# Reading Scientific Images

*The Iconography of Evolution*

**Richard Mason**
with Tony Morphet
& Sandra Prosalendis

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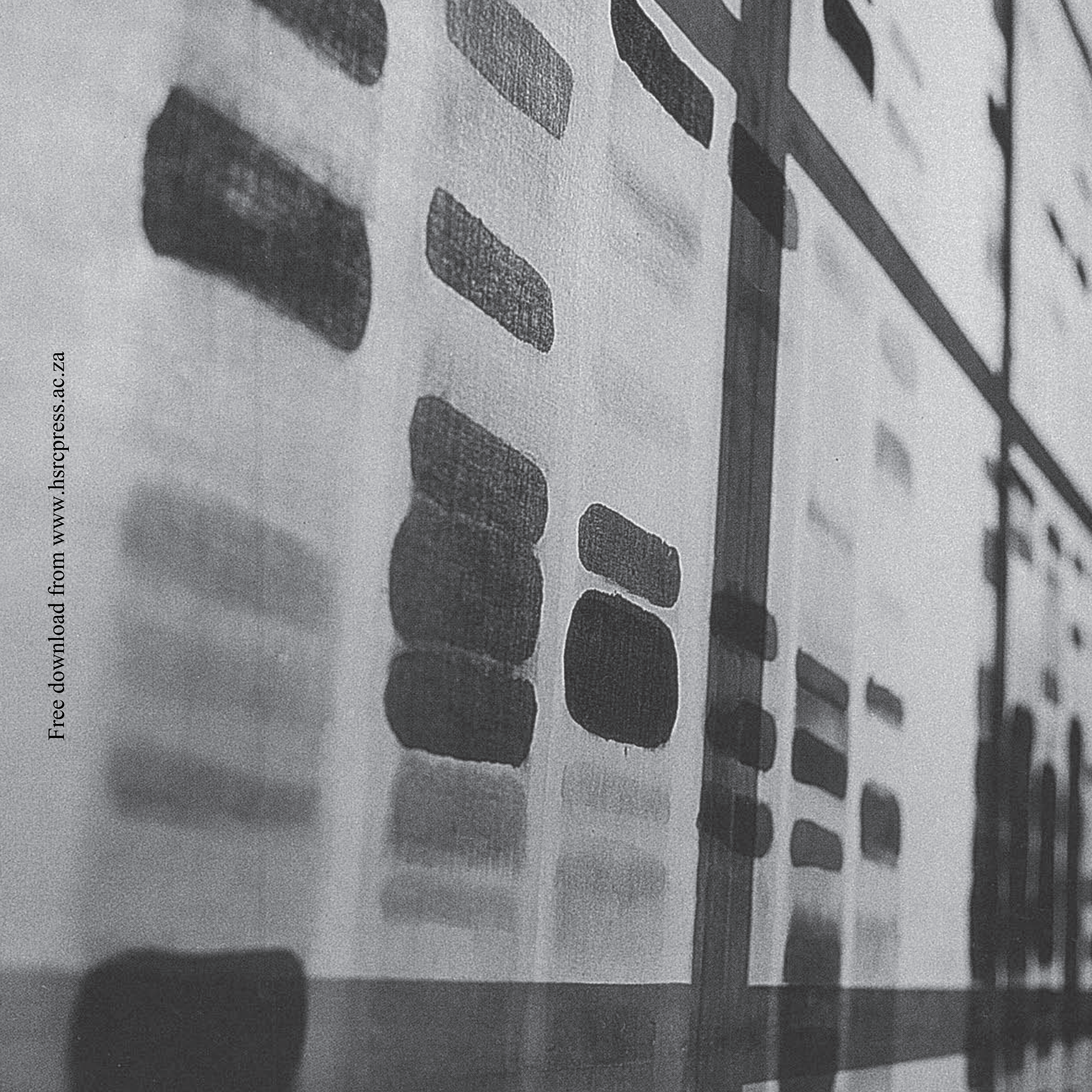
# Contents



# Introduction

Practical, everyday knowledge is different in structure and purpose from what we call 'scientific' knowledge. The distinction is not new. In pre-modern societies there was a similar distinction between the practical knowledge required for everyday activity on the one hand and religious understanding on the other. Religion was required to provide answers to the big questions which face every form of social life: 'Who are we? Where have we come from? Where are we going?' Under modern conditions we look to science for answers to these same questions and the multitude of others which spin out from these basic concerns – questions about human difference, about suffering and pain, about the best ways to develop resources for life and the best ways to organise social life.

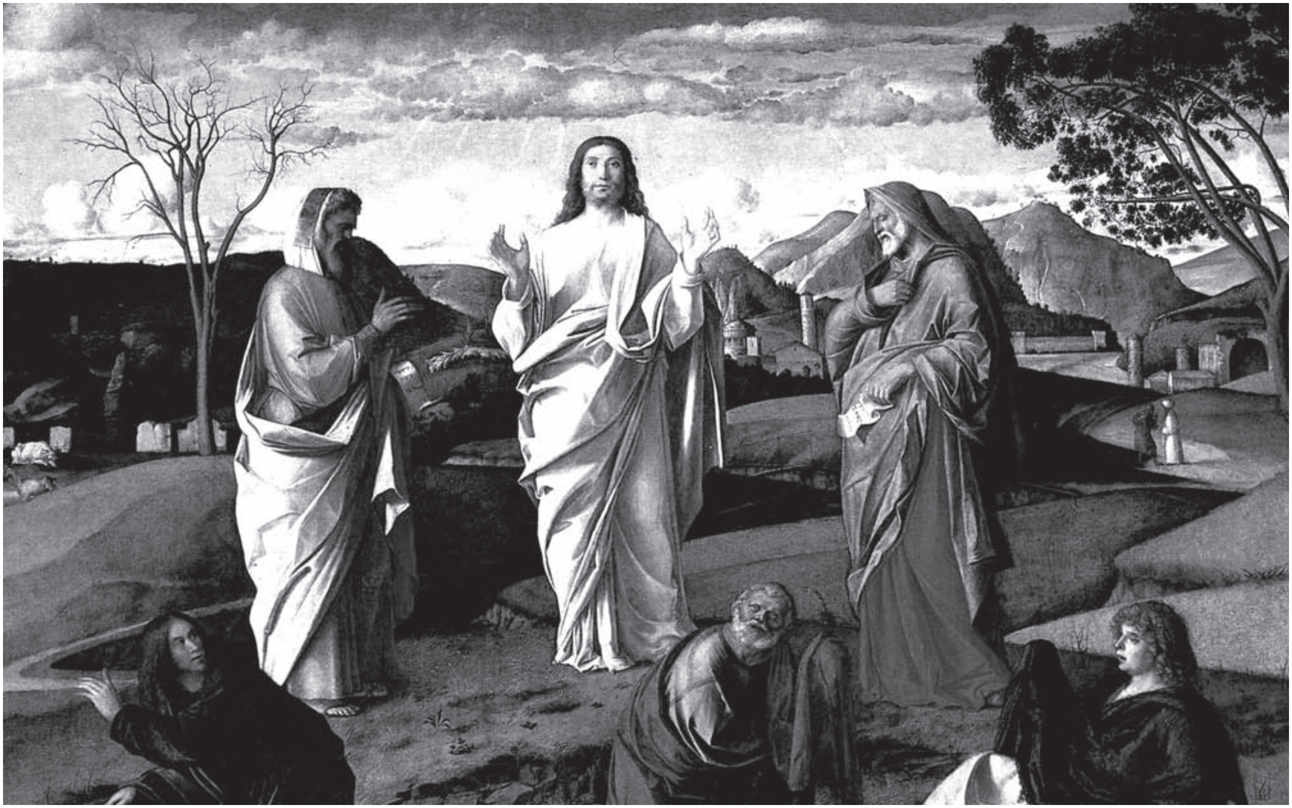
Science has been exceptionally successful in uncovering potential answers to these critical questions and it is often thought that science has displaced religious interpretations of the world. Science and religion do differ in crucial ways (most notably in what each will accept as the standard for truth) but it is important to recognise that, in knowledge terms, they share some important common features. Emile Durkheim, the great French sociologist, classified both science and religion as forms of 'sacred' knowledge – distinguishing both from the practical everyday understanding which he called 'profane' knowledge. He intended 'sacred' to give a strictly social description to the form of knowledge which both religion and science shared. He saw them both as systems of related but unobservable concepts. They were unobservable in the sense that they were not tied to any particular events or facts. Moreover they were objective in the sense that they were shared, social understandings, external to the perceptions of individuals, and therefore experienced by people as relatively fixed and unchanging. Science and religion occupied the same 'knowledge-space' in social life; they stood together in their manner of interpreting life although they differed sharply in the content and procedure of their interpretations. Science demands empirical evidence; religion insists on the divine revelation of truth.

This book is about science and the ways we have of understanding its systems of concepts. What do we mean when we say that these systems are unobservable? How, if that is true, can we then grasp the meanings embedded in scientific work?

It is clear the debates and advances in modern science, especially in the field of evolution and genetics, have been slow to reach South African classrooms. Yet in the world beyond the school, teachers and students become aware of fresh thought and new discoveries through the mass media. Frequently these ideas are being presented through compelling images. In the popular media the 'sacred' knowledge of science is most powerfully evoked through the use of images. Written scientific reports are dense, lengthy and complicated, but images are able to carry complex information in a single perspective. But we have to learn how to read images. We have to become visually literate if we are to decode the layers of information which images hold together and the worry is that those of us without adequate visual literacy skills may not be able to interpret and critically judge these images for ourselves.

The historical Church faced an inverse of the same problem in the times before ordinary people had learned to read written language texts. The Church itself taught visual literacy. Images of the saints and especially of the life of Jesus and the prophets, provided the means of carrying the truths of religion into the lives of ordinary folk. The creation and interpretation of images became a prized skill. Images were employed to teach the most complex doctrinal issues – among them the nature of the Trinity, the meaning and process of virgin birth, and above all, the significance for the human world of the crucifixion. The great visual interpreters were the artists and architects whose work is preserved still in the great religious art and architecture of the past. We, in our time, have well-developed skills in writing and reading words but we have to relearn the skills of reading images.

This book about scientific visual literacy focuses on the most dynamic area of contemporary human discovery. The theory of evolution, though long established in its basic terms, has seen dramatic new development since the discovery of the structure of DNA.



## Four related aims guide the book

1. To bring teachers into contact with current evolutionary theory and debate
2. To improve the teaching of molecular biology
3. To convey the complexities of evolution through visual means
4. To convey an understanding of the function of visual icons.

The book is grounded in a critical examination of the images and icons of evolution as they appear in scientific and in popular contexts. In the process it will seek to build visual and scientific literacy skills which will provide the means to read the visuals with accuracy and depth of interpretation.

## The book is divided into five sections:

| | |
|---|---|
| Section 1 | Visual Literacy |
| Section 2 | Evolutionary Iconography |
| Section 3 | Development of New Icons |
| Section 4 | Literature Review |
| Section 5 | Glossary |

**Section 1** poses three questions:
1. What is visual literacy and why should we study it?
2. How are scientific images created?
3. Types of scientific images

**Section 2** focuses on icons that relate specifically to the theory and concepts of evolution. Five such icons and their contexts-of-use are identified:

| | |
|---|---|
| **1. Amoeba-to-man** | Scientific/specialised/popular |
| **2. Tree of Life** | Scientific/specialised print |
| **3. Double Helix** | Popular science/illustration |
| **4. Genome sequencing** | Specialised/computer generated |
| **5. Mutation** | Film, graphic novels & web |

These icons will be critically examined in their historical and contemporary contexts.

Note: It is assumed that both teachers and students will already have some knowledge of the icons and that they will also be readily accessible for further study.

**Section 3** uses the issues arising from the preceding critical analysis as a way to develop a new Tree of Life icon. This icon is not expected to be perfect representations. The aim is to highlight misconceptions and simplicities evident in current icons and to generate debate around current evolutionary theories and the broader questions of visual literacy.

**Section 4** lists the reference material used in making this book. A short summary of the content covered in each listed book will be given. This will assist further research into the themes presented in this book.

**Section 5** gives a glossary of important terms used in the book.

# Section 1: Visual Literacy

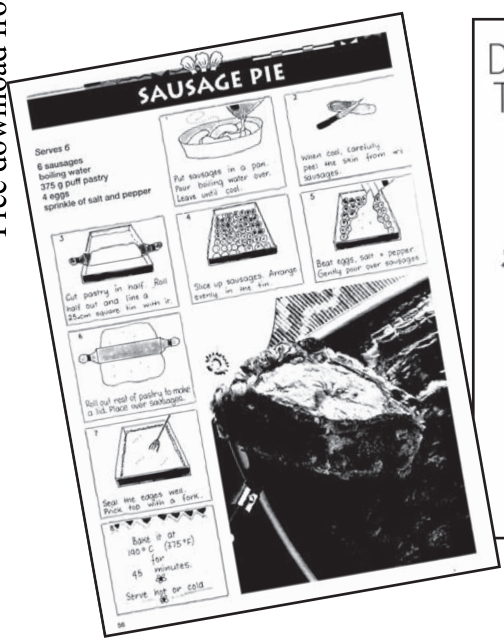
## What is visual literacy and why should we study it?

