GLOSSARY & REFERENCE

This section provides an alphabetical presentation of terms, phrases and background information relating to the two practical volumes in the series, namely:

- *"Drawing on Both Sides of the Brain", which concentrates on line-drawing from observation, a subject that relates to the perception of edges and contours as opposed to surfaces.*
- *"Painting with Light and Colour", which focuses on the depiction of 'qualities of surface', 'sense of space', 'ambient illumination', 'local colour interactions', 'colour-mixing' and many other colour-related topics. It also deals with 'whole-field lightness and colour relations' and with 'shadows and shading' in both monochromatic drawings and colour paintings. All these subjects relate to the perception of surfaces rather than of edges and contours.*

The subject matter can be subdivided into three main topics: (a) the physics of interactions between light and surfaces (including those of paintings), (b) the science of visual perception, and (c) the history of artistic practices and ideas. However, there is a great deal of overlap, not least because of the importance of the first two topics in the evolutions of the third. Of particular importance was the relatively new interest of scientists in the role of the eye/brain in the creation of visual experience (the forerunner of the subject of visual perception) and the neurophysiology that underpinned it.

Words or phrases that are printed in bold italics relate either to section headings or to core topics discussed in the main body of one or other of the two practical books.

The diagrams and illustrations at the back are divided into two sections:

- *Diagrams with explanations that elucidate issues relating to the functioning of eye/brain systems.*
- *A miscellany of diagrams and illustrations that refer to a range of other topics.*

Much of the information to be found in this "Glossary and Reference" relates to research explained in "What Scientists can Learn from Artists" and/or to ideas discussed in "Fresh Perspectives on Creativity". Both of these more theoretical companion volumes are freely available on the Internet for consultation by anyone who wishes either to go deeper into the science or to better understand how the ideas and suggestions in the more practical books relate to the main purpose of the series as a whole, namely to help artists with their personal creativity, no matter what their current level of achievement.

The Glossary

Abstract Art: In the domains of painting and drawing, there are many words and phrases which are used in different ways by different people: one of these is "***colour***", another is "***abstract*** ".

The concept of "***abstract art***" was made current by ***Modernist Painters***, who had learnt from ***perceptual scientists*** that visual experience is a construct of the brain. No longer being content with what they increasingly saw as the banality of photographic or ***measured reality***, they focused attention on "***experienced reality***"and began asking questions such as:

- What remains constant beneath the ever changing surface of appearances (Cézanne)?
- Can ***exaggeration*** and ***distortion*** be used as means of self-expression (Van Gogh, Toulouse-Lautrec)?
- What are the minimum pictorial cues necessary to trigger ***recognition*** (Toulouse-Lautrec)?
- Can ***expressive mark-making*** be explored independently of the pictorial image (Berthe Morisot, Toulouse-Lautrec)?
- When is a painting finished (Toulouse-Lautrec)?
- Can either ***colour-contrast phenomena*** or dynamics based on ***whole-field colour relations*** be explored independently of the pictorial image (Van Gogh, Gauguin, Cézanne, Matisse, Bonnard)?
- Can colour tap into the emotions, either by means of genetically determined factors or through associations and connotations (Gauguin, Kandinsky, Mondrian, Rothko)?

And finally:

- Is the image needed at all (Mondrian, Kandinsky, Klee, Malevitch, Pollock, Rothko)? Or, to put the same question another way, can ***pictorial dynamics based*** on the basic building blocks of the artists construction kit (lines, marks, shapes, shading, colours, textures, etc) take over the role of nature as the source of visual excitements and thereby provide a viable alternative for artists to explore?

The list of new questions is far from exhausted but it is long enough to show that there was a long list of them asked by the ***Modernist Painters,*** and history shows that they gave birth to a wide range of new approaches to painting and drawing. They also led to an evolving vocabulary. While to start with artists used the word "***abstract***" to mean "*bring out the essence*", it later came, first, to include art that went too far in the direction of distorting appearances to be called representational and, later, anything nonfigurative.

The outcome has been a continuing confusion between the use of the word in its original meaning and its now popular use for describing work that rejects nature as a source of inspiration.

The artists themselves found more appropriate words to use for the latter, such as *"**constructivist**,* "***nonobjective***" and, in France, *"**concrète***", but none of them gained universal currency.

The confusion is also fuelled by the fact that, while it made sense to use the word "*abstract*" to describe the nature-based works of Cézanne, Matisse, Bonnard and Picasso, etc., its use in relation to ***nonfigurative art*** in any of its manifestation violates its original meaning. Current usage is unsatisfactory because it both embraces this violation and looses touch with the notion of finding the essence.

The Academies: The French *Académie Royale de Peinture et de Sculpture* was founded in 1648 and the British *Royal Academy of Arts* was founded in 1768. An important part of their function was to codify, promote and where necessary add to what they believed to be universal truths relating to painting and sculpture. These included laws that were believed to govern natural appearances (often referred to as the "***laws***") and rules relating to current beliefs concerning compositional principles (often referred to as the "***rules***").

The Academic Method was an approach to the practice and the teaching of painting based on the ideas, discoveries and methods of the acknowledged "*masters*" of the ***Italian Renaissance***, as codified, promoted and developed in the ***Academies*** of Europe and criticised by the ***Impressionists*** and their ***Modernist*** successors. *Chapter 3* in *"Drawing on Both Sides of the Brain"* provides some examples of the ideas and introduces examples of procedures by which paintings were to be made. The starting point, an ***idea*** (conceptual framework), which was to be developed by means of ***sketches*** and ***studies*** that were used to prepare the way for a detailed mapping out of the composi-

tion and ***whole-field lightness relations***, known as the "***cartoon***". Following that came a loose mapping out of the colour composition, known as the "***ébauche***". Finally, one of a variety of ***image transfer*** methods could be used to reproduce the outlines of the objects in the composition, either at the same scale or scaled up, onto the picture surface upon which the final painting was be made. Both the ***cartoon*** and the final painting based upon it would have to abide by certain ***compositional rules*** as well as the rules of ***linear and aerial perspectiv***e, ***anatomical proportions*** and ***lightness relations***.

Accuracy: When this word is used in "*Drawing on Both Sides of the Brain*" it means ***literal or photographic accuracy*** in the representation of the contours of objects, that is to say the kind of accuracy that can be achieved by making a tracing of an object on a ***tracing glass*** or of a photograph of it on tracing paper. When used in "*Painting with Light and Colour*" it means reproducing colours and relationships between them as they are in nature.

However, before accepting these definitions too easily, it is important to realise that, whether with respect to drawing outlines or reproducing the colours and relationships between them perceived in the external world, ***accuracy*** is theoretically impossible to achieve, even with the most efficient mechanically controlled devices. Three reasons for this are:

- That the actual contours of objects, which artists have no option other than to represent with lines that are necessarily of a certain width, have themselves no thickness.
- That colours in paintings or any system of mechanical reproduction can never be true to nature since there is no pigment or combination of pigments that can, either alone or in mixture, match natural or even artificially produced colour as perceived by means of reflected-light in the real world, no matter what combination of primary and/or secondary light sources are currently illuminating them. This is the case, whatever the colouring medium used and also whether the attempt at accurate rendering of colours is presented as a traditional painting, in hard copy or on a screen.
- That the range of light intensities available from the variably illuminated multiplicity of surfaces that are likely to be found in real world scenes are regularly, if not quite always, many times greater than the range of light intensities reflected off any multicoloured flat surface,

even if it contains both blacks and whites.

To these theoretical limitations must be added the physical ones due to the limits of ***eye/brain systems*** with respect both to ***measuring with the eyes*** and to ***eye/hand coordination.*** Even if the theoretical limitations did not exist, the physical ones would ensure a degree of inaccuracy. This is evident in the case of line drawing as can be seen by comparing any freehand copy of the outline of an image with a traced one, or even by comparing a traced outline with a mechanically produced one. In the latter case the differences may be marginal but they will be evident.

Accuracy Aspiration. In this series of books this phrase means the aspiration to achieve ***literal*** or ***photographic accuracy.*** However an important distinction is made between:

- Seeking to achieve accuracy as an aim in itself.
- Using ***accuracy*** as a means of developing ***analytic-looking skills*** with a view to becoming more sensitive to and amazed at the unvarying variability of appearances.

These books reject the former usage and embrace the latter.

It is possible to use of the ***accuracy aspiration*** as a tool for extending awareness because all learning requires a ***goal*** if it is to make use of ***feedback***. The ***accuracy aspiration***, by providing artists with criteria for "*good*" (accurate) and "*bad*" (inaccurate), gives meaning to the word " ***mistake***" and, thereby, provides us with the possibility of learning from our errors. A more valuable gift for artists aspiring to see and do in new ways would be hard to imagine.

Action Instruction: Instructions given by the brain that guide actions. One example would be the actions that guide ***line production*** when ***drawing from observatio***n, another would be those that determine the direction of gaze.

Aerial Perspective. Between any viewer and the object at which they are looking lies the earth's atmosphere. In addition to the transparent gases that make up the air, this contains quantities of water vapour and dust that create a screen between our eyes and the objects we are looking at. Although the proportions of these components can vary considerably with variations in weather conditions, there is a tendency for their presence to influence the appearance of surfaces according to the rule that objects that are further away appear to be greyer and, if in sunny blue sky conditions, bluer. Also if identical

objects or surfaces are viewed from different distances the further ones will be perceived as less evidently textured. If this rule is applied in paintings, such that the depicted objects and surfaces grade from less grey or blue in the foreground to more grey or blue in the background, it will encourage the perception of ***pictorial depth***.

However there are many other variables which can work against this tendency, sometimes dramatically so. Indeed it is rare to find a real landscape in which there are no examples of the rules of ***aerial perspective*** being contradicted. This being the case, it is no surprise to find that both Monet and Renoir questioned their value. What they found was yet another example of a general rule, namely that the act of questioning rules, whether or not they apply in the case in hand, will always lead to greater awareness of the matter in hand.

Ambient Illumination is provided by the sum of all the light sources that effect the appearance of what is being looked at, whether these be ***primary*** or ***secondary***. It is the ambient illumination that tells us that it is a sunny or cloudy day, whether we are inside or outside, whether the light comes from natural or artificial sources, etc.. The fact that we can distinguish between these different light conditions means that the eye/brain systems can provide the information necessary for doing so. "*Painting with Light and Colour*" shows how knowledge of the processes by which they do so can not only help artists to conjure up the illusion of different qualities of light in their paintings but also both to enhance effects of ***illusory pictorial-space*** and to create experiences of ***harmony*** or ***discord*** according to choice.

Ambiguity occurs in any domain of sensory experience when there are two or more interpretations of the same input are in competition with one another, It is of fundamental interest to artists if they are seeking to create either ***harmony*** or ***discord*** in their paintings, or if they wish to explore ***illusory pictorial space***.

The key to the importance of ***ambiguity*** with respect to ***harmony*** and ***discord*** is that ***eye/brain*** abhors the degree of uncertainty that comes with the alternative interpretations. To escape this, it is has to make use of one or more of the kitbag of strategies it has available for that purpose. Not counting that of looking away altogether, these depend on concentrating attention on details at the expense of wider ***context***, either by ***focusing down*** or by ***moving closer***.

Although both these strategies work well enough for everyday visual perception, the ***eye/brain*** can seldom exclude the influence of alternative interpretations altogether. Sometimes this is more evident than others. A good example of a high level of ambiguity is provided by the well known vase/face illusion (*Figure 18),* in which we can see either a vase or two silhouetted faces. Although we can choose between the vase or the two faces interpretations, we cannot stop the ***ambiguity*** of the situation providing a degree of tension. How this affects our experience of seeing can be sensed by comparing the right hand side face with the identical face in *Figure 19,* in which there is no left hand side face to create the vase shape. By removing the ambiguity between vase and face interpretations, the face is easier to look at.

However, being "*easier to look at*" is not necessarily the goal of artists, who might prefer a certain amount of irresolvable ambiguity between interpretations. One example would be that they might be seek to create a face with an enigmatic, in other words, ambiguous, expression. Another is the importance given by many ***Modernist Painters***, to tensions created between perceptions of the ***real picture surfac***e and ones of ***illusory pictorial space***.

The ***Modernist Painters*** were also interested in another kind of ambiguity in which attention is drawn in competing directions. For example, the drawing illustrated in *Figure 23,* shows Pierre Bonnard going a long way towards obscuring the features in his wife's face, presumably with a view to allowing the telling gesture of the hand to take on more significance than it would have done had the eyes, nose and mouth been more clearly delineated. However, since this strategy has failed to override completely the ***eye/brain's*** tendency to give faces more importance than hands. The upshot is that it is difficult to look at either the hand or the face to the exclusion of the other. The pull in both directions creates the dynamic equilibrium that is so important to the experience of looking at this particular drawing.

Another area of competition between interpretations is that between the ***image*** and ***nonfigurative relationships***, such as those involving colours, textures and/or geometric shapes. The more the ***Modernist Painters*** became interested in the latter, the more they sought ways of removing or at least minimising the influence of the former. The obvious way to do this was to reduce the strength of the cues that enable ***recognition*** and, thereby minimize the deadening effect of ***familiarity***.

One result was an interest in ***minimal cues***, such as those that are used for

the face in Pierre Bonnard's drawing. What the artists found was that the more subtle cues became, the more likely it was that alternative and consequently ambiguous interpretations would arise with desirably mind-teasing outcomes

A manifestation of ***ambiguity*** that is integral to painting and that had a particularly profound affect on the history of ***Modernism in Painting*** is that which exists between perceptions of the ***real picture-surface*** and ***illusory pictorial space***. Up to the arrival of the ***Impressionists***, artists had sought to reduce this by doing their best to remove all traces of the picture surface in the interests of better deceiving the eye. However, the whole attitude to the ***real picture-surface*** was revised as a response to the arrival of photography, which many painters saw as threatening their value in the eyes of society. They felt that, if painting was to survive, advantageous ways of a distinguishing it from photography had to be found. Faced by the need to escape from this predicament, the young ***Impressionists*** hit upon the idea of giving greater visibility to surface characteristics. An early approach to doing this was the new emphasis expressive mark making. A longer term consequence was the growth of interest in abstract relations that was to pave the way for the twentieth century revolution in artists attitudes to figuration.

For many artists another outcome was the widely explored project of bringing the picture-surface and illusory pictorial space into a dynamic, eye/brain teasing equilibrium. For others, any suggestion of an illusory pictorial space implied a deception. Accordingly, they set about the task of eliminating all cues to ***illusory pictorial space***, an ambition they found surprisingly difficult to achieve. No matter how hard they tried, they found that their ***eye/brains*** were capable of creating perceptions of the ***in front***/***behind*** relations between the different areas of colour on the picture surface.

In the end, the only solution seemed to be one colour paintings, of which many appeared in the 1950s and 1960s. The only ***ambiguity*** remaining now lay in the question as to whether these were correctly classified as *"paintings*". Perhaps instead they should be described as *"sculptures"* or, merely, as *"objects on the wall"*. For those who (in my view falsely) identified the search to remove the ambiguity, as being of the essence of ***Modernism in Painting***, it was time for ***Post Modernism***.

Meanwhile, other artists were excited because they saw the removal of figuration as clearing the way for purer experimentation with relationships between ***colours***, ***textures*** and ***shapes***. This aspect of *Modernism* is still with us, as is its involvement from its earliest days with ***"conceptual art"***

Amblyopia (sometimes referred to as "***lazy eye***") is a condition caused by decreased vision in one eye that inhibits the coordination between the two eyes required to produce ***stereopsis***. A likely contributory factor is extreme ***long-sightedness*** (See under "***stereopsis***" for the advantages of one eyed viewing when ***drawing from observation***). If desired ***amblyopia*** can be corrected with appropriate correction lenses and exercises. Some say correction is only possible for young children, others claim success with adults.

The Amygdala is part of the "***old brain***" which plays a key role in both ***drawing from observation*** and ***training the feel system***. Other parts worth special mention are the ***hippocampus*** and the ***frontal eye fields***. For more on the importance of the ***amygdala***, the ***old brain*** and its component parts see *Figures 13, 14 and 15*.

Analytic-Looking: To interact visually with objects, such as when picking them up or drawing them from observation, we have to analyse their relevant characteristics. This requires ***analytic-looking*** and the use of the ***analytic-looking cycle***.

Two of the major topics in this book are:

- The reasons why ***analytic-looking*** so seldom produces accurate drawings.
- The advantages of unintentional ***inaccuracy***.

Analytic-Looking cycle: *Figure 1* shows the analytic-looking cycle starting with ***visual area 1*** which receives information from the ***optic nerve*** that originates in the ***retina,*** with its 150 million or so light-sensitive ***receptors*** and the four layers of massively interconnected neurons. From there is an arrow showing the information being directed into the regions in the brain that enable ***recognition***. It also shows that this vital step in all visual processing, besides needing information from the visual world, also requires input from the ***context and feeling based memory***.

The fact that it is only after ***recognition*** that ***analytic-looking*** can take place, poses a problem for artists when ***drawing from observation.*** It

does so because inputs from ***memory*** are necessary for the organisation of all analytic looking strategies. The problem is that these are necessarily based on generalised properties of object-types.

Anatomy: The subject matter of anatomy for artists is the structure and working principles of human (or other animal) bodies, with particular reference to skeletons, muscle structures, fat distribution and relative proportions. Hard won and comprehensive knowledge relating to these has been used over the centuries to help artists when constructing images from the imagination.

Unfortunately, they have also been widely employed as aids to ***drawing from observation***. The problem is that rules relate to commonalities, while artists when drawing from observation aspire to characterise uniqueness.

Book 1: *Drawing with Feeling*, the first of the two books in this volume, ignores the subject of ***anatomy*** for three reasons:

1. The discussion of ways in which knowledge of *anatomy* can help or hinder ***drawing from observation*** is reserved for *Book 2*, "*Drawing with Knowledge*".
2. Although both knowledge of ***anatomy*** and ***linear perspective*** can be helpful as a guide to looking, both will lead to all sorts of problems if used for constructing frameworks into which images of the objects being depicted are to be fitted.
3. Anyone fully understanding the drawing lesson in *Chapters 11-13* should be able to get on perfectly well without knowledge of anatomy.

Awareness: see "*consciousness*"

Axes of Approximate-Symmetry: *Figure 16a* and *Figure 16b* illustrate ***symmetries*** and ***axes of symmetry***. Since true ***symmetries*** are extremely rare in nature and even in symmetrically constructed man-made objects when viewed from most viewpoints, it is more helpful to talk of ***approximate symmetries*** and ***axes of approximate symmetry***. These are important to people ***drawing from observation*** because one of the ***preconscious*** steps taken by the ***eye/brain*** as a preparation for all ***analytic-looking*** is to do its best to place an ***axis of symmetry*** on the object or any part of fit that under scrutiny. Unless the axis is already vertical or horizontal (or possibly 45 degrees) it is then internally rotated so that, for the purposes of guiding analytic looking ac-

tions, it becomes vertical or horizontal (or, possibly 45 degrees). When such rotation takes place, our perception of the orientation of all features of the objects, object-parts and/or shapes will be effected. Many errors in ***drawing from observation*** can be traced to this unvarying aspect of visual processing. *Chapter 18* goes more deeply into this subject.

Axes of symmetry: It seems to follow that whenever a shape is reflected, there must be an ***axis of symmetry*** *(see Figure 16)*. However, as pure symmetries are not to be found in nature, and very few in the man-made world, they have little significance in everyday visual perception. The same cannot be said about ***axes of approximate-symmetry***, which abound in nature and have the potential to play a fundamental role in the analysis of objects, shapes and curvatures, when drawing from observation.

Axioms of Marian Bohusz-Szyszko (1901-1995)

1. My first teacher, the Polish artist and theorist Marian Bohusz-Szyszko, had strong convictions relating to the role of colour in paintings. These he presented to his students in the form of a **six axioms,** which he saw as a synthesis of ideas originating in the discoveries of the ***Venetian Colourists***, as updated and amended in crucial ways by ***Modernist Painters***, of whom the most important for his ideas were ***Seurat, Cézanne*** and ***Bonnard*** (whom he talked of as a mentor). To make sense of them, it will help to understand that the word "***colour***" as used in them means "***colour in the context of whole-field colour relations"***. It has nothing to do with the ***colour dynamics*** produced by ***local colour-contrast effects*** that have excited so many artists over the years.

According to Marian Bohusz-Szyszko the axioms represented "*all you need to know about painting*" Whether this is true or not (see next section for what he meant by this seemingly extravagant claim), they are important in this series of books, not only because of their more evident practical applications but also because they proved to be one of two main catalysts[1] to the research on the eye/brain processes that gave them more extensive significance, not least for artists who wish either to create ***harmonious colour relations*** or to explore ***illusory pictorial-space***.

The six axioms are:

No 1: "***All good painting is based on colour***".

1 The other being the puzzle of so called "***intellectual realism***"..

No 2: ***"All good colour is based on colour in nature"***.

No 3: "There is ***only one thing necessary to know*** about ***colour in nature***".

No 4: Namely that "***no two colours in nature are ever the same"*** (a claim buttressed by reference, not only to the enormous number of pigment colours in the natural and artificial worlds, but also to the influence on them of the infinitely variable wavelength combinations of light provided by the ***secondary light sources*** as nuanced by the ever varying ***angles of viewing***).

