detail the lab bench in a systems biology department at the Hubrecht lab in Utrecht. And then he ‘cloned it’: each side of the lab bench being identical to each other. Like a *brocanteur* or an archivist, he collects images and objects from this other discipline, systems biology. As Dion says in his interview (See Dion *Infra*), his reconstitution of a lab bench – or any other scientific setup – raises questions about the role of art and its contribution to understanding these other disciplines. The exact relation between this installation and biology is ambiguous. However, the aesthetic used to represent science here is strikingly at odds with most artistic renditions of science.

Here there is no gothic drama, no trace of Frankenstein or fluorescent mutants. There are very human and down to earth notes, memos, post its, name tags, sketches and scribbles, cartoons and notebooks, worn centrifuge machines, scissors and boxes of Petri dishes. Rather than the myth of a science in control or out of control, rather than the science of art historians (cold, inhuman, routine, literal, uncreative) there is an image of a science searching and unsure, routine and creative, literal and figurative, cold and warm, social and asocial... An entirely original – though it is a copy! – artistic rendition of science is made here. Dion allows a new kind of relation between art and genetics.

[REDACTED]
In this show *Genesis* multiple parallels between art and science are allowed. I have described just three here. These parallels all involve ‘information’ and the different metaphors, images, tools, ideas it shaped. Yet these relations were all different. And nowhere could we find – as art historians might have led us to expect – a strict division between the roles of art and science: where art is figurative, warm and creative and science is literal, cold and dogmatic. Instead, we found, on the one hand, art and science structured by a simplistic, ‘dogmatic’ version of information and on the other, artists and scientists struggling with the limitations of this version of information. The relevant distinction is not between art and science, but between reductive works and works which seek not to be.

[REDACTED]
In the show, there was a common thread, information. Information has shaped the 20th century. It has made us capable of grasping some problems and – according to biologists,

artists and computer engineers – makes it harder for us today to understand others. It structures and limits our vision of Life. According to the Bible, God has created Life out of undifferentiated matter. In the beginning there was nothing. According to information theory, this was not possible. Life is information and could come out of nothing if not information. At the end of the age of information, what is Life? What are the metaphors we might use to understand what Life is like? This is an open question, open for experimentation. I hope the show *Genesis* can contribute to this experimentation.

■■■■■

"In the beginning the earth was without form and void". (Genesis)

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"Nothing will come out of nothing" (King Lear, Shakespear)

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"Nothing can come out of nothing ... without information" (Gregory Bateson).

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Part I

Scientific commentaries

History of biology

 Soraya de Chadarevian

Biology is the science of life. Its history has been told in many ways. Often the accounts start in ancient times, notably with the Greek philosopher and naturalist Aristotle. But the term biology was not coined until around 1800 and it was only in the course of the nineteenth century that a unified science of life emerged, which aimed to investigate general life processes such as growth, reproduction and evolution. This development coincided with the formation of other scientific disciplines such as physiology, botany, zoology, and later cytology and embryology. The tradition of natural history aimed to describe and classify the diversity of life forms.

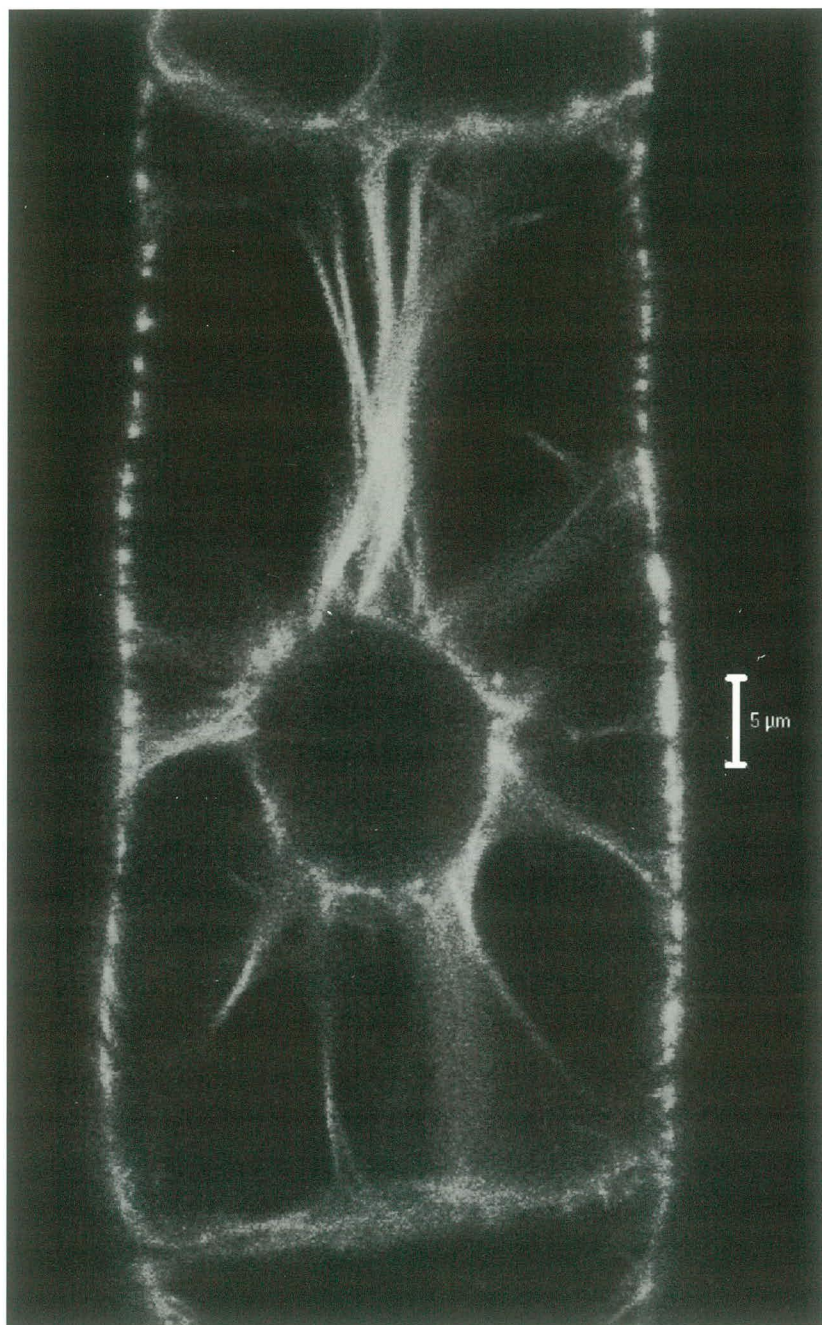
 Traditionally the history of biology is populated with important scientists and their discoveries. We are all familiar with figures such as Darwin, Mendel, Watson and Crick. Their iconic images – Darwin with his long white beard, Mendel in his priest's cassock, and Watson and Crick with their spidery model of the DNA double helix – appear in school books, scientific textbooks and the popular press. Although sometimes contested, these scientists' achievements are celebrated as milestones in our cumulative understanding of life and its processes.

 Another way of thinking about the history of biology is in terms of the artefacts, collections, instruments, models, papers and books left behind by biologists of earlier generations and stored in boxes and cupboards, in libraries, museums and archives. This is where the historians of biology go to work in their attempt to reconstruct the concerns and

practices of biologists and their place in the context of other cultural endeavours of their time. If there is no archive, in the broadest sense, there is no history. This is as true for the sciences as for other cultural disciplines. The preservation of this archive follows certain conventions but is also subject to serendipity. Papers tend to be more systematically preserved than artefacts, but sometimes what may seem an outdated collection of dried or pickled specimens can attain new value as the object of study for historians and biologists alike. Today computers play a crucial role in preserving vast amounts of textual and visual evidence, much of it electronically produced. But as with other archival technologies, electronic databases pose special problems of preservation. The format used to store the electronic data requires frequent translation in order to remain accessible for future generations. In this respect biologists' archives travel through time and alter the histories we are able to tell and thus also the meaning we attach to present accounts of our biological world and ourselves.

 **Opposite:**
Photo: Soraya de Chadarevian





The cell

Soraya de Chadarevian

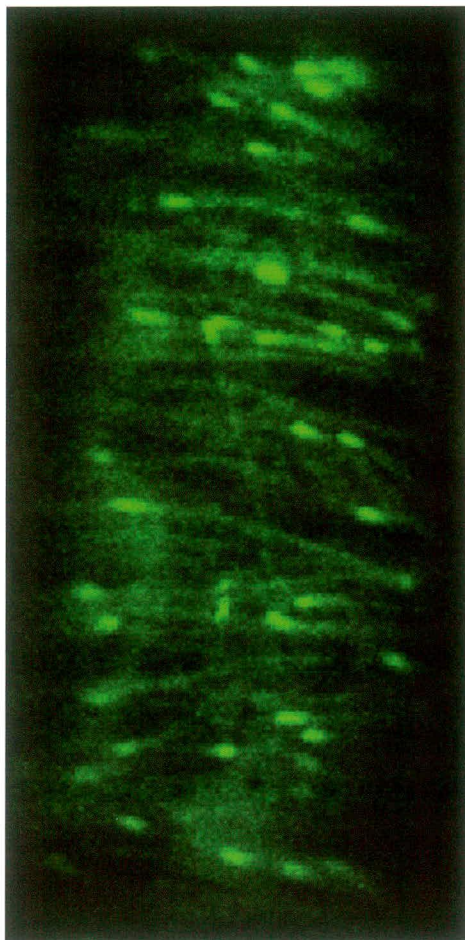
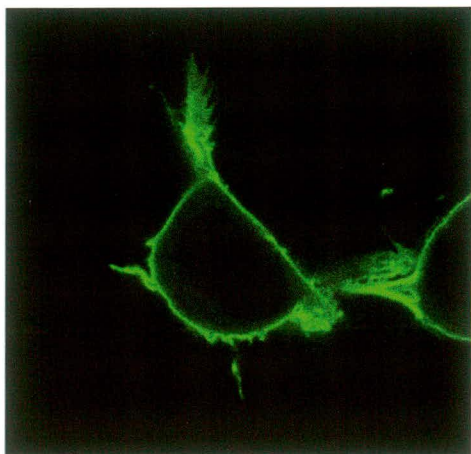
The cell is defined as the smallest living unit. This means that all life starts with the cell and that all organisms comprise one or more cells. This raises the question whether viruses are alive, which cell biologists tend to deny since they rely upon other cells to replicate. Cells exist in many forms and fulfil all kinds of different functions. They can be all-rounders like bacterial cells or the omnipotent stem cells, or highly specialised like the red blood cells whose exclusive function it is to store the protein that transports oxygen in the bloodstream. Nerve cells can be many meters long while egg cells can be as large as an ostrich egg. But most cells are invisible to the naked eye.

The most basic technology for viewing the cell is the light microscope. This enables us to discern some structures such as the cell wall and various bodies in the interior of the cell. With staining techniques other structures can be revealed. This enabled biologists in the late nineteenth century to identify the cell nucleus and the chromosomes within. These thread-like structures, which condense and duplicate when the cell divides, are the genetic material that is transmitted from generation to generation.

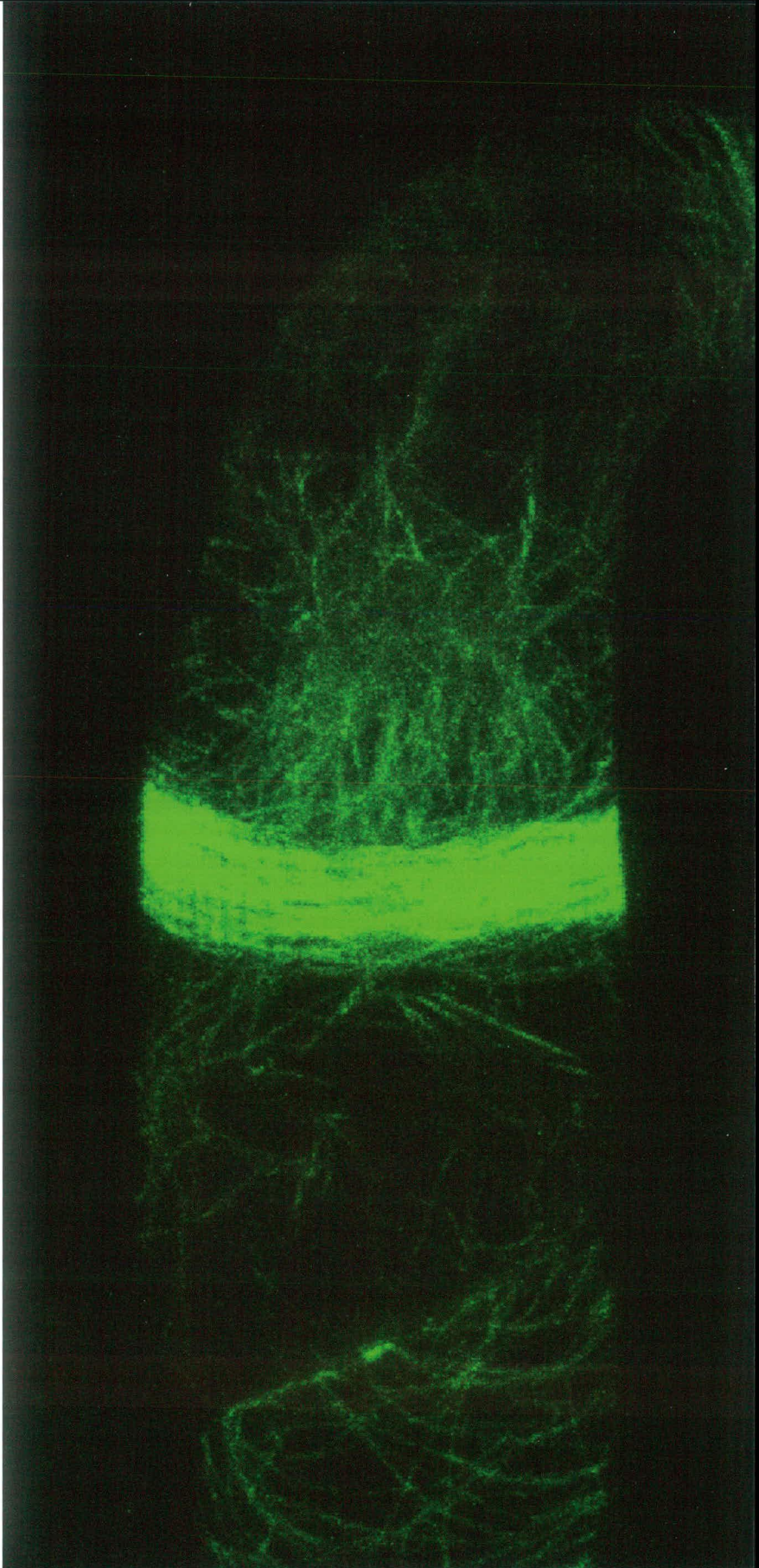
With the development of electron microscopes, more complex techniques of preparation and staining and a wealth of technologies aimed at separating and analysing organic particles, we have been able to detect a multitude of internal structures in the cells of higher organisms that serve different functions such as transport, communication, digestion, energy production and communication within and between cells. These so-called organelles allow the cell to

perform its multiple functions in a localised and structured way. Several studies suggest that some of these organelles may have evolved from independent bacteria-like organisms that were trapped inside the ancestors of the current cells and developed a symbiotic relationship. This would explain why some cell organelles, notably the energy-transforming organelles in plant and animal cells, carry their own genetic material and are surrounded by a double membrane, the inner one thought to derive from the membrane of the original organism and the outer one used by the host organism to engulf it.

Biologists have long attempted to achieve a 'complete' description of the cell with the final aim of reproducing life in the laboratory. Today this would seem to consist of a full list of all the molecules in a cell and their interactions. Whether such a description, stored in large electronic databases, would bring us closer to understanding life's inner functions and enable us to produce life artificially *in vivo* as well as *in silico* remains an open question. But any move in this direction will certainly alter our understanding of what we consider to be 'alive'.



This and previous spread:
Stills from movie by Joachim Goedhart, Merel Adjobo
and Dorus Gadella, University of Amsterdam.
Photo's: Erik Manders



Computer art

■■■■■ Arie Altena
Translated by David Alexander

What can you call art that has been made on a computer? When can you rightly say: this has been made on a computer, it's been made with software, this matters, and that's why we call it computer art? This is not the same as art for which a computer and software were used, but without being an essential part of the production. For example, we rarely call digital photography computer art: we just call it photography.

Lejaren Hiller created the first computer music at the end of the 1950s – music generated by computers in which the sound was processed and performed. Some time earlier, this was preceded by Iannis Xenakis' compositions, in which a good calculator was a necessary tool for working out the equations which would determine which notes had to be played. We call the former computer music, and sometimes the latter, too, even when it is played on 'real' instruments or electronically. Do we call contemporary laptop music computer music? Not always, but sometimes we do: when, for example the sound is produced by software-interactions on the basis of small custom-made software machines.

The first visual computer art – images generated by software – was made in the 1960s in various places in Europe and America, often in scientific and technical laboratories, as these were the only places where there were computers. The output was provided by plotters and calculators.

A lot of such computer art was geared towards research into automatic image generation and visual composition. The artist provided the

rules and the art itself was produced automatically by the computer.

What did this mean for the concept of art? And how can the artist's role be defined? Just like early computer music, visual computer art was very much part of the digitally based aesthetic and cybernetics that were then in full development. Even if most pioneers of computer art made 'finished' objects (the output medium was the plotter, monitors not yet being a standard part of the computer set-up), their poetics stressed a process-based aesthetic.

Algorithmic art and generative art – where art works evolve or come about through the application of rules – existed before the genesis of computers as we know them today. Generative and algorithmic art are connected to the idea of an art work that grows and evolves, changing over time as it interacts with its environment. No two performances are identical.

These days computers are everywhere and not all the art in which they play a role is necessarily computer art. If we bear the twentieth century conception of art in mind, we might say that computer art includes a type of art that investigates its own medium – the computer, the software-instructions. It is an art that is about the preconditions for its own production.

Terms are subject to fashion. Digital art was very fashionable in the 1980s and early 1990s. When I think of digital art, I think of colourful computer-generated images that express being in love with a future in which we can fly through virtual realities. Cyberspace – the final frontier. Or –transposed to 2007 – the hyper-capitalism of the Second Life web environment.

 I like the word computer art. I also like computer art itself – not only the primitive but sometimes surprisingly subtle plotter prints of the pioneers (who have recently been able to count on renewed interest from the youngest generation of artists): the conceptualists, the generative school of software artists with their politico-cultural approach. But most of all I love it when something is ‘made’ – when computer, software, electricity are the building materials with which one plays around, makes knots, links, scripts and programs. That’s a kind of art that is as much about the world as it is about computers.

Cybernetics

■ John Tresch

The term 'cybernetics' refers to a set of approaches for studying the flow of information and communication. It considers how messages are sent, received and obeyed at various points of any system – whether brain, body, computer, factory or society. Using cybernetic terminology, all such systems can be considered as functionally analogous; since their systematic properties depend purely on relations of 'information', they may be treated as identical. Thus cybernetics treats machines and organisms in exactly the same way. Cybernetics first came into existence in a series of interdisciplinary conferences sponsored by the Josiah Macy Jr. Foundation between 1946 and 1953 under the guidance of the MIT mathematician Norbert Wiener. Originally entitled *Circular Causal and Feedback Mechanisms in Biological and Social Systems* the meetings generated a vocabulary for looking at the processes by which systems regulate themselves, merging perspectives from engineering, biology, mathematics, psychology and the social sciences.

The defining notion of cybernetics is the 'feedback loop', the circular causal mechanism of the Macy conferences' original title. Wiener wrote: "The control of a machine on the basis of its *actual* performance rather than its *expected* performance is known as 'feedback', and involves sensory members which are actuated by motor members and perform the function of 'tell-tales' or 'monitors'."¹ Wiener's own first work in the field, during World War II, involved the design of self-correcting weapons: missiles aimed at a target which changed its course, and thus had to

adjust their direction according to input from the external world, i.e. the target's changing trajectory.