Visual literacy is the ability to read and understand images in a way which is similar to the way one reads and understands written text material. In our first years of schooling we are taught to read and write words. We learn to compose meanings by interpreting the relations between sets of signs appearing in sequence on a page of paper. However, we are not taught to read images or to draw except perhaps to illustrate our own work with attractive images. Such images are secondary to the written words and are not given the same level of critical attention. Classified as either 'expression' or 'art' they are not intended to convey complex ideas or concepts in themselves – that is understood to be the task of the writing. There is an assumption that visual literacy will develop 'naturally' and no focused attention is given to teaching the skills in school. In fact little value is attached to the capability itself.

It is easy to see that as students progress through school images gradually fade from their books and textbooks. The same trend, away from images and toward printed words, is echoed outside of the classroom. Children's books are bright and colourful with many images while adult books only very rarely contain images.

However, in the Life Sciences images continue to carry power and authority. Images remain in the form of diagrams or drawings developed for specific interpretative purposes. They are considered indispensable for communicating ideas and concepts and they are not seen as mere illustrative supplements to written texts. But the skills to grasp their full meaning often remain beyond the students' (and teachers') capacities. The reason is that they have not been given the opportunity to learn to read or value images in a similar way to written text. Students (and teachers) are therefore not able to draw on a source of information which is critical to an understanding of the Life Sciences.




SAUSAGE PIE

Serves 6
6 sausages
boiling water
375 g puff pastry
4 eggs
sprinkle of salt and pepper


DEEP-FRIED TOFU WITH TOMATO-BASIL SAUCE

6 ripe tomatoes, skinned and quartered
180 ml (¾ cup) fresh basil leaves
15 ml (1 Tbsp) olive oil
1 medium onion, quartered
3 cloves garlic
a pinch of sea salt
a pinch of coarsely ground black pepper
10 ml (2 tsp) fructose
500 ml (2 cups) sunflower oil for deep-frying
4 blocks fresh tofu (about 100 g each), cubed
chopped fresh basil to garnish

Blend the tomatoes, basil, olive oil, onion, garlic, salt, pepper and fructose. Place the mixture into a saucepan and cook on low for about 1 hour.

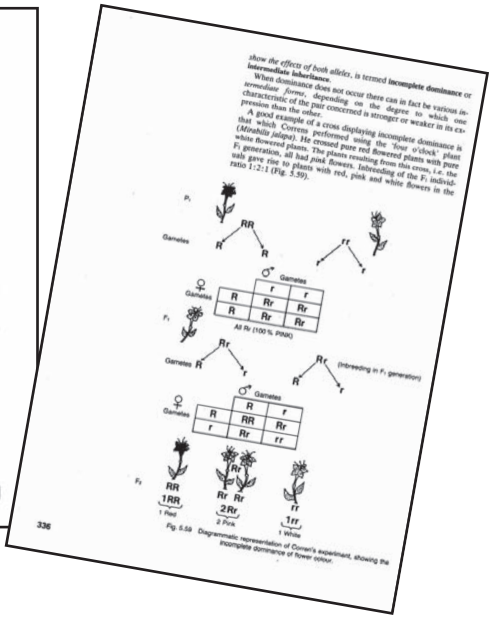
In the meantime, heat the oil in a wok and, when very hot, plunge the tofu into the oil until it turns golden in colour. Lift it out immediately and place into a colander to drain.

Put the tofu cubes in a serving bowl. When the tomato sauce is cooked, pour it over the tofu and garnish with chopped basil.

This dish can be served hot with a grain of your choice (see pages 60–62), or cold as a salad.

SERVES 4

55 TOFU


*show the effects of both alleles*, is termed **incomplete dominance** or **intermediate inheritance**.

When dominance does not occur there can in fact be various *intermediate forms*, depending on the degree to which one characteristic of the pair concerned is stronger or weaker in its expression than the other.

A good example of a cross displaying incomplete dominance is that which Correns performed using the 'four o'clock' plant (*Mirabilis jalapa*). He crossed pure red flowered plants with pure white flowered plants. The plants resulting from this cross, i.e. the $F_1$ generation, all had *pink* flowers. Inbreeding of the $F_1$ individuals gave rise to plants with red, pink and white flowers in the ratio 1:2:1 (Fig. 5.59).



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Fig. 5.59 Diagrammatic representation of Correns's experiment, showing the incomplete dominance of flower colour.

Visual literacy is certainly important in the Life Sciences classroom but its value for a person extends into the world well beyond the school walls. A vast amount of information is communicated to us daily through the mass media. This information comes to us primarily through images which are being used with ever increasing frequency. A brief look through a magazine or newspaper will reveal a wealth of images, diagrams and other graphic elements. Advertisers in particular have realised the power of images to communicate with a mass audience. Many contemporary advertising campaigns revolve around a single, carefully crafted image, and words, if there are any at all, play only a supportive role. This is especially the case in multilingual contexts.


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# Monitor

A barometer of governance and development

**Strachan's critical period** There are busy weeks ahead for Celtic's new manager as he decides who's in and who's out **Page 37**

# One builds, one burns

Comment

**Ted Baumann**

As violent protests over lack of housing and service delivery erupt in Cape Town, it is useful to contrast the city's experience with that of Durban.

Cape Town's problems can be understood from various angles. It is no worse off than Durban in terms of human settlement needs — indeed, in terms of absolute numbers, its problems pale in comparison. Cape Town, however, is increasingly volatile.

The arguments about tensions between coloureds vs Africans, and between those born in the Cape and newcomers to the city are well-known.

Now to the less obvious. Since the African National Congress gained control of the Western Cape and city of Cape Town, there has been more emphasis on the needs of African townships. No problem there. The new political leadership, however, has failed to come to grips with the "insider-outsider" phenomenon.

It is reluctant to abandon the housing waiting list, which favours "insiders" such as those living in backyard shacks in Gugulethu and Langa, but the most visible manifestations of urban poverty and homelessness, such as the Joe Slovo informal settlement along the N2 highway, are populated by "outsiders".

This dilemma began to take its current form when the N2 Gateway Project was foisted on the city by the national government. Despite its developmental rhetoric, the project is driven by a desire to change the physical appearance of the city as quickly as possible — hence the focus on newer, "outsider" settlements such as Joe Slovo and Barcelona that greet tourists on arrival, to the detriment of the backyarders of Langa and Gugulethu who are "invisible".

The problem has been aggravated by the political strategy of Cape Town's leaders. Instead of engaging communities in dialogue to explain the strategy and tactics of the project, politicians and senior civil servants naively believed that the ANC's overwhelming victory in April 2004 meant they no longer need to consult anyone — just deliver, fast.

Consequently, instead of engagement and participation, Cape Town has pursued a "marketing" strategy, vaguely promising that everyone will benefit from N2-like delivery — eventually. Combined with deliberate information blackouts and sidelining of community structures other than those controlled by ward councillors, this is the real fuel under the fires currently burning in Gugulethu, Langa, Khayelitsha and Blackheath.

In fascinating counterpoint to events in Cape Town, last Sunday Minister of Housing Lindiwe Sisulu gave the keynote address at a major human settlement-oriented event in Durban — not behind closed doors with politicos and bureaucrats, but in a mass public meeting in an informal settlement, organised by the Homeless People's Federation (HPF). The minister did more than speak: she committed herself to a partnership with the HPF, including financial support for building skills training and, remarkably, a request for HPF assistance in surveying shack dwellers in Cape Town's N2 settlements.

The choice of Durban for this government-people meeting was rooted in that city's strategy of nurturing positive, open relationships with organised residents of its informal settlements. The metro housing department has worked with HPF groups to develop incremental community-based projects that meet real, immediate needs — like building public ablution blocks, surveying informal settlements to determine housing needs, and building houses through the People's Housing Process.

Although elected councillors are often involved in this process, the Durban Metro leadership is wise enough to know that sometimes the authentic voice of the settlements is to be found in informal structures.

Because of realistic, incremental, and participatory strategies like these, Durban, though not immune to conflict, is meeting real development needs, and is seen to being doing so by the residents of its massive informal settlements. Instead of pursuing high-profile projects for a tiny minority in the hope that this will assuage the frustrations of those excluded from them, Durban is active in many places at once, acting incrementally. Instead of rigidly adhering to bureaucratic waiting lists, Durban is responding to community initiative and rewarding it.

But most importantly, instead of keeping its low-income communities at arm's length, Durban is engaging them. That's why Durban is building while Cape Town is burning.

*Ted Baumann is executive director of the Utshani Fund, which is affiliated to the Homeless People's Federation*

**Oceanview residents erect a barricade during a protest this week against the slow delivery of housing in Cape Town.** Photograph: AP

the **dpsa**

Department:
Public Service and Administration
REPUBLIC OF SOUTH AFRICA

**Review of KwaZulu-Natal Poverty Reduction Strategy and Development of Framework for its Implementation. (Tender No. DPSA:11/2005)**

Department of Public Service and Administration, under the auspices of the Integrated Provincial Support Programme, invites interested entities to submit proposals for the review of the KwaZulu-Natal Poverty Reduction Strategy and the development of a monitoring and evaluation framework for its implementation.

**Request for Tender Documents and Procurement enquiries should be directed to Department of Public Service and Administration:**

Mr K Moloto / Mr P Mokoena, Telephone: (012) 314 7179 / 7082, Fax: 086 613 8592 / 8591, Batho Pele House, c/o Van der Walt & Vermeulen Streets, Pretoria or Private Bag X916, Pretoria, 0001

**Technical Enquiries to: Mr J.M.Gumede Cell no: 082 450 7708**

NB: A compulsory briefing session for prospective bidders will be held on 14 June 2005 at 10:h00am at Truro House, Victoria Embankment, Durban in 9th Floor Boardroom.

**Tenders must be hand delivered** to Department of Public Service and Administration, Batho Pele House, c/o Van der Walt and Vermeulen Streets, Pretoria **or couriered** to Private Bag X916, Pretoria 0001, Marked for the attention of the Deputy Director: Supply Chain Management.

Closing date for submission of tenders: **Monday, 27 June 2005 at 11:00AM**

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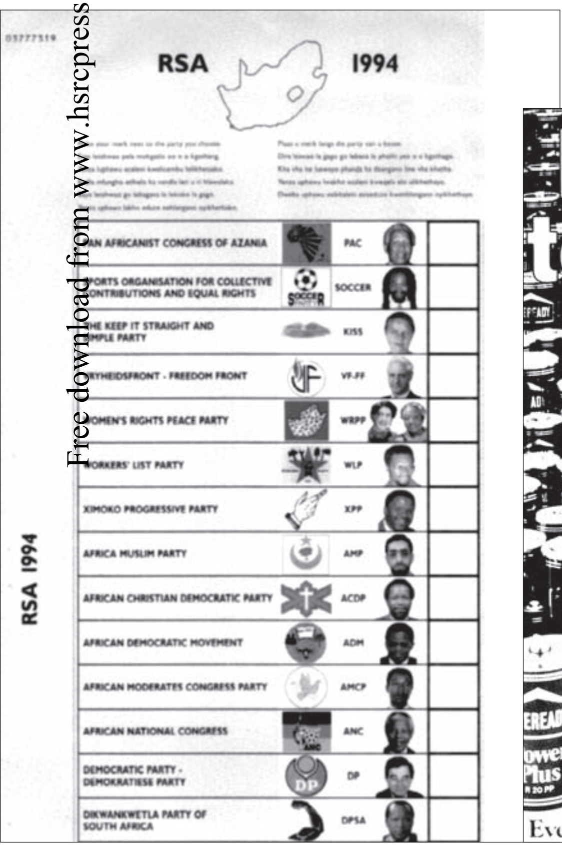
While it is true that we intuitively learn to read these images through simple repetition, often this form of understanding remains superficial or unconscious. Because we lack the necessary skills we are not able to engage critically with the image and unlock its full meaning.

We need to make an important distinction between 'looking' and 'seeing'. 'Looking' is a physical process – the image of a tree falls on the surface of the retina of our eye. It is a passive event. 'Seeing' on the other hand is an active process mediated by the mind. In seeing, the image on the retina is consciously grasped and interpreted in the processes of the mind. Untutored, we can look at an image but see nothing. Visual literacy is a skill that requires both looking and seeing. Interpreting and understanding images (i.e. 'seeing them actively') plays a critical communicative role in both scientific and popular contexts. To understand the communicative power of images (and the importance of visual literacy) we need to ask what makes images so 'special'? Why are they so effective in communicating complex concepts?

We can start by saying that images communicate faster than words. Written text is linear. To gain control of its meanings you have to follow the order of words from beginning to end. An image by contrast communicates 'all at once' as it were. You can start anywhere and as you gather information from one point on the image you can cross over and pick up other lines of meaning. This is because an image contains a vast amount of information in a compact space. An image does not have to explain itself as it goes along as prose text has to (as you can see in the text you are reading now). An image makes instantaneous claims on the eye and the mind – it draws both into its visually constructed internal logic.