No 5: It follows from axioms (1) and (4) that "***no region of colour on a picture surface should ever be the same as any other colour on it***".

No 6: Finally, seemingly unconnected to the first five axioms but nevertheless proving to be the key to understanding their significance, "***all the colours on the picture-surface should be mixtures containing some proportion, however small, of complementary colour***".

Many might dispute these assertions, but there can be no doubt of their potential for helping artists when drawing or painting from observation. Even without going into the more abstruse reasons for this, it is clear that:

- ***Dogma No*** (***4***) is valuable because checking out whether it is true or not requires both targeted and rigorous application of ***comparative looking*** of a kind that will inevitably lead to an increased sensitisation to the amazing range of ***colour nuances*** available in the visible world.
- ***Dogma No*** (***5***) is valuable because, by requiring artists to find ways of avoiding repetition amongst the colours on the picture-surface, it forces them to find ways of mixing larger numbers of ***colour nuances*** (most likely, very much larger).
- ***Dogma No*** (***6***) is valuable because mixing in the ***complementaries*** is necessary if the range of colours available to the artists is to be maximized. Without them it would be impossible to mix the range of colours required by ***Dogma No*** (***4***) .

2. Axioms of Marian Bohusz-Szyszko (2). When I first heard the claim of Marian Bohusz-Szyszko that his six axioms represent "*all you need to know about painting*", I thought it extravagant. It still seemed questionable, when I realised that what he actually meant was that abiding by them would enable artists to imbue their paintings with what Cézanne described as a "***harmony***

that runs parallel to nature". However, after much research both as an artists and a scientist, I was won over. I became convinced that, if a painting, consisting of an array of colours on a rectangular, flat surface, contains ***no repetitions*** and, if all the colours in it are ***mixtures containing some proportion of complementary***, it will indeed exhibit a quality that might justifiably be described in this way. Thus:

- My research as an artist consisted in producing innumerable paintings with testing the axioms in mind. What I found was that repeated colours are experienced as discordant and that they can always be rendered harmonious by differentiating them, even if only by the minutest amount, just so long as the colours concerned contained some proportion of complementary. This testing process has been extended and the findings supported as a result of working with students over twenty-five years.
- My research as a scientist is explained in detail in "*What Scientists can Learn from Artists*". It centred on working out how ***eye/brain systems*** solve the problem of separating out "***body-colour***" from "***reflected-light***" (see *Figure 18*), which is a necessary step if a maximum of the information contained in both is to extracted. To understand how they achieve the separation, it helps to know that when we look at a multicoloured surface such as found in paintings:
    1. The ***intensity profile*** of the light coming from it into the eyes is significantly different for ***reflected-ligh***t as compared with ***body-colour***.
    2. ***Reflected-light*** *always contains all the wavelengths, the intensity/wave*length composition of which is ***slow-varying*** in all directions across the entire picture surface, both with respect to intensity and wavelength.
    3. ***Body-colours*** differ in their wavelength/intensity combinations. As a result ***sudden jumps*** in wavelength/intensity profiles occur at the borders between regions of different body colour.
    4. ***Reflected-light*** always activates all available ***light sensitive receptors*** (including rod receptors) across the whole extent of the ***retina***, and do so to much the same degree, .
    5. ***Body colour*** activates a wide range of combinations of three types

of wavelength-sensitive receptors (the ***cones***) that are situated within the tiny region known as the ***fovea***.[2]

The eye/brain systems are able to pick off the slow-varying ***reflected-light*** component and use it as a basis for extracting information that aids the perception of ***surface-solidity***, ***surface-form, in front/behind relations*** and ***ambient illumination***. Once this is subtracted, the eye/brain systems can then separately compute the wavelength combination characteristics of the remainder, that is to say of the ***body-colour***.

This being the case, it is not difficult to see that the addition of complementaries (by ensuring the simultaneous activation of all three ***cone receptor*** types) into all the body colours on a picture surface will confuse the ***eye/brain*** calculations. One aspect of the confusion is that the eye/brain systems concerned erroneously compute at least some portion of the complementaries as ***reflected-light*** and inappropriately add this to the profile of the actual ***reflected-light***.

This ***attribution error*** is of particular interest to artists because:

- It prevents the eye/brain from perceiving the ***picture-surface*** as an integrated whole and frees the colours painted on it to take their place in ***illusory pictorial-space***.
- It provides a way of deceiving the eye into perceiving s***urfaces in pictorial-space*** as reflecting light in the same way as do ***surfaces in the real world***.
- By causing the ***eye/brain*** to confuse the ***complementaries*** with light, it imbues the colours produced with what might be described as a light-filled quality.[3]

3. Axioms of Marian Bohusz-Szyszko: The proposition that all good painting is based on the appropriate management of ***whole-field colour relations*** and the ***addition of complementaries*** provokes big questions in relation to the subject of "***composition***". It suggests that:

- All rules of composition should include a rule concerning ***whole-field***

2 It also activates other wavelength-sensitive wavelength sensitive receptors, but only in exceptional circumstances do these contribute to the colour we perceive. For example, Low intensity evening light, single colour surfaces that take up all the visual field and when the viewer has anomalous colour vision...

3 Thus fulfilling ***Seurat'***s goal.

colour relations and the ***addition of complementaries***.

- If the objective is to produce a ***harmony that runs parallel to nature***, there is no need for any other rule.

4. **Axioms of Marian Bohusz-Szyszko**: If implementing the axioms is necessary for obtaining ***pictorial harmony***, it follows that failing to implement them must result in ***pictorial discord***. This is because the absence of the ***complementary colours*** in the paint mixtures that causes the e***ye/brain systems*** to make the ***attribution errors*** that free the colours painted on the picture surface to take their place in ***illusory pictorial-space*** will reverse this outcome. Instead, the ***eye/brain systems*** compute the colours as being situated where they actually are, namely ***on the picture-surface***. Since they cannot be both ***on the picture-surface*** and situated on surfaces in ***illusory pictorial-space***, the result is an ***insoluble interpretation problem***. It is this that is experienced as ***discord.*** (For more on this subject see the section on "***grouping colours***")

5. **Axioms of Marian Bohusz-Szyszko**: The fifth and sixth axioms are of interest to scientists because the process of making sense of how they work helps them to understand the mechanisms that underpin ***visual perception***. In particular, the separation of ***reflected-light*** from ***body-colour***:

   - Prepares the way for ***colour-constancy***.
   - Provides a means of perceiving ***surface-solidity***, ***surface-form***, ***in front/behind relations*** and ***ambient illumination***.

Ballistic Movement: Every movement of the arm used in drawing for observation (or in any other skilled action) has to be planned in advance. Once initiated the artist has no more control over it than a gunman has of a bullet after the trigger has been pulled. In both cases all preparations, including distance estimates, have to be made in advance.

If the planned action concerns drawing a line 'yz' that is a specific amount longer or shorter than another line 'xy', there are three approaches which will achieve the required result:

1. First, mark the beginning point of line 'yz' (which will be the same as the end point of line 'xy'). Second, make a preliminary visual estimate of where the end point of the line 'yz' should be situated. Third, place the tip of the drawing instrument so that it is hovering above this point.

Fourth, check the relative length of the distance between the endpoint of line xy' and the hovering pen tip and the length of line 'yz'. If the this is either too long or too short, move the tip in the appropriate direction until satisfied that it is in the right place. Fifth, lower the drawing instrument onto the paper so that it marks it with a dot. Sixth join the end of line 'xy' with this dot. With a little practice, the result should be a high level of accuracy. The same method can be used for relative orientations and relative positions on the page. Unfortunately, because it requires so much looking back and forth before committing to line output, it will not suit people who either aspire either to draw rapidly or to put ***feeling*** into their ***mark-making***.

2. Place the drawing instrument on the end point of line 'x'. Draw a short stretch of line in the appropriate direction away from it. It should not be anywhere near long enough. Having checked that it is not, add another short stretch of line. Continue in this fashion until it begins to look as if you might be homing in on the right length. Continue to make adjustments until you are satisfied that the relativities are correct. You have now drawn line 'y'.

   This method can be described as "*bit-by-bit*" and is used extensively by people with little confidence in their ability. There is no reason why it should not achieve accuracy but it will not achieve flowing lines. Nor will it suit people who either who wish to draw rapidly or who aspire to put ***feeling*** into their ***mark-making***.

3. When drawing line 'xy' get a feeling for its length. With this held in memory, take your time to make a visual estimate the length of line 'yz' relative to it. Redraw line 'xy' to reestablish the feeling of it length, look once again at the relative lengths of xy and yz before adding line 'yz' in one smooth movement.. Check back to see whether the result is too short, too long or just right. If adjustments are required, repeat the procedure, including redrawing line 'xy'. If you adopt this approach, you should in time achieve accuracy. However it has its pros and cons. Likely but temporary disadvantages could be the clumsy look produced in the process of overdrawing of lines and the time taken to complete the task. However, a lasting advantage will come from the fact that the method will be training both your ***feel-system*** and your capacity for rapid and accurate ***information pickup***.

With time and not necessarily very much of it, this training will make it possible to eliminate the overdrawing, minimize the need for looking back and increase ***information-pickup*** and ***line-production*** speed. But perhaps the greatest advantage will be that interference between analytic and mark-making activity and ongoing ***feelings*** and ***emotions*** will be minimized. (See also *Chapters 9 and 10*).

Body Colour: *Figure 18* shows white light, containing all the wavelengths, hitting a surface with which it interacts in one of two ways. Thus:

1. It is either reflected directly back from the surface, with the angle of incidence equalling the angle of reflection, in which case it is referred to as "***reflected-light***".
2. Or, it enters inside the surface where it interacts with the pigment particles it encounters such that it is bent by them to a greater or lesser extent. In effect, it is scattered around inside. In the process, some wavelength are absorbed and a proportion of the others are scattered back out again to produce the colour we perceive. It is this portion of the light that in these books is referred to as "***body-colour***".

Perceptual scientists have shown how ***eye/brain*** systems disambiguate these two components and, thereby, make both separately available for use by ***recognition systems***. The ***reflected-light*** component provides information about ***surface-form***, ***in front/behind relations*** and ***ambient illumination***. The information relating to ***ambient illumination*** is also used in the computations that enable ***colour-constancy***.

Brain: The brain is usually described as a part of the ***central nervous system*** of which the other part is the ***spine***. Both are classified as being separate from:

- The ***peripheral nervous system***, which brings information from receptors in the limbs and other parts of the body,
- The ***autonomic nervous system***, which is responsible for control of bodily functions, such as breathing, the heartbeat, and digestive processes.

In this series of books these divisions are regarded as misleading because all the processing-systems, whether classified as "*brain*", "*spine*", "*central*", "*peripheral*" or "*autonomic*" are permanently contributing ***context*** capable of influencing the outcome of activity within all the other systems and, argu-

ably, is doing so all the time.

However, it is sometimes helpful to focus on specific parts of this whole. Thus the practice of coupling the separate words "*eye*" and "*brain*" into the compound "***eye/brain***" is a step in the right direction. However, it is only a part of the story. The eye's interconnectivity with ***all*** sensory input systems should never be forgotten. Thus while it might, on occasion, be convenient to simplify explanations by referring to the *ear/brain*, the *nose/brain*, the *limbs/brain*, etc., this should never be done without recognition of their relation to the other sensory input systems.

Brain systems are ***neural systems***, which are centred in the head but take input from throughout the body, that have thee main functions, namely to ***make sense of*** the visual world, to enable ***recognition*** and to ***guide actions*** (including ***thought-actions***). The flow diagram in *Figure 1* gives a highly oversimplified guide to how this is done for visually guided skills.

Bauhaus: A German design school, founded towards the end of the First World War, that ran a very influential colour course, which, amongst many other things, played an important part in focusing the attention of twentieth century ***nonfigurative artists*** on the possibilities of ***lightness-contrast effects*** and ***colour contrast-effect***s.

Brightness is a quality of appearance that is often confused with ***lightness.*** One way of getting a feeling for the difference between the two is to refer to their opposites namely "*dullness*" and "*darkness*". Another way, is to think of brightness as a "*quality*" and lightness as a "*measurement*", with the quality of brightness being that of "*shining out*" as stars shine out. The difference can also be sensed from the realisation that a leaf perceived by mean of ***transmitted*** sunlight may seem ***brighter*** than the same leaf perceived by ***reflected-light,*** even though the transmitted light has a lower ***intensity*** reading. Accordingly, the widespread use of the word "***brightness***" in the phrases "*simultaneous brightness contrast*" and "*brightness constancy*" is incorrect. They should be "***simultaneous lightness contrast***" and "***lightness constancy***".

Brunelleschi's Mirror. The text accompanying *Figure 1, Chapter 2* tells how Brunelleschi made use of the idea of making a tracing of the Campanile in Florence as reflected in a mirror. This is the first record of an artist using a reflecting device for tracing the image of an object. Brunelleschi got round

the problem of inverted mirror image by making a small hole in the back of the mirror with the image traced on it and looking the image in another mirror placed in front of it.

Cavé: Elizabeth Cavé was an artist, a teacher and a close friend (some say mistress) of ***Eugène Delacroix***. Her book "*Drawing without Teachers*" advocated an ingenious method involving tracing subject matter on gauze and using the result as a guide to making and correcting normal copies from observation. In the process, students not only learned about the nature of the visual distortions that make the task of accurate copying so difficult, but also stocked their memory to the degree that they could reproduced the objects of their analysis from memory. The book, which was reviewed enthusiastically by ***Delacroix***, went through many editions and was taken up by the state school system.

Camera Obscura: a room with a small aperture, in which is situated a lens that can focus light from outside onto a screen inside and thereby create an image that can be copied or traced by artists. Its advantage over the ***perspective frame*** and ***tracing on glass*** is that it can be done without the difficulties associated with having to keep the head still and to close one eye. See *Figure 6, Chapter 2*.

Carrière : Eugene Carrière was a student of ***Horace Lecoq Boisbaudran*** and much admired by the ***Impressionists***.

Cartoon. The cartoon was the fourth stage in the ***academic method*** of making paintings. It came after the "***idea***", the "***sketches***" and the "***studies***", and before the "***ébauche***", the "***image transfer***" and the "final painting", for which all these stages had been a preparation. It consisted of a monochromatic drawing in which the ***compositional ideas***, as worked out in the ***sketche***s, and the ***images of objects***, as worked out in the ***studies***, were assembled into a definitive ***composition***. A key part of this process was the working out of the ***whole-field lightness relativities***.

Changing Criteria. There are always two ways of correcting a mistake. By far the most widely used of them is to make ***same/difference judgements*** and remove the differences.

The other is to ***change the criteria***, an option that has only too often been used to excuse sloppy performance. However it can also provide a spur to ***creativity***, as the history of both science and art make clear, since ***new ways***

of thinking can only occur as a result of adopting ***new*** *or* ***modified criteria.*** See "***Modernism in Painting***" for examples of how the ***Modernist Painters*** made use of ***criteria change*** to bring about what amounts to a sequence of ***paradigm shifts***.

Chéret (1836 – 1932) : Jules Chéret, who was famous for his posters, was a student of ***Horace Lecoq Boisbaudran***.

Chunking is the name given to dividing the outline of an irregular shape into parts that can be analysed separately and in relation to one another. *Figure 8* in *Chapter 11* of *"Drawing on Both Sides of the Brain"* provides an example of how the outline of a nude model can be chunked using changes of direction in the contour as staging posts. In the drawing lesson described in *Chapter 9* and *Chapter 10*, shows how *in front/behind relations* can be used in an analogous way to ***chunk*** the contour of the tree trunk into comparable sections.

CLAM is an acronym for "*continuous looking at the model*". Various books such as "*The Natural Way to Draw*" by Kimon Nicolaïdes and "*Drawing with the Right Side of the Brain*" by Betty Edwards refer to this method by means of the much more ambiguous phrase "***contour drawing***". It requires the student draw the outline of a model on a piece of paper at which they are not allowed to look. The instruction given is that they should imagine themselves following around the outline with their eyes "*as if tracing it*" and, in tandem, to guide their drawing instrument along an analogous trajectory, with its tip continuously touching the paper. *Chapter 4* provides an in-depth analysis of ***CLAM*** with special reference to its strengths and shortcomings.

Eye-movement monitoring machines show that, unless there is a moving object to track (as in the case of tracing), the eyes are incapable of smoothly following a line. Rather they jumps about all over the place, in a seemingly random manner (see *Figure 11)*. This being the case, it is not surprising that ***CLAM drawings*** are full of distortions and exaggerations. However, the similarities between instructions given for making ***CLAM drawings*** and those given for making ***tracings*** are significant in that they show that both processes are essentially banal.

Despite this banality, the combination of the requirements of ***CLAM*** and the inaccuracy that results gives the method at least three hidden advantages for teachers of ***drawing from observation***.

1. All the information in a ***CLAM drawing*** can be relied upon to relate

to features of the model's contour, no matter how inaccurate it may be. This is far from necessarily the case in the normal drawings, and not only those produced by children or beginner adults, which can so evidently ride roughshod over appearances (see ***intellectual realism***). Teachers can help students to look differently at the model by asking them to compare their ***CLAM*** drawings with these efforts. Doing so will invariably draw attention to features that have been badly drawn or overlooked in the normal drawing, which can then be corrected.

2. The high level of control over line production that is regularly achieved by beginners provides evidence of ***line-production skills*** that give confidence to those (of whom there are many) who had previously been inhibited by a lack of self-belief in this respect.
3. Both the nature of distortions and the increased fluidity of line production can be used by teachers as a gateway to expressive possibilities.

It is these advantages that explain why the CLAM method has proved to be so popular with teachers.

Cognition: The mental action or process of acquiring ***knowledge*** and understanding through ***thought***, ***experience*** and the ***senses***.

Cognitive Cues are used by the ***eye-brain*** as an important part of its battery of approaches to ***making sense*** of appearances. Artists can use them as means of directing the interpretations of their productions, for example by means of titles they choose for them. Critics and historians can use articles and books.

Figure 1 helps us to delve deeper into the role of ***cognitive cues*** in visual perception. It illustrates the component parts of the ***analytic-looking cycle.*** It is shown as starting with the ***primary recognition processes***, but giving primacy to any part of the stages illustrated is misleading. Each of them can be thought of as the starting point. Thus, ***recognition*** cannot happen either without attention having been directed or without the involvement of ***context-based memory*** which, by definition, contains previously learnt knowledge. Clearly the ***analytic-looking cycle*** is a chicken and egg affair in which all the processes involved play equally necessary roles. This fact needs to be kept in mind when considering the nature of "***cognitive cues***".

Once ***recognition*** has taken place, one of the most important functions of visual perception is the locate of objects both in terms of their edges and

their surfaces. It is for this reason that the eye/brain has a battery of different processing systems fordoing so. These can be divided into three categories in terms of their role in picture perception.. The first of these cannot be used by artists to create perceptions of ***illusory pictorial-space***, while the other two can. The three categories are:

1. Processing systems that provide viewers with information about the surface-form and distance between them and the surfaces in question, (b) by means of ***stereopsis*** or (c) by means of a number of focus-based cues. Since all these are based on information coming from actual surfaces, they cannot but interfere with the perception of ***illusory pictorial-space***.
2. Processing systems that provide information about ***surface-form, in front/behind relations*** and ***ambient illumination*** as a result of computing rates of change in the reflected-light profile of surfaces (for more on these see the section on ***colour constancy*** under ***the constancies*** in the *Glossary*). Since the information-base upon which these systems make their computations can be mimicked in paintings, knowledge of their working principles can be used to help artists with the creation of perceptions of ***illusory pictorial-space***. Much of the companion volume on painting is dedicated to showing how.
3. Processing systems that derive input from ***knowledge,*** stored in ***long-term memory,*** that relates to the nature of appearances. These provide ***knowledge-based*** cues, otherwise known as ***cognitive cues***, which give added substance to perceptions on the basis of information derived from:
   - The typical volumes, sizes and other characteristics of known ***object-types*** (for example, cups can be assumed to be cup-sized, cup-shaped and capable of containing liquid, or human beings can be assumed to be human-sized, human-shaped and capable of human behaviour).
   - The ***rule of occlusion*** that ensures that anything that obscures anything else must be in front of it.
   - The regularities encapsulated in the ***rules of linear and aerial perspective***.

   Since paintings can be made to contain all types of ***cognitive cues***, all

can be used by artists to encourage perceptions of ***illusory pictorial-space***.

Colour has such an important role in my books that I am proposing four ways if approaching its meaning, under four different headings.

Colour (1): As with all words with a long history, the word "***colour***" has evolved in terms of its meanings and it is therefore it is important to be careful when using it. Most commonly its function has been to describe visual sensations that are experienced as attributes of surfaces or regions of surfaces in the external word. We talk of "*red*" roses or "*green*" grass because we have learnt to use these words to describe our experience of "*red*" and "*green*" objects that we come across in daily life. However, in the eighteenth century, scientists of ***visual perception*** realised that ***colour*** is not anything of the kind. Rather it is a creation of ***eye/brain systems*** based not only on information coming into the eyes from the surface that is being perceived as coloured, but also from the surfaces that surround it. In short, they realised that the experience of ***colour*** is both ***brain-made*** and ***context sensitive***.[4] Together these two insights made it clear that the ***colour*** of a surface cannot be equated with wavelength combinations of the light reflecting from it, as physicists had been doing. For more on this see the section on ***colour constancy*** under the ***constancies*** in this *Glossary* and *Chapters 13 and 14 of "What Scientists can learn from Artists"*.