To understand cybernetics' approach towards questions of information and control, the word's origin is relevant: the Greek root for cybernetics, *kybernetes*, literally means the helmsman of a ship. Steering a boat is not a matter of simply holding a rudder pointed in a fixed direction. Instead it requires constant adjustments to its position, depending on cues given by several different kinds of sensory input: the feeling of resistance on the rudder's handle, which can require more or less exertion to keep fixed; the tell-tales which indicate the position of the wind; and above all, the visual input of the destination, if one is sailing towards a buoy or landmark. It is not a question of simply setting a course and going: one oversteers, one understeers, and most importantly one 'corrects' the rudder's direction on the basis of the changing signals provided by these indicators. Cybernetics stresses that keeping a steady state or a fixed direction requires constant modifications in response to information gathered from the surrounding milieu.

Another frequently cited example is the thermostat, a device that senses changes in room temperature and uses that information either to increase or decrease the heat supplied to the room. Although the sensor is constantly at work, and the heat source may be modifying its output, the room temperature remains the same. The thermostat is a 'homeostatic mechanism' that uses 'feedback' or self-regulation on the basis of sensory observations of its own state and the state of its environment to maintain a 'dynamic equilibrium'. Cybernetics has applied such notions productively to Watt's steam engine, with its centrifugally spinning 'governor' crafted to

¹ Norbert Wiener, *The Human Use of Human Beings: Cybernetics and Society*. Boston, MA: Houghton-Mifflin, 1954, p. 24.

keep the engine running at a steady pressure. Likewise it has been applied to the adjustments made by the counterbalancing muscles that regulate motor function, and whose disequilibrium results in overcompensation and Parkinsonian tremors. Further, the ensemble of self-monitoring processes directed by an organism's nervous, immune, and reproductive systems – including, especially, DNA – has been analysed as cybernetic loops of information and response. In most of these examples, no 'consciousness' in the sense of an intentional mind is needed. All that is required is 'information' and the sense organs, natural or artificial, to perceive and act upon it.

For cybernetics, information is order – a pattern of differences. It may be as simple as the difference between a 1 and a 0, the presence or absence of an electrical signal or the codes and cues running through the most elaborate calculating engine, brain, body or ecological system. Information resists the universal tendency towards entropy or loss of order, a tendency in both machines and organisms. This identification was visible in the early robots designed by the first generation of cyberneticists. These 'sensitive' machines such as Grey Walter's light-seeking 'tortoises' (which exhibited 'social' and 'narcissistic behaviour') and Claude Shannon's labyrinth-tracking 'mouse' observed and responded to their environment.

Beyond such whimsical identifications between animals and machines, cybernetics has had a major impact on the sciences of life. It has contributed heavily to the metaphor of DNA as 'information'. According to this widespread approach, DNA is treated as a script or program that is faithfully replicated and enacted in an uninterrupted chain. This assumption underwrote what Francis Crick called the 'central dogma of molecular biology':

that during the process of replication, DNA and RNA do not interact in any significant way with the cell's nucleic acid. Crick later said that he could just as easily have called this claim a hypothesis; it was simply an unproven assumption that could be used to guide research.² Interestingly, however, this 'dogmatic' assumption implies that DNA itself functions as a kind of 'dogma' within the system of a cell: the 'message' is received and replicated with the same faithfulness and determinism as an unquestioning member of a church obeys orthodox proclamations.

Yet the process of information transfer implied by the central dogma may be critiqued in terms that also derive from cybernetics. The field's basic concern is to establish the conditions under which a message can be sent and received with integrity. This means that the deterministic, encapsulated transmission implied by the central dogma can only be assured by constantly monitoring its passage and sites of possible modification. Cybernetics must embrace the endless opportunities for alterations of the message: disturbance, randomness or *noise*. This means careful attention all along the course of the message to the mechanics of sending and receiving, securing channels, passing through various states, and maximising redundancy. What is true of sound transmission is true for genetic information: "the efficient use of amplitude modulation or any other form of modulation must be supplemented by the use of decoding devices adequate to transforming the received information into a form suitable for reception by human receptors or use by mechanical receptors. Similarly, the original message must be coded for the greatest compression in transmission".³ There are many steps in the coding and decoding of a message, many filters and templates that shape and reshape it on its way to its destination. The moral for the

² Francis Crick, 'Central Dogma of Molecular Biology' in *Nature* no. 227, 1970, pp. 561-563.

³ Norbert Wiener, *Cybernetics: Control and Communication in the Animal and the Machine*. New York: J. Wiley and Sons, 1948, p.67.

geneticist is clear: cybernetics-inspired approaches of 'systems biology' draw attention to the loops of priming, verification and adjustment established between DNA, RNA and their surrounding nucleic milieu. The shortest distance between two points requires many detours through regions that had been set as off-limits by the central dogma.

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Broader lessons can also be taken from cybernetics for the study of life. While DNA is surely involved in processes of growth, at a higher logical level the organism itself is constantly involved with and shaped by its environment. The overlapping loops of information that regulate DNA replication are part of much bigger systems of cells, tissues, organs, all the way up to social groups, ecosystems and the planet as a whole. In other words, the 'reductive' programme encouraged by the metaphor of DNA as information is constantly undermined by cybernetics' focus on system and context; there is always a wider pattern to consider. For example, the growing field of epigenomics considers variations in regulatory sequences and inheritance due to factors beyond genes, looking, for instance, at variable processes of DNA methylation. For epigenomics, the limited system addressed by the central dogma fails to explain the "multiplex modifications" actually involved in inheritance.⁴ Further, the 'second-order cybernetics' developed by Heinz von Foerster concentrates on the impact of the observer upon the system being observed. In cognitive science, these cybernetic themes have directed attention away from the assumption that thought can be reduced to a linear, determinate programme or algorithm. On one hand, cognition is treated as an emergent property of various parallel processes; on the other, consciousness is considered from the point of view of the organism's enmeshment with its environment and its physical embodiment.

Cognition and perception become 'relational' phenomena emerging at the interface between an observer and the system of which he or she is a part.

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In these cases 'information' is treated as much more than a direct, deterministic transmission between sender and receiver. Instead, multiple layers of mediation, multiple levels of causality, and the temporality of an ongoing 'process' are implied. Wiener spoke of the opposition between the reversible time of Newtonian causality and the irreversible time of growth and development. Since the self-regulating machines he described are endowed with circular causality – their future state may be unpredictably modified according to changes in their environment – machines now also partake of irreversible time. He drew a philosophical conclusion: "Vitalism has won to the extent that even mechanisms correspond to the time structure of vitalism."⁵

■■■■■
Yet for Wiener this was no cause for celebration by those who believe in a distinct substance of life or thought. Rather, "this victory is a complete defeat, for from every point of view which has the slightest relation to morality or religion, the new mechanics is fully as mechanistic as the old."⁶ However, Despite Wiener's warning, cybernetics has, almost since its inception, fostered thinking with close affinities to religion. To name just a few: Gregory Bateson's inquiries into the informational criteria of 'grace' and 'the sacred'; Marshall McLuhan's cross-fertilisation between cybernetics' interest in automation and media with Teilhard de Chardin's 'divine milieu'; Joanna Macy's work on the common ground between systems theory and Buddhist notions of dependent origination and Francisco Varela's influential theorisation of 'autopoiesis' or the principles of self-organisation in cells, organisms, and

⁴ Pauline A Callinan and Andrew P. Feinberg, 'The Emerging Science of Epigenomics' in *Human Molecular Genetics* 15, (Review Issue 1) 2006, p. R95.

⁵ Norbert Wiener, op. cit., 1948, p. 44.

⁶ *ibid.*

⁷ Gregory Bateson, *Steps to an Ecology of Mind: Collected Essays in Anthropology, Psychiatry, Evolution, and Epistemology*. Chicago: University of Chicago Press, 1999 (1972)

minds.⁸ Perhaps cybernetics' alignment with religious thought has something to do with its quasi-monistic ontology, its interest in big questions such as the origins of life and consciousness, or the extremely general, even cosmological sweep of its arguments. Whatever the specific causes, this proof of cybernetics' adaptability shows that despite its role in reductive approaches in biology, its treatments of feedback, learning and development have encouraged open-ended and frequently unorthodox investigations into the nature of thought and life.

⁸ Francisco Varela, Evan Thompson and Eleanor Rosch, *The Embodied Mind: Cognitive Science and Human Experience*. Cambridge, MA: MIT Press, 1991.

Development: who and where are the main players?

Cor van der Weele

In accordance with the idea that genes are the main causal agents in biology, and inspired by the discourse of information and computers, the metaphor of a genetic program took hold of developmental biology in the course of the 1960s and 1970s. DNA provides the program that controls the development of the embryo; that was the basic idea guiding developmental research. Although the idea is still around, it has lost much of its explanatory power. Biologists are experimenting with other images of development. Perhaps development is better seen as a meeting, a village or a jazz orchestra? The newer images tend to reflect complex processes with multiple resources, or multiple actors involved in a more or less chaotic and democratic process. DNA is among those resources or actors, and it is sometimes downplayed as being just the servant of proteins, or the messy memory of the cell. What happened?

The other actors and resources which have gradually become more prominent were not all new. For example, already in 1909 the biologist Woltreck discovered that the morphology of water fleas is influenced by the presence of predators. He (rightly) thought that the predators exerted their influence through some

chemical, and he coined the term 'reaction norm' in order to grasp and visualise this idea of environmental influence in development. Because causal attention in biology was heavily focused on genes, reaction norms remained marginal, but from the 1960s onward, Richard Lewontin and others tried to revitalise their conceptual and experimental importance. Lewontin stressed that DNA is a very passive molecule, which can do nothing by itself and is regulated by many other molecules. A reaction norm perspective highlights the difference the environment makes, genes being equal, rather than the other way around. It foregrounds the causal influence of temperature or altitude or food or pollution in development, thus exposing the plasticity of organisms and the need for an ecological approach to development.

Newer insights into DNA have not only confirmed DNA's passivity but also surprisingly have shown it to be far messier than it had been assumed to be. In the 1980s, it was found that large stretches of DNA consisted of endless repeats that did not belong to genes, seemed to have no function and were therefore called junk DNA. The finding did not fit comfortably with the idea that DNA was the well-organised master of the cell. Since that time, the picture of genes and how they function has grown ever more complicated. Here are some of the phenomena:

- Fragments of DNA that are transcribed to make mRNA and protein (exons) are dispersed amidst large stretches of seemingly non-coding DNA (introns). Only about two per cent of the human genome codes for proteins.
- It had been assumed that complicated organisms have more genes than simple ones. Humans were expected to have more than 100,000 genes. But humans have probably no more than 25,000

protein-coding genes, about the same amount as the small mustard weed *Arabidopsis thaliana*.

- Stretches of mRNA are spliced and put together in different ways. mRNA is also 'edited', that is to say that individual bases are added, deleted or modified. The result of such processes is that there can be many times more different proteins than there are different genes. In humans this is certainly the case.
- RNA is much more variable and influential than was formerly thought. Micro-RNAs and other RNAs influence many cellular processes. In part at least, such RNAs are transcribed from introns, that is, 'junk' regions, which are not so completely junky after all.
- DNA is surrounded by a coat of proteins. The state of this coat influences gene expression and this state in its turn is influenced by many factors from the cellular and extra-cellular environment; through this coat genes are activated and silenced in many complicated ways.
- Because of overlapping transcription, the idea of discrete genes is vanishing. More generally, given the above phenomena and more, it is now hard to find satisfactory definitions of the gene concept and it becomes doubtful to what extent the gene is still a useful unit within the genome.

Genes and the genome are still very much at the centre of biological attention, but given the complexities in their structure and regulation, attention is also shifting to RNA and proteins and further. DNA turns out to be more chaotic and vulnerable, and its expression more subject to regulating and modifying influences than the old image of the genetic program suggested. There is now a tendency to regard it as memory or data rather than a program, as

servant rather than master. New putative main players are proteins, cells, organisms or organism-environment systems. A dominant successor to genetic programs has not yet emerged. But we may wonder whether we really need one favoured metaphor, one favoured level of causal analysis or one favoured main player.

DNA diagnostics for hereditary breast/ ovarian cancer

■■■■■ Marianne Boenink

"I will probably die relatively young", Iris Leffert often stated until recently. After all, her mother suffered from breast cancer at the age of 62, her grandmother died aged 56, probably from ovarian cancer, and some years ago a cousin even died from breast cancer at the age of 42. Moreover, cancer in general seems to run in the family. Iris always thought it best to be realistic and to get as much out of life as she could: who knows, she might not be here next year.

■■■■■ A talk show she saw on TV recently, however, made her think. It discussed a new test for genetic breast cancer. Apparently the doctors can now tell from a drop of blood whether you are likely to get breast cancer. Moreover, if you are, they can remove your breasts in advance. Some people in the programme thought this too drastic a solution ("this means cutting a healthy body!"), but Iris is not sure. If it allows you to live longer without continuous worries about your health, it might be worth it. She decided that she at least wanted to find out more about this simple test.

■■■■■ Today is her big day: she finally has an appointment with an outpatients' department

for clinical genetics. She was asked to fill out an extensive form on her family's history of disease in advance. It has taken her quite some time to collect all the names, birth and death dates, diseases and causes of death of her family members, and some lines she had to leave blank.

■■■■■ When Iris sits down in the consultation room and unfolds the form, Dr Summer says: "I see you have done your homework." The clinical geneticist explains that she will first draw up a pedigree on the basis of the family information. After about half an hour, Dr Summer thoughtfully concludes: "Well, I'm not absolutely sure, but it seems to me that there are indeed more breast cancer cases in your family than you would expect on average, so there might be a genetic factor at work. You probably thought so yourself, didn't you?" Iris admits that this is no surprise to her.

■■■■■ Dr Summer continues: "In order to be sure, however, we would need your late grandmother's medical records. Did she really have ovarian cancer? It might have been cervical cancer, you see; in the past doctors were not always able to distinguish them correctly. This is highly relevant information, because breast and ovarian cancer are genetically linked, whereas breast and cervical cancer are not. And it might be helpful to have your mother and cousin's records as well. So the first thing I want to ask you to do is to ask your mother for permission to retrieve her and her mother's medical records, and to approach your uncle and aunt for your cousin's records." Iris agrees to give them some consent forms, although she does not yet know how to approach her uncle and aunt. After all, her request might reawaken their grief.

■■■■■ "But even if we stay with the preliminary diagnosis of hereditary breast cancer," Dr

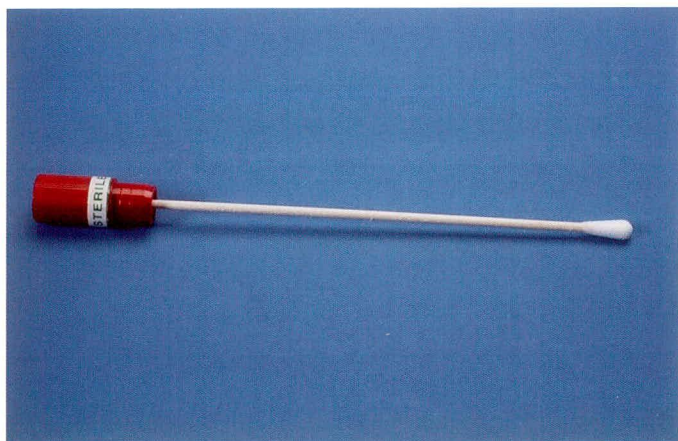
Summer says, "I cannot offer you a DNA test right away. This test does not yet enable us to see all genetic errors, you know. At this moment, the test looks for errors, or mutations, in two genes: BRCA1 and BRCA2. In about twenty-five per cent of all families with a pedigree suggesting hereditary breast cancer, a mutation is found. So in three quarters of all cases, while we indeed think a genetic factor is at work, we cannot identify it exactly. As a result, if we test you right away and do not find a mutation in your blood, we won't be sure what this means. Maybe your family does not carry a mutation at all. But it may equally well be that there is a mutation unknown to us, for example in a gene that is not yet identified as being related to breast cancer. And in this case, you may or may not carry the unknown mutation. So it would not be very useful to test your blood immediately. However, if your mother, who has had breast cancer, would be willing to donate some blood, we can examine her DNA first, and if we identify a mutation in her blood, we may search your blood for this mutation as well. So, my next question is, would your mother be willing to have a DNA test? And, most important of all: are you prepared to ask her?"

■■■■■
"Oh, I really don't know", Iris answers. "My mother is just glad she has survived this disease, and she feels she has put it behind her now. Usually she is quite uncomfortable when someone reminds her of it."

■■■■■
When Iris leaves the room about half an hour later no blood has been taken. She has been provided with an information brochure of approximately thirty pages about hereditary breast cancer, its diagnostics and preventive options. She also has several consent forms for her family members to retrieve their medical records, and some forms for her mother to indicate her consent to cooperate in DNA

diagnostics. "So much for the simple DNA test for breast cancer," she tells her husband afterwards, "it's going to be hard work for me if I really want to find out about my own risk."

■■■■■
This scene and the characters in it are fictitious; it is based on observations of consultations on DNA diagnostics for breast cancer in a Dutch centre for clinical genetics during 2002 and 2003. I want to thank the clients and medical professionals who enabled this research for their openness and cooperation.



Top:

Bottom:

Figure 5: 'Sterile' cheek swab for collecting evidence.
Photo: Michael Lynch

DNA fingerprinting

Michael Lynch

When molecular biological techniques were first used in the mid-1980s for purposes of paternity testing and identifying suspects from trace evidence, three analogies were used. The most famous was 'DNA fingerprinting' – the technique developed by Sir Alec Jeffreys was patented under that name. Figure 1 (overleaf, bottom left) is an example of an early DNA 'fingerprint' comparing a blood stain from an unknown individual to several suspects. The other two analogies were with 'bar codes' and 'signatures'. All three analogies suggest an expression or mark of individual identity. The early form of profile also resembled a bar code.

Figure 2 (overleaf, bottom right) is a schematic diagram, showing an idealised sequence: evidence collected from individuals or from crime scenes is run through a series of laboratory procedures to become a legible graphic device – a DNA profile.

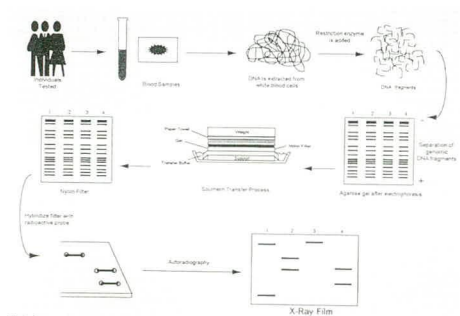
As the schematic diagram illustrates, a DNA profile is extracted from a much more complicated matrix of bodily material – it is not a direct visualisation of individual DNA, but an imprint of an abstracted sample of selected DNA fragments that vary from one individual to another.

In addition to being abstracted from bodily material and trace evidence, a DNA profile is abstracted from a laboratory matrix in which sources of 'contamination' threaten the legibility and legal credibility of the evidence. Sociologists of science often tell us that

laboratories are 'messy' places, from which purified samples and clean data are abstracted and inscribed. Figure 3 (overleaf, top) is a photograph from a state-of-the-art forensic laboratory showing evidence samples collected by the police stuffed into a closet and awaiting analysis. The question is: How does 'clean' data emerge from such a mess?

Purification is not simply the end product of a series of practices, it is built into the walls, the equipment, the warning signs and the paper forms that pervade the laboratory. These administrative devices produce a fragile order from which 'DNA' emerges as a powerful form of techno-legal evidence.

Signatures and bar codes are no longer metaphors; they are devices to ensure the continuous identity of DNA evidence when samples move through the laboratory. Real bar codes stand guard over metaphorical bar codes.