These are some of the reasons that we find ourselves living in an increasingly visual world. When we have developed some visual literacy skills we can quickly and easily assimilate and remember large volumes of information. The images that surround us are made to be attention-grabbing, visually appealing and easy to remember. This is one of the main reasons why images are used to virtual saturation point in our fast-paced consumer society – because they are quick to 'take in'. Finally images are 'special' because they cross language boundaries. They avoid the forms of inclusion/exclusion that language always carries. If we recall the voting ballot of South Africa's first democratic election we can see how important this characteristic of images is. You did not have to be text-literate to 'read' the simple icons and images of the party leaders. This holds true for both scientific and popular images.





There are of course important differences of character between popular and scientific images. The images of popular culture are created to grab attention and communicate information as quickly as possible, and they must be novel and entertaining at the same time. If images are to communicate quickly they need a simple message. They cannot ask the viewer to process too much information. The result is that popular images tend to be eye-catching and easily understood but without internal complexity. They ask for no more than a simple and superficial understanding. In the never-ending flow of visual materials they are often quickly forgotten.

By way of contrast as anyone who has recently read through a Life Sciences textbook will realise, the images in the book are not dedicated to grabbing attention and entertaining the reader. The book assumes that the reader is already interested and will be giving full attention to the subject. Scientific images are similar to popular images in that they aim to communicate a specific idea or concept but they offer themselves as vehicles for analytical thought and extended interpretation. Scientific images are exceptionally rich in content because the concepts they carry are meaningful only within the context of the network of scientific principles and procedures which have brought the concept into being in the first place. If we think back to the religious images mentioned earlier the analogy clarifies the point. The great European painters of the Renaissance painted the faces and bodies of people whom they knew but by selecting the clothes they were dressed in and the scenes around them, not to mention the colours and textures of the paint, they placed them in the contexts of religious meaning. The result was that the images carried much more than just the visual impression of the individuals themselves. Because they are so rich in content, scientific (and religious) images almost always need to be accompanied by a text which explains not only the meanings which the image carries but also its process of creation. The marvel of an image is that its process of creation and its presentation of meaning are one and the same thing. Popular images which convey 'profane knowledge' require no explicatory text for their understanding. They make only simple assertions.

Within the school context the teacher assumes the role of the written text of an article or textbook. The same is true of the priest in the established Church. It is his or her function to guide the student to an understanding of the images. The teacher becomes a bridge between the student and image. By explaining the meaning and the content of the image the teacher is also teaching visual literacy. A proper understanding of a scientific image cannot be separated from a visual reading of the image. And a correct reading of the image needs to be facilitated by information that is not contained within the image. It is important to note that there is a correct (intended) reading of a scientific image as opposed to a popular image which is more open to personal interpretation.

However, it is necessary to remember that it is still the image that is the primary focus of attention and not the written text. As an example, consider the original Crick/Watson article that revealed the structure of DNA – the double helix. Very few people will remember what the text in this article is about but everyone remembers the image. This is the power of images. But the text was needed to 'introduce' the image – to reveal its creation process. Therefore, within the scientific community images are understood not as additions to written texts but rather primary texts in themselves. This is in contrast to the general under-valuation of images, and consequently visual literacy, in schools.


No. 4356 April 25, 1953 NATURE 737

equipment, and to Dr. G. E. R. Deacon and the captain and officers of R.R.S. *Discovery II* for their part in making the observations.

[1] Young, F. B., Gerrard, H., and Jevons, W., *Phil. Mag.*, 40, 149 (1920).
[2] Longuet-Higgins, M. S., *Mon. Not. Roy. Astro. Soc., Geophys. Supp.*, 5, 285 (1949).
[3] Von Arx, W. S., Woods Hole Papers in Phys. Oceanog. Meteor., 11 (3) (1950).
[4] Ekman, V. W., *Arkiv. Mat. Astron. Fysik.* (Stockholm), 2 (11) (1905).

MOLECULAR STRUCTURE OF NUCLEIC ACIDS

**A Structure for Deoxyribose Nucleic Acid**

WE wish to suggest a structure for the salt of deoxyribose nucleic acid (D.N.A.). This structure has novel features which are of considerable biological interest.

A structure for nucleic acid has already been proposed by Pauling and Corey[1]. They kindly made their manuscript available to us in advance of publication. Their model consists of three intertwined chains, with the phosphates near the fibre axis, and the bases on the outside. In our opinion, this structure is unsatisfactory for two reasons: (1) We believe that the material which gives the X-ray diagrams is the salt, not the free acid. Without the acidic hydrogen atoms it is not clear what forces would hold the structure together, especially as the negatively charged phosphates near the axis will repel each other. (2) Some of the van der Waals distances appear to be too small.

Another three-chain structure has also been suggested by Fraser (in the press). In his model the phosphates are on the outside and the bases on the inside, linked together by hydrogen bonds. This structure as described is rather ill-defined, and for this reason we shall not comment on it.

We wish to put forward a radically different structure for the salt of deoxyribose nucleic acid. This structure has two helical chains each coiled round the same axis (see diagram). We have made the usual chemical assumptions, namely, that each chain consists of phosphate diester groups joining β-D-deoxyribofuranose residues with 3',5' linkages. The two chains (but not their bases) are related by a dyad perpendicular to the fibre axis. Both chains follow right-handed helices, but owing to the dyad the sequences of the atoms in the two chains run in opposite directions. Each chain loosely resembles Furberg's[2] model No. 1; that is, the bases are on the inside of the helix and the phosphates on the outside. The configuration of the sugar and the atoms near it is close to Furberg's 'standard configuration', the sugar being roughly perpendicular to the attached base. There is a residue on each chain every 3·4 A. in the z-direction. We have assumed an angle of 36° between adjacent residues in the same chain, so that the structure repeats after 10 residues on each chain, that is, after 34 A. The distance of a phosphorus atom from the fibre axis is 10 A. As the phosphates are on the outside, cations have easy access to them.

This figure is purely diagrammatic. The two ribbons symbolize the two phosphate—sugar chains, and the horizontal rods the pairs of bases holding the chains together. The vertical line marks the fibre axis

The structure is an open one, and its water content is rather high. At lower water contents we would expect the bases to tilt so that the structure could become more compact.

The novel feature of the structure is the manner in which the two chains are held together by the purine and pyrimidine bases. The planes of the bases are perpendicular to the fibre axis. They are joined together in pairs, a single base from one chain being hydrogen-bonded to a single base from the other chain, so that the two lie side by side with identical z-co-ordinates. One of the pair must be a purine and the other a pyrimidine for bonding to occur. The hydrogen bonds are made as follows: purine position 1 to pyrimidine position 1; purine position 6 to pyrimidine position 6.

If it is assumed that the bases only occur in the structure in the most plausible tautomeric forms (that is, with the keto rather than the enol configurations) it is found that only specific pairs of bases can bond together. These pairs are: adenine (purine) with thymine (pyrimidine), and guanine (purine) with cytosine (pyrimidine).

In other words, if an adenine forms one member of a pair, on either chain, then on these assumptions the other member must be thymine; similarly for guanine and cytosine. The sequence of bases on a single chain does not appear to be restricted in any way. However, if only specific pairs of bases can be formed, it follows that if the sequence of bases on one chain is given, then the sequence on the other chain is automatically determined.

It has been found experimentally[3,4] that the ratio of the amounts of adenine to thymine, and the ratio of guanine to cytosine, are always very close to unity for deoxyribose nucleic acid.

It is probably impossible to build this structure with a ribose sugar in place of the deoxyribose, as the extra oxygen atom would make too close a van der Waals contact.

The previously published X-ray data[5,6] on deoxyribose nucleic acid are insufficient for a rigorous test of our structure. So far as we can tell, it is roughly compatible with the experimental data, but it must be regarded as unproved until it has been checked against more exact results. Some of these are given in the following communications. We were not aware of the details of the results presented there when we devised our structure, which rests mainly though not entirely on published experimental data and stereochemical arguments.

It has not escaped our notice that the specific pairing we have postulated immediately suggests a possible copying mechanism for the genetic material.

Full details of the structure, including the conditions assumed in building it, together with a set of co-ordinates for the atoms, will be published elsewhere.

We are much indebted to Dr. Jerry Donohue for constant advice and criticism, especially on interatomic distances. We have also been stimulated by a knowledge of the general nature of the unpublished experimental results and ideas of Dr. M. H. F. Wilkins, Dr. R. E. Franklin and their co-workers at

Scientific and popular images are created with specific audiences in mind. Often this creation process is not transparent. By understanding their creation process we will get a better insight into their meaning and function, and be better armed to evaluate them critically. We will begin by looking at the conventions of scientific images and then look at specific types of images that you may have come into contact with – namely; photographs, diagrams, models and finally icons.

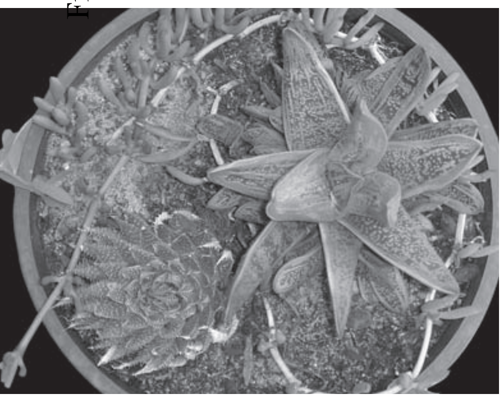
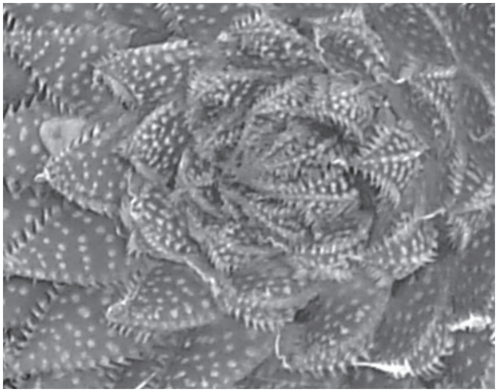
## How are scientific images created?

If we can understand the process through which scientific images are created we can get a better insight into their meaning and function. The first, and often overlooked point, is that the images are created. They are not direct representations of nature. They are constructed with a particular purpose in mind. Their aim is to channel meaning, which means 'to reduce the potential proliferation of meanings that artistic images exploit'. This is achieved by removing all visual data that is extraneous to the intended meaning of the image. These may include colour, perspective, background, organic elements, depth and texture. A quick comparison between a popular science magazine and a scientific journal will make this point. The magazine will be filled with exciting, full-page, colour illustrations and diagrams, while the journal will consist mainly of flat black and white line drawings and photographs.

Meaning is channelled by removing all information that does not contribute to what one is trying to communicate. For example, most scientific images are black and white because colour does not add meaning to the image; others are devoid of perspective as it does not contribute to the intended meaning. The process of channelling meaning can be summarised as 'framing', 'focusing' and 'filtering'. 'Framing' is where the whole object is shown without cropping (the procedure for altering the outer frame). 'Focusing' is like zooming in on, and cropping, the object so that only the part of the image that is of interest remains within the frame – thus removing non-relevant information. Finally, 'filtering' simplifies what has already been framed or focused. This is achieved by simplifying the forms, removing colour, texture, perspective, depth and background. The result is a highly modified image. Collectively the process of channelling is known as mathematisation. Mathematisation is the process of applying mathematical order to natural objects. This involves removing all possible traces of the natural organic forms and replacing them with more geometrical representations.

Channelling may sound grand and complicated but it is something that we all do everyday. When we look at the world we don't see everything there is to see but rather only that which interests us or catches our attention. We filter out information constantly, making it simple so that we

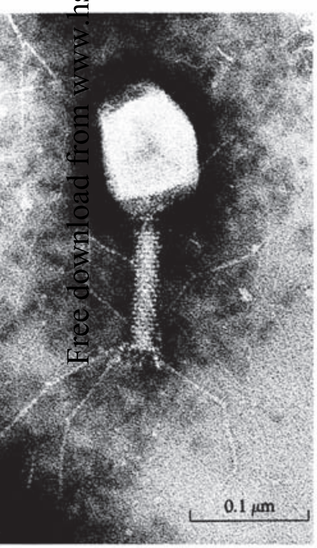


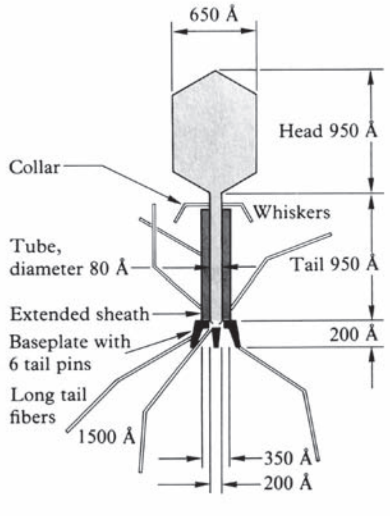




are able to make sense of our surroundings. The daily world confronts us with a chaotic flood of information which we order in terms of our projects and interests. We simply filter out all that doesn't register within our pattern of interests. The same is true in scientific contexts. Scientists start seeing something once they stop looking at nature and focus completely on constructed images on paper.