Soon after the ***physicists*** made new contributions to the progress of understanding about ***colour*** by going deeper into the subject of the information that the eye/brain picks up from surfaces. What they found was that it is made up of two components with very different properties. In this series of books these are called "***body-colour***" and "***surface-reflectio***n". *Figure 18*[5] shows that when daylight, containing all the visible wavelengths strikes a surface it is divided into two parts:

1. One part penetrates the surface. When inside, some of its wavelengths are absorbed and others, having been scattered around inside, are scattered back out again into the eye of an observer. This is the "***body colour***" (what we see as the green of leaves, the yellow of ripe corn,

4 Gaspard Monge (1746-1818) showed how whole-field colour relativities could explain the phenomenon of ***colour-constancy***.

5 The diagram in *Figure 18* is analogous to the one upon which Seurat based the ideas for painting with light.

the flesh colour of flesh, etc.). As far as I know, nobody has estimated the number of different body colours in the visible world, but there are clearly at least many thousands.

2. Another part never enters the surface. Rather it is reflected directly off it according to the rule the angle of incidence is equal to the angle of reflection. Since no light is absorbed during this process, the incident light and the reflected-light contain the same wavelength combination. In the diagram both are shown as being the same "*white*" light.

To simplify its message, *Figure 18* only shows one ray of incident light. In the real world light arrives at surfaces from a combination of ***primary light sources*** (coming from one or more different directions) and a multiplicity of ***secondary light sources*** of different of intensities (coming from all directions). While primary light sources can have fairly predicable wavelength/intensity profiles, secondary light sources never do. Physicists will tell us that any possibility that any two of them will be the same is extremely remote. It is for this reason that no part of any surface will reflect the same wavelength/intensity combination as any other part of it. Likewise, no two surfaces in any scene reflects the same wavelength/intensity combination.

However, though for the physicist, the variety of in the composition of the reflected-light that results is infinite, for the perceptual scientist, the limitations on the sensitivity of their visual systems restrict the number of nuances of which human eyes can be aware. How many is disputed, but it is generally agreed to be in the millions.

More recently, the discoveries of the physicists have been combined with the ideas of the perceptual scientists to explain how the eye/brain is able to separate ***surface-reflection*** from ***body-colour***. Details of how this is done are given in "*What Scientists can Learn from Artists*", *Chapters 13 and 14.* However one part of the computation depends on the sudden changes in the profile of the reflected-light that regularly occur at the edges of regions of colour (whether at edges of colours within the same surface or at edges of the surfaces themselves) being equated with changes in ***body-colour***. However it turns out that the computations concerned cannot distinguish these sudden changes in actual body-colour from those that occur at the edges of ***shadows*** that are due to sudden changes in intensity. Accordingly our eye-brain systems classify these erroneously as ***body-colour***. For how knowledge of this neural computing error can help artists, see the section in this

Glossary on "***shadows*** and ***shading***".

Colour (2): In the 1980s Semir Zeki, when investigating area V4 of the visual cortex, found twenty-two "*colour coded cells*". These respond to ***body-colour*** independently of wavelength profiles. The twenty-two not only included violet, a colour that has no simple wavelength equivalent, but also black and white. This meant the eye/brain was responding to achromatic regions of surfaces in an equivalent way to regions of blue, green yellow, orange and red. This definitively resolved the question as to whether ***black*** and ***white*** are colours, although the fact that they are indeed so was already a widely accepted implication of the discovery well over 150 years earlier that colours are made in the head.

Colour (3): From the above it is evident that when people use the word *"colour"*, they might mean several different things. Three of the possibilities are:

1. The sensations of ***colour*** that in our everyday visual perception we mistake as properties of surfaces. The eye/brain computations which enable this illusion do so by separating out the two main components of the light that enters the eye and then recombining them (What follows is diagrammed in *Figure 19*).
    - The first of these components is the part of the light that enters the surfaces before interacting with the pigments in them, such that some of its wavelengths are absorbed and the remainder scattered about with in the surface. A proportion of these is then scattered back out again. It is this "*scattered-back-out light*" that gives surfaces their "***body-colou***r", enabling us to see them as red, blue, brown, grey, etc.
    - The second of the separated out components is the incident light that never enters the surface but is reflected directly back from it without changing its wavelength combination. Thus if it is white light that strikes the surface, it is the same white light that is reflected back from it. This not only provides information that enables the ***eye/brain*** is able to create the experiences of ***surface-solidity*** and ***surface-form***, it also nuances our experience of body colour.
2. Sensations of ***colour*** that are extracted from the light that enters surfaces, and, after some wavelengths are absorbed, is scattered out the

other side. This ***transmitted light*** gives us the colours such as those provided by stain-glass windows and translucent leaves when seen against sunlight. In the absence of surface-indicating ***reflected-light***, we perceive these colours as both surfaceless and formless. Other familiar colours in the natural world that we perceive as surfaceless include the blue of the sky and the prismatic colours of the rainbow. These are the nearest we can get to an experience of pure "***body colour***" (see *Colour (3)*, below in this *Glossary*)

3. The gamut of paints, pastels, crayons and any other medium used by artists to "*colour in*" paintings. Thus we talk about the "*colours*" in a paint box" or the "*lemon yellow*" and "*pale blue*" tubes of paint to be found in it.

Colour (4): While in everyday language "***colours***" are referred to with words like "*red*", "*blue*", "*yellow*", "*pink*", "*brown*", "*grey*", etc., and we are all familiar with what they mean. In contrast ***physicists*** have preferred to describe them in one or other of two ways, namely:

- Wavelengths and wavelength-combinations of electromagnetic energy
- The three variables of ***hue***, ***saturation*** and ***lightness***. In addition they conceive them as inhabiting a ***colour space*** constituted of all the wavelength combinations to which the eye is sensitive. This can be represented in terms of a ***colour sphere*** as shown in *Figure 24*.

However, when considering these descriptions, it is important to keep in mind that the ***properties of light*** they refer to are not at all the same thing as ***colour***. Light has no colour. As should be clear from the definitions above, colour is a creation of ***eye/brain systems***. One consequence of this fundamental truth is that, although there is a correspondence between wavelength profiles and the colours that they stimulate, this is not as simple as physicists would have us believe. It is only valid if all the wavelength profiles entering into the eye during the colour-creating process are taken into account.

Similarly, our experience of colours in paintings does not depend on the absorption/reflection properties of individual regions of pigment-colour but on the absorption/reflection properties of all the regions of pigment-colour on the picture surface and the interactions between them. In my books, these are described as "***whole-field colour relations***".

Colourist: As with the word "*colour*", the word "*colourist*" can mean different things to different people. Below are two approaches to giving it a meaning**.**

Colourist (1): Colourists are artists who gives priority to the creation of colour-based experiences in their paintings. However, this can mean different things for different artists. I had two teachers who described themselves as "***colourists***". One was interested in ***whole-field colour relations*** and the other in ***local colour-contrast effects***. The former thought in terms of a multiplicity of colours (in principle many hundreds of thousands) and the effect of each and every colour on the picture surface on each and every other colour on it. The other thought in terms of a very limited number of colours (for example, two, three, four or five) and was principally interested either in ***local interactions*** between them or in their ***denotative*** function. Other artists, such as Ellsworth Kelly, have felt that both these approaches divert attention from the experience of colour as itself. These concluded that the only way of providing a pure experience of colour was to cover a surface such that the entire colour experience of the spectator is taken up with a single colour viewed from a distance at which its actuality (indicated by the texture either of the canvas or brush marks) plays no part in the experience. Other artists seem to think that being a colourist means covering a canvas with more or less any array of fully saturated colours and it would seem that some viewers think it fine to do so.

Colourist (2): There is a significant difference between the way the word "***colourist***" is used when used (a) to refer to the painters of the ***Italian Renaissance***, who came to be known as "***Venetian colourists***" and (b) when it is applied to ***Modernist Painters,*** such as Gauguin and Matisse. The significant difference between them is that while the former gained their name by putting into practice the idea that "*no two regions of colour in nature are of the same lightness*", the latter gained theirs by including all dimensions of colour (hue, saturation and lightness and texture). For them the rule became "*no two regions of colour in nature are never the same in any of the dimensions of colour"*. Along with the then recently publicised knowledge that colour is both ***made in the head*** and ***context-dependent***, this second, all-inclusive definition was responsible for the explosion of colourfulness in the work of the ***Modernist Painters.***

These fundamental differences explain why the word "***colourist***" when applied to Titian, Vermeer or Rembrandt has a significantly different meaning than when it is applied to Gauguin, Matisse or Bonnard, as should be evi-

dent to anyone who compares their work.

Colour-Contrast Phenomena: in his 1837 book, Eugene Chevreul proposed his theory of ***simultaneous colour contrast***. It asserted that when any two colours are juxtaposed the differences between them with respect both to their lightness and their hue will be exaggerated at their common border. Artists were particularly interested in the discovery that reductions in the influence of the lightness-contrast component, made the hue-contrast ones more evident and more exciting; The result was a growing interest in reducing the lightness range within paintings. This was one of the factors that led to the greater colourfulness of Modernist paintings and, eventually, was to lead to the iridescent colours of "*Op Art*".

Colour space: For scientists, this means the theoretical space inhabited by all the visible ***wavelengths of light*** at all their possible levels of ***intensity***. In books on colour technology it is often referred to as the "*colour solid*".

For artists this means all the colours in the ***colour-circle*** at all possible levels of grey, from ***white*** to ***black***. This can be represented by the ***colour sphere*** (See *Figure 24*).

Comparison: As indicated under the heading "***accuracy aspiration***" learning cannot take place without ***feedback*** and feedback cannot take place without a ***goal***. In this book, which treats ***drawing from observation*** as a strategy for learning about appearances, the chosen ***goal*** is ***accuracy*** and the feedback is provided by ***comparisons*** using ***same/different judgements***, that reveal differences between:

- Different parts of the model,
- The model and the copy
- Different copies.

Since ***accuracy*** is the goal, these differences can be described as "***mistakes***", which is why the combination of making them and recognising that they have been made plays such fundamental role in learning to ***draw from observation***. This is true whether the learner is a beginner, engaged in the early stages of the process, or an advanced practitioner seeking to record the ever-present but always unknowable uniqueness of appearances.

Comparative Looking is required for making the ***same/difference judgments*** that reveal differences between compared objects or forms. Particularly useful for

the artist when ***drawing from observation*** are comparisons involving ***near-symmetries*** (See Glossary diagrams 17a and 17b). These may be:

- N***ear-symmetries*** found in ***nature*** due to the mirror symmetrical structure of most living forms, for example, the outstretched wings of a butterfly, the two profiles of a front-facing human being (or any other animal) and, even, the two side of a tree trunk).
- ***Near-symmetries*** between different examples of the same object type.
- ***Near-symmetries*** between marginally different views of the same object type.
- ***Near-symmetries*** between objects in nature and drawings of them made from observation.
- ***Near-symmetries*** between different attempts at making corrections.

It is because the differences call attention to themselves that comparisons force "***seeing in new ways***". Of particular importance for artists trying to achieve ***accuracy*** are the difference that can be found between the objects being drawn and the aspect of our representations of them that we call "***mistakes"***.

Complex curves: The characterisation of ***complex curves*** provides a major challenge for the ***line-output systems*** of artists whose goal is to achieve accuracy in drawing from observation. For explanations as to why, see the section on "***generalisations***"

Composition: In this series of books, the definition of a good *composition* is one in which the ***pictorial elements are arranged in such a way as to best serve the objectives of the artist***. However, this leaves open the question as to what this might mean in relation to any particular artist or any particular artwork.

Not surprisingly, this is a question that has been given much thought by artists over the centuries and the resulting history of ***rules of composition*** is a fascinating one. Of particular interest with respect to European art are the ***rules*** used by the ***old masters***, codified by the ***Academies*** and often scorned by the ***Early Modernist Painters***. Some of these were related to spiritual significance, for example, when the main elements of an image were fitted into a triangle symbolising the Holy Trinity or were organised around the ***golden section*** with its various perceptual and mystical implications. At other times it was a matter of tricks for directing the eyes of the viewer

towards significant aspects of the image, for example by means of gestures or faces turned in the direction of the Christ child in the manger. Other compositions were also much influenced by the ***laws of nature*** and, in particular, ***linear and aerial perspective***.

All these were thrown into question when Monet, Renoir, Pissarro, Sisley and other early ***Modernist Painters*** set out to paint nature as they saw her. They found that objective analysis revealed that both the ***rules*** and the ***laws*** as promoted by the ***Academies*** the scenes were regularly broken**.** So great was their disillusionment that Monet is on record as questioning their existence.

Another reason why the early ***Modernist Painters*** questioned the dictates of the ***Academies*** was their reaction to the Japanese woodblock prints which were flooding into Europe at this time. Despite breaking just about all the ***rules,*** they were greatly enjoyed by a wide range of people. The early ***Modernist Painters*** saw this as support for their belief in the need for alternative rules for their own paintings. In the long run, the search for these by their successors led to the discovery that, no matter what rule proved satisfactory for one artist or even if only in the context in one work, there are always other equally satisfactory ones to be found. Some of these were seen by the community of artists as being based sufficiently universal principles to be worth codifying. Perhaps the best examples would be those developed by the artists of the ***Bauhaus,*** as exemplified in the teachings and writings of Paul Klee and Johannes Itten that were later to be widely taught in European Art Schools and reproduced in a multitude of how-to-do-it drawing and painting books.

Conceptual Framework. All drawing and painting starts with a number assumptions about the nature of the activity and its objectives. These provide one aspect of the *conceptual framework* within which the artist is working. They may concern the nature of the image to be drawn or the approach to making it (what medium to use, which method of applying the paint, what size of picture support, what level accuracy will be sought, etc., etc). In this book a main objective is ***literal accuracy***. However, it is not conceived as an ultimate goal but rather as a means of enabling "***seeing in new ways***", for example, by means of:

- Discovering more about the nature of "***objective reality***".
- Discovering more about the nature of "***experienced reality***".

- Establishing a basis for the exploration of "***distortion"***, "exaggeration" and "***abstraction"*** since all three depend on having a base plate that can be subjected to distortion, exaggeration or abstraction.
- Seeking a basis for "***personal expression"***,

A second aspect of the conceptual framework within which an artists works concerns ideas that motivate and provide a context for the kind of work that is to be done. For example, The Renaissance artists had a story to tell as well as mythologies (classical and Christian), an established iconology and new ideas about perspective and anatomy to draw upon.

- The Impressionists were wanting
- Georges Seurat sought to find a way of painting "*light*"
- , Paul Cézanne wanted to represent that which remains stable beneath the ever changing face of appearances
- Vincent Van Gogh was intent upon using exaggeration to maximise the force of his social message
- Mondrian dedicated himself to the goal of creating a "spiritual space"
- Mark Rothko did his best to enable a sense of entering into the dynamics of his coloured surfaces,
- Michael Kidner wanted to honour the creativity of the universe,
- For myself, I kick-started my life as an artist with the project of testing the efficacy of the axioms of Professor Bohusz-Szyszko.
- Throughout history, painters have sought to use their work as a means of conveying social messages and making political points

Conceptual Art: The name given to a large number of late twentieth and early twenty-first century art works in which the presentation of a concept provides the ***conceptual framework***.

Consciousness: Of all the eye/brain processes indicated in *Figure 1*, the only ones that involve *consciousness* are those that enable ***analytic-looking***. All the other processes are either ***preconscious*** or ***subconscious***. Among these are the ***recognition processes*** that enable access to the ***context and feeling based memory*** (better known as LTM or Long Term Memory). The role of this store of all our knowledge is the ***organisation of task related actions*** (including ***analytic-looking behaviour*** and ***task related thoughts***). The in-

escapable implication of this arrangement is that our ***looking strategy*** has been determined *before* we are consciously aware of the object or layout of objects to which we are about to react. In terms of the theory of ***intellectual realism***, "*we know what we are looking at before we see it*".

For artists who are ***drawing from observation***, this order of priority ensures that, if the object or any part or aspect of it is ***familiar***, they will look at it in ways that they have looked at it before. In the context of achieving ***accuracy*** in ***drawing from observation*** this is a disadvantage both for beginners and for more experienced artists:

- For beginners, the problem is that their formerly used ways of looking will not have been related to the task of drawing from observation. Accordingly, they will almost certainly be to a greater or lesser extent dysfunctional.
- The problem for experienced artists follows from the fact that their knowledge of how to approach the analysis of objects or scenes, however familiar they may believe them to be, can only be based on previous experience. Accordingly, however impressive their knowledge-base, looking strategies guided by it will result their overlooking any features that are unique. In other words, it will act as a barrier to the main objective or drawing from observation, namely that of characterising what is special about appearances.

In contrast, if an object is ***unfamiliar***, everybody, whether unskilled or skilled, will be in the same situation, and luckily so. The situation would be hopeless if it were not for the fact evolution has catered for dealing with seeming unfamiliarity. We would all be in a pretty predicament if there were to be no way of making sense of subject matter that we have never seen before. Since, as *Figure 1* indicates, we need ***knowledge*** to guide our looking behaviour, we have no alternative but to look for what is ***familiar*** in the current, seemingly ***unfamiliar*** visual input.

This is why, in the absence of any instructions of how to look at the objects we are describing as "*unfamiliar*", the ***knowledge-driven eye/brain systems*** know that their only recourse is to go down the levels of description until they reach a level of ***familiarity***. Thus, if their search fails to bear fruit at any one level, it will inevitably descend to the next level until they reach the level of the ***visual primitives***. It is at this level that the downward search can stop. The reason why is that at it ***existing knowledge*** corresponds most

nearly to ***measured reality***.

Drawing teachers have various approaches to helping students find what they describe as "*unfamiliar*" aspects of appearances. For example, they encourage them to look for "***negative shapes"***, to copy ***"upside down photographs"*** or to try "***CLAM".*** Other helpful strategies include ***chunking***, drawing attention to on ***how elements fit together*** and, most common of all, ***pointing out mistakes***. In all cases the objective is to bring to *consciousness* aspects of appearances that they have previously overlooked.

The value of all these teaching methods is that they help students to go down the levels of description. In the last resort, they will reach the level of familiarity provided by the ***visual primitives***, the common feature of which is that they relate to properties common to all objects, rather than properties relating to one specific object or object type. Here, at last, is knowledge that can be used in the organisation of actions. Here also is a method of bringing consciousness to the only way of achieving accuracy in drawings from observation.

The **Constancies** of ***lightness***, ***colour***, ***size, orientation*** and ***shape*** were evolved by the ***eye/brain*** over millions of years as a necessary step in making sense of the visual world. They are the product of the need to recognise objects as being the same on different occasions despite the fact that the pattern of light that enters the eyes, even from the same object on different occasions, will always vary due to changes in lighting conditions and/or viewing distances and/or angles. In other words, the *constancies* underpin our ability to classify different patterns of light as coming from the same familiar object or object-type. S***ize constancy, orientation constancy*** and ***shape constancy*** are of key importance in the arguments presented in "*Drawing with Both Sides of the Brain*". ***Lightness constancy*** and ***colour constancy*** play a crucial role in *"Painting with Light and Colour"*.

- ***Size constancy:*** The eye/brain systems produce changes in the opposite direction to those that form the basis of ***linear perspective***. Accordingly smaller and further objects appear as relatively bigger, whereas larger and nearer objects appear as relatively smaller.
- *Orientation constancy* means that, when looked at out of context, the ***axis of symmetry*** of any shape that is not vertical, horizontal or at forty-five degrees relative to a ***plumb line*** (real or hypothetical) will tend to be perceived as more vertical, horizontal or nearer to forty-five degrees than, *measured realty* would indicate. If analysis is not in terms

of shapes, but in terms of straight or approximately straight stretches of contour, these will tend to be seen as more vertical, horizontal or nearer as to forty-five degrees than, *measured realty* would indicate.

- ***Shape constancy*** means that rectangular or circular surfaces of objects such as boxes or cylinders, when not viewed form directly in front or above, will seen as more rectangular or more circular than they would appear if traced on glass or photographed, and that this tendency will occur for all surfaces. For example, shape constancy will ensure that the seeming height from the lowest point to the to highest point of a box-top or a cylinder-top will always be perceived as greater than ***measured realty*** would indicate. Similar distortions occur for less regular shapes, examples of which would be certain fields in a ***receding*** landscape or parts of the human body in ***recession***.
- ***Lightness constancy*** means that eye/brain achieves a transformation analogous to that produced by an automatic camera when it stabilizes the amount of light arriving at its array of photosensitive receptors by adjusting its aperture size and/or its exposure time. The eye/brain produces similar results mainly by using ***lateral inhibition*** between the ***neurons*** in the ***retina***, although it also relies to an important extent on adjustments of the aperture size of the eye's pupil.
- ***Colour constancy*** means that we perceive colours as the same even when illuminated by light of different wavelength/lightness combinations. There are two kinds of colour constancy, namely, ***spatial colour constancy*** and ***temporal colour constancy***. Both influence the way paintings are perceived.