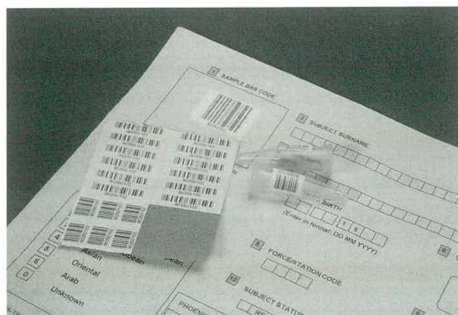
Top:
Figure 3: Mess. Photo: Michael Lynch

Bottom, left:
Figure 1: DNA fingerprint. Photo: Michael Lynch

Bottom, right:
Figure 2: Schematic DNA Typing. Photo: Michael Lynch



Determine origin of bloodstain on the	
using the method of STR profiling.	
n/a	
Murder & sexual assault.	
Name and rank of Supervisory Officer	<i>[Signature]</i> Clerk
ing submission	
of delivery of articles to laboratory - *By Hand, Registered Post or Recorded Delivery	
Name (Block letters)	
Signature	
Name (Block letters)	
Signature	



Top:

Figure 4: Sterility – barriers, clothing, colour coding.
Photo: Michael Lynch

Bottom, left:

Figure 9: Clerical signature on a form to certify
a transfer of evidence. Photo: Michael Lynch

Bottom, right:

Figure 8: Bar codes on a form used to track samples.
Photo: Michael Lynch

DNA molecules in the cell

■■■■■ Astrid Visser

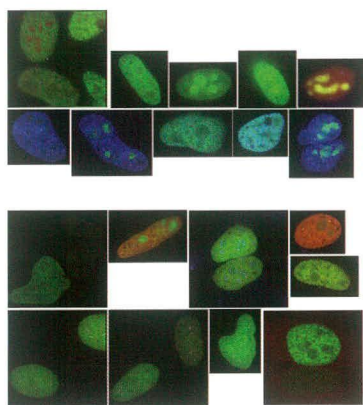
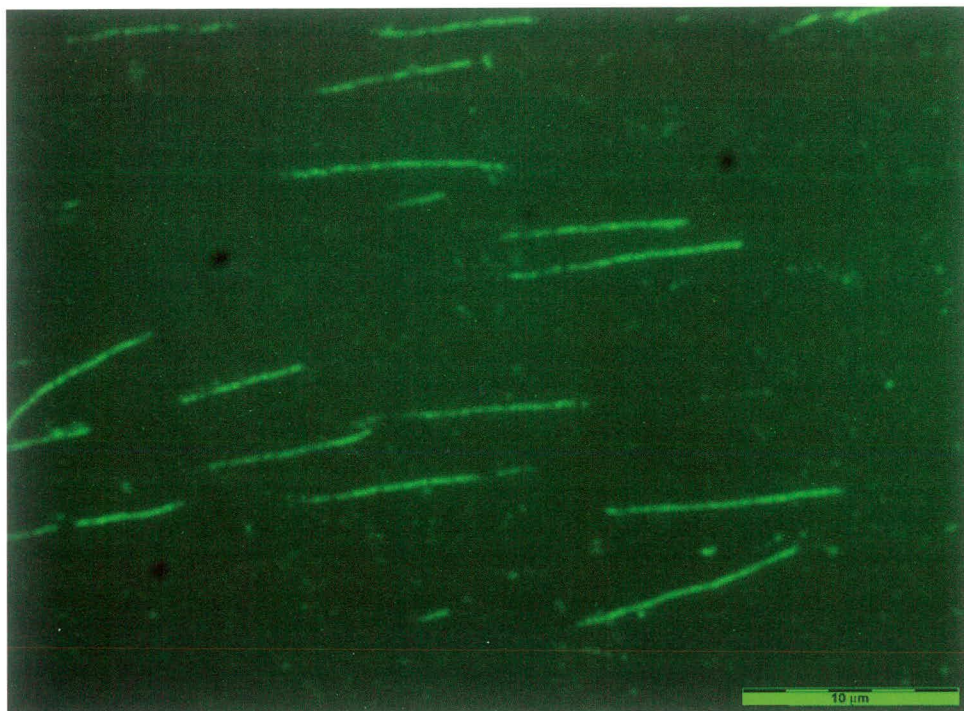
The double stranded DNA helix can form extremely long molecules. Human chromosome 1, for example, is made up of 245,203,898 base pairs. Because each base pair is 0.33 nanometres (10^{-9} metre) wide, the entire length of this single DNA molecule spans an enormous eight centimetres.

■■■■■
The DNA in all forty-six chromosomes together spans some two metres. However, within the cell, this length is tightly packed into a cell nucleus with a diameter of approximately ten micrometres (10^{-6} metre). Therefore the DNA has to be packed efficiently so as not to get knotted. Imagine squeezing a hundred kilometres of sewing thread (which corresponds to two metres of DNA at an enlargement of fifty thousand times) into a space hopper. As an average gene spans ten centimetres at this scale, it is easy to understand that the way the DNA is packed plays a crucial role in the cell's ability to find and express the right genes, which are scattered across the chromosomes.

■■■■■
The DNA is packed intensively. Firstly the double helix is wrapped around complexes of 'histone' proteins (the so-called nucleosomes), like a pearl necklace. This necklace is then folded into a thicker chain, similar to an old-fashioned telephone cable. This cable is again compacted in so-called higher-order structures and domains. The exact way the DNA is packed is under active investigation. The packaging of the DNA helps to regulate which genes can be activated and

which cannot, and therefore determines which proteins are made.

■■■■■
Each cell in a body contains the same DNA, however each type of cell makes different proteins. It is now clear that the particular proteins packed within the DNA also help to determine that a skin cell is a skin cell and a muscle cell is a muscle cell. At the molecular level it is now known that the structural proteins – the histones – within the DNA are modified locally by small chemical additions. Together with several other molecules, these histone modifications form a regulatory layer on top of the DNA. This regulation is called 'epigenetic'. The Greek prefix 'epi' means 'upon, beside or above; thus over and above that which is contained in the DNA sequence. Like a recipe book, the DNA code tells us what can be made, while the epigenetic code influences which recipes are used in any particular cell (resulting in the difference between a fancy four-course dinner or fast food). The answer to the philosophical question: 'Who are we?' thus lies not only in our DNA, but also in the integrated epigenetic layer above it.



Top:
Individual DNA molecules. Photo: Astrid Visser

Bottom:
Images of cell nuclei made by fluorescence microscopy. A number of proteins that organize the DNA are tagged with a fluorescent label.
Photo: Astrid Visser

Folies vegetales

Bruno Latour

Is it a scientific demonstration? Is it the poetical dramatisation of a scientific experiment? Or, on the contrary, is it a subjective aestheticisation of a piece of nature? Or a beautiful poem about nature? Or a wildly subjective interpretation of Darwinism? It is difficult not to ask these questions when viewing *Folies Végétales* by the artist, gardener and botanist Patrick Blanc in the Espace EDF Electra in Paris.¹

One exhibit, for instance, was especially striking: two identical versions of an environment of rocks and plants: one plot was brightly lit while the other received only one per cent of the sunlight provided to the other. Not surprisingly, the first plot was a rampant abundance of vast tropical plants while the second displayed merely a few sparse patches of stunted specimens. But to our great surprise, we slowly discovered that the first plot harboured very few animal species while the other, because competition is almost impossible with such rare resources, had become the habitat for many more different species, each occupying its own impoverished patch. With ample space and thus no need to encroach upon, let alone compete for, their neighbours' space, each species was able to thrive. One plot was bright and lush, but with little diversity; the other was dark and poor but with a proliferation of species, all else being equal.

As a demonstration it was indeed striking, as striking as those before/after adverts for hair transplants. The label's explanation and Patrick Blanc's own gloss on this demonstration, was that competition is not a general fact of nature and that biodiversity is better served in

environments with very scarce resources. One cannot help seeing in this work of art a moral lesson on the new global order: social Darwinism is not as simple as the *Wall Street Journal* makes it out to be.

And yet the conversation between art and science has been made terribly boring by a more important (and more ancient) distinction between those who are able to speak 'literally' and those who speak only 'figuratively'. The 'two cultures' fallacy is not built on any other foundation. This distinction is incredibly resilient despite the fact that even a quick glance at any scientific document proves that it is entirely devoid of any practical meaning: scientific texts comprise merely figures.² As Michel Serres summarised many years ago: "The only myth is the idea of a science freed from all myths".

The difficulty, of course, is to go beyond this traditional distinction without being immediately understood as saying that scientific discourse is mythical, poetical, figurative or rhetorical and thus as bad as literature. To overcome this knee-jerk reaction, it is necessary to abandon the very distinction between literal and figurative, and to become attentive to an entirely different phenomenon: what happens to the figures mobilised in documents so that one of the effects they produce is to leave behind them the certitude that some pertain more to fiction while others pertain to the establishment of sturdy referential chains?³

No matter whether you wish to talk about the disintegration of atoms, the worm population in the vents along the Atlantic rifts, what happens to water droplets in a rainbow, what you would see from the other side of the Moon or what sort of differences there are in tropical jungles, between what thrives at the edge of forests and what grows under the dark protection of the canopies, you have to populate your

¹ Patrick Blanc, *Folies Végétales*, Espace EDF Electra, Paris, 8 December 2006 until 7 April 2007.

² Françoise Bastide, *Una notte con Saturno. Scritti semiotici sul discorso scientifico*, Rome: Meltemi, 2001.

³ See: Frédérique Ait-Touati, *Cosmopoetics. Seventeenth-century Cosmological Literatures*, Cambridge: Trinity College, 2006.

description with figures endowed with some sort of activity and which undergo some transformation along the way. So, in that sense, if a scientific text had to be literal rather than figurative, it would be entirely mute. Saying nothing at all is the only way to be literal.

And yet, we do actually mean something if we say there is a difference between, let's say, Cyrano de Bergerac's travels to the Moon and Galileo's sketchbook descriptions of the Moon's mountains. We know that Galileo would never have been able to draw what he saw through his makeshift telescope without a good training as a draughtsman, especially in his perception of projected shadows.⁴ So it is precisely because the distinction between art and science was *not* made in his time that he was able to make sense of this most innovative discovery. We also know that Cyrano de Bergerac was quite conversant with the new sciences and that he was actually flirting with political cosmology to tell a moral tale not so different, in his use of science, from Patrick Blanc's demonstration of what plants have to say about social Darwinism. So, once again, it was because Cyrano was not (yet) living in an age with a clear distinction between art and science that he was able to be so innovative in his literary genre.

Nonetheless, it would be silly not to recognise the differences between ways of travelling to the Moon. Of course this difference is not well understood by the distinction between the literal and figurative – all travel requires the vehicle of figures – and yet this very distinction is symptomatic of yet another distinction, which has been poorly registered. What could it be?

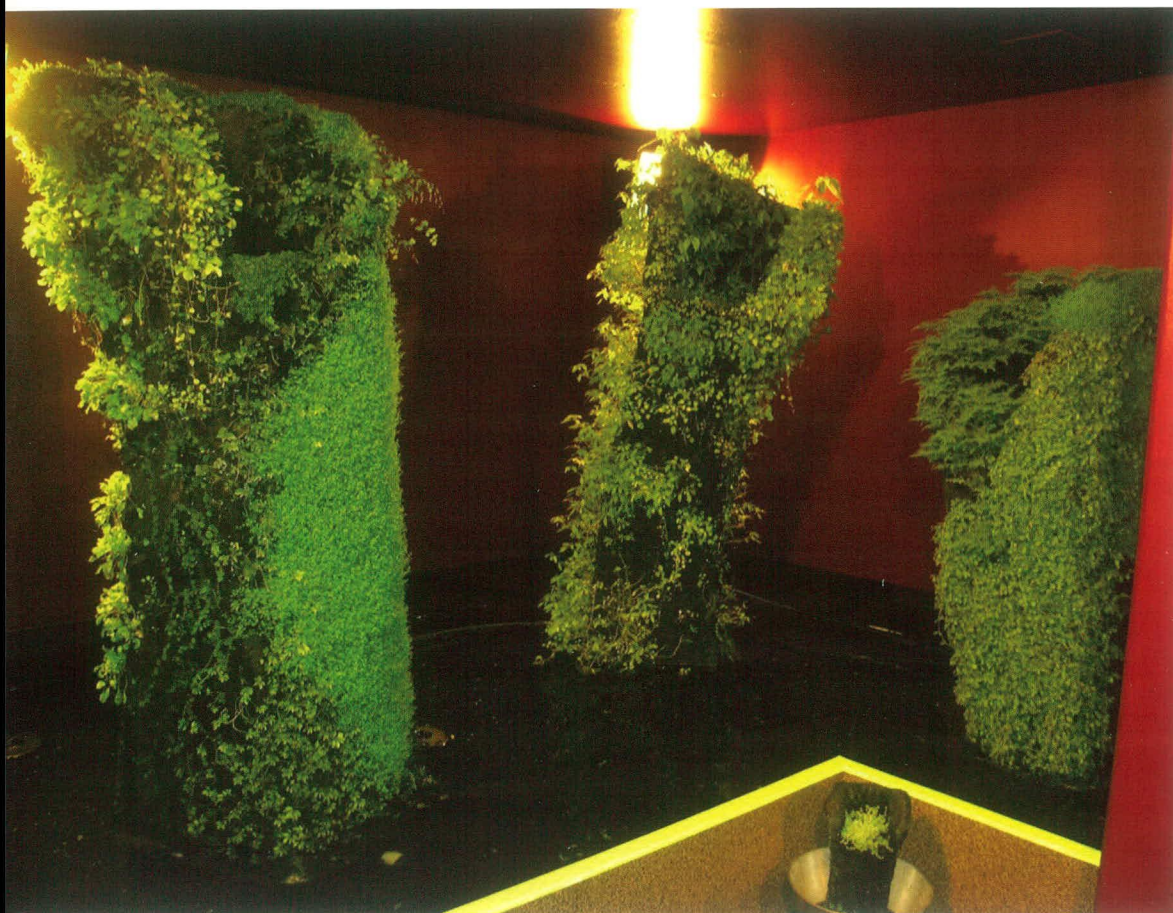
The answer might lie in the ways figures are 'disciplined' in the different registers – and these might be many more than two. To go anywhere you need figures, but if you insist

on bringing them back in order to send them again, thus establishing a two-way regular connection between the site where you do the speaking and the remote site 'about which' you wish to speak, then, and only then, does the destiny of figures generate a difference. Galileo may have used all the resources of projecting shadows and all the tropes of classical education, but he also reined in this procession of images, narratives, drawings, similes, metaphors in a way that forced them to bend themselves to the two-way conveyance of a reference that established his observatory as the apex of a relationship, of which the other terminus was the Moon. Galileo did not speak literally, of course, but he tried to discipline his figures so as to be able to speak *referentially*.

Fiction, on the other hand, does not contain more figures, metaphors, tropes, flowers of rhetoric, similes or dramatisations than 'scientific' texts, but it gives each of them much more leeway and, more importantly, does not charge them with the task of sending references back and forth. They go, but then don't come back so easily. This is why, in reading documents that appear to us as fiction, we tend to say that they are 'imaginative'. Not that 'scientific' texts are not imaginative (what could be more daring than Galileo's narrations and more entertaining than his dialogues?), but they entirely transform the site from which the utterance is made.

To shift from the barren distinction between figurative and literal to another set of nuances between the ways figures are delegated and disciplined, might become even more important in the new age of political ecology, as was demonstrated so beautifully in Patrick Blanc's installations. It is as true now as it was in the age of the Renaissance: we need *all* our skills back. And we need them working together.

⁴ Erwin Panofsky, *Galileo as a Critic of the Arts*, The Hague: Martinus Nijhof, 1954.





Opposite:
Patrick Blanc, Baie d'Along

Above:
Patrick Blanc, Begonia Pavonina

Genetic determinism

Sahotra Sarkar

Genetic determinism is the thesis that the genetic makeup of an individual organism is entirely responsible for what the organism turns out to be. In general, philosophers view determinism as a very strong claim about the nature of the world. Imagine two systems that are identical to each other at any given moment of time. Then, if the systems are deterministic, they will continue to be identical at every future moment of time no matter what happens. Understood in this way, genetic determinism is trivially false. Consider the case of two identical human twins, who are genetically as identical to each other as biologically possible in sexually reproducing organisms. At the moment at which the initial fertilised egg splits into two distinct embryos, these individuals are identical in their properties. In particular, they have the same DNA sequences in their nuclei. However, imagine that one of the individuals is nourished and well fed through adulthood while the other is starved. In spite of their genetic identity, the two individuals will not be remotely the same, if the second lives at all.

Because of such obvious counter-examples, biologists typically mean a much weaker thesis by genetic determinism, one that is better called genetic 'reductionism', which means that genes are mostly responsible for and explain an organism's structural and behavioural traits, that is, its *phenotype*.¹ This weaker claim is all that is usually at stake when someone claims that genes are responsible for eye colour, obesity, sickle-cell disease, schizophrenia,

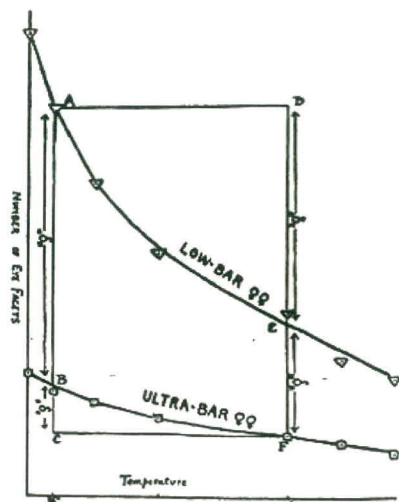
intelligence, criminality, etc. There is no doubt that genetic and environmental factors both play some role in the origin of every trait. But, beyond this non-controversial claim, little meaningful information is conveyed by phrases such as 'has a genetic basis' or 'has a genetic component' for any complex trait, including all those in the list above except eye colour and sickle-cell disease.

The crucial point is that the origin of most traits depends not only on genetic and environmental factors, but also on the complicated history of their interactions during an organism's development. This point is best illustrated using a diagram known as a norm of reaction. Figure 1 is taken from Lancelot Hogben's *Nature and Nurture*, a definitive critique of genetic determinism that was published just when the Nazis were assuming power in Germany armed with their doctrines of genetic superiority over other ethnic groups.² In Figure 1, the two curves describe the response to temperature of the phenotype, eye facet number, of two different genotypes (*low-bar* and *ultra-bar*) of the fruit fly, *Drosophila melanogaster*. For both genotypes, the phenotype varies with temperature, ruling out genetic determinism. More importantly, the two curves are not parallel which shows that the contributions of environmental and genetic factors are not additive: they interact with each other, and there is no possibility of quantifying to what extent either type of factor is responsible for the trait.

From the crimes of the Nazis to more recent attempts to denigrate the intelligence of people of colour, the political harm done by genetic determinism is well known. But genetic determinism, or rather reductionism, is also at stake when irresponsible claims are made about the power of DNA sequences to solve

¹ Sahotra Sarkar, *Genetics and Reductionism*. New York: Cambridge University Press, 1998.

² Lancelot Hogben, *Nature and Nurture*. New York: W. W. Norton, 1933.



biological and medical problems. These were among the promises made in the late 1980s to initiate the Human Genome Project with inordinate amounts of public funding.³ Any claim that a person's behavioural capacities or susceptibility or resistance to a disease can be deduced from the individual's DNA sequence is an endorsement of genetic reductionism. Complicated norms of reaction that are routine throughout nature show that such claims should be treated with scepticism. In fact, what we have so far learned most from the human genome and other sequencing projects is how little we can determine from the DNA sequence alone. Genomics has given rise to proteomics and, in the last few years, to systems biology. In other words, though the results of these sequencing projects are adding significantly to our biological knowledge, there is no shortcut to investigating the biology of the entire organism.

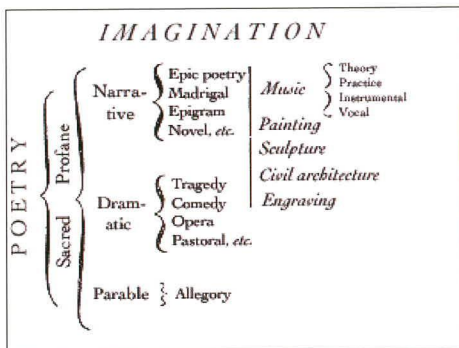
Above:
Norms of Reaction. Norms of reaction for eye facet number dependence on temperature of *Drosophila melanogaster* females (from Lancelot Hogben, *Nature and Nurture*, 1933, p. 384.)