This simple transformation – from looking at chaotic three-dimensional forms to seeing less confusing images on paper – is often overlooked. The original objects are discarded and all that remains are the extracted images or data. This extraction is what counts in making the image. Not much can be said about the original objects but a great deal can be said about the images or data that represent them. Thus for the scientist, 'the symbol becomes the reality.'





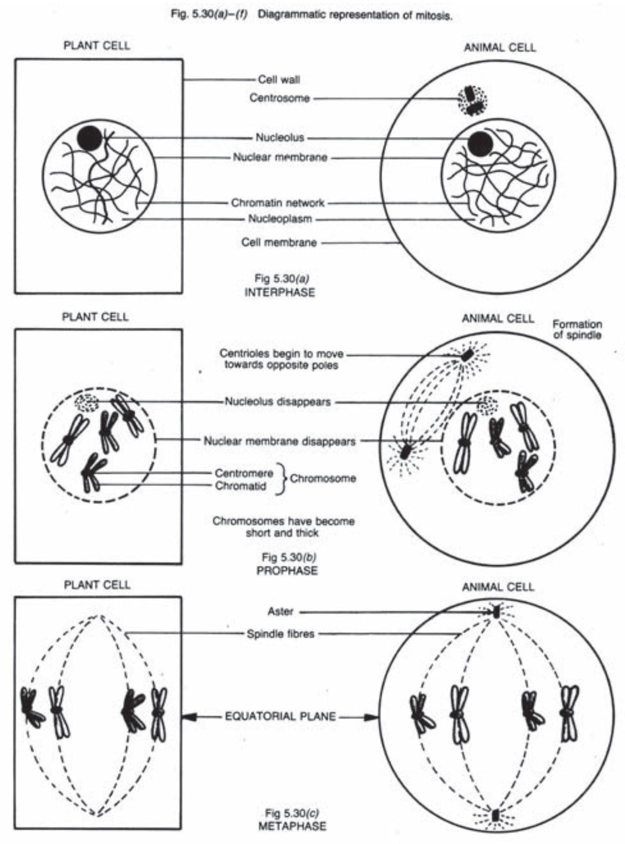

The interesting thing is that in the making of scientific images the filtering processes of everyday vision are reversed. Instead of an object being transformed by the perceiver into an idea which is then made tangible through representation, in science an idea is made tangible through a representation that becomes an object. The retina has been turned inside out – as it were 'externalised'. The substrate (paper, monitor, poster) on which the image is inscribed becomes the retina (the raw data), but in a form that makes it 'mobile' and open to enquiry and detailed investigation. It is important to note that although the image has become visually more ordered by the selection and removal of information, it has become more theoretically complex. Selection of what is to be removed is evaluated by the established way scientific methods of visualisation simplify and schematise objects of study. Over time this process, consistently applied, has resulted in images that are said to be 'optically consistent'.

Optical consistency is a manifestation of the channelling process. Through long-established usage in the scientific community the process of creating scientific images has become conventionalised and institutionalised to the point where the created images display similar visual conventions. The advantage gained is that the creation process, and thus the thought process of the image, becomes inscribed within the images themselves. The result is that scientific images are able to cross both linguistic and contextual boundaries. The disadvantage however is that people who do not grasp the creation process and the conventions which govern it will not have easy access to the wealth of meaning and information. This is the reason that education in visual literacy within the Life Sciences is vitally important.

We will now list some of these conventions and explain their importance.

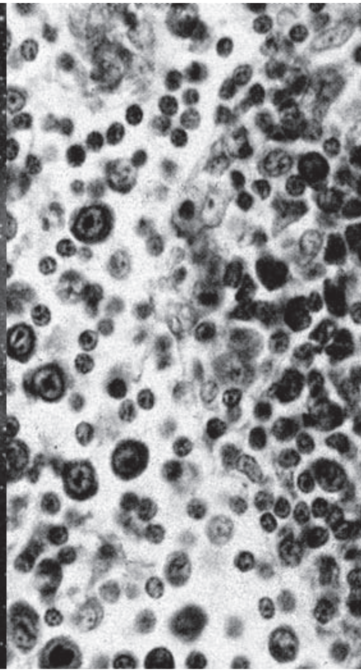
**Labelling**

Labelling is something that we have all come into contact with. There are conventions about how to label diagrams which we are all taught early on in our school careers. At times these conventions may seem to be pedantic but they are simple and important steps in optical consistency.




## Representation on paper

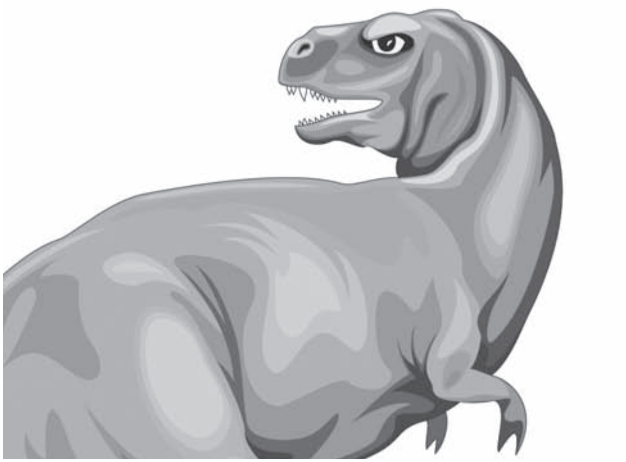
The second type of optical consistency is that images are produced on paper. Scientists don't look at nature but rather look at paper images. As mentioned earlier, if scientists were looking at the observable world they would not see anything. What they look at are images or data represented on paper (and, to an ever increasing degree, computer monitors). The effect of this is that whatever they look at is represented at relatively the same size. Whether scientists are looking at stars or cells, which in reality are on a vastly different scale, they will be the same size when reproduced on a piece of paper. Thus the images are optically



consistent in size. The advantage of this is that the images can be easily compared or evaluated. A further advantage is that paper makes distribution possible. Not only does the image look the same but everyone can see that it looks the same. The information is easily shared which makes it possible to debate on a global scale and in 'real-time' the questions which the image has raised.

## Objects of investigation – making the world visible

Images become objects of investigation. The gain for science made through the investigation of images is that it becomes possible to study things that no longer exist or even those that have never existed. We cannot study living dinosaurs – they can no longer be observed in living form – but through constructed images we make them visible. It is through the images that we *see* the dinosaurs. The same is true of DNA. It is the minute size of the genes that renders them invisible but once represented on paper with visual consistency we can critically evaluate them. Thus it is literally true that through images we represent and understand our world.



**Conventions and their origins**

The conventions of image-making did not originate within the Life Sciences. Scientists appropriated many of the pictorial conventions and image-making techniques from other picture-making disciplines, especially, as we have already suggested, from painting. The advantage of using these existing techniques is that people already know how to read or interpret them. They form part of our visual vocabulary.

For example, 'relief', the technique of raising the profile of the image on the paper, is rendered by the shading produced from a source of light apparently situated outside the frame at the upper left corner of an image.

A different example is perspective. We readily understand the construction of space on a flat surface because we are able to read converging lines as 'going back in space'. We also take it for granted that strongly textured objects are closer to the viewer and lighter shaded objects are further away in the background. These conventions did not always exist. They are not a 'natural' way of seeing. They were invented by artists and painters. South African rock art demonstrates a totally different way of seeing because it was made before the conventions of classical painting had been invented and accepted. We inherit the conventions and they become fixed in our minds by the canons of classical painting.

## Types of scientific images

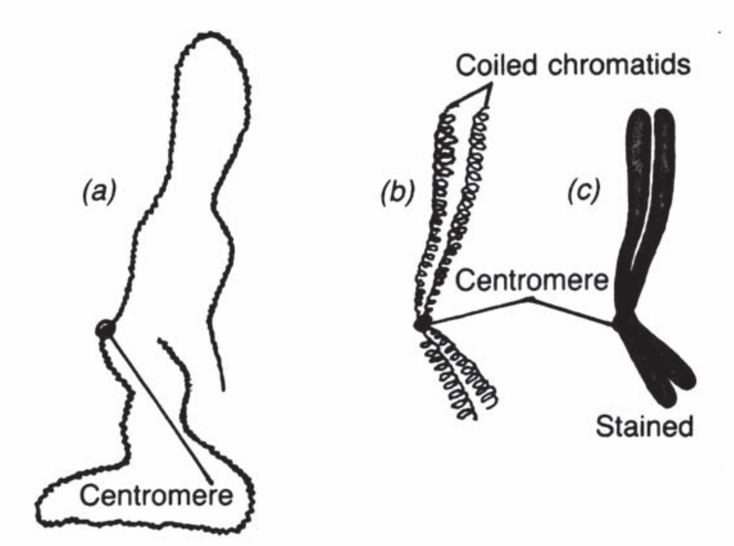
Earlier we looked at the relationship between object, image, text, teacher, and student. We will now look at the relationship between four different types of image commonly used within the Life Sciences – photographs, diagrams, models and finally, icons. Our aim is to show further the degree to which seemingly natural objects are manipulated to conform to the purpose of the scientist who determines the form of the image. If we cannot understand the capacities and limits of the different types of image we run the risk of misinterpreting the particular image. Once more we are confronted with the need to develop our visual literacy.

Photographs are generally thought of as objective recordings of the natural world due to their high formal definition. Because of their high modality photographs are often presented as a guarantee to the authenticity of the text and diagrams to which they are adjacent. But this masks the fact that they have been manipulated; the object or specimen to be photographed is prepared before the photograph is taken. Photographs of cells, for example, are often stained to highlight the purpose of the scientist. In addition, in order to make the image simpler to read, cells are frequently photographed in a sliced or flattened state and not shown in their entirety. With the exception of occasional explanatory diagrams, perspective is rarely used in photographic illustrations in scientific articles, and black and white photography is often used before colour, since colour is usually regarded as irrelevant to the meaning of the image. Moreover the photograph is invariably framed and focused, sometimes with the addition of labelling, or pointing in the form of arrows, directed to specific areas within the photograph.

In short we can see that the potentially objective photographic image has been highly refined and its meanings channelled before the photograph has even been taken. In fact the popular representation of DNA looks nothing like the 'real thing' as seen through a microscope.

A diagram is a rendering or transformation of a photograph. Relative to the diagram, the photograph appears to be more 'original' material, whereas the diagram is more evidently analysed, labelled, and mentally constructed. We might as a result be inclined to say that the diagram is a 'reduction' of the photograph, a simplification that is more refined or worked on. There is a paired relationship between them and it is not only sequential; each photograph is not simply more original 'in time' but is presented relative to the diagram as original evidence. The photo's photochemical transfers can be invoked to explain its image as something 'more real' than an artistic creation. It is as though the image is imparted by the object itself. Of course, as we have already discussed, this is not necessarily the case

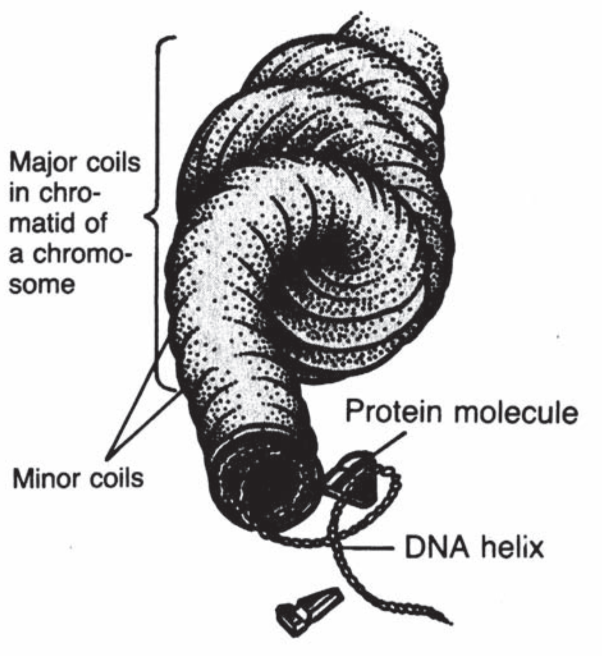




– the photographed materials may have been extensively handled in order to prepare them for the picture. Relative to the juxtaposed diagram, however, the photograph less obviously shows the 'hand' of the artist. Perhaps the most important hidden effect of the photograph is that it strives to identify what might be thought of as 'universal properties' in the particular specimen under study. It appears to be objective evidence and to 'solidify' the object in reference to the current state of the discipline. The diagram has to be seen as a more mathematical and ordered version of a given photograph. Yet the diagram is not an 'ideal' image against which the photograph is registered as 'empirical'. Both photograph and diagram represent some worldly object on a common textual surface and as such both are constructed through the conventions of inscription and interpretation.

A model is an assemblage of various diagrams into a single image with the aim of unifying and representing theoretical information which cannot be found in any single image. A model offers a visual image of information which can neither be directly observed nor photographed. A model sometimes appears as a fragmented image since it is made up of multiple other images but it asks to be interpreted and understood as a single unified image. Compared to diagrams and photographs, the model is the most abstract and theoretically laden type of image. The model image composes the diverse representations, labels and indexes, into a unity and in the process creates theoretical information which cannot be found in any single micrographic representation. In this way it provides a document of phenomena which cannot fully be observed by the scientist or represented by photographic means. A model integrates and assembles the visible, normative, and mathematical products of diverse research projects.