  1. ***Spatial colour constancy*** means that where a number of regions of the same pigment colour, with the same absorption/reflection characteristics, are to be found in different parts of a picture-surface, the eye brain will compute them as being the *same.* They regularly do so despite the fact that the intensity and wavelength combination of the light being reflected from them into the spectator's eyes will always be different.
  2. ***Temporal colour constancy*** is the phenomenon by which the appearance of regions of colour perceived on different occasions is not influenced by changes in the wavelength combination of the light illuminating them. Temporal colour constancy only occurs

when the colour region in question is embedded in an array of other colours and if the light illuminating them extends across the whole spectrum.

The ways in which eye/brain systems achieve these two types of colour constancy are fascinating. They should be of special interest to artists because of their profound effects on the way we experience paintings. Anyone who reads "*Painting with Light and Colour" will find a great deal more about their implications for artists. In "Drawing on Both sides of the Brain*" there is an abundance of new information on:

- The perception and painting of ***shadows*** and
- The continuity of the surfaces upon which they fall, of
- Effects of ***ambient lighting conditions***
- The creation of an i***llusory pictorial-space.***

However, for a fuller treatment of this key subject readers are recommended to consult the chapters on "***colour constancy***" in "*What Scientists can Learn from Artists*".

Constructivist: See the section on "***abstract art***".

Context: All modalities of perception and cognition, including the neural processing which makes them possible are ***context-based***. If this were not the case, human experience would be impossible.

A consequence of this fundamental truth is that all aspects of visual perception (including ***recognition,*** the ***laying own and using of all manifestations of memory, analytic looking***, ***what we notice*** and ***what we overlook*** and, most importantly of all, ***how we feel***) all take place in the context of our ***personal life experience***.

Of particular interest to artists is the facts that all judgements of ***scale***, ***lightness*** and ***colour*** are ***context dependent***. This must be so for we could not think of these qualities of appearance without such concepts as "bigger", "smaller", "lighter", "darker", "more or less fully saturated", "greener", "bluer", etc.

Indeed, by definition, all relativities are context dependent, including not only relativities of ***"length", "size", "orientation", "position", "curvature", "lightness"*** and ***"colour",*** but also those provided by ***"whole-field" and "time-related"*** relations.

For artists two implications of the fundamental role of context in visual perception are that:

- Accuracy in drawing or painting from observation can only be obtained with the help of ***comparative looking***.
- The uniqueness of our ***personal life experience,*** as stored in our context based memories, ensures that we all have unique ways of ***seeing*** and ***feeling*** that offer everyone the possibility of enjoying not only the rewards of journeying in uncharted territories but also the satisfaction of extending the awareness of others.

Contours can be defined as outlines that depict the boundaries of shapes and forms. Thus strictly speaking any drawing that represents these boundaries with lines can be classified as a "***contour drawing***".

"**Contour Drawing":** In addition to its literal meaning, the phrase "***contour drawing***" has been used to describe a method of drawing, pioneered by artists like Auguste Rodin and Henri Gaudier-Brzeska and formalised by Kimon Nicolaïdes, in which the contours are drawn while looking continuously at the model (represented in this book by the acronym or ***CLAM***). *Chapter 4* provides an in-depth analysis of this process with special reference to its strengths and shortcomings.

Creativity (six approaches to a definition)

1. ***Creativity*** is the process of producing something new, whether it be in the domain of ideas, processes, objects or, as is most likely, some combination of all three.
2. **Creativity**: Readers of a book that lays stress on the advantages of seeking ***accuracy***, may wonder where *creativity* comes in. Surely if everyone achieved ***accuracy,*** there would be no room for originality or the creativity necessary for achieving it? But, throughout all my books, emphasis is placed on the distinction between accuracy as a goal in itself and accuracy as a tool for enhancing awareness. The difference between the two is fundamental. Success with respect to the former would crush individuality, while success in the latter inevitably leads to an opening up of creative potentials.
3. **Creativity**: Achieving creativity in drawing and painting involves ***seeing, feeling*** and ***doing in new ways***. Achieving it presents a problem because, as *Figure 1* in the *"Section on Diagrams"* illustrates, the ***eye/brain*** is only ca-

pable of ***memory-guided activity*** and the contents of the ***memory*** that does the guiding can only have been derived from past actions and perceptions (even if sometimes in the very recent past).

It follows that one way for human beings with human brains to achieve novelty is by tapping into some kind of external source. In practice this means organising interactions with the world outside, which can be done by using some combination of ***sensing systems*** to seek out information coming from it. Fortunately for the human race the unfailing uniqueness of every ***perceptual input*** and of every ***personalised memory-store***, means that these interactions will unfailingly produce ***unpredictable and personalised outcomes***, even if on most occasions the unpredictably is scarcely measurable and goes unnoticed.

Examples of environment fed routes to creativity are provided by the learning strategies advocated by teachers of drawing and painting, whether in the classroom or in books. In this book particular emphasis is placed on the use of ***comparisons*** to draw attention to ***differences*** between similar aspects of appearances. One common manifestation of these is the differences are between the ***model*** and the ***copy*** that we describe as "***mistakes***". Since, by definition, these cannot be made on purpose, the process of identifying them invariably draws attention to aspects of appearances that have been overlooked. Accordingly ***mistakes*** can be used to force artists of all levels of attainment beyond their habitual ways of looking and, thereby, enable them to extend their visual awareness in potentially creative ways.

Unless the mistakes are very great, the differences between model and copy to which they draw our attention can a be described as "***near-symmetries***". If so, in this case, the phrase, "*we can always learn from our mistakes*" can be translated as,"*we can always learn from near-symmetries*". Or, to put it more colloquially, *"we can always learn from small differences between similar things"*.

A main difference between these statements is that whereas the word "***mistake***" has negative connotations, the word-combinations "***near symmetries***" and "*small differences*"does not. This is significant because the bad feelings associated with "*mistakes*" can deter people from seeing them in a positive light. This is a pity, for they can also motivate attempts to correct them. All that is necessary is reclassify the "*mistakes*" as "*small differences*". Disengaging the emotions in this way, allows more objective analysis using the

workhorse of creative visual analysis, namely *"**comparative looking**"*.

Nor is the ***comparative looking*** just a question of refining awareness in the short term. It can also lead to questions as to why the discrepancies arose. The books in this series provide examples of how the search for answers can lead both to a greater awareness of our ***visual world*** and, beyond that, to an interest in the operating principles of ***visual systems.***

4. **Creativity:** As hinted earlier, there is another approach to generating novelty, for stored in our memories are many things, whether they be images or concepts, that are similar enough to be compared with one another. As always, where there are comparisons between similar but different inputs, there is the potential of jogging the system out of habitual ways. When it does so, we praise the person's powers of "***imagination***".

5. **Creativity**: Amongst the many things that can be learnt from ***mistakes*** is that what is noticed and what is overlooked is largely determined by the ***personal history of the viewer***. Another is its corollary, namely that each and every person will be aware of different aspects of appearances: Nobody "***sees***" in quite the same way.

   Nor is this merely a difference in terms of the purely visual dimension. Just as importantly, it concerns the ***feelings*** that are associated with perceptions. Accordingly, even if it were possible for two people to have the same visual input when looking at the same person from the same point of view, the chances of them having identical ***feelings*** about him or her are negligible.

   The fact that each individual both ***sees*** and ***feels*** in unique ways means that they all have the possibility of sharing unique experiences and, accordingly, of expanding the awareness of others. In other words, everyone has the possibility of having a ***creative*** influence on others.

6. **Creativity:** If we accept at its face value the definition of ***creativity*** as the process of producing something new, logic tells us that it must be almost impossible to make a ***painting*** or ***drawing*** that is not an example of it. The almost limitless ***relativities* of *size, length, orientation, curvature, colour, lightness and texture***, all in the context of the complexity of ***whole-field relations,*** provide far too many ***variables*** to allow for ***repetition***.

   But, despite this, one hears people talking of artistic productions as "*derivative*". To judge from the confidence with which this or analogous derogatory remarks are pronounced, it is clear that at least some people believe

themselves capable of detecting similarities within the inevitable riot of differences confronting them. How can this be?

Or, more positively, how is it that, just by looking at a painting, is it so often possible to name the artist who painted it, despite the fact that none of the artworks he or she have made has a single detail in common?

The short answer to both questions is that to perceive different things as the same it is necessary to resort to "***generalisations***" that gloss over differences. Luckily this is just what the ***brain*** excels at. It has to, for without generalisations, neither the c***lassification*** nor the ***recognition*** of objects would be possible

So, how is it possible to produce works that are both the same and different. My belief, supported by years of observing students, is that anybody who puts their trust in the uniqueness of their own vision and their own feelings will find themselves on a personal path to creativity. If they do, they are likely to find unique personal pathways opening up before them. Each will lead to adventures into the unknown but of these will bear the stamp of the adventurer.

Cross-Correlation is an essential part of the strategy that enables the ***eye/brain*** to ***recognise*** objects as being the ***same,*** even though they are actually ***different***, whether because they are structured differently (as two chairs of different design) or because, despite being structured in exactly the same way, they are perceived under different ***viewing conditions*** (distance, angle, lighting, context, etc.). For more on this see "***recognition***" in this "*Glossary*" or in my book "*Drawing with Feeling*" (the second part of *"Chapter 4 : The sketch")*.

Decorative Colour can be defined as ***colour*** that is used to decorate objects and surfaces in pleasing and/or interesting ways. Unlike ***denotative colour***, it is not necessary for visual perception. However, besides the important matter of giving pleasure, it can play a role in attracting attention and in motivating visual research processes capable of facilitating learning and creativity.

Denotative Colour can be defined as ***colour*** that is used to ***represent*** a property of a surface, region or object that distinguishes it from other surfaces, regions or objects of otherwise similar characteristics (for example, a bride traditionally wears a white dress that both distinguished her from the wedding guests around her and symbolized virginity) or to denote membership of a group of elements (for example, a pattern made using repetitions of

a number of different shape-types is made easier to follow if each of the shape-types is ***denoted*** by its own colour and, more difficult if repeated shapes are given a different colours).

Delacroix (1798 – 1863): Eugène Delacroix's approach to painting was much admired by the progressive artists of the next generation, including Fantin-Latour , ***Alphonse Legros*** and several other students of Horace ***Lecoq Boisbaudran***, as evidenced by their appearance in his painting "*Homage à Delacroix*". His interest in training the capacity for drawing from memory is evidenced by his support for the "*Drawing without Teachers*" by his friend (by some characterised as his "mistress") ***Elizabeth Cavé,*** which was published about the same time as Horace ***Lecoq de Boisbaudran***'s book "*The Training of the Memory in Art and the Education of the Artist*", with which Delacroix was also acquainted. It can be speculated that the ability of memory training to increase information pickup speed may lie behind his claim that any artist worth his salt **"s***hould be able to draw a man thrown out of a sixth floor window before he hits the ground*."

Distortion: If the aim of those who are ***drawing from observation*** is ***accuracy*** then it is in their interests to avoid *distortion*. However, if the aim is ***personal expression***, then *distortion* is necessary. This must be the case since, if all drawings were accurate, they would be identical and, accordingly, they could not reflect or represent individual differences in responses either to the subject matter in question or to the characteristics of the ***emerging artwork***. In other words, logic supports the evidence of our eyes that none the great drawings of history can be truly ***accurate***.

Other evidence leading to the same conclusion comes from the capacity that we all have for making attributions on the basis of personal style. For example, we can all recognise differences between the drawings of Michelangelo, Dürer, Degas, Toulouse-Lautrec, Bonnard and Matisse reproduced in "*Drawing with Feeling*", *Chapter 1.* We can also see not only that they are all to a greater of lesser degree *distorted* but also that, in each of them, the distortions play an important role both in our ability to identify them as the work of the artist concerned and in our reason for enjoying them.

At this point, the question arises, "*If all the best drawings are distorted, why teach* ***accuracy***?" As reiterated on several occasions, in this series of books there is a critically important distinction made between teaching ***accuracy as an aim in itself*** and teaching it as a means of ***helping people to extend***

their awareness, not only with respect to the nature of the ***visual world*** but also of themselves as ***knowledge-acquiring*** and ***feeling*** beings. In favouring the latter approach I am much influenced by the example of Matisse and the many who, like him, believed it to be necessary to find out as much as possible about his subject-matter before embarking upon the definitive version of a painting. This is why ***preliminary studies,*** guided by the ***accuracy aspiration***, played such an important part in his working practice. To his way of thinking, these were a means of opening the way to greater freedom of ***expression*** and, consequently, to the possibility of more meaningful ***distortions***.

Drawing from Observation: Means using observational skills to gather information from a chosen subject with a view to making drawings of it. [6]

Drawing Skills combine both ***visual analytic skills*** (for guiding looking behaviour) and ***manual skills*** (for guiding line-production and other forms of ***mark-making)***. This book concentrates on the skills needed for achieving accuracy when using ***drawing from observation*** as a means of encouraging ***new ways of looking, doing*** and ***feeling***.

All skills are based on "***learnt habits***" (in this case habits of looking and doing). Problems arise because the information that enables the eye/brain to organise habits is necessarily stored in ***memory.*** This causes difficulties because memories can only be ***generalisations*** based on past perceptions.

Accordingly, they cannot direct attention to unique aspects of current appearances. How then can the artists go ahead with making drawings of these unattended to aspects? At first sight, this seems to be an insuperable problem. Surely if all actions depend on recourse to the ***knowledge-base,*** residing in memory stores that can never provide information about unique aspects of current appearances, accurate drawing from observation must be impossible?

Luckily, this is not quite true, for there is another possibility. This exists because the ***eye/brain*** has learnt ***habits/skills*** that enable it to organise is ways of drawing attention to the overlooked aspects of appearances. It is that of using ***comparisons*** to force the necessary ***interactions with the environment***.

Since the comparisons are ***knowledge-driven*** they can be directed at specific targets. Particularly useful for artists (and others interested in creative looking) are searches for aspects of appearances that are ***similar*** but ***different***.

6 **"***Drawing on Both sides of the Brain*" is concerned exclusively with ways of helping people who wish to make ***monochromatic line drawings***, done using pencil, charcoal or ink. The use of ***chiaroscuro*** in monochromatic drawings can be found in *"Painting with Light and Colour"*

This is why ***mistakes*** in drawings from observation or in colour matching can help us to see in new ways as, indeed, why any ***near-symmetries*** between the contours or colours of compared objects or object parts can do so.

What comparisons do is draw attention to ***differences***. When these are great or many in number, they may only signify some kind of global difference that has no contours or nuances of colour to analyse. But, when the differences are small, they not only direct attention to formerly overlooked details but also provide information about the direction of the difference (longer/shorter, more obtuse/acute, rounder/flatter, lighter/darker, bluer/greener, etc, etc.). It is this information that is revealed by ***comparative-looking*** and which is required for the organisation of more accurate ***line-output instructions***.

In summary, the skill of looking for ***near-symmetries,*** including those provided by ***mistakes*** in ***drawings from observation,*** enables artists to expand their awareness. It also can supply the ***feedback*** necessary for training ***eye/hand coordination skill***s.

Early Modernist Painters: See the *Section on* ***Modernism in Painting.***

Ébauche: The fourth stage of the ***academic method***, which comes after the "***idea***", the "***study***" and the "***cartoon***", and before the "***image transfer***" and the "***final painting***". It consisted of a roughing out of the colours to be used in the final painting. The fact that the ***cartoon*** came before the ***ébauche***, which was only to be roughed out, provides an insight into the level of importance accorded to ***whole-field colour relations*** by the artists working with the academic tradition. Thus, it adds to the evidence that:

- C***olour*** was thought of as being of marginal relevance to the creation of effects or ***space*** and ***light***. The teaching of the academies was that these could be achieved by means of ***shading***, ***highlights*** and ***whole-field lightness relations***, helped only by ***cognitive cues***, including ***linear and aerial perspective.*** According to the academic method only function for ***colour*** was that of adding blue to create a sense of distance in landscapes.
- The role of ***colour*** was conceived as being primarily ***denotative*** (blue for the Virgin Mary's dress, white to symbolise the bride's virginity, etc). Certainly, there is little evidence of colours being chosen with a view to creating either ***colour-contrast effects*** or ***colour harmonies*** of the kind that we find being explored by the ***colourists*** of the late

nineteenth and twentieth centuries.

Another importance of the *ébauche* was the part it played in the evolution of the interest of the early ***Modernist Painters*** in ***mark-making***. Manet's teacher Thomas Couture advised his students to put a little of the freedom of mark-making found in the ***ébauche*** when producing their final paintings. Whistler, Monet, Renoir and Sisley all studied under Charles Glyere, who taught them to increase the freedom of expression in their ***ébauches*** by pre-mixing the colours they were going to use. The more evident ***brush marks*** that resulted proved a double godsend to the **Impressionists** and other ***Modernist Painters***, whether in the context of seeking ways of expressing their feelings or that of asserting the actuality of the picture-surface.

Emerging Artwork: There are at least three important potential roles for the ***emerging artwork*** in the creative process:

1. In ***drawing from observation*** the depicted features, objects or scenes can be compared with the features, objects or scenes that they are intended to represent. If the objective is ***accuracy*** then there will inevitably be a large number of differences between the model and copy. Whether these are regarded as "***mistakes***" or as opportunities for making ***same/different judgements***, they will provide opportunities for extending awareness.
2. It is widespread practice for artists, when painting from observation, to cover the whole picture-surface. The implementation of this simple project forces them to look at the entirety of the scene they are depicting. To complete it, they will have to represent an enormous number of features of appearances that would escape their notice in every day vidual perception. One of the joys of painting is the experience that it brings with it of having one's awareness extended.
3. The fact that an artwork is necessarily made a bit at a time forces new experiences of abstract relations. In as far as every mark and every colour is compared with its predecessor or some other feature (colour, lightness, texture or contour), the relationship between them will be experienced as dynamic, and the accumulation of such experiences will contribute to the growth of each person's sensitivity to pictorial dynamics.

"Experienced Reality": When perceptual scientists try to pin down the experi-

ence of "***seeing***", they find themselves facing many puzzles relating to the structure and working principles of the eye/brain. For example:

- All the information that enables those parts of our visual perception that we see in detail and in-focus is channelled through the "***fovea***". As illustrated in *Figure 2*, this key constraint on the structuring of visual perception occupies an extremely small part of the "***retina***". If, when looking at a scene, we hold our thumb at arms length, then the part of the scene that is covered by our thumbnail corresponds approximately to the proportion of our visual field taken up by the fovea.
- As illustrated in *Figure 11*, the eyeball is always on the move. Even if the head is kept quite still (which it seldom is), it is either rotating slowly and smoothly (***gliding)*** or in sudden jumps (***saccading***). This being the case, we are left wondering how it can be that our experience is of an extensive and stable visual world. Whatever the answer, it must involve both a decoupling from the constantly changing input to the retina and the intervention of constructive processes.
- As shown in *Figure 1*, the primary function of visual processing is ***recognition***, a miracle of biological evolution that depends on two powerful classifying principles. The first of these is ***multimodal processing***, a procedure that exploits the mathematically demonstrated classifying power of ***cross-correlations*** between a number of ***crude*** and, accordingly, highly ambiguous ***generalisations*** that have been derived from a number of ***independently varying modalities*** of input ***crude generalisations*** that are detached from dimensional and other contextual information. The second is the use of real-world ***context*** to restrict candidates (for example, red in a wardrobe is unlikely to signify the presence of a tomato, but likely to indicate a dress that is known to be in it).

  Here it is worth noting that the fact that the processes that enable ***recognition*** depend on ***crude generalisations*** that are detached from any anchoring spatial relations information, means that, even if they were available to consciousness (which, as it happens, they are not), they could not provide help with drawing or painting from observation. Indeed, absolutely nothing at this stage of processing has any of the characteristics that we would used to describe what we consciously see.

- The function of the ***constancies*** of size, orientation, shape, lightness and colour is to regularise appearances in such a way that objects in the visual world that are actually different can be ***recognised*** (in other words, classified) as being the same. Accordingly the experience of ***seeing*** is to an important extent freed from the constraints of ***measured reality***.

Expression: See under "***self expression***".

Expressionist artists: A list of artists described by this phrase would include Van Gogh, Munch, Soutine, the German Expressionists (Schmidt-Rottluff, Kirchner, Münter, Nolde, etc.), Kandinsky and the ***American Abstract Expressionists*** (Pollock, Motherwell, Kline, etc.). All have been classified as belonging to a movement which first surfaced in the literature of art criticism in the early twentieth century, largely on the basis that all the above artists were believers in using ***distortion***, ***exaggeration*** and ***mark-making*** for expressive effect. (See also: "***self-expression"***).

Eye: *Figure 2* shows a cross section of the *eye,* with its ***lens system*** at the front and its ***retina*** at the back while *Figures 3 - 11* focus on the structure of the ***retina*** with its hundreds of millions of cells linked by an unimaginable number of neural connections. Those that know nothing about this doorway to visual perception will surely be astonished by a good proportion of the structural principles elaborated in the diagrams.