³ Alfred I. Tauber and Sahotra Sarkar, 'The Human Genome Project: Has Blind Reductionism Gone Too Far?' in *Perspectives on Biology and Medicine*, vol.35 no.2, 1992, pp. 220 -235

Metaphors

Nik Brown

The connection between scientific expectations and aesthetics is not arbitrary. The imagination and the future are fundamental to defining aesthetics as a discipline from around the 1700s. In *The Modern System of the Arts* (1965) Paul Kristeller traces the first real connections between aesthetics and the imagination to Joseph Addison, whose essays on the imagination first appeared in *The Spectator* in 1712. It is important to note, as Kristeller does, that as aesthetics develops as a discipline during this period, the arts become synonymous with the imagination, especially in Germany. Aesthetics is literally imagination, the mind's eye, envisioning. He makes note of an engraving printed in Weimar in 1769 representing the tree of the arts and sciences – putting the visual arts, poetry, music etc. under the general branch of imagination.



The designation of aesthetics to imagination is part of an incredible jostling, pushing and shoving, as key thinkers of the period work out different and competing schemata separating one discipline from that of another.

Nevertheless, aesthetics comes to be variously attached to the imagination, the sublime, emotions, sentimentality and beauty in work as diverse as that of Goethe, Kant, Burke and numerous others. But there are striking contemporary illustrations of the way aesthetics and science have been drawn closely together, if indeed they were ever separate. For instance, let's look at the branding – or rather the rebranding – of biotechnology at the close of the twentieth century.

The aestheticisation of the biotech future

Aestheticisation plays a crucial role in directing the futures of science and technology, both in terms of actual experimental practice and wider cultural portrayal. The following story may be familiar to some, but for me it has come to represent one of my favourite recent episodes in the politics of bioscience aestheticisation. In the late 1990s, as the debate over GM reached its peak throughout much of Europe and elsewhere, a representative conglomerate of European and American biotechnology companies (EuropaBio) commissioned a consultancy report from the public relations firm Burson-Marsteller. In the worlds of industrial and environmental public relations, Burson-Marsteller has earned a reputation for managing numerous public relations disasters – including the Exxon-Valdez oil spill, the Bhopal tragedy and even the BSE crisis in the UK – and proved itself capable of reshaping deep-rooted perceptions of high-risk sectors ranging from the nuclear to the petrochemical industries. Controversially, its 1997 biotechnology consultancy report was leaked.

What caught my eye at the time was the way the report stressed the importance of the imagination and the need for a new way of steering the debate towards intangible and aesthetic considerations of future values. In its

Above:

The encyclopaedia of Diderot and d'Alembert 1769

recommendations to the EuropaBio group, Burson-Marsteller made what was to become a highly prescient set of recommendations. In particular it suggested that the biotech industry should move away from issues about facts, messy material squabbles about health, risk and hazard and instead start to offer 'symbols' – a new qualitative vocabulary capable of fostering, and I quote: "hope, satisfaction, caring and self-esteem".

■■■■■

A debate conducted within the highly restrictive confines of variously challenged 'truths' had in effect resulted in two things. First, it had distracted consumers, the market and policy makers from being able to grasp the promissory potential of the future of GM products. The closed present tense of current and past truths had occluded the future open tense of potential and possibility, or so Burson-Marsteller believed. And just as significantly, they recognised that given the normative positions assumed by most parties within the European controversy, all truths would be continually and unremittingly open to challenge. Science and technology studies scholars would recognise in this the ubiquitous problem of infinite epistemological regress so common to controversies involving incredibly complex proofs circulating in volatile cultural and epistemological environments. The only hope would lie in a widespread shift in the basis of the biotechnology debate from irreconcilable and untrusted truths towards the nascent and as yet deferred potential of a utopic technology to mesh with deeply held cultural values of progress, the future of nature and enlightenment advancement. A romanticised nature had become somehow diametrically opposed to technology in the debate and biotechnology would have to make a new bid for compatibility with the future of nature and life. This would depend on laying claim to future-oriented abstractions rather

than messy details.

For Burson-Marsteller, biotechnology had become negatively entrenched in a closed and circular controversy about evidence. Its first recommendation was therefore to stay away from the problem of truth, describing facts as the killing fields of the bioindustries:

"Public issues of environmental and human health risk are communications killing fields for bioindustries in Europe. As a general rule, the industry cannot be expected to prevail in public opposition to adversarial voices on these issues... a basic discipline of EuropaBio's communications strategy must be to stay off these killing fields – no matter how provocative the invitation to enter into them may be."

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Instead, the bioindustries would have to substitute a debate about evidence for one about abstract future-oriented values, representing a shift towards more aesthetic and symbolic references. Symbols and values – and especially those eliciting "hope, satisfaction, caring and self-esteem" – would come to represent the bioindustries' escape route from messy evidential regress:

"Symbols – not logic: symbols are central to politics because they connect to emotions, not logic. Adversaries of biotechnology are highly skilled in the cultivation of symbols eliciting instant emotions of fear, rage and resentment. Bioindustries need to respond in similar terms – with symbols eliciting hope, satisfaction, caring and self-esteem."

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Just as importantly, Burson-Marsteller diagnosed this not just as an evidential problem but also quite specifically as an affective or emotional problem about the aesthetic and romantic attachments of people to the complex ideographs of

nature and the rural:

“Food itself is a powerful vector of cultural – and even political – values virtually everywhere in Europe. But these values differ from country to country. And in many parts of Europe there also exists a strong corresponding emotional attachment to idealised images of rural society, farming and the countryside.”
■■■■■

Following Burson-Marsteller’s report to the bioindustries, representational change followed quickly. Members of EuropaBio – such as Genencorp, Pfizer, Eli Lilly, Monsanto and Nestlé – lost very little time in taking this message to heart. Within a year or so, the biotechnology firm Monsanto had rebranded itself with the logo ‘Food, Health and Hope’ – in benign green lettering against a leafy background. More recently still, Monsanto has shifted again to a new level of future-oriented abstraction replacing the former logo with the simple message ‘imagine’. In this way, Monsanto’s new strap line resonates directly with the historical fusion of imagining with the disciplinary formation of eighteenth-century aesthetics.
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This anecdote represents a small episode in the aestheticisation of the debate around science and technology. But, as Mike Michael and I have argued, it is part of a much broader change at the very basis of the politics of the biosciences. In particular it represents a shift from facts and evidence (regimes of truth) towards conducting debates through the meta-abstractions of hope, expectations and the future. Of course, given that such futures are available only through abstraction, that future must be mediated through the evocation, performance and practice of symbols and values as a means of connecting with emotions, desires and longings. This is an illustration of the shift from ‘authority’ to ‘authenticity’.
■■■■■

Modernity and science counterpoised facts against values, the emotions against rational thought, intuition and desire against direct evidence, intangible wishes against tangible proofs. What we are seeing in contemporary debates about biotechnology is evidence of a movement in the modern epistemological picture. The language of rationalistic authority is being supplemented (at the very least) it seems with a language drawn from values and aesthetics with its connections to desire, longing, the imagination and authenticity. In her eponymous book Martha Nussbaum goes as far as to describe this as an ‘upheaval of thought’, in which the capabilities of rationality are losing their effectiveness for popular persuasion. Nussbaum describes these subtle changes as, “intelligent responses to the perception of value”.¹ Nussbaum’s observation correctly diagnoses the rising significance of the affective in the public sphere. Within the contemporary climate, the language of rationality must therefore embody and register its modernistic opposite if credibility is to be successfully sustained.
■■■■■

The change of heart – the shift towards shared symbols and the language of hope and promise – has emerged as a means of belatedly reuniting divergent parties around a joint market agenda. The imagination (or simply ‘Imagine’ as it is now expressed in Monsanto’s company logo) has become a haven for an industry intractably bogged down in deadlocked controversy and debate. The future has here come to represent a means of opening up that impasse, injecting a new scope – a ‘possibility space’ – for open-ended future potential. The imagination is, after all, the basis of an economy organised through ‘promissory capitalisation’ in which latent potential is of increasingly greater importance than present value.
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¹ Martha Nussbaum, *Upheavals of Thought: The Intelligence of Emotions*, Cambridge; New York: Cambridge University Press, 2001, p. i.

The divisions separating futures from presents are increasingly disintegrating. The imagination and the politics of values and aesthetics have become fundamentally integral to determining any number of recent debates in the life sciences. This runs parallel to a crumbling of the distinctions between technicist realism and cultural values. Helga Nowotny, Peter Scott and Michael Gibbons make precisely this point when writing about the role of future-oriented abstractions and their articulation with concrete non-abstractions:

“Visions, images and beliefs cannot sharply be demarcated from knowledge. Far from being dangerous illusions or utopian projections, visions are a precious resource, an intangible asset that may help to provide the necessary (but typically missing) link between knowing and doing... It is important to recognise how visions and images interact and also how wide the gap separating images from practice can become before an uncontrollable backlash is provoked.”²

Far greater attention now needs to be given to the articulation between temporal formations (past-present-future) as well as the disciplinary domains distributed between aesthetically mediated futures and science’s present-dominated realism.

² Helga Nowotny, Peter Scott and Michael Gibbons, *Re-thinking Science: Knowledge and the Public in an Age of Uncertainty*, Cambridge: Polity Press, 2001, p.232.

Reductions

■■■■■ Annemarie Mol

There are a great many techniques designed to know the body. They all have different objectives, and, upon closer examination, they also appear to have different objects. X-rays enable us to know the interior of the opaque body. Look at the white shadows that bones leave on the black background of what is all too hastily called a 'photo' even though it does not result from light. If you inject an opaque contrast fluid into the bloodstream, you can see its shadow as well, as it flows through the body's vessels. Thus, or so it seems, you can see the vessels. Other techniques might assess the concentration of substances in an easily accessible fluid such as urine or blood. Are there bacteria in this urine? What is the level of sugar in this blood? It doesn't hurt to find out. Getting to know about spinal fluid, on the other hand, is painful for the body to be known. And there is more, so much more. A neurologist may test reflexes. When a body is hit with a small hammer on the appropriate sites the limbs respond with sudden, jerking movements. This indicates NORMALITY – OR NOT – or not. When a thermometer is inserted into a bodily orifice, the body emerges as something too cold or too hot.

None of these techniques takes anything away from the body that they seek to know. But there are techniques that do so, quite literally: a sample of fluid or a bite of flesh is carried to a lab in order to examine it. But the resulting knowledge is not a reduction. It does not subtract. It adds. One more image, one more set of numbers, one more version of reality. They all combine to form an ever more heterogeneous body patchwork. Each of them adds yet more complexity to the juxtaposition that preceded it.

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So, too, do the techniques of genetics. Open a mouth. Scrape some tissue from the loose upper layers of the inside of a cheek. There you go, cells enough. Take your material to the lab and engage in knowing it. Count the chromosomes. Look for two X's or for one X and one Y chromosome under the microscope. It's a girl! It's a boy! Mix a few other cells in a grinder, add the appropriate solvents and multiply the parts of the genome you are curious about. The lab is full of wondrous equipment that makes it possible to add more and more knowledge. Confusing amounts of it. Even if countless gaps remain.

■■■■■
For therapies to emerge from all this, something else is needed. Laboratory knowledge is not enough. The golden road to an 'effective treatment' is to test an unproven one in what is called a clinical trial. Where? On whom? How to assemble volunteers? This used to be a matter of asking those people whose problems were to be attended to. If you visited your local hospital as a patient, you might be asked to be a research volunteer. And indeed, you might not only be willing to do so, but you might actually be eager to participate. If, say, you had AIDS and the alternative to being an experimental subject was a certain death, then why not try it? If the experimental treatment worked, you might live a little longer. And if it didn't, you would at least have helped your fellow patients. That would be one more treatment they would not need to be subjected to.

■■■■■
These days research subjects and the patients to be treated are no longer necessarily the same people. Too much money is involved. There are so many rules and regulations and yet (or therefore?) so many slippery slopes. Since all research is risky, why not do it where the risk doesn't count for much? Where it can hardly

be discerned among the overall misery, the abundant poverty and the excess of disease. In places that outsiders are well trained to ignore. This is what happens. These days trials are done in India, Brazil, Argentina and in the Philippines but, mind you, not in the rich neighbourhoods.

■■■■■
The danger of current genetic research practices is not that 'we humans' will be reduced to our genes. Not at all. It is, instead, that some people will be reduced to research objects while the results of the research will be sold – for hard cash – to others, the subjects to be treated. By being turned into an object of genomic research you risk being turned into a reduction to such an extent that, while your genes are being attended to, your problems, diseases, daily concerns and questions are not.

■■■■■
The high hope of the researchers (and of the venture capital behind them) is that something marketable will come out of the trials being carried out around the world. A commercial product. A commodity that many will be willing to pay for. But what about those who are presumed to do the paying: the buyers, the potential recipients of the results, the rich? Are they, in turn, elevated? Or might it be more appropriate to say that they too are being reduced? Reduced to being the consumers they are.

■■■■■
So much for science under capitalism. But, mind you, the questions raised by art are not so different. Here again the question as to how faithful, holistic or true representations or imaginations are is rapidly overtaken by another one. Is it a joy or an honour to be depicted by an artist? The answer does not necessarily depend on how moving and true the image is. Sometimes, maybe, being turned into an image may not quite be what one was hoping for. Instead, it might resemble being devoured.

■■■■■
One might have hoped for food instead of pictures.

■■■■■
And where in all this are *you*? Onlooker. Viewer. Silent public. Buyer. You are made to see. Reduced to eyes? Dreaming that you are an outsider to all this. Dream on!

Literature:

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- Annemarie Mol, *The Body Multiple. Ontology in Medicine*, Duke University Press, 2002.
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Part 2

Artistic commentaries



Above:
Hubrecht laboratory. Photo: Mark Dion



Expertise and amateurship. On the relationship between art and science in Mark Dion's work.

Christine Heidemann:
Interview with Mark Dion at the
Biologische Forschungsstation Alster,
Hamburg, 30 May 2002

Mark Dion has been working on the history of our relationship with nature since the mid-1980s. He is particularly interested in analysing representations of nature in the (natural) sciences as symptoms of ideological discourses. His projects often include a performative aspect, i.e. that Dion himself conducts his artistic practice 'on site', whether in the exhibition space or outside. The results of his fieldwork are often presented as highly detailed installations. Since the mid 1990s Dion has become increasingly interested in archaeology. He has worked on digs all over the world and has exhibited the excavation process as well as the processing of the finds and the cleaned and systematised objects themselves. The following interview with refers mainly to Dion's archaeological projects but also touches upon some of the general aspects of his practice.

CH: I would like to talk with you about your adaptation, or rather appropriation, of scientific methods and the relationship between your way of working and various sciences (mostly biological ones) and the actual sciences themselves. In quite a few of your projects – for example your archaeological digs over the last few years – the performative aspect of your practice is very important. In many of these projects your presence is crucial and you playing with the role of the scientist or with the stereotypes in the reception of this character. To what extent are you concerned with discussing the scientific action itself and the concepts or construction of this action?

MD: I think, in a lot of these projects – even though I'm borrowing aspects of the methodology of the different sciences – I'm not really doing these sciences. Clearly what I'm doing is a kind of hybrid. It is similar to certain elements of the history of these sciences, the way they were practiced in the past, perhaps a hundred years ago. The tools are similar. But what archaeology was in the nineteenth century is very different from what archaeology is today. What I'm doing in some of these projects at least looks, superficially, very much like what archaeologists were doing a hundred years ago or even fifty years ago. But also it looks like what people think archaeology looks like, more than what archaeology actually looks like. If you go to an archaeological laboratory at a university there is very little of that kind of stuff going on. But in terms of people's popular imagination what I'm doing is probably closer to what people think archaeology is than to what archaeology actually is.

Do you want people to recognise this gap or break?

I don't think it is possible to recognise it. If I

want to be able to recognise that, I would have to do archaeology and emphasise just how drastically different this is from what they think it is.

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When you play with the role of the scientist you do not deny that you are an artist. When you put on a white lab coat, for example, it is not a disguise. You are not imitating a character. But you appropriate certain modes of behaviour, of dress. Would you say that there has been a development of these artistic roles since you started in the mid-1980s?

I think the important development comes from the repetition. If you do it once, you can very easily appear to be the expert – in art restoration, in marine biology, in botany, in whatever. But if you do it all of the time and you are changing your roles it is not that reliable any more. Obviously to be an entomologist, for example, is a lifetime job. It takes a minimum of eight years of very serious study to be able to do this at a very high level. And the last thing you're going to do is change your outfit and be an archaeologist. So I think that by shifting these things I really cause a kind of suspicion about the whole relationship to expertise in some way.

There is a serious interest in the amateur. But there is also an interest in Flaubert's Bouvard et Pécuchet, in this kind of absurdist idea of working your way through the sciences. Trying to master one and then getting bored or not finding it fulfilling or not being up to the rigorous work it would take to do it. And then going on to the next one.

■■■■■
How do you deal with questions that people ask about your practice during the working process? Do people ask those kinds of questions?

Yes, and they have some different levels of engagement with it. What do you tell people when they come? It is always a tricky thing. My policy has always been to be very

straightforward about it, to say that I'm an artist, that I'm not an archaeologist, that it is an art project that has some resemblances to an archaeological endeavour. I never present myself as being an official, it's not about pretending.

■■■■■
No, not at all. But your work is really something in-between.

Yes, it is quite complicated because it is neither one thing nor another. It has methodological resemblances to archaeology or biology and at the same time it is visual art and emphasises different things. But what exactly those things are is really hard to say.

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So you don't want to open the black box of science?
No I never want to inform. But in some sense I think there are things we could add to their discourse, precisely along those lines. But it would have to be on their terms as well.

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You once mentioned that there is sometimes tension between you and the scientists you occasionally cooperate with on projects. Do you experience that as a productive tension? How is your communication with scientists?

I think it goes case by case. Certainly with the archaeologists I had very productive connections in Britain and in the United States and there also were some unproductive ones as well. One of the things that these pieces emphasise is the reason people got into archaeology. They were attracted to this field because of a passion for particular kinds of behaviour, for being out of doors, for being engaged with actual stuff. And what they actually end up doing is spending hours and hours on the computer or in the laboratory and spending very little time actually doing what they want to do. But this is the time they heroicise. They often sympathise with my way of working as it is close to the real fieldwork they would love to do.

**Expertise and amateurship.
On the relationship between art
and science in Mark Dion's work.**

Christine Heidemann

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In your working process how important is it for you to stress what you could call the scientific cul-de-sac? When nothing works out the way you expected it to?

I think that all these projects emphasise failure in many ways. Because in many cases we don't find anything. We certainly never find anything of 'value'. That is what everyone always asks.

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When you chose archaeology that obviously reflected your personal interests. But it is also about the relationship between time-consuming scientific processes and the limited nature of the 'results'.

Yes, but that is never seen. I think one of the things that always interest me is the gap between what people in scientific fields do and what the public thinks they do. That is always a very interesting space for me. This gap is filled at its best by scientific journalists, popularisers of science such as Stephen Jay Gould. At its worst it is filled by Hollywood where there is this really quite ridiculous idea of the scientist. I think I'm interested in the middle ground.

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But do you think there is still a large gap between what the public – whatever that may be – thinks about science and what science really means?

I think it is pretty huge actually.

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You often refer to the history of science, to outdated methods and modes of representation. They are interesting because they tell us about historical ideologies and they also influence the way science is conducted today. When you mention 'behind the scenes' lab work it reminds me of how genetic engineering and biotechnology are communicated to the public today. There is a lot going on 'behind the scenes' but only the results are presented outside the laboratory. The public is very sceptical about current developments in this sector and information politics are not always very transparent.

Yes, that is because there is a lot of energy put into public education around biotechnology because it is a potential huge industry. But the public can stop this industry at any time. In order for the industry to continue it has to educate, it has to present propaganda for its cause because there is so much misunderstanding and such a lack of understanding. It is very easy for the public to react against biotechnology and it is suspicious of it. So there is a huge amount of government and private energy being spent on trying to educate.

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But this still leaves a big gap, which needs to be filled from outside government or industry.

Yes. I don't necessarily think that it is my job as an artist to educate the public about science but at the same time I think that is an interesting area. Working inside the area is quite interesting.