Where other forms of scientific image fragment the specimen under study to reveal its details, models reconstruct a holistic entity and seemingly return the viewer to a state of the object before it was analytically disassembled. What



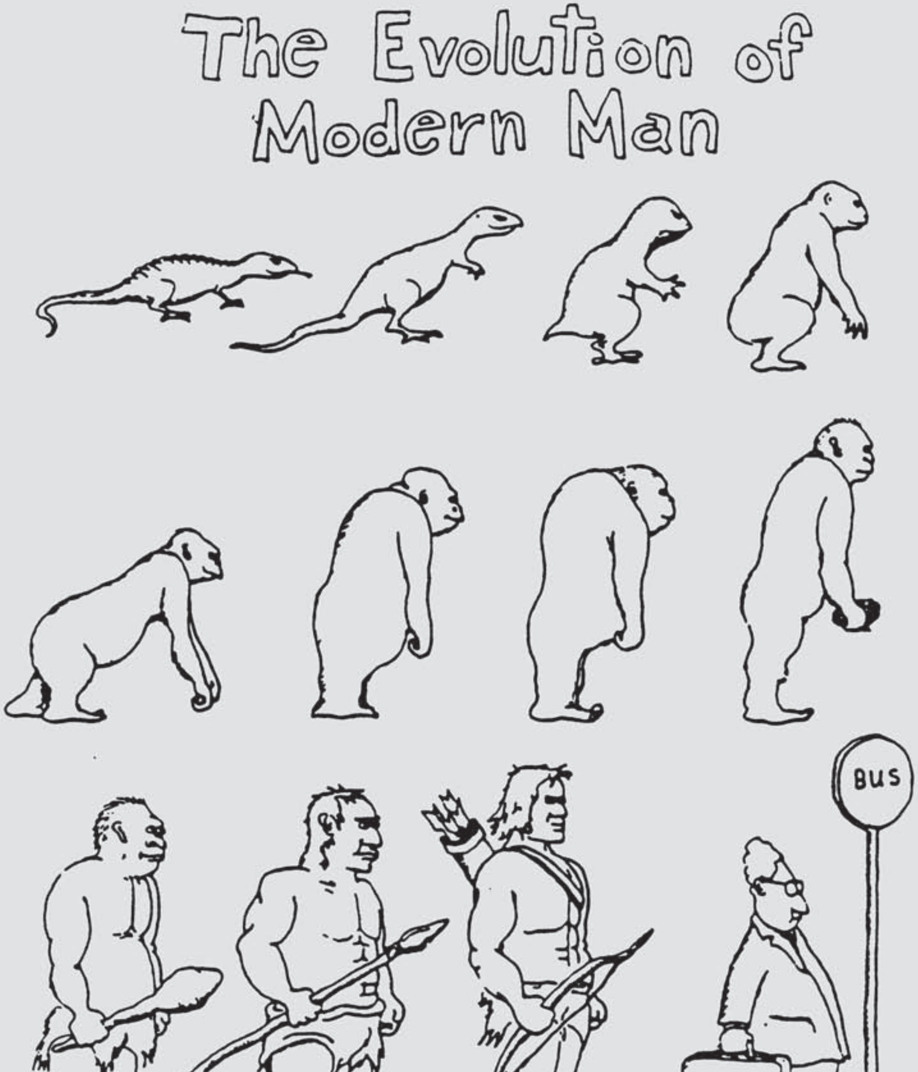

the viewer sees however is not the same as the 'original' specimen before it was killed, dissected, stained, and otherwise prepared for microscopic viewing. Instead, it provides an imaginary re-assembly of the specimen based upon multiple fragmentary remains.

An icon can be thought of as the synthesis of the popular and the abstracted scientific image. It is both theory-laden and visually appealing. It can thus happily coexist within both the popular and scientific contexts. This accounts for its power to communicate a vast amount of information quickly and easily within diverse contexts on a global scale. Certainly our perception of what is iconic is as much formed by the frame (society, our culture, the methods of presentation) as it is by the core object itself. Icons change appearance depending on how you look at them. The image channels meaning but the viewer still plays a role in the interpretation of the image.

Icons are repositories of meaning at a certain time and place and for a certain audience. They therefore have to be updated as knowledge and times change. This process of change and updating is called cascading of images and is likened to the process of evolution itself. This is one of the functions for this booklet, to disseminate current theory and content in the new Life Sciences curriculum – to update it.

However, good design, it turns out, does not always solve problems. Instead, it makes us aware of both problems and potentialities. It frames and forms the spaces we inhabit and the tools we use into coherent constructs that reflect our own humanity, which is our ability to make a world for and of ourselves. Good design makes us wonder. And so visual skills with which one can critically look at images become vitally important. Without these visual skills one cannot see the problems and potentialities. One does not see, one only looks.




The Evolution of
Modern Man
BUS

## Section 2: Evolutionary Iconography

This part of the discussion focuses on familiar representations of evolution. We will use the terms of visual literacy that we have already established to analyse five iconic images and to evaluate the character of the knowledge that they carry and communicate.

Icons are images imbued with power. They are visible representations of processes and conditions which can be imagined and felt but cannot be seen. The icon stands for more than it shows. It is a symbol of energies and activities and presences that are active in the imagined world but which cannot be directly demonstrated. One of most potent forms of an icon is the small religious painting which provides the focus for private prayer and veneration. The icon carries the power of God and makes it visible to the faithful worshipper. Icons invoke awe in the viewer as they articulate the unseen. Because they mediate between the seen and the unseen icons take on an existence of their own. Viewers grant the representation its own independence. The result is that icons become highly persuasive images, able to communicate and convince people more than words will ever be able to.

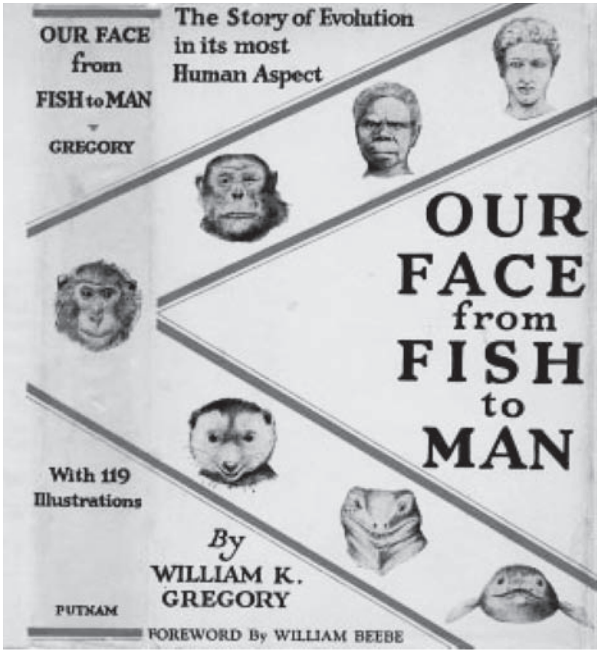
The custodians of power, whether religious, scientific, political or simply commercial, all know and use the evocative power of a well-crafted iconic image. The icon is the symbol which will win and hold the loyalty of the believer. In religion, loyalty to the denomination or creed (think of the cross or the crescent); in politics loyalty to the party and its leader (think of the swastika); in commerce loyalty to the 'brand' (think of Castle or Nike). However the power which icons carry brings with it some particular dangers. The icons of evolution in particular can seem so 'true' and so 'simple' that they take on the character of unambiguous facts of nature. Of course, as we discussed earlier, this is not, and cannot be, true. These images are the thoughts of those who make them.

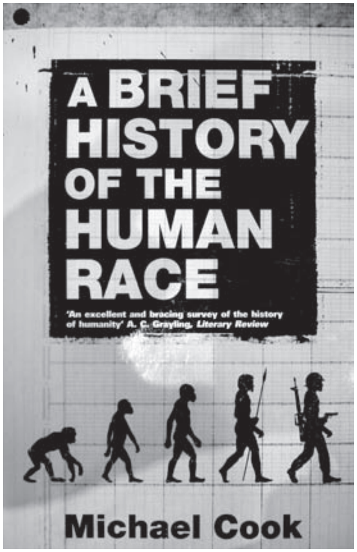
In the following parts of the discussion we first describe the familiar icons of evolution and then move on to analyse and critique them as particular theoretical constructions. Finally, in the third section of the paper we will create our own icons in response to the critiques that have been given.

### Amoeba-to-man

The amoeba-to-man icon is frequently featured in mass media because it proposes a narrative – a movie-like progression that is easily grasped. The viewer is invited to work a little in making the connections between each separate image and as a result is rewarded with an apparently comprehensive grasp of a long and complex process. As in a film strip, the successive images depict changes and at the same time suggest the concept of a generalised process over time. One result is that the structure and the meaning which the icon creates appears to have a stable, timeless essence – it appears to give us the 'truth' about life on earth. This is the reason why the icon is so powerful – and so risky. Its simplicity belies the complexity of its subject.

As we unfold the narrative of the images we see first an amoeba, next a fish and then a frog and so on until we end with a man. We make sense of the sequence as an amoeba becoming a fish, a fish becoming a frog and so on. Essentially this is a conventional graph with an x- and y-axis which makes possible the representation of time. In the graphic convention time moves from left to right along the y-axis. Thus evolution moves from left to right. The reader



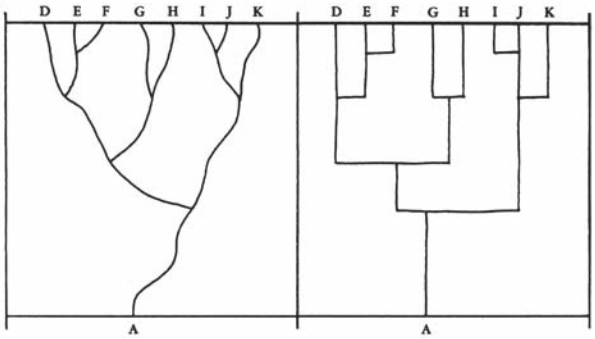




animates the static images and recreates what is happening from one image to the next in the same way that a reader creates meaning in the spaces between words on a page. The effect is that evolution unfolds as if under the eyes of the observer. The same process takes place on the vertical axis. The amoeba, the shortest figure in the far left corner of the images is seen as the least evolved, and man, the tallest figure in the far right corner is interpreted as the most evolved and advanced in the sequence. The result is a hierarchy among species. It is also worth noting that there is no background to the images. The environment and context has been removed from the story. The process seems in some way to be autonomous and automatic.

There is a certain fairly obvious truth in this icon but it also opens itself to a number of possible mis-readings. Firstly it might be taken to imply that the evolution of species follows a smooth and gradual pathway through time. Secondly it suggests a simple progression which culminates in man, and thirdly, at the same time a simple progression towards greater organismic complexity. Fourthly, because in the interests of simplicity it excludes context, it removes the role of the earth itself in evolution. We can explore each of these questions in more depth.

**1. Evolution follows a smooth gradual pathway**

Evolution does not follow a smooth gradual path from amoeba-to-man as this icon would have us believe. There is no evidence that says things change in a gradual predictable pathway. Rather evolution follows a jagged path or even, as Stephen Jay Gould has called it, a stepped or punctuated path. Such a path has periods of rapid evolutionary change after which there are long periods of stability with relatively little change occurring. But even these periods of great change would be difficult to predict and do not occur at regular intervals. Evolution, when seen more fully, is a more chaotic and unpredictable procession of random events than the icon would have us understand.




**2. Simple progression culminating in man**

Our second critique of the amoeba-to-man icon is that man (representing humankind) appears at the end of this. The implication is that the culmination of evolution is man. This is simply not true. We are not the latest 'product' of evolution. Because evolution is random and unpredictable, if some small variation had occurred during our development we would not be here in the same way as we are today. We are just one outcome of an infinite number of plausible and actual possibilities. Such a realisation should dispel any belief that a history culminating in human beings is factual or correct.

We can pursue the matter further. It seems that our assumptions about ourselves, our thoughts and convictions, carry in-built biases which set limits to our conceptual understanding. The narrative form of the icon encourages us to find a hero for the story, and understandably perhaps, we choose ourselves for the role. We see ourselves as the most important organisms on the earth and this is the story that our pictures tell. What we lose sight of when we look through the prism of the amoeba-to-man icon is that all life on earth should be valued. The fauna and flora have their own meanings and are not present simply for humans to exploit. Once we take the broader view we realise that we should rather care for, and be grateful for, what the earth provides for us. The broader view also shows us the danger of destroying the earth through the wanton exploitation of its natural resources or through polluting its sources through environmentally unsustainable practices.

But there are more questions that we can ask of the icon. What implications are carried in the progression from amoeba to frog? Does the one just become extinct once the next one appears? Obviously not but one would never know that from the diagrams. They simply do not appear again; their independent evolution or progression is never depicted despite the fact that it goes on all the same. If one could imagine a diagram of evolution drawn by a frog it would look very different to anything we know. Palaeontology (though still an incomplete science) can give us a broader, less human-centred picture of the path that evolution has followed and will perhaps eventually allow us to imagine a frogs-eye perspective of the process.