Eye/Brain: The ***eye*** on its own can do nothing besides start the process of organising the continuously changing sequences of patterns of light that strike the ***retina*** for use by the interpretive and action-guiding systems found in the remainder of the ***brain***. As indicated in *Figure 1*, it is the eye and the brain in combination that enables ***recognition***, ***analytic-looking, visually guided skills*** and ***consciousness*** of both our seemingly external and our seemingly internal visual worlds.

Eye/Brain Systems: For diagrams illustrating these see *Figures 1 - 15.* Taken together these make clear that ***Visual perception*** does not happen in the ***eye*** alone. It also involves the participation of many ***systems*** located in the ***neocortex*** and the ***old brain***. Without these we could not ***classify*** objects, ***recognise*** them, guide ***actions*** relating to them (including ***analytic-looking***) or have ***feelings*** about them.

Eye/hand Coordination: All visually-guided actions depend on information

contained in the patterns of light entering the eyes being converted into instructions that guide a complex of muscle systems in fingers, hand, arm, shoulder and head in appropriate ways. As indicated in *Figure 1*, the way this is done uses ***recognition*** as a means of accessing relevant instructions residing in the ***context and feeling based memory.*** It is these that guide ***eye/hand coordination,*** which requires a combination of ***analytic-looking*** and ***organisation of actions***. The fact that both are ***knowledge-driven*** ("***habit-driven***") ensures that, when being used for making drawings from observation, errors will be made whenever novel features are being depicted. In other words, every one of those that provide the uniqueness of appearances that artists seek to characterise. In the case of outline drawings made by young children and so-called "*naive adults*", these ***knowledge-driven*** drawings have been described as "***intellectually realistic***".

However no matter how expert the artists and illustrators, they also depend on learnt habits to guide ***eye/hand coordination*** (there is no alternative) and, consequently, ***knowledge-driven*** errors abound in their drawings and paintings as well. The difference is that, once away from the subject matter, the artists' productions look sufficiently accurate for them to be widely assumed to be ***realistic***".Those who are thus deceived, erroneously assume that they are drawing or painting "***what they see"***. Actually they are just as "***intellectually realistic***" as the productions of the young children.

Eye-Movements (1): The eyes are always on the move, whether as a consequence of movements of the body, the head or the eyeballs.

- Movement through the environment provides information about: the distance from surfaces, their relative positions, the speed at which they are being approached and many other matters.
- A combination of head movements and eyeball rotations underpin the ***comparative looking*** that produces the ***same/different judgements,*** which enable artists to detect differences between ***near-symmetries***, including those they identify as ***mistakes*** and, thereby, draw attention to formerly overlooked aspects of appearances.
- The eyeball rotations known as ***glides*** and ***saccades,*** (illustrated in *Figure 11)* are occurring in sequence, virtually all time.[7] Even when we are under the impression that our eyes are still, the relatively slow moving glides are providing a stream of ***same/different information***

7 Except when tracking a moving object

based on ***lateral inhibition***, while the much faster moving saccades enable an averaging of input, which is useful for ***neural computations***, such as those that mediate ***temporal colour constancy***, require knowledge of ***ambient illumination***.

Eye-Movements (2): The visual analysis of objects or any feature of our visual world requires that the eyes focus on them. For this purpose there must be ways of locating them. *Diagram 1* at the end of this glossary shows that the instructions for guiding actions are stored in the long term memory, which is characterises as being *context and feeling based"*. In other words, there are neural systems that "know" where to look and that this knowledge is somehow linked to the feeling centres. They also must know how to manipulate direction of gaze.

Eye-Movements (3): The direction of gaze can also be determined by outside events such as a flash of light or an unexpected sound. These do not depend on ***eye-brain systems*** in the ***neocortex***, but on the ***superior colliculus***, an old brain system that is involved in all eye-movements, both intended and environment driven.

Expansion rates: When we approach a surface it expands according to the rule that "*the nearer we are to it, the faster the rate of expansion*". Two corollaries of this are that:

The eye//brain can make use of this rule to keep us moving at a steady speed and, to control our speed of approach when we wish to come to a halt. It can do so because the receptors in the retina need time to maximise information pick up. When expansion rates are above a certain limit they can only produce a record blurring. Accordingly by monitoring changes in the extent of regions of the retina where blurring occurs, the eye/brain can monitor our speed.

Familiarity: Something is said to be *familiar* if patterns of light arriving into the eyes from its surface provide information that is ***recognised*** as being a known ***object-type*** or ***scene-type***. The function of ***recognition*** is to access appropriate responses as stored in ***long term memor***y (see diagram in ***Figure 1***). In the context of ***drawing from observation*** these responses take the form of ***actions,*** whether they be the ***eye-movements*** used for ***analytic-looking*** or the coordination of the ***muscle systems*** required for controlling the production of marks on the ***picture-surface***. One consequence of this

state of affairs is that ***analytic-looking*** and ***mark-making*** are guided by the contents of ***memory*** and only indirectly by the current input from the external world. For how this applies to ***drawing from observation***, see the *section on* "***Intellectual realism***".

Fast Drawing: There are a number of reasons why artists want to draw fast. These include:

- Time pressure when there is a risk (or certainty) that the object being drawn will move.
- The need to meet *deadlines* for delivering commissions.
- The belief that ***self-expression*** requires dynamic mark-making.
- The desire to ***loosen up*** at the beginning of a drawing session.

If any of these reasons apply and if the artists are seeking accuracy, they will find themselves engaged in a trade-off between ***speed*** and ***accuracy***. Suggestions of how to simultaneously increase both speed and accuracy can be found in ***feel-based drawing lesson*** proposed in "*Drawing with Feeling*", *Chapters 9, 10* and *11*.

Feedback: Learning cannot take place without ***feedback*** and feedback cannot take place without an objective. Any person or machine that engages in a task with an objective can either succeed of fail to achieve it.

To improve success rate it is necessary to have ***feedback*** relating to the extent of the failures. In drawing from observation the ***feedback*** is provided by:

- The ***analytic looking system*** using ***comparative-looking***.
- The ***feel-system*** sensing characteristics of the line just produced in relation to its predecessor.

The ***comparative-looking*** provides information about the extent of the ***differences*** between model and copy, widely referred to as the "***mistakes***", and the ***feel-system*** can relate these to the action instructions that guided line production. In both cases the ***feedback*** indicates the nature of adjustments necessary if performance is to be improved. These will always be perceived in terms of relativities such as larger/smaller, longer/shorter, acuter/obtuser, lighter,/darker, redder/yellower, etc..

However it is not just ***mistakes*** that provide ***feedback***. Any ***comparison*** provides information about similarities and differences and does so in terms of

relativities. This is why it is helpful to look for ***near-symmetries*** or ***similar colours*** in the scene being depicted when ***drawing or painting from observation***. To give two examples:

1. When the drawing the shoulder of a model, it helps to compare it with the other shoulder with respect to relative length, orientation, curvature and the characteristics of the way it fits into the neck. The same applies to the many other near symmetries provided, not only by the human body but also by the overwhelming majority of other objects.
2. When painting any scene it helps to look for groups of similar colours with respect to their ***hue***, ***saturation*** and ***lightness***. Eventually, this process can extend to comparisons between all the regions of similar colour on the picture surface.

Luckily for artists, near-symmetries and regions of similar colour abound in the visual world, and all of them can prove useful in their efforts to master the skill of using ***accuracy*** as a tool for learning to ***see in new ways***.

Feeling: See the next section on the **"*feel system*"** and, more comprehensively, in **"***Drawing with Feeling", Chapter 4.*

The Feel-System is a ***brain-system*** that has an essential role in ***learning***. The reason why this is so is because:

- Learning requires meaningful ***feedback.***
- Nothing can have meaning except in the context of some kind of ***value judgment***.
- In eye/brain systems the relevant value judgements are made by the ***feel-system*** (for example, right or wrong, better or worse, lighter or darker, longer or shorter)

An important implication of this is that there can be no errors in terms of ***accuracy*** unless an artist is aiming to achieve it, thereby providing criteria upon which to make judgements or take decisions relating to what to do next.. Without these, the word "***mistake***" would have no meaning and, for this reason, there would no motivation with respect to correcting them. For a much fuller explanation see *Drawing with Feeling, Chapter 4*.

Fibonacci Series: This is a series of numbers constructed according to the rule that the next number is the sum of the two preceding numbers. Thus it goes, 1, 2, 3, 5, 8, 13, 21, 34, 55, 89, 144, 233, 377, 610, 987 and so

on for ever. Mathematicians find great interest in the product of the division of any one of these numbers by its predecessor. For example, 3/2=1.5; 34/21=1.619047619; 233/144 = 1,618055555; 987/610=1.618032786. What they found was that the higher the pairs in the series, the nearer the outcome is to the ratio known as the ***golden ratio*** **(**which to 11 decimal places is 1.61803398875). According to mathematicians every increase in the number of decimal points brings it nearer to this goal: to get all the way requires and infinity of decimal points. In this way the Fibonacci can be seen to be series is related to the ***golden section***.

Figurative is a word used to describe paintings and drawings that depict objects and scenes. Its usage can vary according to context and custom. Thus, it is legitimately opposed to ***nonfigurative*** and ***nonobjective***.

The word "***figurative***" also is sometimes opposed to the word "***constructivist***", but doing so raises a problem. Although the artistic movement described as the "***Constructivists***" made constructions from nonfigurative elements, there have been many artists who have *constructed* as opposed to *depicted* elements of natural scenes. They have had to do so whenever they want to paint a painting containing objects that they cannot see. For example, those of Piero della Francesca, in which he uses ***linear perspective*** constructions to create images of far away scenes that he has to imagine. Also, all conscious simplifications, such as those need to depict the canopy of a tree, invariably involve a degree of construction. Finally, many people have opposed ***figurative*** and ***abstract***. As the *Section on* ***abstraction*** explains this can only be done by ignoring the original meaning of the word "***abstract***".

Focus is a verb that can be used in two contexts: Thus,

- "*Focus on*" can be translated as to "*direct attention to*".
- "*Bring an image into focus*" can be translated as "*making a blurred image clear*".

To focus attention on an object or feature, the gaze must be in the right direction. If two eyes are in use, both must be directed at the same point, a process known as ***accommodation***. In addition, the ***lens system*** consisting of the ***cornea*** and the inner ***lens*** (See *Figure 2*) must be bringing into focus the light coming from the object or feature onto the ***retina***. Since the shape of the two corneas of each individual remains constant, so does their focal length. Thus, (assuming that

varifocal lenses are not used) in order to bring an edge that is blurred into focus, it necessary either to (a) change the distance between the eye and the feature, or (b) to adjust the shape of the inner lens, which can be done by means of the ***ciliary muscles*** (see *Figure 2*). Since there is a reliable correlation between ***focus*** and ***viewing distance***, either of these manoeuvres will provide information about the latter. Although the distance from which the object or feature will be in focus varies, both with the shape of the cornea and, more importantly, with the distance between the front and the back of the eyeball, both these focal-distance determining factors remain constant for each individual. Accordingly, in theory at least, every ***eye/brain*** is provided with information available that could enable it to use focus to determine viewing distance. To what degree it does so is a matter for discussion. Certainly, focus-related distance estimating cues are not as important in everyday life as the cues relating to:

- ***Expansion rates***.
- ***In front/behind relations***, whether they are provided by, (a) ***cognitive cues,*** (b) ***stereopsis or (c) motion paralla***x.

Fovea: As illustrated in *Figure 2,* the fovea occupies an extremely small part of the "***retina***". Yet it is only here that we find the three types of wavelength sensitive ***cone receptors*** that enable conscious ***visual analysis*****,** including our everyday experience of ***colour*** in nature. Any rods found in the fovea would be bleached out in daylight conditions. Even if this wasn't the case, they would only be of use in low levels of illumination, approaching or going lower than the levels at which the cones would no longer be activated.

Frontal Eye Fields: The ***frontal eye fields*** are in the front a part of the ***neocortex***, next to the part of the motor cortex which is responsible for the control of eye/brain directed eye movements. They play a key role in ***drawing from observation*** since they mediate the ***learnt actions*** that enable the "***context and feeling based memory***" to direct looking activity. Their connections to:

- The ***hippocampus*** provides them with a convenient spatial map,
- The ***mid brain*** keys them into the ***feel system.***
- The ***superior colliculus*** allows them to control ***eye movements*** that are independent of current visual input.

Generalisations: The two main functions of the brain are (a) to ***make sense*** of and (b) to ***make use*** of. These require ***brain-systems*** that can: .

- ***Classify*** objects in terms of their appearance, their functional properties and their likely ***context*** in time and space.
- Store the outcomes in ***LTM***, thus providing an ever accumulating store of existing knowledge capable of providing ***action instructions***.
- Tap into this store on future occasions by means of ***recognition systems***, with a view to guiding ***actions,*** included those required for ***analytic-looking***, ***stroke-production*** and ***thought-processes***.

The problem that the processes of evolution had to confront was the fact that the ***appearance*** of any one object is never the same on two occasions. This is due to the infinite number of possible variations in:

- ***Viewing angle***, ***viewing distance***
- Other ***viewing conditions***, for example, different extents of ***occlusion*** by nearer objects and relative intensity of light sources.

What this means is, not only that the number of possible manifestations of any one object is only limited by the sensitivity range of the eye/brain systems but also that the recognition of the object in question in any one of these positions, would require that the particularities of that unique view of it would have to be to be stored in memory. Clearly to store every possible view would be far beyond even the brain's astonishing storage capacity.

Nor is this all, for the just explained difficulty of recognising an object of unchanging physical characteristics, would pale into insignificance by the challenge of being confronted by objects that, although of the same object-type, differ with respect to structure (for example, chairs of different design) or whose structure is not stable (for example, living creatures and plants can take on different shapes, due to movement, age, weather conditions etc..

With all these problems to overcome, common sense would suggest that ***recognition*** must be impossible. But we know that it is not.

So what kind of descriptions would have to be used? One evident and, indeed, necessary characteristic is that of not being invalidated by the variability of appearances. In effect, this means they must be *generalisations*". Precision must give way to vagueness".

Luckily for the human race, the processes of evolution hit upon a way of

making use of vagueness to provide a powerful solution to the problem of ***recognition***. It is based on the mathematically proven classifying power of ***cross-correlations*** between ***crude descriptions*** (***crude generalisations***) coming from ***independently varying modalities*** of information that are detached from dimensional and other contextual information. (For more on this see the section in this *Glossary* on "***multimodal processing***")

However, even these cross-correlations between multiple modalities of crude descriptions of objects as themselves have their limitations. The possibilities of multimodal processing as an aid to recognition can be exponentially expanded by adding ***contextual*** information derived, not only from ***visual systems*** but also from any or all any or all of to the list of crude descriptions mediated by ***non-visual sensory systems*** (For more on this see the section in this *Glossary* on "***context***").

A more task-related way in which ***generalisations*** are fundamental to ***drawing from observation*** becomes apparent if we take the example of artists making a copies of ***complex curves***. Once their ***eye/brains*** have characterised these in terms of ***visual input***, the information gathered must be translated into ***instructions*** that enable the organisation of cooperative interactions between the muscle-systems that guide body, arm, hand and finger movements. The mind boggles at the number of factors that has to be taken into consideration for each and every completed act.

Evidence from the drawing class supports the common sense conclusion that to attain the skills required for guiding actions it is necessary to progress from simpler to more complex configurations. In other words, it is necessary to progress from more inclusive and relatively crude ***generalisations*** to more targeted, relatively refined ones. In the case of acquiring the skills required for ***drawing from observation***, the ***eye/brain*** needs to progress from more general, cruder or more holistic descriptions to increasingly particular and precisely defining ones. More specifically it means changing focus progressively from whole objects, to parts of objects, to non figurative aspects, such as complex contours, curvatures and relativities of length, orientation and position.

This need to progress form the general to the particular can explain many common error-types. These include:

- Those that have been classified as "***intellectually realistic***".
- The smoothing out of ***complex curves***.

It is well known that both of these phenomenon occur routinely in the productions of children and adult beginners. Less widely acknowledged is that they are also omnipresent in the work of more experienced artists.

Glides: *Figure 11* illustrates the fact that, when engaged in analytic-looking, the eyeball is constantly rotating either relatively slowly or much faster. The slower movements are called "***glides***" and the more rapid one "***saccades***". The ***glides*** generate the stream of ***same/ different judgments*** that provide the foundation for the bulk of visually derived information. For information on ***Saccades*** go to the section on them.

Golden Ratio: There is a point on any straight line that divides it into two unequal parts such that the ratio between the longer part "*a*" and a shorter part "*b*", is the same as the ratio between the whole line to the longer part (Thus "*a"* is to "*b"* as "*a + b" is* to "*a")*. This has come to be known as the "***Golden Ratio***"

Mathematicians draw much significance to the fact that this ratio can be related ***Fibonacci series***.

Artists are impressed by the way the ***Golden Ratio*** can be found in the structure of many natural phenomena, such a snail shells, honeycombs, sunflowers and plant-branching patterns.

Golden Section

Since the golden ratio divides a line into two parts, there is a point at their junction which has been given the name of the "***golden section***". If the golden sections of both the horizontal and vertical dimensions of a rectangular picture surface are made to coincide, the result will be a point on it that is situated neither at the stable centre nor at the centrifugal edge of the surface, but in a dynamic equilibrium between the two. Many artists have attracted by this balance between tranquillity and dynamism and, accordingly, based their ***compositions*** on the ***golden section***.

Grouping: This subject has many implications of importance to artists, some of which have only become evident as a result of recent research. It has particular relevance to anyone who wishes to understand how axioms of Marian Bohusz-Szyszko relate to the creation both of ***illusory pictorial-space*** and of ***harmony*** or ***discord*** in paintings.

Psychologists of Visual Perception, particularly those known as the ***Gestalt***

Psychologists, have long recognised the process of the ***grouping*** of similar elements as a key step in the ability of the ***eye/brain to*** make sense of the patterns of light entering the eyes. Amongst their suggestions for ***grouping principles***, they attached particular importance to the principle of *"similarity"***,** particularly when referred to as "*symmetry"* or *"near-symmetry"***.** Thus, for example, in a pattern made of squares and triangles, the ***eye/brain*** will group the two different shape-types separately such that, at any one time, attention will be drawn either to the squares or to the triangles.

Likewise, in a pattern made of red elements and blue elements, the elements characterised by the different colours will be grouped and attended to separately.

This basic fact of visual perception has implications for both artists and scientists. For example, taking account of it to it can help ***artists*** who are interested in ***pictorial dynamics,*** since grouping principles provide opportunities for:

- Linking elements for ***compositional reasons.***
- Creating ***eye-teasing ambiguities***, such as those which would be caused by a pattern made with squares and triangles in which the colours are applied randomly to the different shapes (See *Figure ??*).

Also interesting to explore is the question as to:

- How different from one another can elements be, whether in terms of shape or colour, and yet still be perceived as belonging to the same group? There is no cut and dried answer to this question since the answer to it can vary enormously according to the context.

All the above factors can lead to a deeper understanding, for both artists and scientists, of the implications of the ***axioms of Marian Bohusz--Szyszko***, with their roots in the findings of the community of artists over the centuries, of which they are a synthesis.

As an approach to delving deeper into the significance of these axioms, imagine a painting in which they have been implemented . Thus:

- All the colours in it are mixtures containing some proportion of complementary colour
- No two colours are the same, with the exception of a number of small regions made using the same red paint. For example, imagine a still-

life painting, containing at least two, identically coloured red flowers, in which the remainder of colours follow the rules of Professor Bohusz-Szyszko. More specifically: all of them are mixtures containing a proportion, however small, of complementary colour and all of them are different from all the other colours.

In this situation, in accordance with the ***principle of similarity,*** the unmodified reds will be grouped on the basis of their colour (and, possibly, their shape and other characteristics), an outcome that leads the ***eye/brain systems*** to visually extract them from the ***context*** of the remainder of the pigment colours on the picture surface.

When they do so, they will find that the, while the absorption/reflection properties of the ***body-colour*** component of the identical reds will be the ***same***, the wavelength profile of the ***reflected-light*** component coming into the eyes from each red will be ***different*** to that of the others. Moreover, they will find that the differences will be exactly the same as if the same reds in the same positions were to be integrated into a uniformly painted ***flat picture-surface***. For this reason, they will be perceived as being situated on that surface.

But what about gestalt groupings of similar regions of colours, each of which contains a proportion of ***complementary colour***? Now, added to the ***wavelength-profile*** due to the ***absorption/refection properties*** of the main paint colour, are the wavelength profiles due to the ***absorption/refection properties*** of the added complementary colours. Assuming that the artist is following the rule of no repetition of colours, each of these will be different from all the others and each of which will scattering back different ***wavelengths profiles***, all containing light from across the visible spectrum? In these circumstances, the ***algorithm*** by which the ***eye/brain systems*** that separate out the ***reflected-light*** from the ***body-colour***, erroneously adds these ***body-colour*** generated wavelengths to the ***reflected-light profile.***

As a result, no matter how small this erroneous addition, it cannot be consistent with the ***reflected-light profile*** of the actual flat picture-surface. As a result, the modified, complex colours will not be perceived as being situated on it.