Tuboid

Erwin Driessens and
Maria Verstappen

Introduction

Emergence is one of the intrinsic properties of nature's dynamic forces: complex matter-energy flows are capable of spontaneously generating order out of chaos.¹ Under the right conditions, wholes that are more than the sum of their parts can emerge out of the local dynamics of their components. Small changes can sometimes lead to dramatic transformations. Although chaos research tries to explain the generation of the new, forecasting what will happen next remains uncertain. In our work we explore the expressive potential of such self-organisation. We design and build autonomous processes to produce visual results that are unusual and unpredictable. Besides working with physical and chemical processes generating morphological transformations, we use the computer for the development of artificial worlds with emergent properties. Our approach fits the broader research field of Artificial Life.² But whereas A-life knowledge emphasises the 'knowing and understanding' of complex behaviour and self-organisation, we are more interested in 'making and becoming', to give expression to the desire for an activity exploring the unseen, the unimagined and the unknown. In these projects we want to see what happens when you can describe all the aspects of a development and growing process yourself. Not simulating the laws that exist in our physical world, but instead defining an artificial nature, with fictive laws that constitutes a world of its own: a parallel universe that has its own creative principles and expressions. These software systems are capable of creating complex but coherent

images or situations, without determining beforehand what they would look like and without imposing any specific meaning.

Artificial Evolution

Darwinian evolution is the natural process of variation and selection, often summed up by the phrase: "survival of the fittest". This process has led to the creation of many of the complex and wonderful phenomena of our world. Computers are powerful machines to harness artificial evolution to create visual images. To achieve this we need to design genetic algorithms and evolutionary programs. Evolutionary programs allow forms to be 'bred' rather than designing them by hand. Through a process of mutation and selection, each new generation of forms is increasingly well adapted to the desired 'fitness' criteria.

Tuboid is an example of such an evolutionary computer program. It is a program that generates a three-dimensional tunnel by linking up segments that slightly differ in shape at each turn. The continual addition of further segments extends the form infinitely in time and space. The segments are generated by an internal drawing mechanism of four rotating axes that are connected to each other. An almost infinite amount of different drawings can be generated because the length of the axes and their rotation speed are variable. But not every result will be accepted because there is one important criterion that all segments have to satisfy: the circumference of the drawing may not self-intersect. Therefore the software uses an evolutionary component to create the new segments. For each consecutive segment, form mutation and form selection takes place. Every mutation is tested against this criterion – an outline without intersections – only valid settings will be selected and added to the existing form.

¹ Emergence: the process by which properties come to existence unexpectedly.

² Artificial Life: systems, designed by human beings, which provide evidence of spontaneous and unpredictable behaviour and therefore may be called 'living'.

The worm-like membrane can be perceived in two ways, as a space or as a sculpture. By means of real time computer visualisation you can make a virtual journey through the interior, the Tuboid sculptures show the three-dimensional external shape.

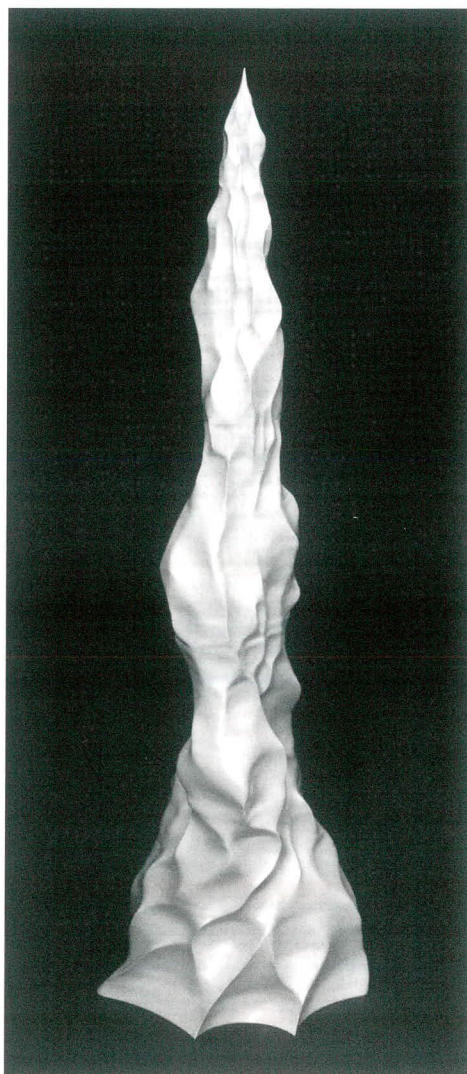
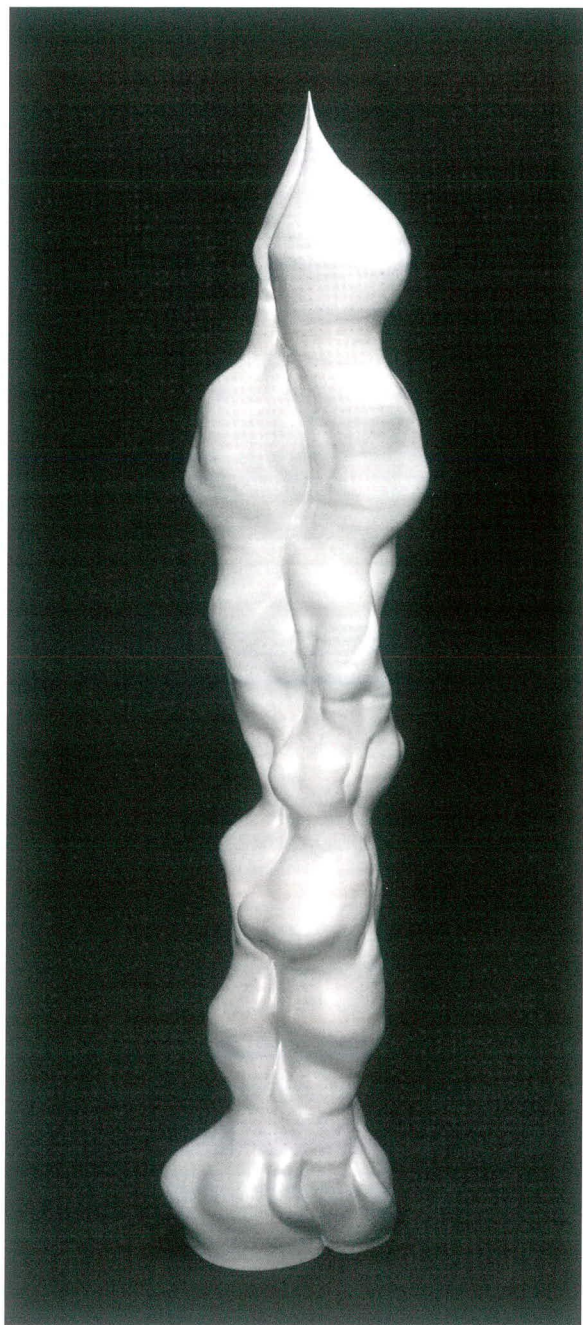


Computational Sublime

Tuboid exhibits a very pure expression, one that makes apparent the internal structure of an artificial nature. This approach in art, encompassing and embracing technology, provide a new possibility of experiencing nature. The artist Jon McCormack introduced the term the 'computational sublime'.³ It is a meaningful concept in relationship to our work. He points out that an important aspect of the sublime is the tension created between pleasure and fear. The pleasure consists of being conscious of things we cannot experience, the fear of things existing that are too vast or powerful for us to comprehend. The feelings of computational sublime are evoked by an uncontrollable process taking place in the computer. The generative process is not directly comprehensible but we are capable of experiencing this by means of a machine. Through real time generation and visualisation of internal processes, the viewer can become overwhelmed by an out of control sensation and simultaneously take pleasure from this spectacle of artificial nature. Mitchell Whitelaw: "Evolution, an idea that has become the most powerful organising narrative of contemporary culture, appears to unfold on a screen. A-life proposes not a slavish imitation of this or that living thing but, at it strongest, an abstract distillation of aliveness, life itself, re-embodied in voltage and silicon."⁴

³ Jon McCormack and Alan Dorin, *Art, Emergence, and the Computational Sublime*, Second Iteration conference proceedings, CEMA, Monash University, Melbourne, 2001, pp. 67-81.

⁴ Mitchell Whitelaw, *Metacreation: Art and Artificial Life*, Cambridge, MA: MIT Press, 2004 p. 5.



Left:
Driessens & Verstappen
Tuboid spiro 3-7, 1999
Courtesy:VOUS ETES ICI, Amsterdam

Right:
Driessens & Verstappen
Tuboid speedA1, 1999
Courtesy:VOUS ETES ICI, Amsterdam



■■■ **Above:**
Photo: Roeland Koning

What do plants signify?

George Gessert

European civilisation is built on grass, oats, rye and barley, but especially on wheat. It was domesticated at least 10,000 years ago, perhaps somewhere in south-eastern Turkey, and spread west from there. Wheat fields brought with them an assemblage of opportunistic organisms: fungi, rodents, birds and many different weeds. From an ecological perspective weeds are not usurpers or out-of-place, but plants adapted to live in disturbed soils. Tillage creates disturbance. One of the most widespread weeds of wheat fields is the corn poppy, *Papaver rhoeas*, which is widely admired for its brilliant red flowers. Plant breeders have selected poppies for colours not seen in the wild, that is, in fields: whites, pinks, oranges and rose-coloured flowers with or without basal spots. Breeding has also produced picotees and forms with extra petals, sometimes so many that the flowers resemble shredded paper.

Demeter is the goddess of wheat and the harvest. Among her attributes are poppy pods and shafts of wheat. 'The goddess with the beautiful hair' was the sister of Zeus. The two were lovers, they inbred like plants and their child was Persephone. You know the story: Persephone caught the eye of Hades, god of the underworld. He asked his brother Zeus for Persephone and Zeus consented, without consulting Persephone or Demeter. One day, while Persephone was picking flowers she noticed a narcissus, "a marvellous, radiant flower ... it smelled most sweetly, so that ... heaven and earth laughed for joy."¹ As she

reached out to pluck this wonderful flower, the earth opened, for Gaia assisted in the plan, and Hades burst forth in a golden chariot driven by immortal horses. He seized Persephone and carried her down into the realm of the dead.

Demeter was overcome by grief and fury, and as she searched for her lost daughter, winter settled upon the world. Wheat and all other crops failed and would not grow again. In time food gave out and humans began to starve. Finally they faced extinction. At this point the gods intervened. Love for humanity had nothing to do with it. The gods do not love us, but they crave the burnt offerings that human beings provide. The smoke of offerings affects the gods like cigarettes, and to protect the supply the Olympians worked out a compromise. The story about the seasons does not concern us – we have better explanations for annual cycles than that a goddess ate pomegranate seeds. What is important is that Demeter grieved at our expense. The great goddess of fertility was – and always will be – willing to let the human race perish. But perhaps 'willing' is the wrong word, since it implies choice. Perhaps Demeter did not choose. Maybe she was driven by forces that she did not understand. So too Hades, Zeus and Gaia – all of the deities – all are driven by forces that they do not understand. The deities are like plants, like our DNA.

We know the story of Demeter and Persephone from the *Homeric Hymn to Demeter*, a sacred hymn that was recited at the Eleusian Mysteries. Every Greek could travel to Eleusis at least once in his or her life to participate in the Mysteries. To the best of our knowledge, in the thousand years that Demeter was worshipped at Eleusis, not a single Greek wrote down the experience of the

¹ *Homeric Hymn to Demeter*, translated by Hugh G. Evelyn-White, Cambridge, MA: Harvard University Press, Loeb Classical Library, 1914.

Mysteries. Probably the experience was literally inexpressible. All that we know is that the Mysteries involved the *Hymn to Demeter* and the 'kykeon', a potion that probably contained ergot, a hallucinogenic fungus parasitic on grasses.²

■■■■■
We have nothing resembling the Eleusian Mysteries today, and nothing equivalent to the story of Demeter and Persephone. Most of our stories are secular, about people pursuing the inward spiral of exclusively human-centred interests. Plant stories have become peripheral and rare. I enjoy *Little Shop of Horrors* but it has nothing to tell us about plants. I was reminded of other possibilities as I prepared to draft these notes. I was in New Mexico and attended a Corn Dance at Santo Domingo Pueblo. The Corn Dance is a fertility dance or prayer engaged in by people of all ages, but most conspicuously by women. The women wore tablitas, flat green headdresses with silhouettes that resemble stepped pyramids and evoke corn. I wondered whether the women represented corn plants. Or did the dance reveal that women and corn plants share an essential identity?

■■■■■
A bolt of lightning is no less awe-inspiring because we do not believe it comes from Zeus. Over the centuries philosophical materialism has grown sublime. But very rarely does science provide us with fully realised stories. More often science leaves us with raw facts, anecdotes, hypotheses and fragmentary images. Science has helped make culture what it is today, a heap of fragments, a global midden.

■■■■■
Some art is like plants and represents nothing except itself. Such art is about materials and process and about how our minds overlay matter with meaning. Art that matters: Pollock's drip paintings; Frank Stella before

he got sidetracked by protractors; Morris Louis, Donald Judd and Dan Flavin, Cy Twombly and Mark Tobey at their best; Robert Smithson when he wasn't trying to make metal look like crystals or treating entropy as if it were black magic; Gerhard Richter's smeared so-called abstractions; colour in Josef Albers and Henri Matisse; brushstrokes in Redon, Chi Pai Shih and the great eccentric painters of the early Ching dynasty – for that matter in almost all of the literati painters; Wolfgang Laib's pollen installations; Andy Goldsworthy's exquisite ephemera; African stripweaves; philosophers' stones and ancient bonsais; chrysanthemums with petals like purple noodles; chocolate-coloured goldfish round as baseballs. Such works don't pretend to be outside the matrix of nature. We provide the meanings to matter and energy, but not by choice. Meaning begins like photosynthesis, before we think.

² See: Robert Gordon Wasson, Albert Hofmann and Carl Ruck, *The Road to Eleusis: Unveiling the Secret of the Mysteries*, New York; London, Harcourt Brace Jovanovich, 1978.

Kilowatt Dynasty

■■■■■ Saskia Olde Wolbers

Kilowatt Dynasty (2000) The yet-to-be-conceived foetus tells the story of her conception: her father an environmental activist, her mother the presenter of the underwater shopping network at the bottom of the Three Gorges Dam in China. A twisted tale of hostage taking, victim collusion and an Inverted Dream Syndrome which confuses waking and sleeping time. A conspiracy theory which leaves an entire nation doubting what was seen; perhaps it was just an affair of the psyche, the melting of two mind's desires transmitted through opposite sides of a TV screen. (Patricia Ellis)

Transcript from:
Kilowatt Dynasty, 2000
Voice over Jean Lee
Video, 6 min.
Courtesy Galerie Diana Stigter
Collection Centraal Museum

■■■■■
Let's try to imagine that I am going to be born in 17 years...
let's in our heads go forward to the year 2016.

■■■■■
The year in which I will be conceived by the country's most famous hidden couple.
The year the worlds largest Dam, The three Gorges Dam will have just been built in our province.

The year one million people will be relocated to prefab towns, for the creation of the large water reservoir.

■■■■■
And the year...

The notorious TV programme, Kilowatt Dynasty will be on.

This Tele-Shopping programme will be broadcast from a flashy underwater centre... at the bottom of the newly formed lake.

■■■■■
The country's biggest multinational, selling electrical appliances...

will expect a big shopping craze and finance the programme as a marketing tool.

■■■■■
People will still be able to watch their old valley...

while being seduced into buying a washing machine.

And no one other than my mother...

will get the privileged job of presenting it.

■■■■■
A divorced mother-of-one-ex-quiz-show-host...

then in her late thirties...

will give it her best in a tangy coloured two-piece.

Leaning casually on shiny washing machines...

in front of various underwater scenes.

■■■■■
But in the third month the slick backdrops will change due to heavy siltation.

■■■■■
What happens next depends on who you'll speak to.

The man who is going to make a difference in her life...

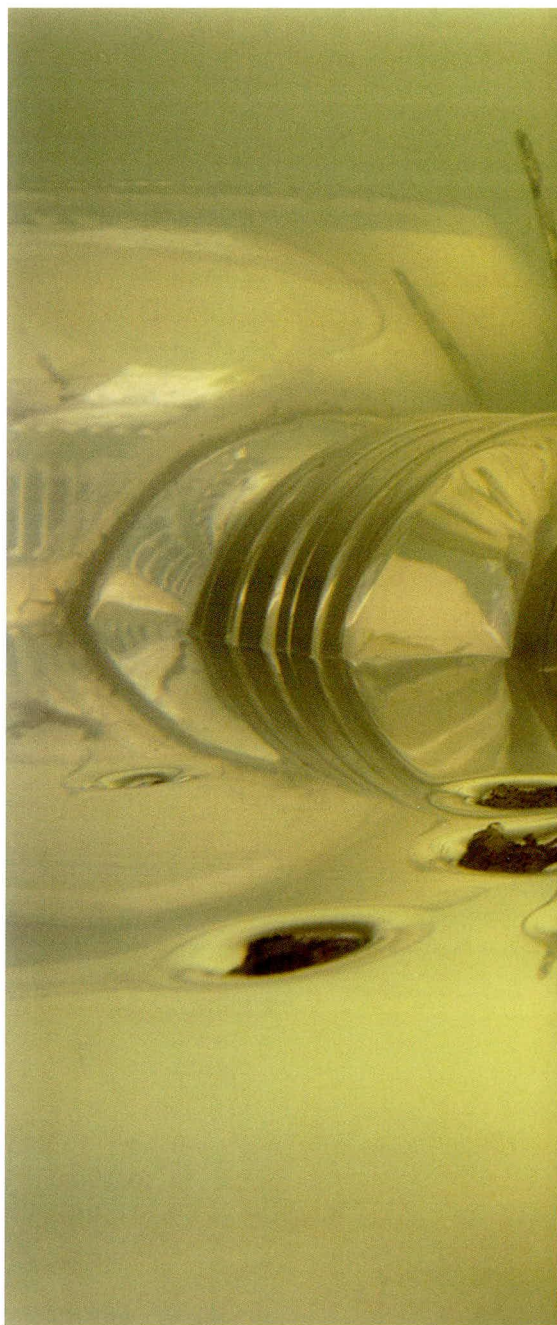
is then still slumped in front of the television in his new living room.

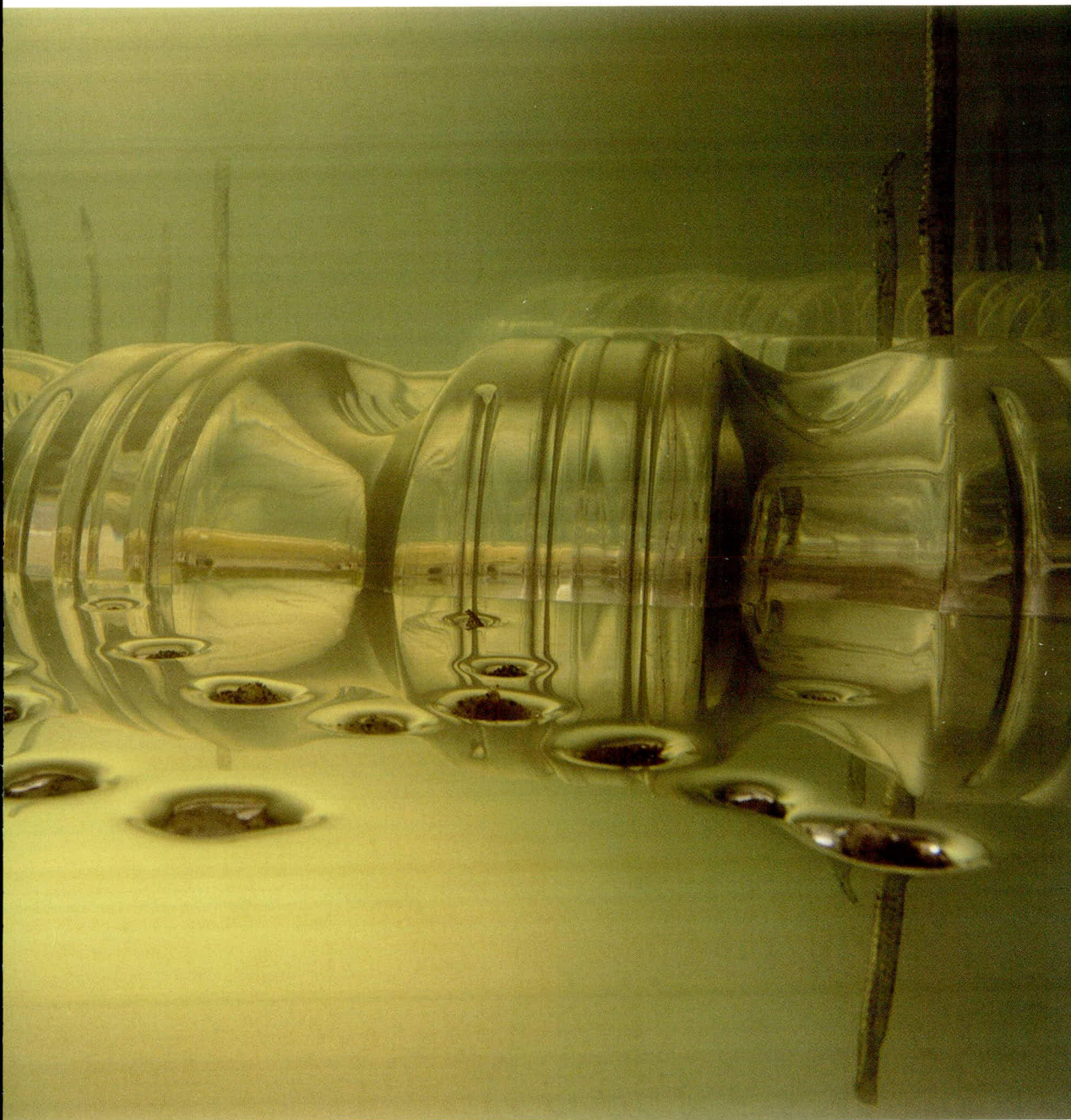
■■■■■
My future father is neither here nor there...