Looking back at the icon we can also notice that it is always a man that is depicted and recent social history has taught us to ask the question 'where are women in this tale of evolution?'. From this icon one might assume that women do not exist. But obviously man and woman have evolved together and should be depicted as such. We can carry the point further by noting that the image is almost always that of a white European male. In earlier versions other races were depicted as prior to (and less evolved than) their European counterparts. Such a racial bias, now generally erased


from the images, gave what seemed to be scientific support to the exploitation of non-European peoples through slavery and oppression.

**3. Simple progression towards complexity**

The third point that we noted about the icon was its implication that there was a simple progression from less to more complex life forms. The implication is that the evolutionary process is necessarily and always a movement towards increasing complexity in living organisms. Once more there is some truth to the observation but at the same time important counter-truths are obscured. Some bacteria, which have been evolving for billions of years, are still as simple as they were all that time ago. While it is true that evolution has moved from single cells to multi-celled organisms of great complexity there is evidence (although at this time inconclusive) to suggest that as they evolve organisms could also become simpler.

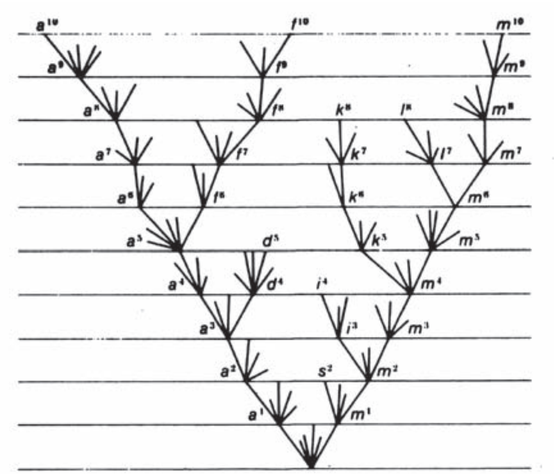
**4. The icon does not represent context and its role in evolution – the earth**

All graphs remove the background context and environment from the representation under study. The actors in our movie have been decontextualised. The background is plain and neutral. Depth is reduced or absent. The angle is frontal and objective. The implication is that the critical relations are between the actors themselves alone – the amoeba with the frog, the frog with the fish and so on. The problem with this is that evolution always occurs within a context or environment. The environment itself is a major actor. It is the relation between each of the actors and their environment which gives the context such a vital role in the story of evolution. Critical though it is, the role of the environment is entirely absent from the icon.

To return to the truth, which the icon does capture, it is not entirely inaccurate to say that life has followed from invertebrates, to fish, to reptiles, to mammals to humans. We cannot and do not deny this truth; what we do deny is the tendency to view evolution as progressive, and to see humans as the predictable culmination of this process. The wider, more complete, truth is that humans are in reality somewhere at the outer edge of the Tree of Life.

## Tree of Life

The concept and the icon, Tree of Life, originated with Charles Darwin in the early 19th century and has, since then, been the centre of much debate and controversy. For this reason we will look first at the historical evolution of this icon and then give a critical analysis of the Tree of Life as it appears in its current form. It is important to note that all icons undergo change themselves (in this case echoing the process of evolution itself). The scientific term for this is 'cascading images', where each new image is a modification of an earlier one. In science this process is driven by changes in theories or evidence within a particular field, as human knowledge develops.



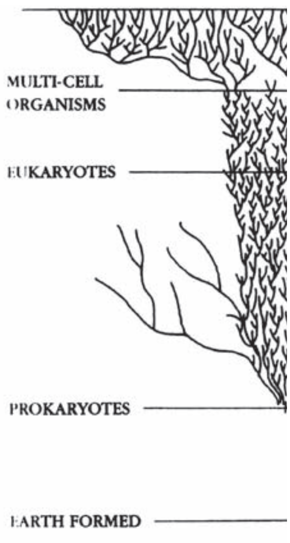
Darwin's original Tree of Life was in itself an evolution of a previous theory of humans, deriving from the metaphor of a ladder. Although, in its various forms, the Tree of Life opens itself to many of the same misinterpretations as the amoeba-to-man icon we will not dwell on these but focus instead on a visual critique of the Tree of Life following a number of its different representational forms.

**The Tree of Life icon**

The Tree of Life is similar to the amoeba-to-man icon in that they both represent evolutionary change as a pathway in the form of a graph. The Tree of Life however is a visually more abstract representation. Naturalistic details are eliminated and the background is transformed into a grid. The elements of narrative events (time, space, and subject) are transformed by the peculiarities of a graph – a two dimensional image. Within these confines we have Darwin's visualised theory of evolution. But this is no conventional graph or tree for that matter.

As a graph it is rotated 90° counter clockwise, with the past beginning at the base of the graph and moving towards the present at the top. This is a hierarchical representation with the aim of ranking phenomena in relation to one another. Man, mistakenly thought of as the most recent and final species to develop, is at the top. The form of the representation places man in a dominant position but it also has the added (and mistaken) effect of freeing humankind from being dominated by its modest origins. In contrast to this, conventional trees are depicted inverted in relation to Darwin's Tree of Life – they are more like a pyramid.

What is not being said by this icon is how life on earth began. It is merely stated that millions and millions of years ago life on earth began. This is the beginning point of the Tree of Life. But in contrast to the amoeba-to-man icon the Tree of Life does represent change in a somewhat more random way. There is the implication of a wandering path, in a similar way to which each real tree and its branches are unique. What is more important is the overall shape of the icon, beginning with something singular that 'grows' or diversifies into many. A critical difference to the image of a real tree is that where a real tree grows more of itself, the Tree of Life grows more different branches.

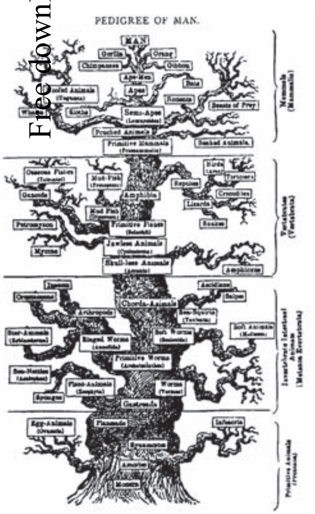


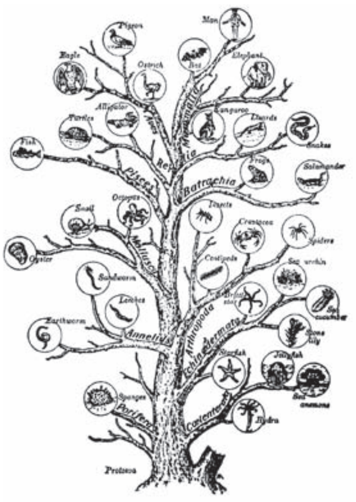
The difference is qualitative rather than quantitative. However, what is not portrayed is how this diversity is achieved.

The result it seems is that compared to the amoeba-to-man this icon replaces complexity with diversity, which is really just complexity between species rather than within species.

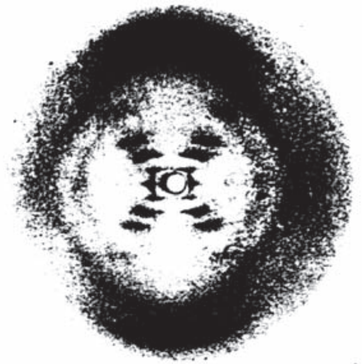
We also have to look at the rate of change depicted in this icon. In earlier versions the rate of splitting occurred in a uniform manner. We have already mentioned why this is problematic in the analysis of the amoeba-to-man icon. It should rather depict an explosion of diversity early on, followed by periods of longer lines representing species that survived. In the early period of the explosion there will be greater extinction of unsuccessful species. These will become less common as we get closer to the present.

Even though the idea of evolution is generally accepted as fact, the Darwinian revolution remains woefully incomplete. Many are still unwilling to abandon the comforting view that evolution means, or at least embodies the principle of, a progress through time which will, of necessity and thus predictably (perhaps even inevitably) produce the appearance of something like human consciousness. It is proving very difficult indeed for us to abandon the idea of ourselves as the heroes of the story of life.



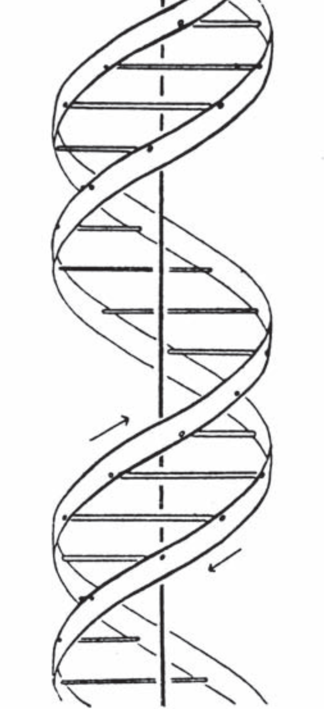



## The Double Helix – a modern icon



The double helix represents something tangible whereas the previous two icons represented an abstract theory. This is not to say that the double helix exists in nature in the same way as it looks in its iconic form. Its representation is also imbued with theoretical ideas.

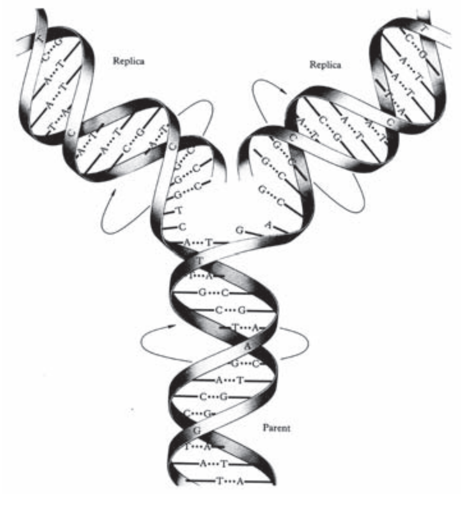
The structure of the double helix was first photographed by Rosalind Franklin, a South African. It was only later in Watson and Crick's 1953 *Nature* article that the icon first appeared in its present form, as a representation of a photograph. It is interesting to note that the text from that article is remembered by few people but the icon, in the form of a line drawing, has remained with us to become the most widely recognised scientific icon of our time. Indeed, the double helix has become an icon for science itself, representing the pinnacle of scientific thought and discovery as well as hope for the future. So when a scientific periodical prints



the images of a double helices in the sky, with lines coming down from them to the extremities of various humans and animals, it is assumed that most readers can understand the genetic control of animals. Is this the case? What does the structure of the double helix tell us? We can all recognise it but what does it mean?

When James Watson and Francis Crick described the structure of the DNA molecule in their epoch-making paper of 1953 they gave molecular biologists the conceptual tools to uncover the way in which DNA stores the information necessary to direct protein synthesis. In 1955 Crick first proposed the 'sequence hypothesis', suggesting that the specificity of amino acids in proteins derives from the particular arrangement of chemical constituents in the DNA molecule. According to the sequence hypothesis, information in the DNA molecule is stored along the spine of DNA's helical strands in the form of specifically arranged chemicals called nucleotide bases. Chemists represent these four nucleotides with the letters A, T, G, and C (for adenine, thymine, guanine, and cytosine). By 1961, as a series of brilliant experiments confirmed DNA's information-bearing properties, the sequence hypothesis became part of the so-called 'central dogma' of molecular biology. What emerged from the research was the startling discovery that the DNA molecule carried coded information in a manner similar to linguistic texts or written codes. Just as the letters in the alphabet of a written language may convey a particular message depending on their arrangement, so too do the sequences of nucleotide bases (the A, T, G, and C inscribed along the spine of a DNA molecule) convey a precise set of instructions for building proteins within the cell. It is the specificity of the sequence which carries the information for the reproduction of the particular cell.

As an example of how this message can be distorted (and a reason why visual literacy is so important) we will now briefly look at the role played by DNA in Michael Crichton's novel *Jurassic Park* (1990) and the Steven Spielberg film based on the book. The basic storyline is that dinosaurs are 'reborn' by scientists using dinosaur DNA that they had been able to recover from a piece of fossilised amber. This is a fantasy. Even a complete dinosaur DNA would not be able to make another dinosaur without the aid of a dinosaur-DNA-reader and those are just as extinct as dinosaurs – they are dinosaurs ovaries. Dinosaur DNA by itself, even complete, is only half useful. Every species can only recognise its own DNA. Neither the book nor the film raises the problem of the DNA-reader. Instead frog DNA is used to fill in whatever is missing. The use of frog DNA is an interesting error because human DNA is in fact closer to that of dinosaurs. Human DNA would have been



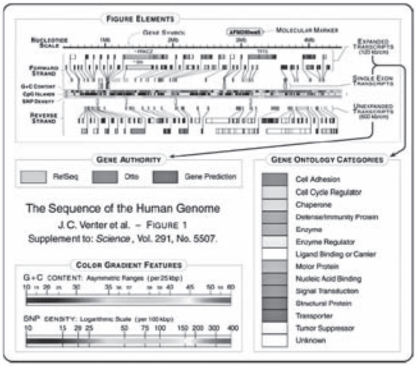
a better choice than frog DNA. The writers obviously chose to ignore the amoeba-to-man icon. The only reason frog DNA was chosen was because it could change sex which was necessary for the movie dinosaurs to replicate. This sequence shows the different pursuits of the scientists and the movie-makers. Science was distorted in the interests of crafting a compelling narrative.