And, if they are not perceived as being on the picture surface, where

would they appear to be situated. The answer can only be that they would appear as being be liberated into an "***illusory pictorial space***".

What all this adds up to is that the eye/brains of the viewers will be presented by incompatible interpretations.

Since there is no way of resolving this inevitable ambiguity, the eye/brain is faced by is an irresolvable situation. As a result, the ***eye/brain's interpretive systems*** are drawn in two directions at the same time which it experiences as an intrinsically disturbing situation. There have been various words used to describe the colours in paintings that place the ***eye/brains*** of viewers in this predicament. These include "*discordant*", "*jarring*" and "*garish*". Whether artists want to avoid or encourage these qualities in their paintings is up to them.

But this is not the end of the matter, for, when faced with irresolvable situations, our eye/brains have their way of taking evasive action. One of these, that everyone is skilled at, is looking away. Otherwise, there are two easy ways of implementing choices. Thus the viewer might:

- Try to isolate on one or other of the repeated colours to the exclusion of the others. For example by masking off individual colours.
- Move close enough to the picture-surface to ensure that ***textural*** and other ***real-surface-indicating*** cues overwhelm ones that indicate ***illusory pictorial-space***.

In either case, this means narrowing the focus of attention to a smaller region of the picture-surface (in a figurative drawing this will usually mean to an object or object-part) and, thereby, excluding repetitions and blocking off information derived from whole-field colour relations (including the perceptions of ***illusory pictorial-space)***. This is why the five axioms of Marian Bohusz-Szyszko imply two refinements of their meaning, namely:

- Groups of repeated, unmixed colours in paintings impede perceptions of ***illusory pictorial-space***.
- Groups of differentiated, ***complementary-containing colours*** will always significantly enhance such perceptions.

All the above is of interest to scientists because it supports the hypothesis: that ***Eye/brain systems*** can separate out the ***reflected-light*** from the ***body-colour*** even within groups of repeated colours situated on separate parts of a picture-

surface, If so, any plausible model of eye/brain processing will have to be able to explain how this seeming miracle is achieved..

Highlights in paintings are small regions representing a gathering of reflected-light from the main light source(s) to make them the lightest part(s) of the scene. See the section on "***Shadows and Shading***" for the explanation as to why the ***eye/brain*** erroneously interprets them as ***body-colour*** and why, in consequence, they are perceived as significantly lighter relative to other colours, than they are in measured reality. Also explained is why, if artists want the highlights in their paintings to keep their place in illusory pictorial space, they should add complementary colours to the paint mixture they use when depicting them.

The **Hippocampus** is a region of the brain located in "***old brain***". It plays an important function in the laying down and making use of the ***memory stores*** used for mapping the relative locations of:

- Objects in the outside world
- Information stored in the brain, allowing it to perform the function of the ***lookup table*** familiar to computer programmers.

See *Figure 15* where its importance in drawing from observation and ***training the feel-system*** is indicated.

Idea : The "idea" was the first stage in the "***academic method"*** of making paintings. It preceded the "***sketches***", the "***studies***", the "***ébauche***", the "***image transfer***"and the "***final painting***", for which all the other stages were a preparation. In fact, whether consciously or not, it is the necessary foundation stone of all art, including:

- Representational paintings, in which the "***idea***" is to represent something
- "***Conceptual Art***" a movement that came after "***Modernism in Painting***" and gave priority to the initial concept. Since the word "***conceptual***" means the same as the phrase "***idea-based***", its use seems best explained as an attempt to give the impression of offering something new.

Illusory pictorial-space (1): An assumption throughout my books is that drawings and paintings are made on flat surfaces. However, one of the most appreciated ways of perceiving the images and marks that artists create on them is when they seem to take their place in illusory ***three dimensional space***.

The essential ambiguity of this situation has provided artists with a much exploited and appreciated pictorial dynamic.

Illusory pictorial-space (2): Before the advent of the ***Early Modernist Painters***, the aim of artists was to make sure that awareness of the picture-surface did not interfere with perception of ***illusory pictorial space***.

However, the ***Early Modernist Painters*** had different ideas. The reason why was based on two assertions, namely that:

- Illusions are forms of deception
- Deception is immoral

Believing both to be true, they concluded that perceptions of ***illusory pictorial-space*** should never obscure perceptions of the ***reality of the picture-surface*** in their paintings. It was a moral imperative that both should be a part of all picture-perception. As a corollary of taking on this self-imposed constraint was that they found themselves confronting the ambiguity of conflicting interpretations. Luckily, as it turned out, this challenge, far from being a hindrance to their creativity, was to open up new dimension of pictorial dynamics, ones that were to inspire painters to this day.

However, the virtues of ambiguity were not to go unchallenged. Morality had not had it final say. ***Mondrian*** and other artists argued that, if deceit must be avoided at all costs, all intimations of ***illusory pictorial space*** must be eliminated. Fortunately for the history of painting, this was easier said that done. In the event, it was not until the 1960s that a satisfactory solution to the problem emerged. In the meanwhile, failed attempts to solve it were responsible for many of the paintings which are now regarded as masterpieces. Meanwhile, the solution had to await ***Ellsworth Kelly***, and others, who came to the conclusion that the only way of completely removing spatial ambiguity, is to cover the whole surface of a painting with one uniform colour. Beyond the immediate fruits of this realisation, there was nowhere to go, except shaped canvases, sculpture, ***Post Modernism*** and a renaissance for the value of ***ambiguity***.

As a footnote, I believe it is worth emphasising how strongly artists felt about the issue of morality. It played a critical role in:

- The mid 19th century awakening of interest in the creative potential of the ***real surface/illusory pictorial space*** ambiguity

- Mondrian's break with his best friend because he included a depth-implying diagonal in a painting.
- The motivation of both Marian Bohusz-Szyszko and Michael Kidner, my two most important teachers, as I learnt from them in the 1960s.

Image-Transfer Methods: These include, squaring up, the carbon copy type, pouncing, the light box and the pantograph. For more on these consult "*Drawing with Both Sides of the Brain*", *Chapter 2*.

Impressionists is the name history has given to a number of artists who began meeting as a group in the 1860s. They included Manet, Monet, Renoir, Sisley and Pissarro. Their common aim was to paint nature as directly experienced through their eyes and feelings, uninfluenced by other preconceptions and rules, including a good proportion of those taught in the ***Academies***. Monet spoke for them all when he when he reported that, "*in order to succeed in conveying correctly what I feel, I totally forget the most elementary rules of painting, if they exist that is*."

The rejection of ***rules*** taught in the ***Academies*** was far from the only radical new direction taken by these artists, their contemporaries and friends. Important amongst these were Édouard Manet who, having a rather different agenda, refused to exhibit with the ***Impressionists***, and both Paul Cézanne and Berthe Morisot who, although exhibiting with them, set in train the exploration of a whole range of new issues. These were taken up by the next generation of artists, most notably including Henri Toulouse-Lautrec, Vincent Van Gogh, Émile Bernard, Paul Gauguin and Georges Seurat. The outcome was a root and branch questioning of every aspect of painting, which gave rise to an astonishing range of new initiatives and which, accordingly, can legitimately be described a ***paradigm shift***. It was this that signified the birth of "***Modernism in Painting".***

Inaccuracy is widespread in all drawings from observation due to the limits on human capacities for visual measurements and eye/hand coordination. There are many reasons why this state of affairs should be welcomed by artists. Here are two of them:

- The presence of inaccuracy offers artists an opportunity for having attention drawn to aspects of appearances that they would otherwise overlook. To take advantage of this, all that is necessary is to make ***comparisons*** between a model and any inaccuracy in any copy of it.

The ***same/difference judgements*** required will invariably draw attention to the differences between them that are commonly referred to as "***mistakes***". Since, by definition, these will not have been made on purpose, neither their location nor their form will be predictable. Accordingly, ***same/different judgements*** will invariably force artists to look at unpredictable aspects of appearance. It follows that they have contributed to the process of opening up new levels of awareness.

- ***Personal expression*** in figurative drawings and paintings is incompatible with strict accuracy. This must be the case, since it removes the possibility of individual differences.

Industrial Revolution: See under "***Revolutions***" and in Chapter 2 "***Modernism***".

Information Pickup: Drawing from observation depends on the ***eye/brain*** providing the instructions that guide mark-making. These have to be assembled and organised, a process that requires holding information about relativities of position, length, orientation and curvature in the temporary store known as the "***working memory"*** . The process of gathering this information can be described as "***information pickup***".

The ability to pickup information is a ***skill***, and, like all skills, it has to be learnt. As with all learning, the way it is accomplished can be more or less effective. One of the advantages of the drawing lesson described in *Chapters 9, 10 and 11* of "*Drawing with Both Sides of the Brain*" is that it provides a sound basis for concurrent improvements in both accuracy and speed. A major reason for this double benefit is the priority the method gives to training the ***feel-system***; and one of the great advantages of feel-based drawing is that it opens the way for ***personal expression***.

In Front/Behind Relations provide one of the most powerful cues to ***depth perception***. They work whenever objects that are "***in front***" obscure parts of objects, shapes and surfaces that are "***behind***".

Looking for overlap cues can greatly help artists when drawing or painting from observation. Unlike the depth cues that rely on ***body movement***, ***stereopsis*** or ***focus***, which can only indicate the flatness of picture surfaces, they can be used to create illusions of ***pictorial depth***.

In addition, the search for ***in front/behind relations*** has many other beneficial outcomes. This is because the act of looking for them:

- Involves ***comparative looking***.
- Necessitates perceiving them ***in context***.
- Counteracts the influence of on appearances on the ***constancies***.
- Can be used as an aid to ***chunking*** (see *"Drawing on both Sides of the Brain", Chapter 11, and in the* sections on "***In front/behind relations***" and "***chunking***" in this *Glossar*y).

Integrity of the Picture Surface: The need to guard what they described as the "*integrity of the picture surface*" was a main priority for the ***Early Modernist Painters***. The word "*integrity*" has two meanings, one of which is to do with morality and the other with physical reality. Some background history will help explain why they were both of such fundamental importance for these artists and many of their successors, at least up until the 1960s.

When the photograph made its appearance in the middle of the nineteenth century, many artists saw it as a threat. Particularly worrying for them was the ability of the camera, not only to produce illusions of reality that were as good at deceiving the eye as those produced by the best artists, but also to do so in a tiny fraction of the time it takes to make a painting. The question arose as to whether these developments meant that artists had were on the way to losing their role in society.

Faced with the threat of becoming irrelevant, the group of artists, who were to become known as the "***Impressionists***", embarked upon a major stock-taking of their predicament. They started by asking, "Is there anything that painting can do that photography cannot?

Although they found a number of answers that, in their view, gave painting the advantage, the issue of the superiority of the photograph as an eye-deceiver gave them pause.

Luckily for the history of art, they were astute enough to sidetrack this obstacle, which they did by moving the goal posts. This they did by declaring deception to be morally wrong. If this were to be the case, in as far as photographs deceive the eye, they are inherently immoral. The same applied to ***trompe l'oeil*** paintings. This is why progressive artists, instead of joining in the praise this art-form had received since the ancient Greeks, opted for treating it with scorn.

Since the it probably never occurred to the Impressionists to give up on rep-

resenting objects and scenes in their paintings, their nature of their attack on photography, left hanging the awkward question as to whether any kind of figuration is possible without implying an illusory, three-dimensional, eye-deceiving and, consequently, immoral space. Later artists, such as Mondrian, were to argue correctly that the logical answer must be "*no*". However, the ***Impressionists*** were able to rationalise. They argued that they could rescue viewers from clutches of deception by emphasising the objectness of the picture support and by avoiding too much realism. Their contention was that:

- Visible ***brush marks*** and evident the ***textures*** would encourage perceptions of the ***picture-surface*** as a physical presence in the real world.
- The lack of relation between the ***marks*** and the ***image*** would nudge matters in the same direction by freeing the former to be perceived as being on the ***picture-surface***.

It is for this reason that they and like-minded successors prioritised the following of practices:

- More evident brush marks
- More textured surfaces
- Less correspondence between marks made and the content of the illusory image
- More image-distortion,
- Less realistic colours.

Once an awareness of the ***actual picture-surface*** had became a priority, the issue of its relation with the ***illusory pictorial-space*** came to be of pivotal concern. Could the independence of both be preserved?

To the Early Modernist Painters this was a key question and it was finding answer it was what led to their belief in the importance of maintaining the "***integrity of the picture surface***".

Morality was no longer the issue. The word "*integrity*" was now being used in its second meaning relating to the notion of being "*whole and undivided*". To better understand what this meant for these artists, some context may help. Thus, when looking at the work of their academic predecessors, the early ***Modernist Painters*** reported seeing blacks as "*surfaceless holes*" and colours as jumping in front of objects situated in ***illusory pictorial-space***. Both the surfaceless-holes and the jumping colours were perceived

as breaking the ***integrity of the picture surface***.

However, the question as to what was remaining "*whole and undivided*" was not answered. Although it is self evident that surfaceless holes and jumping colours would disrupt unity, it was not clear what was being disrupted. Was it the "***integrity of the picture surface***"? Or, was it the "***integrity of the illusory pictorial space***"? The artists jumped to the conclusion it was to the former but, as shown by the recent research explained in my books, they were wrong.

Fortunately, from the practical point of view, it did not matter which explanation was given. Both of them related to the same outcome, namely the disruptive effect of regions of the same colour in different parts of a picture surface. In other words, both of them were consistent with the synthesis of Professor Bohusz-Szyszko.

Finally, as a consequence of interfering with perceptions of illusory pictorial space, the jumping colours and black holes interfere with the eye/brain processes involved in ***making sense*** of the depicted image. More on this in both "*Painting with Light and Colour*" and in "*What Scientists can Learn from Artists*", where there are detailed explanations as to why:

- The repeated blacks lack a sense of surface.
- The colours jump.
- Visual disruption occurs.
- It is more difficult to make sense of depicted image which contain repeated colours.

Also to be found are details of the steps that are required to avoid these outcomes.

Interactions with the Environment provide the only way of escaping what would otherwise be the stranglehold of the ***habits of looking*** that underpin existing looking skills). The interactions may be due to the changes in relativities consequent upon movements of body, head and/or eyes. These may never reach the level of consciousness, such as those required for keeping a car on track or those that separated ***surface-reflection*** from ***body-colour***. Alternatively, the may be consciously targeted, such as those that enable ***comparative looking***.

Interactions with the environment also occur as the result of attention being drawn to external events by an unpredictable sound, such as a knock on the

door or instructions relating to a new subject, given by teacher. Other useful movements are indicated in the drawing lesson described in *"Drawing with Both Sides of the Brain", Chapters 9, 10 and 11*.

Intellectual Realism: see "***The Theory of Intellectual realism***".

Italian Renaissance: The word "*renaissance*" means "*rebirth*" and it was used to describe the attempt by fifteenth century Italian philosophers, poets, architects, sculptors, painters and craftsmen to give renewed life to the way the ancient Greeks and Romans had approached their different domains of activity.

Important for painters was the new importance given to "*realism"*, which had been deliberately suppressed by their Christian-influenced predecessors, on the grounds that it might lead the faithful to mistake the characters in images for the people they represent. At all cost they must avoid making images of Jesus, the Virgin Mary or God.

The ***Italian Renaissance Painters*** dumped these worries about deceiving the eye as a means of freeing themselves to concentrate their attention on obtaining a new level of realism. It was for this purpose that they developed the ***aids and practices*** described in *"Drawing with Both Sides of the Brain", Chapter 2*.

As explained there, these can be divided into two categories, namely those that can help artists to:

- Produce accurate copies of objects and scenes using quasi or actually mechanical means.
- Construct realistic images from the imagination.

The former category included the use of the ***perspective frame*** and the ***camera obscura***, while the latter category included rule-guided image production, for example, by making use of knowledge of ***anatomy*** and ***perspective*** (both linear and aerial).

The findings of the artists relating to ***anatomy*** and ***perspective*** were later codified by the ***academies*** in the form of "***laws***" or the "***rules***".

The ***Young Impressionists*** questioned both categories of practice. They found that:

- The mechanical devices, though effective as a means of obtaining accurate representations, separated them too much from their feelings.

- The ***rules*** and ***laws*** were too often in contradiction with what they experienced when confronting the actualities of nature. This was because the rules regularly failed to take enough variables into consideration.

John Peter Russell: An Australian artist who studied in London at the Slade School of Fine Art, under ***Alphonse Legros***, who had been a student of ***Horace Lecoq Boisbaudran*** and an enthusiastic promoter of his memory-training methods. From the Slade, after a year back in his home country, Russell moved to Paris and joined the studio of ***Fernand Cormon***. As luck would have it, his fellow students included ***Vincent van Gogh, Henri Toulouse-Lautrec*** and ***Emile Bernard***, three of the most innovative pioneers of new approaches to painting that were to make special links with a fourth, namely ***Paul Gauguin*** (Bernard was the cofounder of the now celebrated Pont-Aven School with him, and Van Gogh persuaded him to come to Arles). It is plausible that Russel introduced him to them all to the ***memory-training method*** of ***Horace Lecoq Boisbaudran***. Certainly Gauguin was to become an enthusiast of memory drawing and one of the things we know he did, when he joined Van Gogh in Arles, was to encourage his new companion to paint from memory.

Later Russell was to introduce ***Henri Matisse*** to the work of ***Van Gogh*** and to enthuse him with his knowledge of ***Toulouse-Lautrec, Emile Bernard, Paul Gauguin*** and ***Paul Signac***. Matisse wrote "*Russell explained colour theory to me. He was my colour teacher*".

Knowledge can be equated with information stored in memory. As illustrated in *Figure 1* , this includes the knowledge-base that, having been activated by ***recognition***, guides both the ***analytic-looking*** and the ***mark-making*** behaviour of artists when ***drawing from observation***.

"Laws of Nature". One of the avowed functions of the ***academies*** when they were set up in the seventeenth and eighteenth centuries, was to codify regularities in appearances. Their starting point were the discoveries of the artists of the ***Italian Renaissance***, of which particular importance was given to the laws of "***linear and aerial perspective***" and to various regularities in the structures of ***human anatomy*** (with particular emphasis on muscle structures and measured proportions).

However, unlike the many artists who have misused their findings ever since, the Renaissance artists were not so silly as to depend on them for achieving

accuracy when ***drawing from observation***. They realised, as Monet, Renoir and others were to do later, that when faced with actual appearances, the laws never quite work. Indeed, that they can be extremely misleading. For example ***measured proportions*** take into account neither individual differences nor the effects on them of poses in which different body parts are seen in different degrees of recession. For more on this see "*Drawing with Knowledge"*, *Book 2* of "*Drawing with Both sides of the Brain"*.

Lateral Inhibition: In the ***retina*** and throughout the ***nervous system*** neighbouring cells and groups of cells on the same level of processing are interconnected by ***nerve fibres*** by means of which they influence the behaviour of one another. A main way they do this is to inhibit each other's activity. In effect this means that relatively more-active cells close down their relatively less-active neighbours and thereby cause them to stop firing. This simple process results in two bits of information being passed onto the next level, namely what is the *same* (represented by the level at which the less active cell is closed down) and what is *different* (represented by the level of energy remaining in the more active neuron), thus providing the basic building blocks of ***neural system computation***.

Learning to See in New Ways: Visual attention can only be directed in three ways, the first internally, but based on current input, the second externally and third hybrid.

1. The first involves use of the ***analytic-looking cycle*** (diagrammed in *Figure 1*). In this case, the focus of attention is organised internally on the basis of information residing in ***memory*** that has been accessed through the process of ***recognition***. Accordingly its operation can be described either as a "***learnt skill***" or as "***habit-driven***" .
2. The second occurs as a consequence of *attention-catching events* taking place in the environment. For example, a flash of light, a sudden noise or a sudden movement. The sensory systems that provide information about any of these unpredictable happenings bypass the ***visual cortex***. The ones stimulated by visual input are routed via the ***superior colliculus*** and emotion-mediating parts of the ***mid-brain*** to the frontal lobes where they interact with inputs coming by various routes from ***Visual Area One***.
3. The third makes use of movement of body, head or eyes to gener-

ate *attention catching events.* For artists ***drawing from observation***, the most widely used are the ***eye-movements*** that underpin targeted ***comparisons*** between similar but nevertheless different shapes. For example:

- When looking for ***near-symmetries*** either in nature (where pure symmetries do not exist) or in man/woman crafted objects (where symmetries are rare), attention is automatically drawn to the differences. Since these are ***unpredictable***, attention is inevitably attracted to aspects of appearances that would otherwise have been overlooked.
- When accuracy checks are made, the differences that are commonly described as "***mistakes***" are automatically brought to attention. As with near-symmetries, these are ***unpredictable*** and, once again, this means that attention is inevitably attracted to aspects of appearances that would otherwise have been overlooked.

The significance of the third, hybrid alternative is worth emphasising because it affords a way of using ***knowledge*** (***habit, skill***) to go beyond ***knowledge*** (***habit, skill***) into the unknown and, accordingly, provides artists with a strategy for extending awareness. What this means is that looking for ***near-symmetries*** and correcting ***mistakes*** provide a way of *learning to see in new ways*.