■■■■■
During the construction of the dam...

he will have handcuffed himself to the fence around the visitors' centre.

While activists chained elsewhere will be locked up...





Above:

Saskia Olde Wolbers, *Kilowatt Dynasty*, 2000,
videostill, courtesy Diana Stigter Amsterdam

he will have luckily put himself in a place...
where a lot of national and international
camera crews will film him...
so he won't be arrested.

■■■■■
Now he will be disrespected in the activists'
hidden scene.
And having nothing on his CV...
other than handcuffing himself to a fence...
will have made him a lonely man.
While irregularities rush through his mind...
he thinks of a way of reinstating his activist's
grace.

■■■■■
In the night of October the 18th he goes up to
the centre...
walks past the sleeping guard...
comes live on air and makes an
announcement...
That he has taken mum hostage.
He makes no clear demands but is armed.

■■■■■
This will be bad news...bad news for him...
because mum won't actually be in the centre
when it happens.

■■■■■
She would have been seen by several witnesses
going around the new town above.
So just as the word will spread her apparent
escape...
her head will appear on the programme's last
ever broadcast...

■■■■■
...in which she just repeats his exact words.

■■■■■
The fact that she will have re-entered the
centre voluntarily...
without telling anyone of her decision...
and leaving her teenage son above water...
will have everyone looking frantically for an
explanation.

■■■■■
Each member of our small family will have
their own theories...

involving her quest for love, fame or just
adventure.

But I think that she will have started suffering
from...

■■■■■
"The Inverted Dream syndrome"...
Which is dangerously common to astronauts.
When the spaces and events in their dreams
will look more real...
than the everyday dark nothingness of outer
space.
Until they are convinced that they are
awake...
while dreaming of their wives in bungalows
back on earth...
and that their empty floaty reality is actually a
dream.

■■■■■
Mum will start believing...
she dreams of being in a transparent building
underwater,
surrounded by an oddly familiar landscape...
while wearing an orange uniform...
and flesh-coloured tights.

■■■■■
And these people she doesn't know, but know
her...
keep ringing her about washing machines.
And when she thinks she is awake...
she sleepwalks out of the centre into the lift...
which takes her up to the new town above.

■■■■■
Here she'll wander around aimlessly...
Looking absent...
Not speaking to anyone...

■■■■■
Just like on the afternoon father thinks he
takes her hostage...
she will be hovering around town.
While dreaming of getting tired...
she will unknowingly return to the centre...
... to go to sleep.

Apocalyptic atmospheres

Iris Dik
Translated by David Alexander

Ever since he was young, Floris Kaayk has regularly had ominous dreams about the downfall of humanity. Nightmares. "But looking back, these are often the nicest!" They provide him with plenty of inspiration for his animation films.

He made his film *The Order Electrus* (2005) during his third year at the Sint Joost Academy in Breda. Set in a post-industrial landscape of factory buildings overgrown with plants, it was filmed in Germany's Ruhr area, where a new species of mutated 'industrial' insects – Kaayk's animations – had found its habitat. As if in a nature programme on Discovery Channel, complete with its British voiceover, we follow these strange creatures – made from electrical resistances and other video-recorder components – during their mating rituals and as they build their nests and drive off their enemies. "At the end of the film, a large group of them marches on humans", says the 23-year-old Kaayk.

"In my next film, my graduation piece *Metalosis Maligna*, I wanted to show how humans themselves are threatened, and how they'll finally be wiped out by technology." The film deals with a life-threatening illness, where implants proliferate in the body, their metal bulges seeking to work their way out. More flesh disappears until people are transformed into robot-like machines.

At the invitation of the Sandberg Institute in

Amsterdam, Kaayk has now begun a third film in this one-man genre, where live action is combined with computer animation. He calls them 'fictional information-service films'. "At the beginning, they look realistic, plausible stories with plausible images, complete with the ugly animations as we all know from popular-science documentaries. Only after a time do we begin to notice that things are becoming more and more improbable."

He found this niche during his second year at art school, when he had to work on an assignment involving a book on insects inspired by *Erik of het klein insectenboek* (Eric in the Land of the Insects) a book by Godfried Bomans. Drawing on texts and illustrations from an old book on insects, he created his own pseudo-scientific variant. "I got components from video recorders at the waste-processing plant in Tiel where I had a Saturday job. Even though this wasn't the purpose I had in mind for it, that book became a sort of script. Two years later I turned it into a film with *The Order Electrus*."

Kaayk used superglue to stick the video-recorder parts together. "I wasn't going to use the insects during the shooting, so things didn't need to be very solid. They only served as models to be digitised later. For this film, I could also have bent the insects by hand, filming them in stop motion, but after being bent twenty times the legs would have lost most of their flexibility. The computer gives me more freedom, partly because it's always possible to go back and correct a mistake."

Kaayk doesn't want to be a slave to technology. Imagination must come first. It begins with an idea, an atmosphere that slowly develops during the research phase into a story. "I keep on developing this atmosphere by drawing

inspiration from film images and music. I listen to a lot of music from Hollywood films; it's exciting to let this very familiar music rub up against my own ideas and images, which are actually very different from Hollywood's."

■■■■■

Only when the script is completely finished does he investigate how to make the story feasible in technical terms. This takes place in three stages: making the models, filming them and then processing them digitally with the help of several software programs.

■■■■■

Kaayk filmed his script for 'Metalosis Maligna' during a three-month exchange programme in Edinburgh. "In the end I was given the run of an old school where I could work really well. I built the seven different spaces using all kinds of materials that had been left behind, including all the stuff from a fully equipped chemistry classroom. But not only was it a pretty primitive set, it was also winter, and as the lead actor had to spend most of his time in the nude, he was always cold. Me too. In the end, I couldn't concentrate properly, so by mistake I glued the little balls for the last scene – reference points for synchronising the animation with the actor's body – to the wrong arm. Later, I tried to correct this manually in the computer – a fiendish job which made me decide to get rid of that arm altogether."

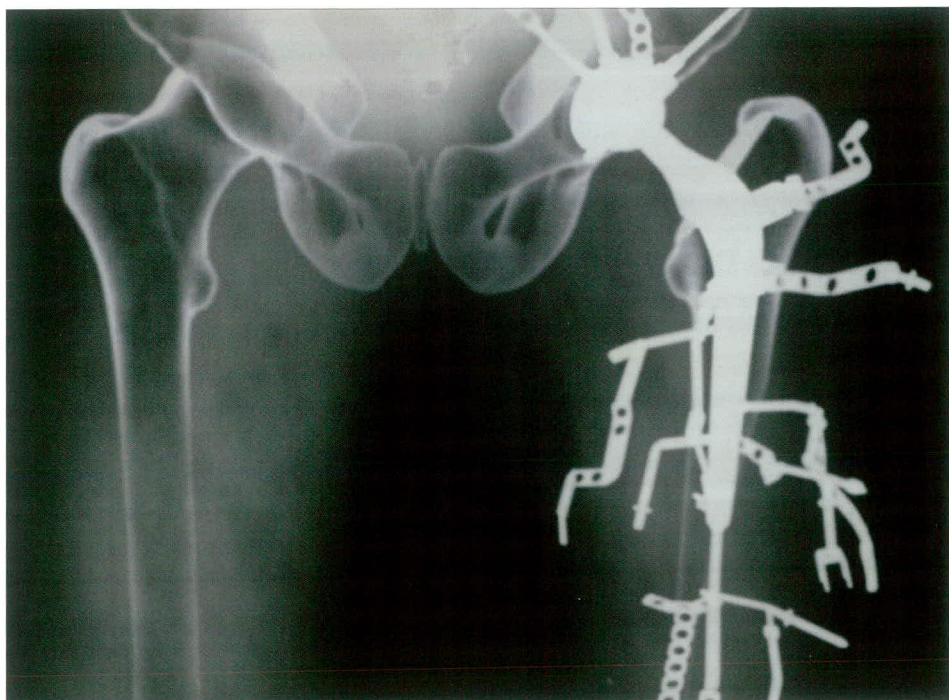
■■■■■

While actors stay anchored in reality, Kaayk prefers his own fantasy world. "I'm happy when the actors are nicely stored away in the computer and I'm completely my own boss again. As far as that's concerned, I'm a real animator. I try to use the power of the computer for something that can't yet be found in reality and to create a world that doesn't yet exist. Kaayk uses science to borrow what suits him, but he doesn't go deeply into theories. "I prefer to invent my own theories and ask my own questions."

■■■■■
Follow Floris Kaayk via www.microbia.nl
■■■■■

This article is an abridged version of an interview published in *KM* magazine no. 60, January 2007.

With thanks to Frank van der Ploeg.



■■■■■ **Top:**
Floris Kaayk, Metalosis Maligna, 2006

■■■■■ **Bottom:**
Floris Kaayk, The Order Electrus, 2005

TransGenesis: From past to last beginnings.

Linda Weintraub

The Genesis account of the 'Beginning' recounts that God created Adam, and Adam created language by naming all the animals. We humans have been creating language ever since. We have, for instance, created the words 'genesis', 'generate', 'gene', 'genetics' and 'transgenic'. These words summarise progressive explanations of beginnings – some derive from myth and religion, while others reveal the interjection of science to elucidate the concept of origins. They exemplify a characteristic of all languages – they evolve.

When Eduardo Kac chose *Genesis* (1998–1999) as the title for his installation, he was referring less to God as the supreme Creator, and more to his own powers to enact the ultimate creative act.¹ Kac's *Genesis* introduces a new form of life created through 'gene' manipulations and 'transgene' modifications. By referring to a sanctified act of creation, Kac chooses a hallowed context for his high-tech explorations.

This inspirational concept greets visitors who enter a hushed gallery in which the murmur of distant pulsing is heard.² The dimly lit space is infused with the glow from a large orb that resembles the vastness of the cosmos. But the source of the projection, which is prominently displayed in the installation, reveals this impression to be false. Instead of God's domain of Creation, it originates from a microvideo camera trained on a Petri dish.

What appeared to be the eternal grandeur of the firmament is actually the magnified world of bacteria replicating in real time. This is Kac's domain of creation, not God's, because he used two forms of genetic manipulation to create the bacteria: he inserted a new gene of his own creation and he introduced a gene from a jellyfish. His form of genesis was not hallowed or mysterious. It involved cloning the bacteria he created.³

Kac extends the pioneering experiments currently being conducted within the biological realm into pioneering experiments with language. Transgenic strategies characterise them both. Whereas his biological transgenics involves the transference of genes between different species of life, his linguistic transgenics involves transference of meaning between different species of language. Since 'the Beginning', humanity has invented approximately 6,500 verbal languages. In this work of art, Kac includes four 'languages', but only one is verbal. In addition to the English alphabet that comprises twenty-four letters, he incorporates the binary Morse code that employs two units (dots and dashes), a code of his own creation that enables the translation from Morse to DNA (C= dot, T= dash, A= word space, G= letter space), and the DNA code that has four elements (Adenine, Guanine, Cytosine and Thymine). In this encompassing approach to language, therefore, the artist works directly with the building blocks of genetic code.

What are the physical and moral implications of inducing genetic change by sidestepping survival of the fittest and the sluggish pace of mutation? Will this capacity assure more success than natural evolution? Kac raises this troublesome question by establishing a sequence of translations between the four

¹ *Genesis* was first shown in 1999 at the Ars Electronica festival in Linz, Austria.

² Original *Genesis* music by composer Peter Gena.

³ Interview with the artist in New York on 8 August 2005.

'languages', moving seamlessly between the linguistic, the binary, and the chemical. In Genesis this process proceeds in the following manner. Kac used the Morse code to translate the verbal language of the Bible into the genetic language of the cell. Significantly, he chose a Biblical passage that sanctions such manipulations of life: "Let man have dominion over the fish of the sea, and over the fowl of the air, and over every living thing that moves upon the earth."⁴ Kac accomplished this transference by reducing the sequences of letters in the biblical passage to a pattern of dots and dashes prescribed by the Morse code. The dots were replaced by Cytosine, the dashes with Thymine, the word spaces with Adenine and the letter spaces with Guanine. Thus the biblical text was translated into Morse code and the Morse code was translated into the genetic 'alphabet' (C, T, A, G) to form new bacteria that carry an 'art gene'. In the gallery the projection of the live bacteria is flanked by the language of chemicals (the Genesis gene sequence) and a language of human invention (the Morse code), in addition to the biblical script.

Images of the new genetic creations were also translated into digital data and dispatched across the globe: a high-tech version of the prophets, scribes and priests who proclaim the awe-inspiring narrative of God's creation. Kac not only announced the creation of his new bacteria via the internet, he invited interaction. People using the computer console in the gallery and surfers worldwide on the web who were hooked up to the streaming live feed could communicate directly with the Petri-dish population. In fact, the bacteria were illuminated only when viewers clicked their mouses. The act was rewarded with an astonishing sight. Kac's bacteria glowed! He used two kinds of bacteria. One type was genetically altered by

the inclusion of the art gene that carried the coded biblical passage; these bacteria also had a gene that produced greenish-blue fluorescence. The other bacteria did not contain the art gene, and were given a gene for yellow fluorescence. Under ultraviolet light the invented life forms were radiant. This digital illuminated manuscript shared the aesthetics of its era – it was technologically enhanced and synthesised.

Kac's bacteria thrived in the Petri dish. They divided and multiplied and divided again. Observing this amazing phenomenon, however, bore an unexpected consequence. Viewers discovered that the ultraviolet lights that enabled them to observe these newly created bacteria also had the effect of accelerating their mutations. Participants who clicked a mouse to see the bacteria, therefore, became co-creators in a new genesis that was not merely biological. As the UV light caused the DNA to mutate, the letters in the scripture text that determined the DNA sequence mutated too. The English translation of the first mutation of the bacteria read: "Let aan have dominion over the fish of the sea and over the fowl of the air and over every living thing that ioves ua eon the earth."⁵

Kac's Genesis replaces the unequivocal and eternal truth of God's word with the multiplicity of its translations. Instead of the sacred word, Kac extends the linguistic evolution that originated when the Hebrew text was first translated into Greek. He guides its mutations, selections and adaptations into unexplored evolutionary trajectories. By linking carbon and silicon, cell and word, parallels emerge between genetic and electronic alphabets. Both are fragile forms of data whose information is transferable and interchangeable. Linking genetics to other languages suggests that all constructions are

⁴ Book of Genesis, chapter 1, verse 28.

⁵ Eduardo Kac, *Telepresence and Bio Art – Networking Humans, Rabbits and Robots*, Ann Arbor: University of Michigan Press, 2005, p. 254.

mutable, and therefore provisional. Kac even applies this principle to his own dominion over the bacteria he had created. Abandoning control over his work, he says, provided an opportunity, "to learn from it, to grow with it, to be transformed along the way".⁶

After the show Kac posted evidence of this communal act of mutation on the internet. It was later engraved on black granite tablets he called *Encryption Stones* (2001). The left half is occupied by an English translation of the Biblical passage along with its equivalent as Morse code and gene sequence. The right side reverses the sequence by starting with the mutant gene sequence and ending with altered English. The jagged contours of the granite tablets made them appear as if an almighty force had wrenched them from a mountainside (like Mount Sinai) and that they recorded an irrefutable truth (like the Ten Commandments). In this manner Kac's *Genesis* conflates the natural law of life processes with the divine law of human ethics. It asks: How much dominion did God intend for humans? Is it our right to take command of biological evolution? Through his democratic distribution of divine-like powers, Kac converted these philosophical abstractions into personal dilemmas. His audiences confront, "the dubious notion of (divinely sanctioned) humanity's supremacy over nature".⁷

Genetic engineering does not make life less precious. Kac insists it reawakens wonder: "The mystery and beauty of life is as great as ever when we realise our close biological kinship with other species and when we understand that from a limited set of genetic bases, life has evolved on Earth with organisms as diverse as bacteria, plants, insects, fish, reptiles, birds and mammals."⁸

Kac begins at the ultimate beginning – the origin of life. He then fast-forwards to an era when the imaginative ruminations of science fictions are being realised in science laboratories. Kac's work coincides in time and spirit with the new millennium. "My goal is to produce an image that synthesises this passage into a new kind of environment, one in which romantic notions of what is 'natural' have to be questioned and the human role in the evolutionary history of other species (and vice versa) has to be acknowledged, while at the same time respectfully and humbly marvelling at this amazing phenomenon we call 'life'."⁹ Art has a vital role to play in this process. "If we leave technology behind in art, if we don't question how technology affects our lives, if we don't use these media to raise questions about contemporary life, who is going to do that?"¹⁰

This essay was first published in: Elena Giulia Rossi (ed.) *Eduardo Kac : Move 36*, Paris: Filigranes Editions, 2005. It is a version of the essay published in *Eco-Centric Topics: Pioneering Themes for Eco Art* from the series: *Avant-Guardians: Textlets in Art and Ecology* by Linda Weintraub, with Skip Schuckmann, Artnow Publications, 2006.

⁶ Daniele Perra, 'Eduardo Kac: Interview', *Tema Celeste*, no. 81, July-September 2000, p. 79.

⁷ Eduardo Kac, 'Genesis' in: Gerfried Stocker and Christine Schopf (eds.), *Ars Electronica 99 – Life Science*, Vienna, New York: Springer, 1999, p. 310.

⁸ Eduardo Kac, 'GFP Bunny' in: Peter T. Dobrila and Aleksandra Kostic (eds.), *Eduardo Kac: Telepresence, Biotelematics and Transgenic Art*, Maribor, Slovenia: Kibla, 2000, p. 111.

⁹ Lisa Lynch, 'Trans-Genesis: An Interview with Eduardo Kac', *New Formations*, no. 49, Spring 2003, p. 90.

¹⁰ Simone Osthoff, 'Object Lessons', *World Art*, no. 1, 1996, p. 23.

Moulding wet materials into replicas of themselves

Adam Lowe

I believe that the same process of moulding of plastic materials into a configuration complementary to that of another molecule, which serves as a template, is responsible for all biological specificity. I believe that the genes serve as the templates on which are moulded the enzymes that are responsible for the chemical characters of the organisms, and that they also serve as templates for the production of replicas of themselves.