## Genome sequencing maps

This icon most often occurs in scientific publication in the form of posters to be hung on the wall of a laboratory or classroom. It is supposed to be enjoyed and looked at in the hope that the viewers would get a 'feel' for what the genome looks like. As this is virtually the only mass distributed form of the genome, it sets our image of the genome. Of secondary importance is what it actually means.

These 'maps' are generally published after the completion of a genome sequencing project along with conclusions of the project. The map is a visual representation of the data, (i.e. the genome) aimed at providing the reader with a high-level understanding of that data.

Creating the icon involves a synthesis of illustration, information design and statistics with the aim of making the complex layers of information as accessible as possible.




Ordinary topographical maps organise and display information in a similar way.

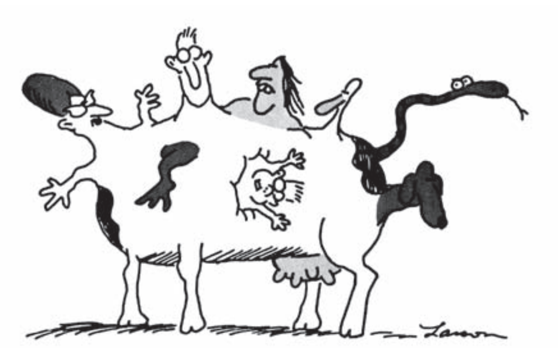
However, calling these diagrams 'maps' also allows negative inferences to be drawn. The implication is that if you can crack one code you have them all. But this is not true. In a different but equally distracting way a reference to the icon as a 'blueprint' carries the implication that it is the plan of some grand predetermined design whereas the truth is that we are literally all unique. There is no single code or grand design.

Unlike the previous icons, the sequencing diagrams virtually always appear in colour. Colour-coding provides a way of communicating the vast amount of information that the icon carries. For example chromosome 20, the shortest of the human chromosomes, requires 61,000 lines for its sequence to be mapped and communicated.

Computers are essential for dealing with the huge data load that the diagrams have to carry. The data is loaded and the computer generates the diagrams. The procedure brings with it major advantages. The computer files can be easily shared by scientists over the internet and they can be made to be interactive. Particular layers of information can be removed to focus on others – a type of real-time and selective channelling. Icons enter the digital age.

## Mutation

All of the icons that we have looked at so far represent an ordering or simplification of nature to make it easier to understand. In contrast to this, mutation, a vital and decisive element in evolution, has no single icon. Because it is a process which seemingly works 'against' order in an evolutionary context, it comes to be represented in the popular media as forms of aberration. Looking at mutation as it occurs in the movies we see that horror or science fiction films generally depict a darker side of life – and often of science. Frequently both scientists and their strange creations are represented as abnormal monsters. Mary Shelley's *Frankenstein* is the archetype of the genre which can be seen as expressing the negative anxiety which lies in balance against the hope and optimism represented by the double helix.

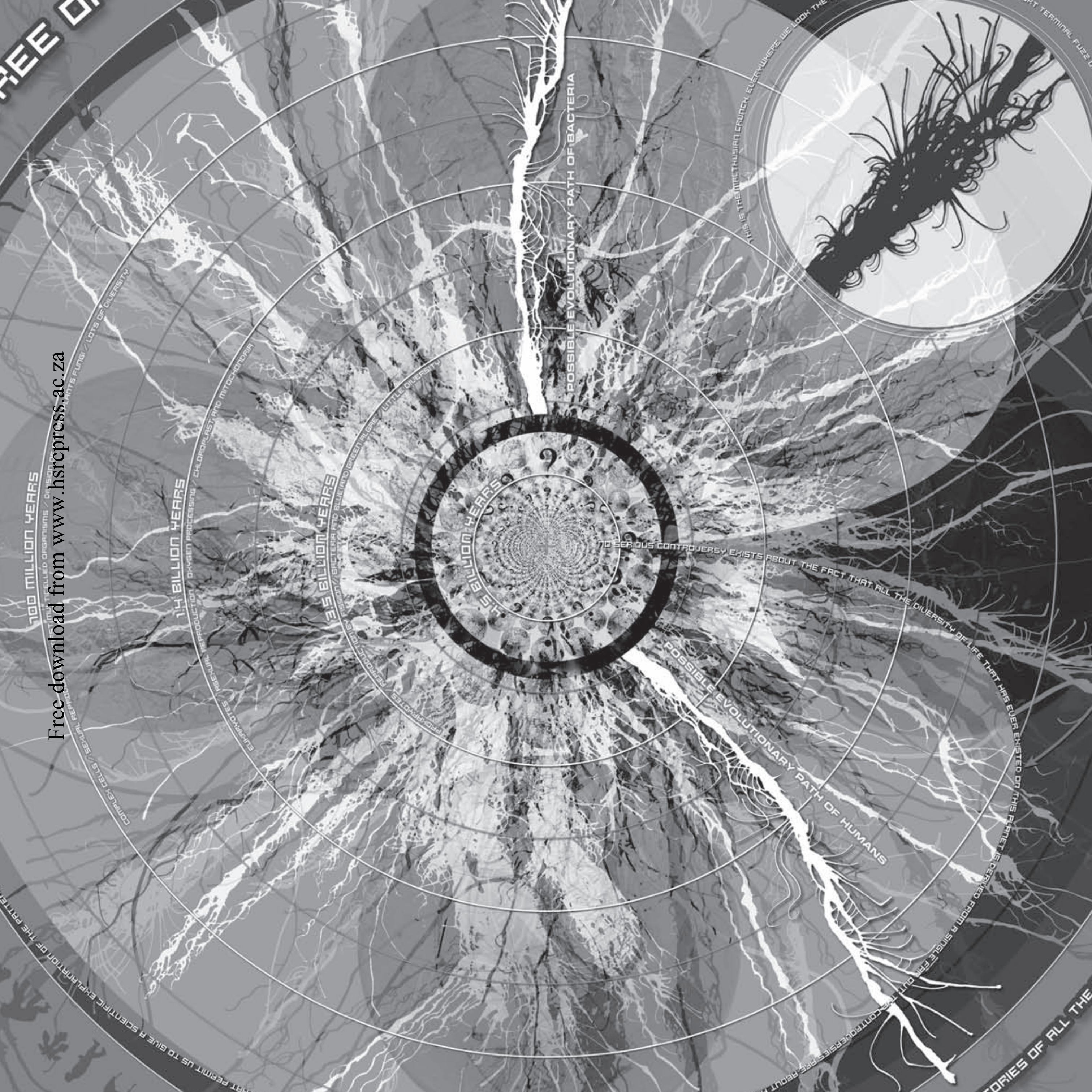


But what, in a scientific perspective, is mutation? In one sense it is a mistake. The nucleotide sequence of DNA is almost invariably accurately reproduced during replication, resulting in two identical DNA molecules. However 'mistakes' do occur resulting in daughter cells that are not identical to their parents. These changes in hereditary materials are called mutations. Gene mutations may have effects ranging from negligible to lethal. In nature, mutations that are not beneficial to the species will generally die out through natural selection while those that are advantageous will continue to exist. Mutation is a very slow process that changes the genetic constitution of populations at a very slow rate. This is because most mutations are what engineers would call 'don't cares' – variations that make no discernible difference to viability. But mutations may also be induced by natural or artificial ultraviolet light, X-rays, and other high-frequency radiations, as well as exposure of the organisms to certain chemicals, such as mustard gas and many others called mutagens. These can create organisms that are peculiarly different in form but almost the same genetically. One mutation in the wrong place can produce a freak – for which deformed offspring the medical term is *terata*, which is Greek for monsters.

In the molecular world mutation and selection events can be directly measured and manipulated and, given that the generation time for viruses is extremely short, massive Darwinian selections can be closely studied. For instance, it is the frightening capacity of toxic viruses to mutate in deadly combat with modern medicine that spurs on and funds much of this research. The AIDS virus has undergone so much mutation in the last decade that its history over that period exhibits more genetic diversity (measured in condon revisions) than is to be found in the entire history of primate evolution.

Movies often display mutations caused by either radioactive accidents or direct human intervention. X-men, Hulk, Superman and Spiderman are all examples. Often the subtext of these narratives can be seen as a warning against the dangers of scientific knowledge and the interventions it makes possible. While the characters of these movies are fiction, the warning is not. There are very real dangers when experimenting with our DNA as we are often not aware of the possible implications of our interventions, or, worse still, of our accidents. As an example, in Australia, in 2002, while scientists were genetically engineering a relatively harmless mouse pox as a contraceptive vaccine for mice, they created a deadly virus. The mouse pox virus is related to the human small pox virus which, if not contained, could infect humans. In the fiercely competitive contexts of international corporate business or biological warfare the dangers for humans are stark and obvious.

Large corporations now fund much of the research and development in the Life Sciences and as a result exert enormous influence and control over the products of research laboratories. The research corporations and the mass media (often one and the same company) dominate and control our current visual language through the articulations of contemporary designers, scientists, image banks and computer-imaging technology. The effect is a 'normalizing' rather than explicitly 'normative' influence on visual communication across the world.



POSSIBLE EVOLUTIONARY PATH OF BACTERIA
POSSIBLE EVOLUTIONARY PATH OF HUMANS
NO SERIOUS CONTROVERSY EXISTS ABOUT THE FACT THAT ALL THE DIVERSITY OF LIFE THAT HAS EVER EXISTED ON THIS PLANET IS DERIVED FROM A SINGLE FAR OUT
700 MILLION YEARS
1.4 BILLION YEARS
3.5 BILLION YEARS
4.5 BILLION YEARS
CHLOROPLAST AND MITOCHONDRIA
LITTLE DIVERSITY
LOTS OF DIVERSITY
PROKARYOTES
EUKARYOTES

# Section 3: Development of New Icons

As new knowledge begins to circulate, so the representational icons need to be updated. Engaging in the construction of new icons will demonstrate how it is possible to think and solve problems with images instead relying on the resources of language alone.

## The new Tree of Life

"New iconography of life's tree shows that maximal diversity in anatomical forms (not in the number of species) is reached very early in life's multi-cellular history" [Matt Ridley talks about this – the shape of life]. "Later times feature extinction of most of these initial experiments and enormous success within surviving lines. This success is measured in the proliferation of species but not in the development of new anatomies. Today we have more species that ever before although they are restricted to a few basic anatomies."

Enclosed in this book you will find our new Tree of Life icon. It is not meant to be complete or unproblematic but rather as a primer for critical analysis. We recommend that you critically analyse this image using the tools contained in the text to come to your own conclusions about our concerns and 'improvements' of the existing Tree of Life icon.

# Section 4: Literature Review

**Darwin's Dangerous Idea**

Dennett, Daniel C. 1995. *Darwin's Dangerous Idea. Evolution and the Meanings of Life*. London, Penguin Books Ltd.

Unlike *Genome* (see below) this book follows a philosophical approach and not a biological one in relation to evolution. Consequently Dennett's defence of Darwin is a logical one, full of 'thought' experiments and philosophy. Nonetheless Dennett builds an argument for Neo Darwinism, arguing that Darwin's idea is dangerous because it is true. He begins before Darwin and takes the reader through the ideas that predated Darwin, thus contextualising the emergence of his theory. This shows what a ground-breaking theory Darwin developed. Dennett then describes evolution and critiques existing more contemporary alternatives. Of interest to us is the idea of design space which is thinking made visual – the (map-like) way that Dennett deals with the possibilities of life developing on earth. Although he mentions that he is not a scientist and has no pretensions about being one, the way Dennett develops his ideas through the use of images (these occur in the book) is comparable to the way in which a 'real' scientist may develop his/her ideas in a laboratory. In a similar vein he critiques and develops his own variations of the Tree of Life – developing visual solutions for origins (which Darwin did not), variations within and between species, move towards complexity and how different species' development may be traced. On the whole this book is a great description and critique of the theory of evolution and the implications it suggests for our place in the world.

**Genome**

Ridley, Matt. 1999. *Genome. The Autobiography of a Species in 23 Chapters*. London, 4th Estate Limited.

Like Darwin's dangerous idea, *Genome* is written for the popular reader. Ridley takes a look at one characteristic of each of the human genes – resulting in a book of 23 chapters. A quick tour of the human genome that questions what makes us what we are, examined in chapters like 'Memory', 'Life/Death', 'Pre-History', 'Free Will' and 'Sex'. Ridley does not make the mistake of claiming that we are no more than our genes – he states that we are made up of more than that. But what has been discovered in research like the Human Genome Project can reveal much about our origins.

Unlike Dennett, Ridley explains complex ideas about the genome in a visual and easy to understand manner. For example the genome is described as, "Imagine the genome is a book. There are 23 chapters called chromosomes. Each chapter contains several thousand stories, called genes. Each story is made up of paragraphs, called exons, which are interrupted by advertisements called introns. Each paragraph is made up of words called condons. Each word is written in letters called bases". Disappointingly, for a popular book, there are no actual images or pictures.

**Icons: Magnets of Meaning**

Betsky, Aron (Ed). 1997. *Icons: Magnets of Meaning*. San Francisco, Chronicle Books.