Uses of head and body movement as a means of drawing attention to aspects of appearances that would otherwise go unnoticed play an important role in the drawing lesson described in *Chapters 9,10 and 11 in "Drawing with Both Sides of the Brain", Volume Two, Part 1, "Drawing with Feeling"..*

Lecoq Boisbaudran : Horace Lecoq Boisbaudran (1802-1897) taught drawing in *"l'École spéciale de dessin et de mathématiques*", commonly referred to as the "*Petite École*" and now known as the "*École nationale supérieure des arts décoratifs*". He was the author of "*The Training of the Memory in Art and the Education of the Artist*", first published in 1847. His influence amongst artists of his time was profound and extensive. His students included (a) ***Auguste Rodin***, (one of whose rapid drawings appears in *Figure 1*, *Chapter 6* of "*Drawing on Both Sides of the Brain*"), (b) ***Jules Chéret***, the prolific maker of posters, which are notable for the seeming freedom of

the mark-making, (c) ***Henri Fantin-Latour***, who was a friend of ***Édouard Manet*** and the ***Impressionists***, (d) ***Eugene Carrière***, a close friend of ***Rodin***, who was much admired by many of his contemporaries, including the ***Impressionists*** and Picasso (whose "*blue period*" is said to have been influenced by him and who drew a great deal from memory), (e) Felix & Marie Bracquemond, who mixed with progressive artists including ***Delacroix*** and the early ***Impressionists*** (Marie Bracquemond treated ***Claude Monet*** and ***Edgar Degas*** as mentors), (f) Jean Baptiste Carpeaux who exchanged letters with Degas and (f) ***Alphonse Legros*** whose friends included: ***Édouard Manet*** and ***Edgar Degas***, who was a close friend of his, as were***Fantin-Latour*** and ***Camille Pissarro***. He was also responsible for introducing Lecoq Boisbaudran's method to ***James McNeil Whistler***, who famously demonstrated it efficacy by publicly painting from memory a landscape he had never seen before. Last but not least in this list, Legros, when in post as a Professor at the *Slade School of Fine Art* in *London*, taught ***John Peter Russell***, who later came to have close links with Vincent Van Gogh, Henri Toulouse-Lautrec, Emile Bernard, Claude Monet, Henri Matisse and others.

Lecoq Boisbaudran developed a method of training ***memory*** that had much in common with the "*Feeling Based Drawing Lesson*" described in *Chapters 9-11 of "Drawing with Feeling", Book 1 of "Drawing on both sides of the Brain".* His students were required to copy progressively complex shapes (starting with straight lines and rectangles) and then progressively complex objects. They were instructed to look at them carefully, before drawing them from memory. The outcomes of this process were then subjected to rigorous comparison with the model, with a view to identifying and correcting mistakes. Eventually, the students graduated to making careful analyses of masterworks in the Louvre, before returning to the studio and drawing them from memory. Examples shown at the back of Lecoq Boisbaudran's book show at least one of them doing amazingly well.

The extremely high level of rigour Lecoq Boisbaudran required from his students when drawing from observation was legendary. He argued that absolute *accuracy* was necessary if the full uniqueness of the models were to be revealed. He also claimed that accurate analysis provided the best way of extending the scope of ***long term memory*** and, accordingly, ***looking skills***. In both cases he was certainly right, for all overlooked features have to be filled in on the basis of previously existing and therefore ***inappropriate***

memories. In other words, the results would illustrate both ***intellectual realism*** and ***academicism***.

As explained in "*Drawing on Both Sides of the Brain*", *Chapter 8,* the steps required to achieve rigorous accuracy also prepare the way for more rapid ***information pickup***.

The most important difference between the memory training method promoted in this book and that of Lecoq Boisbaudran is that he advocated the technique called "***marking***", in which the tip drawing instrument is made to hover over the end point of the stretch of contour that is about to be drawn, as a means of establishing its precise position. This is the "*marked*" with a dot that could be used as a target for the line to be drawn. In contrast, the "*Feeling Based Drawing Lesson*" concentrates on training the feel for relativities.

Legros: Alphonse Legros (1837 – 1911) was a star pupil of ***Horace Lecoq Boisbaudran*** and an important conduit of his ideas about training the memory. He he is known to have explained method advocated by his teacher to his friends, including ***James McNeil Whistler***, ***Edgar Degas*** and, it is reasonable to suppose, ***Édouard Manet***. Later he was to become Professor at the *Slade School of Fine Art* in *London* where one of his pupils was ***John Peter Russell,*** who was later to join ***Vincent Van Gogh, Emile Bernard*** and ***Henri Toulouse-Lautrec*** in the studio of ***Cormon*** in Paris.

Length: In ***drawing from observation***, as in all tasks depending on ***visual perception***, absolute lengths of the kind that can be measured with a ruler, have no useful place. Artists must confine their attention to ***relative lengths*** because the ***eye/brain*** can only compute on the basis of these

Levels of description (1 - a short summary) *Levels of description*" is a phrase used by both scientists and artists, but far from always in the same ways. The scientists are interested in "descriptions" that are used by eye/brain neural systems working preconsciously. Artists are interested in consciously perceived properties of appearance, such as object-type and relativities of object characteristics. In my view, they should also be interested in preconscious processes, because it is these that cause most, if not all, of the problems that confront them when drawing or painting from observation. Below is a short introduction to the nature of these, first the scientists' domain of interest and second the artists'.

As just mentioned, the eye/brain activity that interests scientists takes place

preconsciously. It can be thought of as a number of subsystems:

- Those that use the approximately 150 million ***light-sensitive receptors*** to transform the mosaics of light entering the eyes into mosaics of neural signals
- Those that use ***lateral-inhibition*** and other intracellular activity, first to give structure to these mosaics and, then, to pass on the structured material separately, by different pathways (a) to ***visual area 1*** and (b) to the ***frontal eye fields***, via ***non-visual sensory input systems, spatial mapping systems*** and ***feel systems***
- Those that use the information in **Visual Area 1** to feed the ***recognition systems*** and, by their means, access ***long term memory*** (LTM) and, in particular the action-guiding instructions to be found in it
- Those that gather information from all available sources, including the ***frontal eye fields*** and ***feedback systems*** for use in the guidance of actions, including those that enable the ***mark-making*** and the ***analytic looking*** used by artists.
- Those that are provided by the ***constancies of visual perception***.

More on these subjects will be presented under the heading of "**Levels of description (2 - Scientific)**

In contrast to the scientists, the artists' uses of the phrase "***levels of description***" are familiar to us all, since they involve our conscious experience of "***seeing***". They can be divided into two categories, namely those that list *objects and object parts* and those that describe *characteristics of appearance*.

A list of objects and object parts tells you about the object-types, but nothing about particularities of their appearance: A tree is a tree, a tree trunk is a tree trunk, branches are branches, twigs are twigs and leaves are leaves. Even, a line is a line, a border is a border, an angle is an angle, marks are marks, curves are curves, textures are textures and named colours are named colours.

Descriptions of appearances confront the fact that no two objects ever present the eyes with the same visual information, not even when it is the same object seen on more than one occasion. Two of their defining features are that they:

- Always involve relativities
- Can be used in descriptions of all objects.

A list of them would include, ***relativities*** of length, of orientation, of position, of lightness, colour, texture, etc., whether they be local or whole-field.

Artists who want to achieve accuracy in drawings and paintings from observation will necessarily find themselves starting with *object-descriptions* before progressing to descriptions in terms of relativities. When they get on to the latter, they will find that their main problems are due to the preconscious processes. They will also find that an understanding of these provides the best ways of solving them.

More on these subjects will be presented under the heading of "**Levels of description (3 - For artists)**".

Levels of description (2 - Scientific)" *Levels of description*" is a phrase used by both scientists and artists, but far from always in the same ways. For this reason the different meanings will be given a separate headings. The focus of this **Glossary** entry is on its meaning for scientists interested in ***eye/brain*** functioning.

Before going any further, it is convenient to think in terms the five levels of description that cause difficulties for artists. :

- Those that are used by ***recognition systems*** to link input to the retina to information that already exists in the ***LTM***
- Those that are used by the ***LTM*** to inform ***action instructions***
- Those that enable other ***sensory systems***, ***spatial-mapping systems*** and ***feel systems*** to participate in the organisation of ***action***
- Those that relate to the phenomena known as the "***constancies"***
- Those that all of us, including artists, use to when describing everyday objects, their parts and their characteristics.

The first four of these operate ***preconsciously,*** while the fifth requires ***consciousness***. For this scientific section, the focus is on the ***preconscious*** processes because these are these are ones that are studied by students of ***eye/brain function*** and ***computer scientists***. They should also be of interest to artists. The reason why is that, since the way the ***eye/brain*** works is re-

sponsible for the majority of the problems that face them when drawing or painting from observation, knowledge of why this is the case can help them enormously.

The remainder of this section on the preconscious "*levels of description*" relates to the question as to how "***task-related actions***" are extracted from the complex ***mosaic of light-energy*** entering the eyes and striking an estimated 157 million ***light-sensitive receptors*** in the ***retina.*** What follows is my rough and ready way providing an answer. It is based on a fusion of my discoveries as an artist and teacher of painting and drawing and what I have learnt, with generous help from colleagues at the University of Stirling, concerning ***visual perception***, ***eye/brain structures*** and algorithmic analogies to key aspects of complex ***neural-system processes***.

My purpose is to readers to get a feeling for:

- Why the information received by the ***light-sensitive receptors*** has to go through so many modifications and reconstructions before it is made available to ***conscious visual perception***
- The working principles of the processes involved
- The problems people experience when engaged in visually mediated tasks that can be explained by reference to these, including those faced by artists, when drawing and painting from observation,

It will also help to realise that visual perception works from the bottom up and involves:

- The creation of ***ambiguous generalisations*** as a necessary prerequisite of ***recognition***.
- The function of ***recognition*** as a means of accessing ***action-instructions*** that already exist in ***LTM***. Significantly, these are based on a past history of tasks relating to the recognised objects and never on measurements taken from the objects themselves
- How, nevertheless, the ***action-instructions*** enable practical, measurable and conscious interaction with the visible world.

Some messages for people, including artists, engaged in visually mediated tasks that emerge from the above are that:

- We "*know*"what we are looking at before becoming aware of it

- Since different artists have different degrees of experience of looking at and making drawings of objects, the information in the ***LTM*** of each of them will produce different degrees of disparity between model and copy. Similarly, the same artist may be more or less familiar with making drawings of different objects. This explains why I have had students who were highly skilled at making botanical drawings, yet seemed like total beginners when faced with a life-class model. Or why it is not unusual to find that people who are good a drawing heads can seem all at sea with the rest of the body or with landscapes.[8]

Enabling "recognition"

As just indicated, ***conscious visual perception*** does not occur until after a sequence of ***preconscious*** preparatory steps. Before discussing these in greater detail, it may help to provide a list of them:

1. The activation of a mosaic of over 150 million ***light-sensitive receptors*** by the mosaic of light energies entering the eyes
2. The analogous activation of the mosaic of ***interconnected neurons*** (cells) in the retina by the ***light-sensitive receptors***
3. The interactions between the ***interconnected neurons*** and how they provide the neural descriptions in ***visual area 1***, including the ones by means of which the eye-brain systems achieve ***recognition***
4. The principles upon which the ***recognition systems*** are able to access the store of ***action instructions*** residing in LTM
5. The manner in which the ***action-instructions*** are used to obtain the information necessary to enable them to guide ***analytic-looking*** and ***mark-making***
6. How ***analytic-looking*** provides the ***feedback*** that enables the elaboration and refinement of those descriptions.

With this list of steps in mind, we are ready to start a detailed discussion of the subject "***levels of description***". For this purpose, let us consider a ***retina*** made of a mosaic of ***light-sensitive neurons***, which are differentially activated by a continuum of varying levels of intensities in the light that strikes them.

8 Chapters 9 - 13, which deal with the drawing lesson in "*Drawing with Feeling*", go more deeply into this.

In the human retina there are at least four ***neuron types***, each with different response characteristics, and with each making possible an increase in the range of ***modalities of description*** that can be generated. It is cross-correlations between these that enable the ***recognition systems*** to access the previously learnt ***action-instructions*** residing in ***LTM***, which, in their turn, guide what happens next, namely the activation of the neural processes that enable ***analytic-looking*** (*Figure 1*).

As just indicated, increases in the number of response characteristics within the array of ***light-sensitive receptors***, increases the potential scope of ***visual perception***. However, since for the moment, the goal is to outline the general principles of ***description-building***, it is perhaps wise to limit ourselves to receptors with identical response characteristics.

Also as just indicated, it has been estimated that there are approximately 150 million light-sensitive receptors in human retinas and that, after the neural network within each retina has performed its simplifying functions, these feed the one million nerve fibres that travel up the optic nerve to ***Visual Area One*** (*Figure 2 and 13*) of the ***Neo Cortex*** (*Figure 12 and 13*).

The explanations which follow would work perfectly well for enormous arrays of this kind, but they will work equally well for much very smaller ones. For example, Paul Bach-y-Rita used the output from a video camera to activate an 18 X 18 matrix of solenoid vibrators, strapped to the backs of his blind experimental subjects, to produce a radical improvement in their visually-meditated capacities. (As did I, when I borrowed Paul Bach-y-Rita idea for my "*computer-learning-to-see"* project). For the following argument, any number of receptor cells between these two extremes will do.

The first requirement for the neural computations is the conversion of the mosaic of ever changing light energies into analogous mosaics of ever changing light-sensitive receptor outputs, with the rule that the greater the intensity of the incident light that hits any one of the receptor neurons within the mosaic, the stronger the neural signals.

The second step is to pass on the information provided by the mosaic of receptor neurons to a layer corresponding mosaic of neural-signal sensitive neurons. Neural computations are possible because each of these is able to pass neural signals to its neighbours. In the human retina, the first level of interaction between neighbouring neurons takes the form of "***lateral inhibi-***

tion". What follows focuses on how this workhorse of neural processing can be used to build complex, multi-level descriptions, derived from mosaics of light energies entering the retina.

So what is ***lateral-inhibition***? It occurs when neighbouring, or other interconnected neurons, have different levels of input. If this is the case, the neurons with higher level inputs close down adjacent neurons or neuron clusters with lower level inputs. In effect, this procedure provides two bits of information:

- The signal strength of the common threshold. Important because it provides information of what is the '***same***' in the compared inputs.
- A measure off the '***difference***' in signal strength between the inputs.

The result can be modelled by an algorithm computing a progression of ***comparisons*** (same/difference judgments) across the extent of retinal inputs. At the first iteration, what is characterised as the "***same***" corresponds to the output from the light-sensitive receptors that are receiving the lowest level of light stimulation. In the case in which no light striking a portion of the retinal receptors, this would obviously be zero. More significantly, it would be zero or a common starting point, no matter how strong the lowest input strength.

Although, mathematically speaking, this first level of processing can be said to provide zero information, its importance to conscious visual perception cannot be exaggerated. Amongst other things:

- The zero is crucial for mathematical models of processes using lateral-inhibition, for it provides a stable base-plate for all the calculations involved.
- The zero means that all visual-system descriptions have the same the base-plate. While this commonality means that absolutely no object-specific information is provided, it does inform the system of the vitally important information that "*something is there*". Accordingly, it can be described as the *"**first level of description**"*. As we shall see below, in the context of its role in enabling ***recognition***, it is worth noticing the extreme vagueness of it.
- From the experiential point of view, the zero provides the first and decisive step in the transformation of a "*reality*" that can be measured by light-meters, as degrees of intensity, to one that can only be measured in

terms of relativities of lightness. Throughout my books, I have referred to these as "***measured reality***" and "***experienced reality***".

At the second level of processing, the ***lateral inhibition*** between inputs to the entirety of the first level of retinal neurons will provide a map of all the first level of "*difference*" information. This will consist of the totality of what is left after subtracting the contribution of the first level of weaker inputs.

To help me to conceptualise this process, I imagine the first layer as being like a loosely woven cloth without any holes in it and, the second layer as the same cloth, but now with a scattering of holes in it. Significantly, these holes correspond both to what is not yet described and to the zeros for the next iteration of the neural algorithm.

Like the zeros in the first layer, these provide crucial information. Thus, while the function of the first iteration of processing was only to indicate that "*something is there*", the second layer, embarks upon the process of seeking differences between objects. If we return to the cloth analogy, differences between objects are signified as different patterns of holes. Accordingly it provides a ***second level of description***.

Once again, although the differences are indeed differences and, despite the fact that they now become the base for the next step of processing, they themselves provide *no useful information*. As before, this does not mean they are not important. Far from it. Their importance to description-building is fundamental, for the information they access resides, not in the gaps created by them, but in what remains. In terms of our cloth analogy, it is the characteristics of the array of holes in the cloth that provide the second level of description building. It is these that provide the neural-system with its first differentiated arrangement of what can be described as the "*building blocks of object-descriptions"*.

Whenever the neural algorithm, based on ***lateral inhibition***, is faced with unresolved ***difference information***, it will embark on another iteration. When it does, it will find another level of '***sames'*** and '***differences'***, with the '***sames'*** creating a new level of zeros. In terms of the cloth analogy, they provide a third mosaic of "*holes in the cloth*" and, thereby, refine the degree of object-description specificity. In this context, it must be emphasised that, as indicated above, the only function of the '***difference***' information is to indicate the need for more processing. When it responds to this need, it creates an ad-

ditional mosaic of zeros and thereby provides a further ***level of description***.

And so, on it goes, until a level is reached where the neural algorithm cannot find any more '***sames***'. All that is left is one unmatched level of "***difference***". So what happens next? As it always seems to do, evolution has supplied an answer to this question: Look for "*sames*" within another, but linked processing system. Although fruitless in terms of finding another level of "***sames***" within the first processing system , it can provide a link to another processing system. In the case of the human visual system one of the things it finds is the ***gaze-control system***. This routes the information via the ***superior colliculus***, then via the ***hippocampus*** and the ***feeling centres*** to the ***frontal eye fields***. The purpose of this manoeuvre is to direct the gaze and, consequently, the attention on the location of the last, unrequited difference. Since any shift in gaze direction results in a shift in the region of the retinal input being analysed, a new cycle of processing is launched.

(Incidentally, I cannot help speculating as to whether this link between ***retina*** and ***superior colliculus*** is what determines the seemingly random pattern of eye-movements illustrated in *Figure 11*. The idea seem plausible since the nature of the proposed linkup between the two separate processing systems, leaves no way of predicting the direction, orientation or extent of any shift in direction of gaze that will occur).

If our eye/brains accumulate information using ***same/difference judgements***, as just described, we can hypothesise some generalisations concerning the structure of the mosaic '*holes*' at each levels of description. Returning to the analogy of the moth eaten cloth, the higher the level, the more moth-eaten it would be. Clearly, even if the resulting confusion of holes were to be made available at a conscious level, it would not be the sort of thing that could help an artists when drawing or painting from observation.

Nor does it need to be, since the function of the accumulated levels of description has no direct relation to ***conscious visual perception***. The first priority is for the layered mosaics of "***sames***" to provide the information in a form that can be used by the ***recognition-systems*** to access relevant ***action-instructions*** in ***LTM*** and, thereby, trigger ***analytic-looking*** activity. It is not until all these steps have been taken that ***consciousness*** has a role. Only then can artists (or anyone else) embark upon what we experience as the conscious visual analysis of objects and scenes.

Thus, in summary, the immediate usefulness of the ***early levels of description*** has nothing to do with creating visible images. Their function is exclusively to enable ***recognition*** and, as frequently reiterated, this can only take place by means of "***cross-correlations***" between descriptions that are sufficiently "*crude*" or "*vague*" as to be able to classify multiple manifestations of the recognised object as being as "*the same*". Significantly, the kind of descriptions provided by the processing system described above are exactly what is needed. It would be difficult to imagine anything "*cruder"* or "v*aguer"*.

At this point, it is time to return to the admission, at the beginning of this entry on ***levels of description***, that the model of neural-processing described is extremely oversimplified. The most obvious simplification is that of the description of the retina. To start with, the model as described only posits:

- One receptor-type (instead of four or more).
- One intensity/wavelength sensitivity profile (likewise, instead of four, or more).

Also there is much more going on in the actual retina in terms of neuron connectivity (see, *Figures 3 and 10*).

In contrast to the complexity of its neuron-layers and interconnections, the retina it is severely limited in terms of levels of processing. There are certainly not enough of these to assemble all the building blocks necessary for underpinning the classification power of human eyes.

To deal with this shortage of levels of processing and to diversify the potential for a range of modalities of description, the information extracted by the retina is channelled up the optic nerve and separated out onto a variety of pathways, leading to a number of processing regions, each with their own levels of processing. In this way, it is possible to provide crude descriptions in a number of different modalities. It is only when these '*crude*', '*vague*', non-referential and, in themselves,*"essentially meaningless*' descriptions are ***cross-correlated*** that they become useful. It is not until then that they can perform their function of linking up with and triggering purpose-specific ***action-instructions*** residing in ***LTM***. Amongst these are the instructions that enable the organisation of the ***analytic-looking*** strategies that mediate, not only perceptions of objects and scenes, but also, if needed, provide feedback involving further iterations of the ***analytic-looking cycle***.