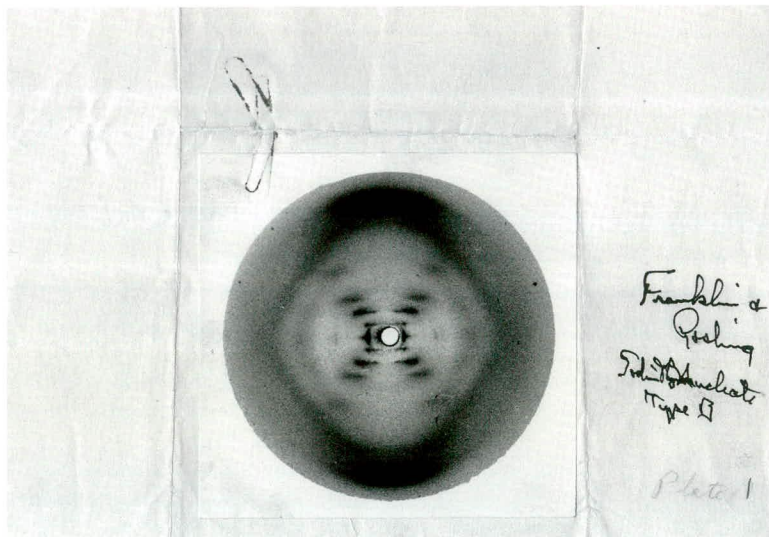
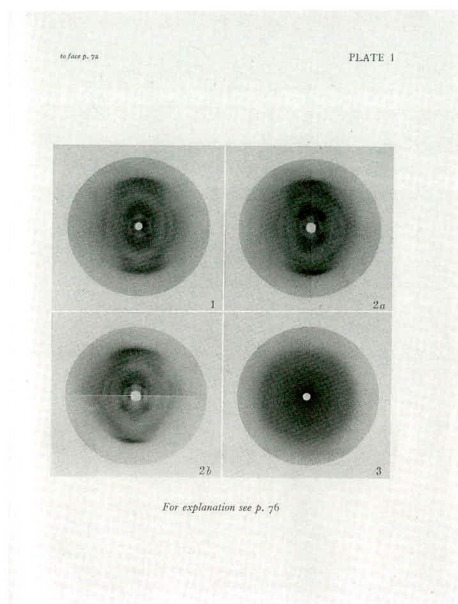
Linus Pauling, Sir Jesse Boot Foundation Lecture, May 28, 1948

Linus Pauling lost the race to discover the structure of DNA, mainly because he had the wrong photographs. He was working from x-ray diffraction photos taken in the late 1930s (with one new photograph from 1947) by William Astbury. In the x-ray diffraction technique a crystal is exposed to x-rays in order to produce a diffraction pattern. The electrons that surround the atoms, rather than the atomic nuclei themselves, are the entities that physically interact with the incoming x-ray photons. Unless the crystal is pure the results contain too much information and cannot be read. Astbury's photos of nucleic acids are beautiful, blurred

circular patterns, resembling out-of-focus Chladni figures or one of the photographs that Margaret Watts Hughes took of her eidophone. In 1951 Pauling requested to see some DNA photos that he had heard were being taken at Kings College, London. He was refused access to these images. The photos he needed to see were taken by Rosalind Franklin, a very skilled x-ray crystallographer. After training in physical chemistry at Cambridge she spent three years at the Laboratoire central des services chimiques de l'Etat in Paris, learning the technically demanding process of x-ray diffraction photography. From 1951 to 1953 at 53 King's College she produced what J.D. Bernal has called, "the most beautiful x-ray photographs of any substance ever taken".

At the start of her research she was working with a mixture of the A and B forms of DNA, which produced a 'muddy' diffraction pattern that seemed almost impossible to interpret. However, from these photographs she realised that DNA was a thirsty molecule and that the phosphates in the molecule must be encased in water on the outside. She then succeeded in developing an ingenious and laborious method to separate the two forms, providing the first DNA crystals pure enough to yield 'interpretable' diffraction patterns. Photos 51 and 52 are in focus and show the pattern of the B Structure of DNA in its pure, extended, wet form. These photographs, clear to those who can read them, show twofold symmetry and a helical structure.

Since 1953 our understanding of DNA has been clarified, cleaned up, theorised, packaged and patented. This development has been parallel to the development of the computer. It is therefore not surprising that the language used to describe both the computer and genetics gets mixed up. It seems



Top:

William Astbury's X-Ray Studies of Nucleic Acids, 1947. Courtesy Ava Helen and Linus Pauling Papers, Oregon State University Libraries

Bottom:

Sodium deoxyribose nucleate from calf thymus, Structure B, Photo 51, taken by Rosalind E. Franklin and R.G. Gosling, 1952. Courtesy Ava Helen and Linus Pauling Papers, Oregon State University Libraries

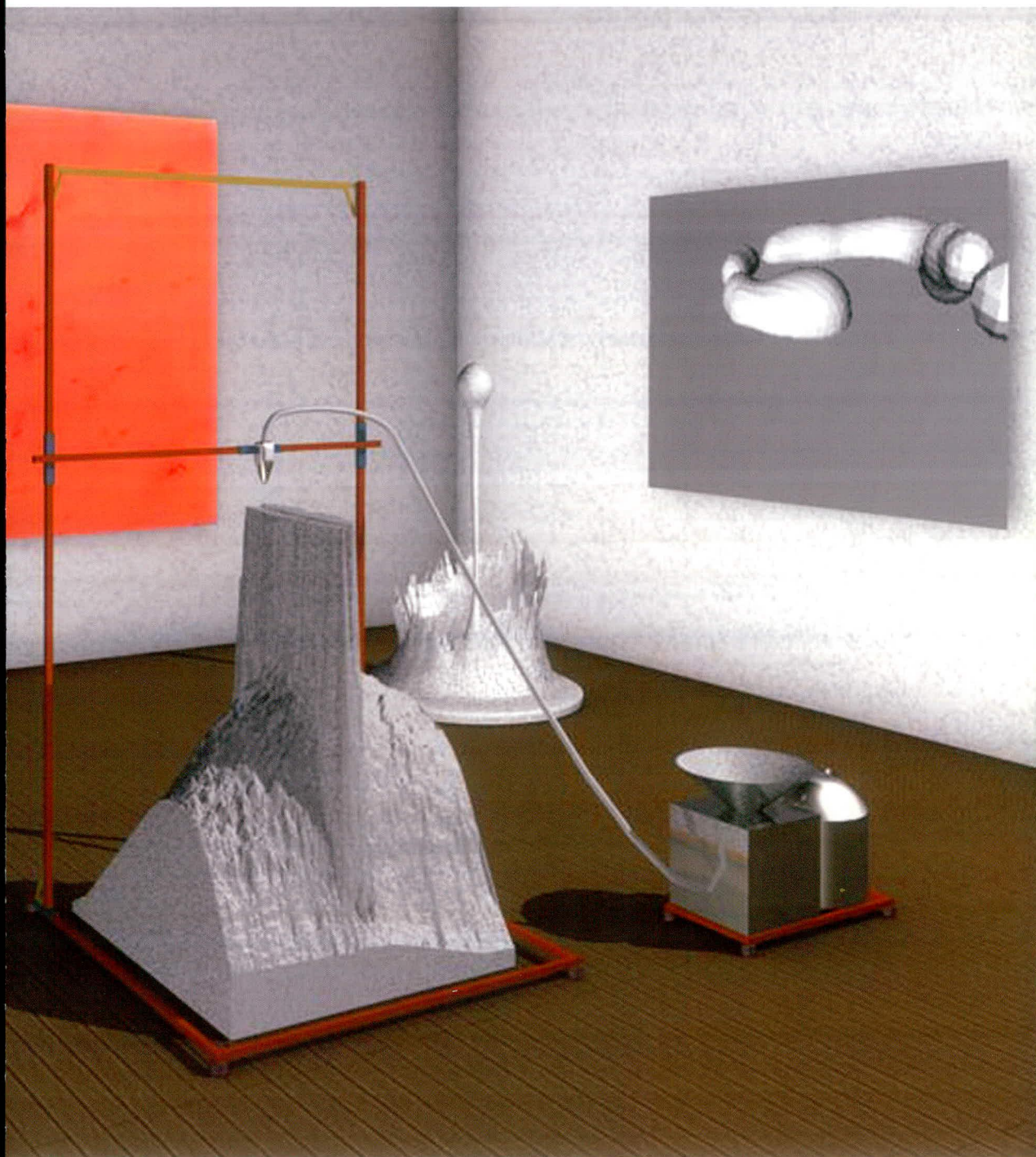
it is now safe to assume that DNA is a 'program' carrying genetic 'information' in a 'coded' and 'sequenced' form. It is therefore logical that these 'instructions' can be 'stored' and 'accessed' at the appropriate time and made manifest using 'compatible software' and the right 'output device'. This reductive view concentrates on the byte-sized units being discrete and with a pre-programmed desire to replicate. But what if they are not? Brian Cantwell Smith has already demonstrated that digital systems are digital only as an abstraction. In the physical world they are actually analogue systems with enough redundancy for them to appear digital. Keeping things discrete takes a great deal of work. At the beginning of twentieth century, William Bateson, the inventor of the word genetics, preferred a messy, noisy model. He observed that, "the appearance of chromosomes is not suggestive of strings of beads of extreme heterogeneity, but rather with that seen for example in drying mud." He went even further to suggest that living things are not matter at all but a vortex through which matter passes.

 If DNA is wet and plastic, why do the metaphors we use to describe it revolve around images of building blocks, chains, and links – dry rigid images based on a Lego world of assembling? This 'dry model' has had a profound effect on our world but what would happen if the metaphor were more about 'making'? If it were more fluid – like cement – with DNA partially taking on the shape and characteristics of the environment in which it forms? Within this 'cement' model there is less control, and as the random mutations churn away they generate not only the potential for disaster, such as cancers, but also the possibility of evolution and transformation.



Above:

The Cement printer was designed and built by Dwight Perry and Adam Lowe. Virtual model of the printer was produced at Factum Arte by Gregoire Dupond



Koen Vanmechelen: The Cosmopolitan Chicken project – a short genealogy

Jo Coucke

Koen Vanmechelen has been engaged in his vast chicken-breeding project *The Cosmopolitan Chicken* since 2000. The international project involving the interbreeding of various national chicken breeds acts as a metaphor for dynamism, fertility and creativity on the one hand and peaceful coexistence on the other. It is an artistic and aesthetic project that touches on many contemporary social issues such as genetic manipulation, cloning, globalisation, multiracialism and multiculturalism. Despite the artist's many inspiring contacts with the medical and scientific worlds, *The Cosmopolitan Chicken* project has found its ideal setting in the art world. In addition to the actual birds, the project also comprises sculptures, chicken portraits, drawings, installations, stuffed chickens, storyboards and videos.

The Cosmopolitan Chicken project officially began in the village of Watou on the boarder between Belgium and France. As his contribution to Jan Hoet's exhibition *Storm*

Centers – Poeziezomers Watou, Vanmechelen crossbred the Belgian chicken known as the 'Mechelse Koekoek' (Cuckoo of Malines) with the French pride 'Poulet de Bresse' (1st generation). Interestingly the 'Cuckoo of Malines' is not only Belgium's most highly prized culinary chicken, it is also related to the artist by name: Koen Vanmechelen literally means *Koen of Malines*. The progeny were named 'Mechelse Bresse' and were in turn crossbred with the typical English chicken 'English Redcap' (2nd generation) for the group show *A Shot in the Head* at the Lisson Gallery, London (2000).

The results of the crossbreeding of the 'Mechelse Bresse' and the 'English Redcap' called the 'Mechelse Redcap' were exhibited in 2001 at Vanmechelen's solo exhibition *Between Natural Breeding and Genetic Engineering* at the Deweer Art Gallery in Otegem in Belgium.

The 'Mechelse Redcap' was then crossbred with the American chicken the 'Jersey Giant' (3rd generation), both in reality at the artist's studio in Meeuwen in Belgium and 'artificially' (i.e. in the form of a transparent glass chicken) at the Miami Art Fair, USA (Berengo Fine Arts). The resulting 'Mechelse Giant' was the subject of an installation presented at the exhibition *3 FEB 2002*, curated by Edith Doove at the Museum Dhondt-Dhaenens in Deurle in Belgium.

The 'Mechelse Giant' was duly crossbred with the German 'Dresdner Huhn' (4th generation), a breed that had been produced to commemorate the bombing of Dresden in the Second World War. Remarkably the pairing of the Dresdner cock with the 'Mechelse Giant' hen produced only male chicks. The breeding itself took place at the artist's studio and the offspring were the subject of a one-man show at the new K4 Galerie in Munich in 2004-2005.


In 2003 Vanmechelen organised the crossbreeding of the 'Mechelse Dresdner' and the Dutch hen the 'Owlbeard' (5th generation). The 'Mechelse Owlbeard' was presented in Amsterdam, at De Brakke Grond and at the KunstRAI (in a presentation by GEM Museum of Contemporary Art, The Hague). In November 2003 the artist undertook his second expedition to Nepal to study the 'Bankiva' hen, the so-called primal chicken from which all domesticated chickens descend.


The 'Mechelse Owlbeard' was then crossed with the 'Louisiana' from Mexico (6th generation). The chicks called the 'Mechelse Louisiana' were shown in the exhibition *Super* in Hasselt in 2005. They were then mated with the 'Thai Fighter Hen' (7th generation) from Thailand, but not before the artist had created the virtual crossing of the 'Mechelse Louisiana' and the 'Thai Fighter' in the 'Virtual Mechelse Fighters' for the eponymous exhibition at the Deweer Art Gallery in 2005. This generation was also the subject of a presentation at the Duolun Museum of Modern Art in Shanghai in 2005 as part of the exhibition *Two Asias, Two Europes*. The 'Mechelse Fighters' were crossbred with the Brazilian 'Auracana' (8th generation) to create the 'Mechelse Auracana', which was born on Easter Sunday 2006.


This was the genealogical status of *The Cosmopolitan Chicken* project as of 23 May 2006.

Biological artworks

Marta de Menezes

The use of biology as an art medium is not a recent phenomenon. It is likely that ever since early humans began domestication, animals and plants have been selected and consequently modified, based on aesthetic values. Modern biology made possible the modification of life in an extremely controlled way, but also offered access to many other techniques: from protein structure analysis to direct visualisation of neurons in the living brain.

Biotechnology was born to explore these new tools for the benefit of humankind. It is becoming possible to develop new therapies for incurable diseases, but at the same time the public fears misuse of this powerful technology. As society becomes aware of biotechnology, with all its hopes and fears, artists have started to include references to biotechnology in their works. Furthermore, modern biology and biotechnology offer the opportunity to create art using biology as a new medium. We are witnessing the birth of a new form of art: art created in test tubes, using laboratories as art studios.

However, it is still uncommon for artists to have a significant academic education in scientific subjects such as biology. Such deficiency in biology training may deter some artists from exploring the opportunities for creating biological art. Furthermore, many of the scientific communications are unintelligible to outsiders to the field. Unfortunately, this includes some books and events aimed at making science understandable to the general public. It is

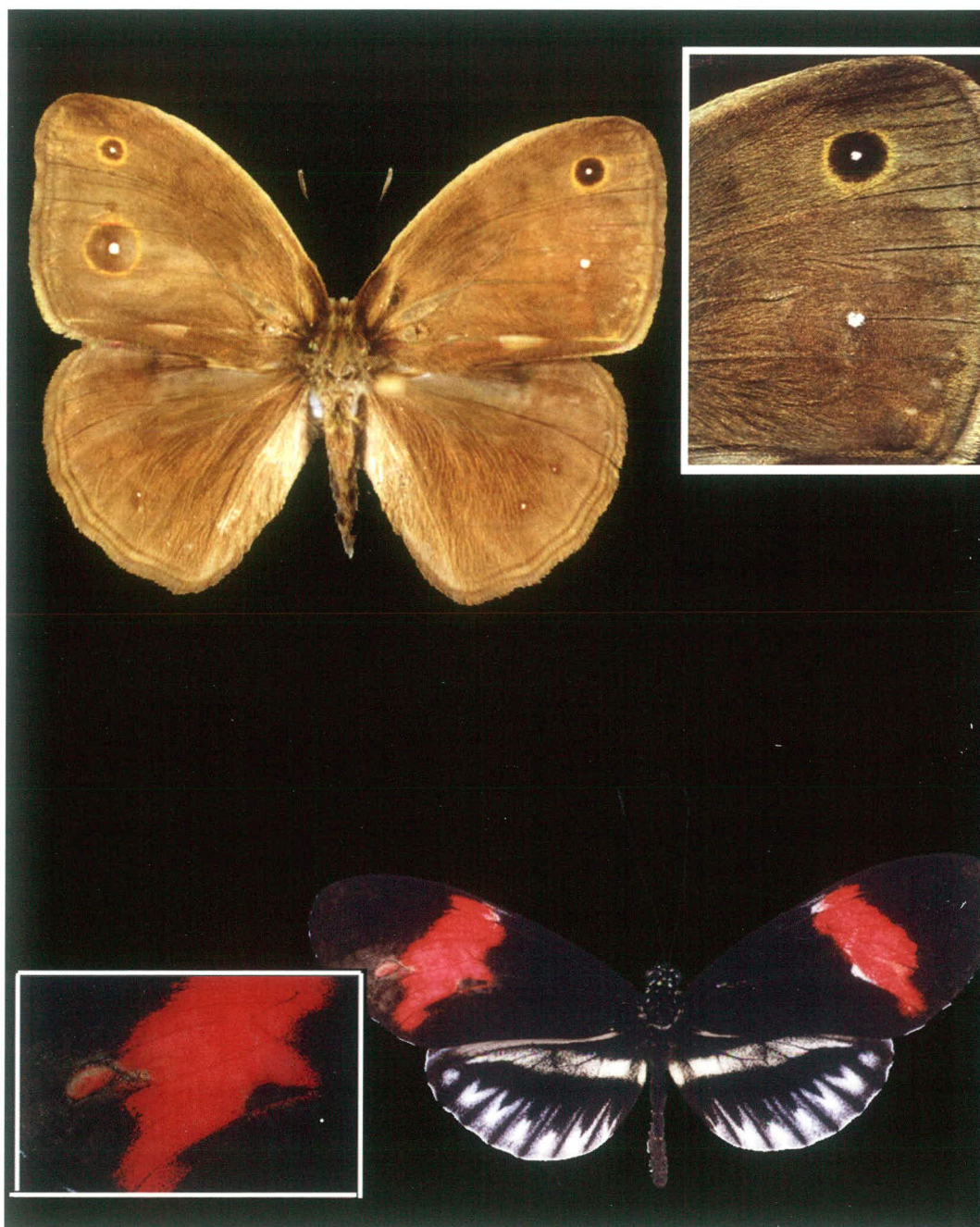
likely that artists willing to use biology as an art medium would have to make an effort in order to learn the basics about the experimental systems they are considering using. Personally, I do not see such a requirement as a major hurdle: several artistic techniques require extensive learning and training. The use of information technologies as a new art medium, for example, is only possible when the artist acquires significant skills in a field that is not by nature 'artistic'. Biology may not be very different from informatics, except for the different availability of computers when compared with biological equipment.

My work focuses on the possibilities that modern biology offers to artists. I have been trying not only to portray the recent advances of biological sciences, but to incorporate biological material as new art media: DNA, proteins, cells and organisms offer an opportunity to explore novel ways of representation and communication. Consequently, although I lack formal scientific training, my recent artistic activity has been conducted in research laboratories.

Nature? – the artificial-natural

Recent advances in developmental biology allow interference with normal developmental programs, thus making possible the creation of novel live organisms. It is common in scientific laboratories to generate animals with characteristics that were never seen before in nature. My work explores this potential in order to create adult live butterflies with wing patterns modified for artistic purposes.

In *nature*? I have created live butterflies with wing patterns never seen before in nature. This has been achieved by interfering with the



Above:

Nature?, Marta de Menezes, 1999-2000.
Live butterflies with modified wing patterns.

normal developmental mechanisms of the butterflies. The butterflies are simultaneously natural (their wings are made of normal live cells, without artificial pigments or scars) but designed by an artist.

I have modified the pattern of only one wing of both the *Bicyclus* and *Heliconius* butterflies. The butterflies thus have one wing with nature's design and one with my design. Through this asymmetry, I have tried to emphasise the similarities and differences between the unmanipulated and manipulated, between the natural and the novel natural.