The structure of *Icons: Magnets of Meanings* is similar to *Genome* in that it explores 12 different icons, more or less one per chapter. But this is a book on popular culture and not of science with the icons being futuristic buildings, blue jeans, computers and Coca Cola – the things we eat, buy, wear, and throw away. Published in conjunction with (and as a catalogue for) an exhibition of these objects at the San Francisco Museum of Modern Art (with the central thesis being that the objects we create and use make us what we are). But not any object can have this power over us – it is only those that become icons that can change us. This power is related to the density of meaning of the object in question. This meaning is a result of the objects being used and they are used because they work best. Thus the meaning is a result of the design. For example, a baseball bat is described as 'the perfect hitting implement', whether aimed at either ball or 'brains' its function is inherent in its form, to strike. These objects are so close to us that we are often not aware of them or what they mean. Hence the exhibition of these everyday objects in an art museum is to isolate them from our environment and give us space to think about them. As stated, "Good design makes us wonder", and by wondering we expose their layers of meaning. It is hoped that this book creates a similar effect in relation to scientific icons and representations.

**The Dark Lady of DNA: A Portrait of Rosalind Franklin**

*The Dark Lady of DNA: A Portrait of Rosalind Franklin*. Accessed, 1st March, 2003. http://www.abc.net.au/rn/science/ss/stories/s5833226.htm

This transcript from a Broadcast Saturday radio programme discusses the role played by Rosalind Franklin in the discovery of the structure of the gene. The panellists discuss the events surrounding the discovery with a focus on the role played by Franklin. It is well known that James Watson and Francis Crick were first to announce the structure of DNA. This transcript questions whether they would or could have made their discovery without the contribution of Franklin. It is also asked why she has never received proper recognition for the role she played.

**Evolution for John Doe: Pictures, the Public, and the Scopes Trial Debate**

Clark, Constance, Areson. 2001. *Evolution for John Doe: Pictures, the Public, and the Scopes Trial Debate*. Accessed 1st March 2005. www.mtsu/ntah/era7/staplesbib.pdf

This essay takes a look at the historical development of representations of humans in evolutionary diagrams from the context of the Scopes trial in the USA in 1925. This trial generated much interest and even more controversy and debate. The first major debate was whether to teach evolution in school (i.e. was there any real evidence for evolutionary theory). The second was about the tension between religion and evolution (where to place humans in relation to other species). Through researching the trial Clark resurrects evolutionary images from the first quarter of the last century that reveal the way that the general public and scientists thought about evolution. For example, Clark notes that in the 1920s the words published by scientists were often at odds with the images that represented them. Her rationale for this gap was, firstly, that scientists create images that are their own scientific language and which the general public do not have access to. (The images are created not only to communicate ideas but also to form them and this can be seen as a type of scientific language that the general public would not understand.) This leaves the door open to misinterpretation and misunderstanding. Secondly it was argued that the ambivalence of these images is a result of the ambivalence in the mind of the scientists at the time they created these images. Evolutionary theory was not as well developed as it is today and any doubts that the creators of these images had may have been represented unconsciously in the images they created. Back to the Scopes trial and the central concern that humans had no special place in the diagrams. No matter how much scientists argued that evolution was a complex and subtle process, public debate was directed by images that promoted linear, goal-directed hierarchical versions of evolution. This was represented in many ways through the use of the amoeba-to-man icon, placing man at the 'end' of evolution.

**Screening DNA: Exploring the Cinema Genetics Interface**

Nottingham, Stephen. 2000. *Screening DNA: Exploring the Cinema Genetics Interface*. DNA Books (ISBN 1-903421-00-4)

This book looks at the relationship between movies and genetics and in particular how biotechnology is represented in the cinema. Chapter 2 brings the reader more up to date with DNA and monsters in Jurassic Park. Its genesis is a result of recent attempts to breed extinct species using DNA.

A close analysis is made of the way in which laboratories have been represented in Jurassic Park. It is noted that Hollywood often uses real scientists in the creation of sets. The author argues that while there is a high attention to visual accuracy (compared to actual laboratories) this 'authenticity' is often undermined by the demands of cinema. For example, in Jurassic Park an otherwise authentic laboratory is rendered unreal by a hatching facility being place inside the lab where in real life it would be in separate room.

This book also explores the relationship between the viewer and the film and the influence that film has on creating our view of the world, and in particular science. Chapter 9 argues that films conform to genre and narrative conventions and are the product of many 'voices'. Their main concern is entertainment. Therefore films are limited in how far they can represent science and in particular genetics. The author argues that although movies repesent genetic engineering negatively, cinema itself cannot be blamed for a misinformed or negative public sentiment towards genetics because the public is increasingly well-informed through other mass media and should be aware of the wider implications of biotechnology. However, elsewhere the author mentions that movies could potentially have a strong influence on public attitudes if made with an ideological intent. In sum this book finds itself somewhere between popular science and film criticism.

**Genomic Cartography**

*Genomic Cartography.* Accessed 1st March, 2005. http://www.acg.media.mit.edu/people/fry/cartography/draft-021219d.pdf

This is a critique of existing visual representations of the human genome. These 'maps' are primarily found in popular scientific journals as wall posters to be appreciated for their aesthetic value rather than their content as one would need specialised knowledge to properly access the information represented. Consequently they are reproduced only to give the public a vision of what a genome looks like, even if it is highly stylised. Of interest is the relationship made between genome maps and cartographic maps. It is argued that visually they follow the same conventions, using simplified shapes and colours, alteration of scale and labelling. The primary function of such representations is to communicate large amounts of data quickly. This according to the author is not properly achieved in current diagrams. Some of the reasons given are the use of too many colours, inadequate labelling and layout. The last section is devoted to the creation of a new sequencing diagram.

**Representation in Scientific Practice**

Lynch, Michael and Woolgar, Steve (Eds.). 1990. *Representation in Scientific Practice*. Massachusetts, MIT Press.

This book is a broad collection of articles by historians, philosophers and sociologists looking at how scientists represent their ideas visually, particularly within the scientific context. But this context can be broken down into smaller contexts such as the laboratory, early representation and illustration.

In the chapter 'The Externalised Retina: Selection and mathematisation in the visual documentation of objects in the Life Sciences', Michael Lynch looks at the types of visual representations used in science (photographs, diagrams, models and so on). Lynch argues that these images are not objective representations of nature but rather loaded with theory. Scientific images are thus the representations of ideas and thought processes. This is evident in the process of 'visual simplification' in which these images are created. The process involves filtering, focusing, framing and mathematisation which are dealt with in the first section of this book.

Bruno Latour's chapter, 'Drawing things together', traces the process of map-making and visual representation by the early European explorers. He argues that inscription techniques opened up a new virtual world of representation where the image became the focus of attention and not the 'original object'. The technology of the printing press was vital in this process as it allowed mass dissemination and communication of ideas on a similar scale. The main advantage of this was not only that everyone had potential access to this information but also that this knowledge could easily be gathered together, compared and altered, which was not possible before. The concept of the externalised retina is also introduced, meaning that the image on paper becomes our objects of examination rather than the objects we see – what we see is what we have drawn.

On a less abstract level, G. Meyers critically assesses the visual representations in E. O. Wilson's *Sociobiology*. In particular he argues that the iconography of science has more of an impact than the words do. Particularly interesting is the analysis of an illustration of a troop of Lemur monkeys which seems a natural representation but in fact is a highly constructed and theory-laden image. Not only is the image analysed but the artist is also interviewed on her thought processes during the creation of the image. An 'academic' book that would probably not be available in a local book store – probably only found in academic libraries.

**Reading Images. The Grammar of Visual Design**

Kress, Gunther and van Leeuwen, Theo. 1996. *Reading Images. The Grammar of Visual Design.* London, Routledge.

This book explores how representations communicate meaning but contrasts to *Representations in Scientific Practice* in a number of ways. Firstly is more general in its approach, taking images from children's books, mass media, fine art and even three dimensional sculptures as its source whereas *Representations in Scientific Practice* derives its images from the scientific context only. Secondly, central to this book is the difference between visual communication and grammar communication. The difference between how words and images communicate. Essentially this is a book on semiotic processes. Kress and van Leeuwen draw on the theories of semiotic theorists such as Sassure, Pearce and Barthes. Much of the book is a contemporary application and explanation of their theories. Of particular interest are the chapters on 'conceptual representations' (how ideas are communicated), modality (how the form of an image suggests an answer), and the meaning of composition – which are not dealt with in *Representations in Scientific Practice*.

# Section 5: Glossary

**Amino acid**
An organic acid containing one or more amino groups, especially any of a group that make up proteins and are important to living cells.

**Channelling of meaning**
Removal of all information that does not contribute to what one is trying to communicate through the process of framing, focusing and filtering, resulting in a highly modified image.

**Complexity**
The state or art of being intricate or complicated.

**Context**
The circumstances or events that form the environment within which something exists or takes place.

**Critical**
Containing or involving comments and opinions that analyze or judge something, especially in a detailed way.

**Darwin, Charles (1809 – 1882)**
English natural historian and geologist; a proponent of the theory of evolution by natural selection. While the naturalist on the *HMS Beagle* for her voyage around the Southern Hemisphere, he collected the material that became the basis for his ideas of natural selection.

**Darwinism**
Belief in, or advocacy of, Charles Darwin's theory of evolution saying that species of living things originate, evolve, and survive through natural selection in response to environmental forces.

**Diagram**
A simple drawing showing the basic shape, layout, or workings of something by representing or illustrating it. A line drawing that presents mathematical information.

**Diversity**
A variety of something.

**Double Helix**
The molecular structure of DNA, consisting of a pair of polynucleotide strands connected by a series of hydrogen bonds and wound in opposing spirals.

**DNA**
A nucleic acid molecule in the form of a twisted double strand (double helix) that is the major component of chromosomes and carries genetic information. Full form: deoxyribonucleic acid.

**Evolution**
The theoretical process by which all species gradually develop from earlier forms of life.

**Filtering**
Filtering simplifies what has already been framed or focused.

**Focusing**
Similar to zooming in on and cropping an object/image so that only the part of the object/image that is of interest remains within the frame.

**Framing**
The outer frame of an object/image which is manipulated to contain the entire object/image.

**Genetics**
A branch of biology dealing with heredity and genetic variations. The genetic makeup of an organism or group of organisms.

**Genome**
The full complement of genetic information that an

individual organism inherits from its parents, especially the set of chromosomes and the genes they carry.

**Sequencing**
The order of the constituent sub-units of a large biological molecule, for example, the order of amino acids in a protein or the order of nucleotides in a nucleic acid.

**Icon**
A holy picture, carving, or statue of Jesus Christ, the Virgin Mary, or a saint, especially an oil painting on a wooden panel, used in worship in the Eastern Orthodox churches. Somebody or something widely and uncritically admired, especially somebody or something symbolizing a movement or field of activity. A word or sign that stands for something else.

**Inscription**
Words or letters written, printed, or engraved on a surface.

**Interpretation**
An explanation or establishment of the meaning or significance of something.

**Life Sciences**
A principal branch of science concerned with plants, animals, and other living organisms. Includes biology, botany, and zoology.

**Looking**
To direct attention to somehting in order to consider it.

**Mass media**
All of the communications media that reach a large audience, especially television, radio, and newspapers.

**Mathematisation**
To consider something in, or reduce it to, purely mathematical terms. The process of applying mathematical order to natural objects.

**Modality**
Textual cues by which we determine if what we see or think is believable (real) or not. We say the higher modality something has the more 'real' or believable it looks.

**Model**
An assemblage of various diagrams into a single image with the aim of unifying and representing theoretical information which cannot be found in any single image. A model offers a visual image of information which can neither be directly observed nor photographed.

**Molecular biology**
The branch of biology concerned with the nature and function, at the molecular level, of biological phenomena, such as RNA and DNA, proteins, and other macromolecules

**Mutation**
A random change in a gene or chromosome resulting in a new trait or characteristic that can be inherited. Mutation can be a source of beneficial genetic variation, or it can be neutral or harmful in effect.

**Neo Darwinism**
A theory of evolution that combines Darwin's theory and modern genetics, especially with regard to variations in populations as a result of genetic mutations.

**Nucleotide**
A type of chemical compound occurring most notably in nucleic acids such as RNA and DNA, consisting of a nucleoside linked to a phosphate group.

**Optical consistency**
The development of similar visual conventions that become conventionalised and institutionalised to facilitate easy access to meaning and information over linguistic and contextual boundaries.

**Palaeontology**
The branch of science concerned with plant and animal fossils.

**Qualitative**
Relating to, or based on, the quality or character of something, often as opposed to its size or quantity.

**Quantitative**
Relating to, concerning, or based on the amount or number of something.

**Representation**
A visual depiction of somebody or something.

**Seeing**
To perceive something with the eyes.

**Specimen**
Something that is representative because it is typical of its kind or of a whole, especially something that serves as an example. An organism or one of its parts preserved as a typical example of its classification.

**Tree of Life**
The representation of evolutionary change of all life on earth as pathways in the form of a graph.

**Visual literacy**
The ability to read and understand images in a similar way to which one reads and understands written texts.

## Acknowledgements

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