I have been trying to express concepts in the butterfly wings that deal with our perception of shapes. By adding, changing or deleting eyespots and colour patches it is possible for our imagination to identify shapes and rhythms familiar to our senses. Another approach includes highlighting particular aspects of the natural wing, for example, the removal of the outer rings of an eyespot to simply show the white centre. I never had the intention of enhancing nature's design in any way, nor did I intend to make something already beautiful even more beautiful. I simply wanted to explore the possibilities and constraints of the biological system, creating (within the bounds of possibility) different patterns that do not result from an evolutionary process.

It has also been my intention to create unique butterflies. The changes are not at the genetic level and the germline is left untouched. As a consequence, the induced modifications are not transmitted to the offspring. Each modified butterfly is unique. The new patterns are something never seen in nature before, and quickly disappear from nature never to be seen again. This form of art has a

life span – the life span of a butterfly. It is a form of art that literally lives and dies. It is simultaneously art and life. Art and Biology.

Acknowledgements

The work *Nature?* was developed with assistance from several artists, scientists and institutions: the laboratory of Professor Paul Brakefield, University of Leiden with the scientists: A. Monteiro, M. Bax, K. Koops and R. Kooi.

www.martademenezes.com

Interactive plant growing

Christa Sommerer & Laurent Mignonneau

As artists we have been working since 1991 on the creation of interactive computer installations for which we design metaphoric, emotional, natural, intuitive and multi-modal interfaces. The interactive experiences we create are situated between art, design, entertainment and edutainment. When creating our interactive systems we often develop novel interface technologies that match conceptual and metaphoric content with technically novel interface solutions. While our main focus is to design interactive systems for the art context, our interactive or immersive systems also often find use in edutainment and in mobile communications areas. This article summarises some of our key concepts for our interface designs and presents one of our interactive projects in more detail.

Introduction

Human-computer interaction (HCI) is a discipline concerned with the design, evaluation and implementation of interactive computing systems for human use, including the study of major phenomena surrounding this theme. Human-computer interaction is concerned with the joint performance of tasks by humans and machines; the structure of communication between human and machine; human capacity to use machines (including the learnability of interfaces); algorithms and programming of the interface itself; engineering concerns that arise in designing and building interfaces; the process of specification, design, and implementation

of interfaces; and design trade-offs. Human-computer interaction thus has science, engineering and design aspects.

Because human-computer interaction studies a human and a machine in communication, it draws from supporting knowledge on both the machine and the human side. On the machine side, techniques in computer graphics, operating systems, programming languages and development environments are relevant. On the human side, communication theory, graphic and industrial design disciplines, linguistics, social sciences, cognitive psychology and human performance are relevant. And, of course, human aspects such as emotions and feelings become relevant as well.

In mainstream HCI science and commercially available interfaces the prevalent human-computer interface of today is still the mouse-keyboard-screen based interface (desktop metaphor), and Bill Buxton observes that, "despite all of the technological changes, I would argue that there has been no significant progress in the conceptual design of the personal computer since 1982".¹ Buxton backs up his observation by looking at the design of the first GUI, the Xerox Star 8010 Workstation, introduced in 1982. When we compare this workstation with currently available systems, not much has actually changed in the design of these systems. After almost twenty years, the computers available today still look much the same as back then. But Buxton also notes that, "despite the increasing reliance on technology in our society, in my view, the key to designing a different future is to focus less on technology and engineering, and far more on the humanities and the design arts. This is not a paradox. Technology certainly is a catalyst and will play an important role in what is to

¹ William Buxton, 'Less is More (More or Less): Some Thoughts on the Design of Computers and the Future' in: P. Denning (ed.), *The Invisible Future: The Seamless Integration of Technology in Everyday Life*, New York: McGraw Hill, 2001.

Interactive plant growing

Christa Sommerer &
Laurent Mignonneau

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Opposite:

Interactive Plant Growing, 1992
Christa Sommerer & Laurent Mignonneau
Interactive computer installation
Collection of the ZKM media museum, Karlsruhe

Above:

Interactive Plant Growing, 1992
Christa Sommerer & Laurent Mignonneau
Interactive computer installation
Collection of the ZKM media museum, Karlsruhe

come. However, the deep issues holding back progress are more social and behavioural than technological. The skills of the engineer alone are simply not adequate to anticipate, much less address the relevant issues facing us today. Hence, fields such as sociology, anthropology, psychology and industrial design must be at least equal partners with engineering and technology in framing how we think about, design and manage our future.”² Buxton has long been one of the most prominent critics of commercially available interfaces and their technocentric design. Buxton proposes a more human centric design, which reflects the importance of usage and activity rather than technology. According to him, the questions that should be asked are:

- Who is using the computer?
- What are they doing?
- Where are they doing it?
- When are they able to do it?
- Why are they doing it?
- How do they do it?

These questions can guide design towards the right solution in the right form for the right person in the right location at the right time and at the right cost. They prompt a concern for design that reflects respect for human skill at all three levels: motor-sensory, cognitive and social.

Clearly the social component, as described by Buxton, is one of the key competencies artists can contribute to the process of interface design. For a long time artists and designers have been aware of the emotional and intuitive quality of objects and situations and since the late 1980s and early 1990s media artists, including ourselves, have designed interactive systems that aim to match emotional and metaphoric content with the actual physical objects, images and sounds employed in these systems.

Let us now look at our conceptual considerations and principles for designing our own interactive systems for interactive art.

Emotional and metaphoric interfaces

Artists and designers have always been skilled in applying metaphors when designing systems, objects or works of art. Metaphors can evoke certain sensations or emotions in the spectators, feelings that often cannot be described with words alone. The power of metaphors is that they tap into cultural, historical and emotional knowledge that we humans have built up in the course of our lives. For example, touching an object that looks like a cat, even one made of fabric or plastic, may evoke a warm feeling or may trigger emotions of personal attachment and care. Through our daily interactions with objects or even beings that we touch, manipulate, look at, perceive or interact with, we have developed a rich intuitive knowledge of how these things work and what kind of emotions and sensations we attach to them.

Using this immanent, intuitive and emotional knowledge, in 1991 we became interested in exploring the power of emotional and metaphoric interfaces. The first such interface we designed in 1992 was a living plant. In this system real plants are the interfaces that users can touch to create artificial plants on a computer screen. The system is described in more detail further on. Users who experienced this system have often reported that they suddenly realised that plants are actually living beings and that they have been astonished that plants really ‘feel something’. When touching a real plant and seeing the effect of this interaction translated into a graphical form on a screen, users are suddenly reminded of that immanent intuition they already had about plants.

² William Buxton, ‘Human skills in interface design’ in: L.W. MacDonald and J. Vince (eds.), *Interacting with Virtual Environments*. New York: Wiley, 1994, pp. 1-12.

To design successful interfaces that make use of this emotional and metaphoric knowledge, it is necessary to ask a few questions before designing a system. These questions are:

- Which emotion or sensation do I want to convey?
- What do I want the user to feel when experiencing this system?
- What is the cultural and historical background of the user?
- What is the emotional and metaphoric knowledge already available to the user?
- What kind of object or interface can convey this desired emotion or sensation?
- If not available, how can I design a new interface that evokes this sensation?
- Which interface would feel most natural and most intuitive to the user?

David Rokeby, a well-known media artist, has noted that, "user interfaces are also a kind of belief system, carrying and reinforcing our assumptions about the way things are. It is for this reason that we must increase our awareness of the ways the interface carries these beliefs as hidden content [...] It is also useful to realise that effective interfaces are usually intuitive precisely because they tap into existing stereotypes for their metaphors [...] A metaphoric interface borrows clichés from the culture but then reflects them back and reinforces them."³

Natural and intuitive interfaces

Closely linked to designing emotional and metaphoric interfaces is the concept of natural and intuitive interfaces. By this we mean interfaces that feel very easy and natural in their use, without the user having to go through a lengthy learning process when he/she wants to interact with this system. Natural interfaces are interactions based upon

gesture, speech, touch, vision and smell or basic actions and sensations that refer to our daily life experiences.

Using living plants as an interface, for example, not only provides a new, emotionally charged and unusual connection between computers and living beings but also poses the questions: what is a plant? How do we perceive it? And how do we interact with it when we touch it or approach it? Natural interfaces also circumvent the annoyance of wearing unpleasant devices before entering virtual space (unencumbered interaction). The natural interfaces we have used and developed include living plants, light, camera-detection systems, a '3-D Video Key' system, a multimodal scanning device and a window touch screen combined with speech input.

David Rokeby's Very Nervous System is another example of a natural and intuitive interface, where the user's body actually becomes the interface to the virtual space. As the users move about in the interaction space they start to learn how to use their bodies for triggering and playing sounds and music. All this feels very easy and intuitive to the user, almost playful, and users will not even realise that they are being tracked and that they have become part of a computerised system.

Non-linear, multi-layered and multi-modal interaction

We also believe that interaction in interactive systems should not be linear but that it should feel like a journey. The more one engages in interaction, the more one should learn about it and the more one should be able to explore it. We call this non-linear interaction as it is not pre-scripted and predictable but instead develops as users interact with the system. The interaction path in our systems should also be multi-layered, meaning that the

³ David Rokeby, 'Constructing Experience' in: C. Dodsworth (ed.), *Digital Illusions*, New York: Addison-Wesely, 1997.

interaction feedback should be simpler at the beginning and become increasingly complex when users interact with the system further, to continuously discover new levels of interaction experiences. And the final cornerstone in designing our systems is the creation of multi-modal interaction experiences that combine several senses such as vision, sound, touch and smell.

In fact over the last few years multimodal interaction has become a mainstream research trend in HCI. It is defined as the combination of multiple input modalities to provide the user with a richer set of interactions compared to traditional uni-modal interfaces. The combination of input modalities can be divided into six basic types: complementarity, redundancy, equivalence, specialisation, concurrency and transfer. Examples of such multimodal interaction system include the Zeleznik Wacom Tablet in which users use a stylus and puck to interact with a conceptual 3D modelling application or Waibel and Vo's series of input modes that include speech, pen-based gestures, eye tracking, lip reading, handwriting recognition and face recognition for applications such as text editing and calendar management.

Creating innovative interaction experiences

Combining the above concepts of emotional, metaphoric and natural and intuitive interfaces as well as non-linear, multi-layered and multi-modal interaction over the last fourteen years we have developed several interactive media systems. All these systems are designed to allow an untrained user easy access to the system's image, sound or haptic worlds. The systems have mainly been produced for media museums, science museums, media exhibitions or temporary exhibitions for visitors of various ages, social backgrounds and technical or cultural knowledge.

Interactive plant growing

One of the first interactive computer art installations to use a natural interface instead of the then-common devices such as joysticks, mice, trackballs or other technical interfaces was our installation Interactive Plant Growing from 1992. In this installation, living plants function as the interface between the human user and the art work. By touching or merely approaching the real plants, users engage in a dialogue with the real plants in the installation. The electrical potential differences (voltage) between the user's body and the real plant is captured by the plant and interpreted as electrical signals that determine how the corresponding virtual 3D plants (which resemble the real plants) grow on the projection screen. By modifying the distance between the user's hands and the plant, the user can stop, continue, deform and rotate the virtual plant, as well as develop new plants and new combinations of plants. As the growth algorithms are programmed to allow maximum flexibility by taking every voltage value from the user's interaction into account, the resulting plants on screen are always new and different, creating a complex combined image that depends on the viewer-plant interaction and the voltage values generated by that user-plant interaction. Figure 1 shows a scheme where the user's hand distance towards the real plant generates voltage values that become higher the closer the hand is towards the plant. We use five different distance levels to control the rotation of the virtual plants, their colour values, their location on screen as well as an on/off growth value. Figure 2 shows the final result of that interaction on the screen as a collective image of virtual plants that were grown by several users.



This text is an abridged version of the essay
'Designing Emotional, Metaphoric, Natural
and Intuitive Interfaces for Interactive Art,
Edutainment and Mobile Communications'
which originally appeared in *Computers &
Graphics: An International Journal of
Systems & Applications in Computer
Graphic*, Elsevier, 2005, pp. 837-851.

Humanoid robots playing language games

■■■■■ Luc Steels

Language is a living system. A language is constantly shaped and reshaped by its users in order to adapt to their changing needs. New words are invented, sounds change, new grammatical constructions pop up or existing ones are stretched and reused for new purposes. Language is not a formal static calculus as Chomsky has argued. It is a complex adaptive system. Viewpoints and perspectives derived from biology are relevant to an understanding of this continuously evolving system. The question of the origins and further evolution of language is no longer seen as a frivolous matter with little scientific interest, but has become the central focus of a new 'evolutionary' linguistics and semiotics.

■■■■■ The question of the origins of language is at least partly a biological question because we need to explain the origins of the neurobiological substrates that make up the language faculty. Is there an innate language organ, as Pinker has claimed? Is there a genetically determined neural structure in the brain that is highly specialised for language and grows like the liver or the heart? If so, how has such a language organ been able to evolve?

■■■■■ There is an alternative view. The origins of language are driven not by genetics but by

culture. Humans were able to pull themselves out of the Darwinian world governed by selfish genes and reached a stage of ultrasociality in which they could afford to develop incredibly rich convention-based communication systems. The neurobiological basis of the language faculty is dynamically reconfigured by the developing brain by pulling together general-purpose neural structures such as associative memories or pattern recognisers and then using them for language. Individuals use such general mechanisms to progressively build their language systems by setting up particular interaction patterns (language games) and using appropriate strategies for constructing, adopting or aligning their linguistic inventories.

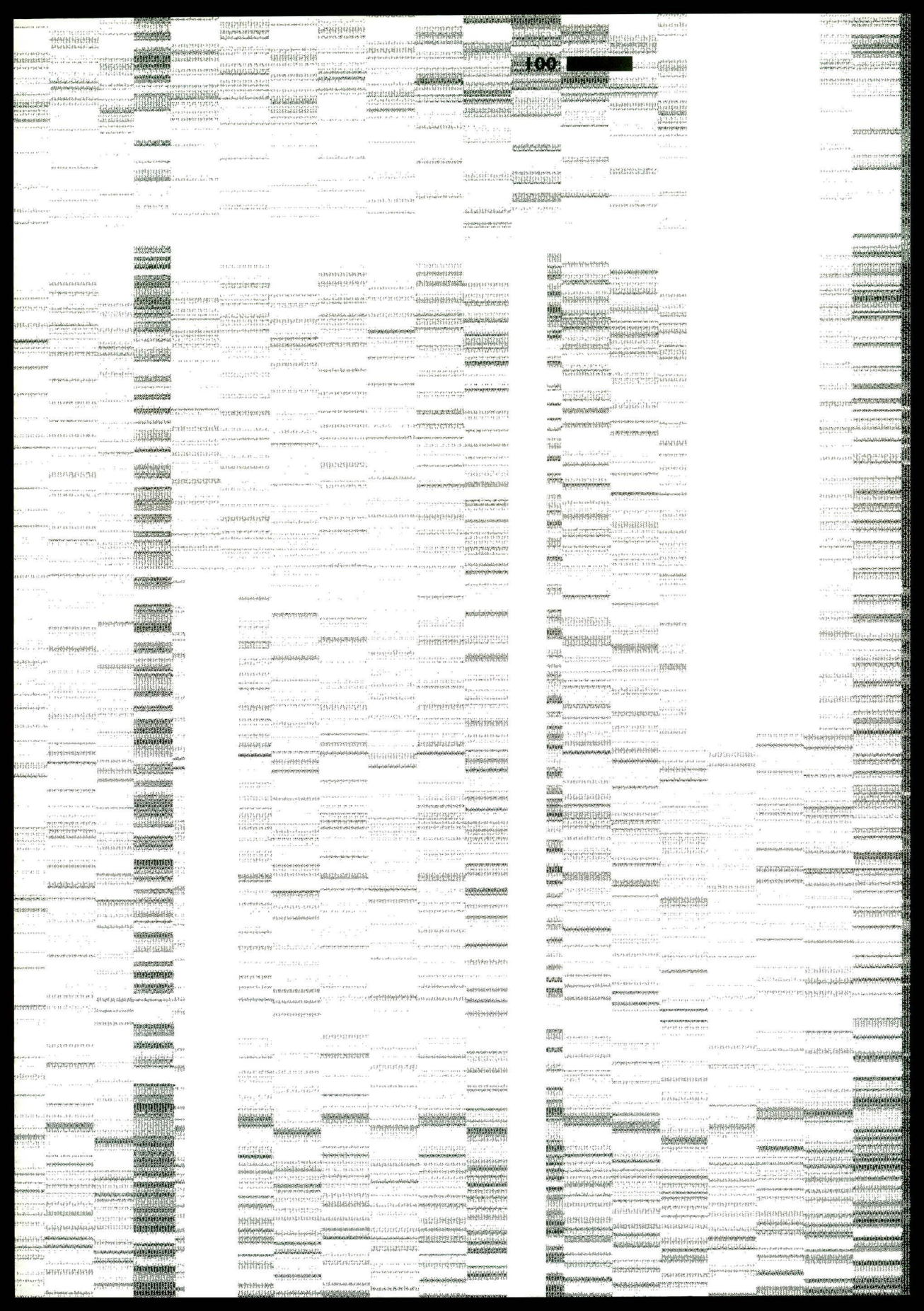
■■■■■ In a series of experiments, we have shown that this hypothesis is viable. We take a design stance. We ask: what it would take for a group of embodied individuals to self-organise a communication system with properties similar to those found in human natural languages. We test our theories by building real physical robots that engage in language games using general cognitive mechanisms and construction strategies and we show that out of a multitude of embodied situated interactions a language indeed gradually emerges.

■■■■■ This contribution to *Genesis* shows the latest incarnation of these experiments. It shows video images of a breakthrough experiment we carried out in January 2007 in Tokyo, in which a group of humanoid robots build a communication system from scratch by playing language games about objects in their environment. This language game experiment, the first ever carried out with humanoid robots, is hugely complex as it involves not only language but also

behaviour, visual perception, joint attention and action. But it shows clearly that the cultural hypothesis for the origins of language is viable.

Further reading:

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Colophon

Published on the occasion of the exhibition
Genesis: Life at the End of the Information Age,
 Centraal Museum, Utrecht,
 14 April – 12 August 2007

Exhibition

Curator: Emilie Gomart

Installation design: Petra Blaisse,
 Inside Outside

Publication

Authors: Arie Altena, Marianne Boenink,
 Nik Brown, Soraya de Chadarevian,
 Jo Coucke, Iris Dik, Driessens & Verstappen,
 George Gessert, Emilie Gomart, Christine
 Heidemann, Bruno Latour, Adam Lowe,
 Michael Lynch, Annemarie Mol, Marta de
 Menezes, Saskia Olde Wolbers, Sahota Sarkar,
 Sommerer & Mignonneau, Luc Steels, John
 Tresch, Astrid Visser, Cor van der Weele,
 Linda Weintraub

Editor: Emilie Gomart

Copy editor: Gerard Forde (all texts but *Life at
 the end of the information age* by Emilie Gomart)

Graphic design: Lesley Moore, Amsterdam

Production: Marije Douma, Leonie Wingen

Printing: Drukkerij Tuijtel,
 Hardinxveld-Giessendam

The publication was made possible in part by
 the support of: NWO's Netherlands Genomics
 Initiative, Mondriaan Foundation, Prins
 Bernhard Cultuurfonds and VSB fonds.

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 Centraal Museum, Utrecht.

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 (Mondriaan Foundation)

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 VSBfonds

Genesis

Life at the end of the information age

Metaphors influence how we perceive the world. It was only in the 1950s, with the first computers, that scientists could say that the brain was a computer and DNA the program that controlled the development of the organism. *Genesis* focuses on the power of one metaphor, the 'information metaphor'. The 20th century is the information age. Everything, life itself, seemed to be based on 'information' – genes, bits, sequences of signs.

Genesis describes parallels between art and the life sciences. Art and science might seem miles apart and have different goals and different venues, "information" has shaped both art and science. In the first part of this show, works of art and science reveal their surprising resemblances. In the second, art and science struggle to overcome the sometimes too simplistic image of life as just a string of code.

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