To arrive at this satisfactory outcome, the processes of evolution had to

solve various problems. These arise from the fact that the task of ***recognition systems*** is limited to establishing the ***category*** of the object that is being recognised and that their way of doing so depends on the use of cross-correlation between numbers of crude descriptions, a procedure that provides absolutely no information about relativities. As accuracy in perceptually-mediated tasks, including painting and drawing from observation, is based on establishing relativities of various kinds, a new starting point is required. One source of this is the information in ***LTM*** that has been accessed by the ***recognition-systems***.

A more homely way of saying the same thing is that we "*know*" what we are looking at before we are able either to ***make use*** of it or to be ***consciously aware*** of it. The only alternative is ***knowledge-guided-looking*** or, to put the same conclusion another way, "*we are stuck with* ***intellectual realism****"*.

Enabling action: using information in LTM

So what happens next? Clearly, since the cross-correlations between vague descriptions of the type that enable recognition can be of no direct use, alternative resources are required. But what are these? The answer is that they can be of two types:

- Ones that previously existed in LTM, that have been triggered by the act of ***recognition***.
- Ones provided by ***sensory systems*** that operate both separately and in parallel with the ***recognition-systems***.

As already mentioned, one example of a route, by which visually mediated information is being obtained systematically, but which avoids ***visual area one*** and the ***recognition-systems***, is the one that goes from the ***retina***, by way of the ***superior colliculus***, the ***hippocampus***, the ***feel-systems***, the ***frontal eye fields*** and, from there, to the action-implementing ***motor cortex***.

The triple significance of the role of the ***hippocampus*** lies in:

- Its capacity for mapping information about ***location*** and ***relativities*** coming directly from the outside world.
- Its capacity to monitor feedback relating to the positions of body parts and their current movements.
- The fact that it takes inputs from multiple ***sensory-systems***, including

the ones that deal with ***sound*** and ***touch***.

The information-stream coming by the collicular route is used for the ***organisation of actions*** that require spatial judgements, including those required for determining the ***directing the gaze*** and those used in ***drawing and painting from observation***.

As mentioned earlier, the function of information stream arriving at ***LTM***, via the ***recognition systems,*** is restricted to tapping into knowledge of ***object-type*** already existing in it. This may be more or less abundant. For example, the information in LTM may be limited to knowledge that a chair as a chair, but provide no information its object-specific characteristics, such as whether it a kitchen chair or a garden chair. It may be more specific, providing the knowledge that it is a particular kitchen chair . It may even bring to mind many details of appearance including its colour. What the LTM cannot contain is information about current relativities of shape, size, length, orientation, curvature or lightness, since these differ with every change in the viewpoint or distance of the viewer,. For the same reason, it cannot contain information about relativities of lightness, texture or colour.

A strong conclusion that can be drawn from the above is that the information in LTM can never, on its own, enable artists, who are seeking accuracy in drawings or paintings from observation, to achieve their objectives. It might enable skilled artists to draw a particular, familiar chair with many of its actual characteristics. It may even provide extra plausibility by making use of relationships governed by laws of nature, such as those of linear perspective and the absence of repetition of colours. However, even the most accomplished artist would be at a complete loss when it came to reproducing the multiplicity of ever changing relativities. This is why Edgar Degas asserted that "*It is necessary to assume I know nothing. It is the only way to make progress*".

Enabling action: Finding the relativities.

Although the object-specific knowledge in LTM identified by the ***recognition systems*** cannot include information about current ***relativities***, it can trigger the processes that can find them. Also available for the same purpose is the ongoing information about spatial relationships, accessed by means of the ***collicular*** route.

Exactly what this would amount to in terms of helping artists with accuracy in painting or drawing from observation will depend on a combination of context and past experience.

To think about what this might mean for the artists themselves, let us take the example of a 7 year old girl making copies of one of her toy, cubic building blocks.[9,10,11] As she will have much experience of playing with them, one glance is enough to ***recognise*** what it is and, thereby, to access in LTM the existing knowledge of her building blocks and of how she has reacted to them in the past. At this point there is a choice, namely, whether to:

- Make a drawing based on what is available in her ***LTM***
- Access action instructions, also in LTM, that can help her find out more about the actual appearance of the block in question.

If the first choice is made, unless the child has much experience of drawing cubes, then it is likely that much of her knowledge will come from the experience of playing with her own set of blocks. As already explained, ***recognition*** is achieved by the ***recognition-systems*** using ***cross-correlations*** between a number of ***crude descriptions*** deriving from ***different modalities*** of input. In the case of a child who is familiar with playing with her own building blocks, these would certainly include ***touch information*** provided by ***touch-system*** processes. The evidence from studies of children's drawings indicates that the touch information stored in LTM may be restricted to the knowledge that the building block is a graspable object with a top, a bottom, a back and two sides, all of which are rectangular.

A drawing based on this knowledge in isolation could be expected to consist a number of rectangles, each adjacent to a neighbour and this is often what we see in the drawings of 7 year old children. *Figure 30a* illustrates the finding that, although only three sides of a cube are visible at the same time, children's drawings of them often include four, five or, even, six rectangles, representing four sides (one of which is not visible), a bottom and a back

9 Phillips, W. A., Hobbs, S. B., & Pratt, F. R. (1978). '*Intellectual realism in children's drawings of cubes*'. Cognition, 6(1), 15–33

10 Pratt, F.R., 1983, "Intellectual Realism in children's' and adults' copies of cubes and straight lines." In, "Acquisition of Symbolic Skills." Eds.: Rogers, D.R. and Sloboda, J.A., Plenum Press.

11 Pratt, Francis, 1984, "A theoretical framework for thinking about depiction." In, "Cognitive Processes in the Perception of Art". Eds.: Crozier, W.R. and Chapman, A.J., North-Holland Press.

(neither of which are visible). On one occasion, I was asked, "*shall I draw the back*?"

But collections of rectangles cannot solve the connectivity problem, posed by the children's realisation that their rectangles should join along their sides. Examples 'c', 'd' and 'e' in *Figure 30b* show typical solutions arrived at by the seven year olds. Clearly none of these was based on visually derived information alone, if at all.

Some may ask whether research into children's drawing behaviour can be generalised to include adult drawing behaviour? From the widespread acceptance of the "***theory of intellectual realism***" it is clear that all who went along with it (and many more) would assert that it cannot. If so, they should read both the evidence and the theory derived from it, as expounded in my books. Together these make it abundantly clear that all the findings relating to children's drawings apply to every single adult drawing ever produced, no matter the skill level of the artist. The only difference is that adult experience is more complex and, as a result their generalisations are more sophisticated, even with respect to the generalisation that gave rise to the "laws of nature". For example those relating to linear perspective.

Of interest in this context is the finding that one of the differences between the children and the adults who took part in my experiments was that the adults used more looking back and forth from model to copy. Indeed, my findings indicate that, the more skilful the person that is making the copy, the more the separate looks at the model they used.[12] Children were most likely to look back and forth from model only one, two or three times, while it was common for skilled adults to use skilled adults use twenty or more. The two reasons for looking more than once are:

- To confirm the object-type classification. For example, consider the example, much used in my books. When I asked "*what object first comes first to your mind when I say the words the 'round', 'red' and 'slightly squishy'*", in a large majority of cases, the object that first came to mind was a tomato. Before going any further it might be wise to have a second look to check whether the object in question is indeed, a '*tomato*' and not a '*round red rubber ball*' or something else.

12 Although the memory training method taught by Horace Lecoq Boisbaudran enabled faster pickup of accurate information, using less glances,. The same is true of my somewhat analogous feeling based method, as detailed in my book, "*Drawing with Feeling*".

Another example would be that, upon recognising input as a tree, it might be important to decide whether it is an apple tree or a plum tree. Clearly checking back will always require extra looks.

- To locate details of appearances relevant to the task in hand. For example, when drinking from the cup, it would be desirable to focus on the handle and establish in what direction it is and how far away. In contrast, when the task is making a line drawing of the cup, the focus should be on making judgements of relative lengths, orientations and curvatures.

Once the object-type has been confirmed and the task-related information acquired via the ***collicular route***, the next stage is the ***organisation of action***. In the case of making ***drawings from observation*** this means organising the pick-up of task-related and, if possible, task-specific ***visual information*** required for guiding the body, arm, hand and finger actions needed for the implementation of the artist's objectives. More specifically, it means finding ways of guiding the actions needed to produce groups of lines of specific relative lengths, relative orientations, relative shapes, relative curvatures, relative positions, etc.. All these tasks require the activation of the ***analytic-looking*** systems.

In light of the fact that the purpose of ***recognition*** is to access ***action-instructions*** residing in ***LTM***, we also have to consider fundamental facts relating to the nature of information available in ***LTM*** in relation to the use to which is to be put. Of particular relevance in this context are the facts that everything stored:

- Derives entirely from past experience,
- Has to be useful in multiple contingencies.

For both these reasons it cannot provide the precise object-specific information required either for accurate visual analysis or for accurate mark-making.

Given this state of affairs, the only option is to go back to an information source that is capable of providing the necessary precision. When we ask where this might be, we find two obvious alternatives:

- Going all the way back to ***retinal input***.
- Finding it stored within the ***visual-system***.

Clearly, the first option of having to go all the way back to the input to the retina would entail both time and instability disadvantages. In contrast, the second option offers the possibility of using information that has been accessed concurrently with ongoing ***recognition*** processes. For this to be possible there has to be an alternative to the ***recognition*** route. I have already mentioned the possibility of information being channelled via the ***superior colliculus*** to ***motor cortex*** via the ***hippocampus***, the ***feeling centres*** and the ***frontal eye fields***. There is also another route. It is one that depends on the input to ***visual area 1*** being shared by more than one processing system.

Having decided on information sources linked to current retinal input, the next question is how to make use of it. The answer lies in "***the constancies***" and the processes that enable them. This may seem surprising in view of the fact that the defining character of these is that they make different things the same. Artist's, in particular, would be puzzled to find that accuracy in both looking and doing is achieved through the mediation of by far the most the most frequent cause of inaccuracy in drawing and painting from observation. However, the situation is very different when considered from the perspective of the functioning of the eye/brain systems. Let me explain why this is so.

At first sight, making accurate measurements that can be made use of in the same timescale as is needed to produce the conscious awareness of objects, seems well nigh impossible and, indeed, truly absolute accuracy is never achieved. This is because all visual measurements are generalisations based on relativity judgments. Since all ***sensory systems*** base their information finding on ***relativities***, none of them can calculate actual measurements. Theoretically, if they want to achieve accuracy their only option would seem to ***home in*** on it. The fact that this is at east on of the things that happen in drawing practice has been demonstrated experimentally by ***Alan Wing***.[13] Using a computer program he had written himself, monitored attempts made by his experimental subjects to join two dots with a straight line. His results show that they did not achieve their aim in one arm/hand movement. Rather, they use something along the lines of Zeno's paradox, starting with an extensive gesture that produces a line

13 Wing, A.M., Haggard, P. & Flanagan, J.R. (Eds.) (1996). Hand and Brain: The neurophysiology and psychology of hand movements. San Diego: Academic Press.

that falls well short of the target dot, and continuing with a series of rough corrections, each taking up a good proportion of the remaining space. It is like Zeno's paradox because, however small the distance left any proportion of it will leave some distance to go, even, if only a miniscule one. The potential accuracy of an incremental system like this is well demonstrated in the efficacy of the mathematical method known as "*calculus*".

While Alan Wing's science may have provided irrefutable evidence of the widespread use of the homing in strategy, most art teachers will not have been be surprised by it. One reason is that they will have seen many beginner students making hesitantly, small, incremental marks in what they suppose to be the right direction and continue tentatively, checking their progress as they go, until they judge the line to have reached its correct length. Another reason is that they will be familiar with the centuries old technique of "***marking***", which depends on the efficacy of the process of ***homing in***. In this the artists choose a starting point (usually the end of the last line drawn). From there, the normal practice is to make a visual estimate of the length of the next line to be drawn and then immediately launching into producing a line based on that estimate. The technique of ***marking*** requires a different approach. After visually estimating the length of the line as before, the artist hovers the tip of their drawing instrument above the estimated end point. Then, while continuing to hover, they experiment with alternative end points. In this way, they can adjust the position of the tip of the drawing instrument until they judge to be the same distance from the starting point they have chosen as is the distance between it and the end of the line they are attempting copy. They then mark this point and join it to the starting point, thereby turning the task into the one required of Alan Wing's experimental subjects.

My drawing experiments and my long experience as a teacher show that we can be extremely accurate when it comes to judging small differences and much less so in judging large differences.[14] For example, if we make a mistake when a drawing a model, we will not know that we have done so, unless we look back at the model and make a direct comparison between it and the copy we have just made. If the error is small, we find that we can reduce the problem to one of judging small differences (which, as just indicated, we are good at). If the error is large we can still use it as a

14 Although we can learn to improve on the latter by taking more context into account.

first step in an incremental approach to accuracy, with each new attempt to improve matters reducing the error and providing an opportunity for additional comparisons. Almost certainly this is why there are multiple contours on so many old master studies.

So far, I have been discussing how artists get round the problems they face on account of the ***constancies***. But, more interesting for scientists of ***eye/brain*** function, is the question as to why the processes of evolution have created these problems in the first place. What is the advantage of providing viewers with a distorted world? This question leads to two further, related questions, both of which concern the virtual impossibility of using information residing in LTM to guide accuracy, since this is derived from past experience and, accordingly, has only an infinitesimally small chance of mapping onto current input. The two questions are:

- How can ***analytic-looking systems,*** set in motion by information in LTM, derive accurate relativity measurements when confronted by the infinite variety of shapes and colours in nature as modified by the viewer's ceaselessly changing viewpoints?
- How, in view of the fact that the information in LTM cannot correspond to "***measured reality***", can the eye/brain ***mark-making systems*** make accurate representations of real world relativities of line-length, line-orientation, curvature, size of regions, position of lines relative to one another and positions on the page or painting support.

Since history shows that, despite these seeming impediments, the action-organising systems of artists are able to produce a high degree of accuracy in their drawings and paintings from observation, a natural question to ask is whether the ***constancies*** play a part in how they do so. Although so far, I have not come across an answer,[15] I have a suggestion to make based on the way I help students with the problems that the constancies pose for them. Its advantage is that, although a bit homespun, it gives a plausible explanation for a number of error types in drawing and painting.

What I do is to share with the students a thought experiment, in which I hypothesise that the brain contains a location of fixed dimensions, into which all the information provided by the ***analytic looking systems*** are fitted. For example if we are looking at a straight line of a given length, it

15 But this does not mean that one has not been suggested by someone else.

is fitted into this location. Similarly, if we then separately look at a straight line of a shorter length, this too is fitted into the same fixed dimension location. As a result, if when copying the lines we look first at one and draw it and afterwards and separately at the other and draw it, the two different length lines will turn out to be nearer to having the same proportional relationship as they actually have. This phenomenon is known as ***size constancy***. However, I also speculate on why the linear relationship between the two lines sometimes fall short of achieving constancy. My hypothesis is related to the fact that all our judgments are influenced by context. For example, the length of both lines may be influenced by perceptions of their relationships with the edges of paper that they are drawn upon.

I also hypothesise that, as well as being of a fixed size, my ***conceptual space*** has vertical and horizontal axes. I explain that these are necessary for explaining why that, if we are attempting to copy a straight line of a given slope that is neither vertical nor horizontal, we will tend to draw it as being more vertical or more horizontal than it actually is. I speculate that this is because the sloping lines are rotated so as to coincide with the vertical and horizontal axes of the hypothesised conceptual space. Again, I speculate that the reason that actual lines in actual drawings do not necessarily rotate to be exactly vertical or horizontal is because we can seldom avoid the influence of context.[16]

The importance of this influence can be tested by anyone. Just try to hang a rectangular painting on a blank part of a wall or other flat painted surface and do so from a viewing point from where no verticals or horizontals can be seen. I have never known anyone who has managed to do this first time. The fact is that we can only realise the extent of our error when we stand back and allow verticals and horizontal features in the context to influence our perceptions. This phenomenon is known as ***orientation constancy***.

It seems plausible that amalgam of these two types of constancy could explain ***shape constancy***.

Artists also have problems with ***lightness constancy***. To explain this ever present phenomenon, I hypothesise that the conceptual space also has a fixed range of lightnesses, into which is fitted the actual range of lightness

16 I may also be a result of the influence of the "***bakery facade illusion***", which shows that it is not edges that the eye/brain rotates but the approximate axes of symmetry.

found in the scene being represented. By this I mean, a scene within which the darkest is very dark and the lightest is very light will fit into the same lightness space as one where the lightest part is relatively less light and the darkest part is relatively less dark. For argument's sake, I suggest that the lightness space is divided into a fixed number of just noticeably different steps (***JNDs***). For this thought experiment, I propose 100 steps. In other words I am suggesting that, as far as the eye/brain is concerned, all ranges of lightness will be stretched or squashed until they comprise 100 JNDs.

As with all constancy phenomena, context and other factors may interfere with the outcome, but the tendency to squash and stretch all scenes into the same lightness space seems to be unvarying. One implication picked up by artists is that this means that the smaller the range of the lightness steps, the greater the sensitive to differences in lightness the human visual system becomes.[17]

This finding has a had a significant effect on the history of painting because it was a major reason why the early Modernist painters moved away from chiaroscuro and embraced paintings with narrower lightness ranges. Influenced by Chevreul,[18] they realised that the smaller the lightness difference between juxtaposed opponent colours[19], the more exciting the colour contrast effects. When I was at art school in the late 1960s, my teacher told his students that "*anyone who wants to be a true colourist should restrict their palette to equal lightness colours*".[20]

So how does all this help us with the precise information required to organise precise actions? The answer is that it provides us with three systems of capable of mediating precise measurement. Thus:

- If a line has to be stretched or squashed to fit into a framework of fixed dimension then, it must be stretched or squashed by a precise amount.

17 The region that the lightness constancy system takes into account is either whatever is in the visual field or whatever is being focused upon. So, if we only look at a small part of a scene, its lightness range will be 100. And if we look at several small parts of the same scene all of them will have the same lightness range. Many problems for artists come from the havoc this creates relative to whole field lightness relativities. More positively, it means that focusing down will be accompanied by an increase in sensitivity.

18 Chevreul, Michel Eugène 1839), "*De la loi du contraste simultané des couleurs et de l'assortiment des objets colorés*."

19 More precisely any pair of colours from opposite halves of the colour circle.

20 He later felt that this was going a bit far.

- If two shapes are of different sizes and both of them have to be extended or squashed to fit into the same fixed framework, then both must be stretched or squashed by a precise given amount.
- If a line is at a given angle in a scene and is rotated to a vertical, then it has to be rotated by a precise given amount.
- If the lightness range in a scene has to be stretched or squashed to fit into a given lightness range, then it will have to be squashed or stretched by a precise given amount.

While I have no evidence to say how these precise measurements could be measured by eye/brain systems, as far as I can see they are the only ones that are regularly made available. Moreover, they have the air of being neurophysiologically plausible. If so, it is reasonable to suppose that the information provided by the constancies would be channelled via what is normally referred to as "***working memory***"[21] (In my ***analytic-looking diagram*** this is subsumed under the phrase "***organisation of action")***.

Finally, it needs to be emphasised that while the above is speculative, other ways of providing accurate information for use in the ***organisation of actions*** are well known. One of particular importance in the domain of painting and drawing from observation has already been mentioned. It is the use of the visual feedback, as provided by ***comparative looking***, to ***home in*** on accuracy, as exemplified by:

- The technique of "***marking***" just discussed.
- The homing in procedure revealed by Alan Wing's experiments.

Or, more generally, by using feedback to guide corrective action.

A summing up of this discussion of levels of description:

In order make drawings or paintings from observation the ***eye/brain systems*** pass through several preconscious stages of processing, each of which provides its own level of description. Here is a list of ones mentioned above:

- Mosaic of activated ***light-sensitive receptors***
- Information created by the ***retinal processing***, as triggered by the light-sensitive receptors and passed up the ***optic nerv***e to ***Visual Area 1***

21 AD Baddeley, G Hitch - Psychology of learning and motivation, 1974 - Elsevier

- Information as passed by a separate pathway, from the retina to the ***superior colliculus***, and from there, via the ***hippocampus***, the ***feeling centres***, the ***frontal eye fields***, the ***working memory*** and, eventually, the ***motor cortex.***
- Information from ***Visual Area 1*** as processed by the ***recognition systems***, in such a manner as to access information about object-type already existing in ***LTM***
- The information on ***object-type***, previously existing in ***LTM***, that is used to trigger ***action instructions***
- Information gathered from a variety of ***sensory sources***, including both ***visual sources*** and the eye/body/arm/hand/finger coordinating systems gathered in ***working memory*** with a view guiding organising ***action-instructions***
- Information that is fed to the various ***constancy creating systems***
- Information made available in the process of generating the c***onstancies***
- Information created by ***analytic-looking*** systems, via ***comparative looking***.

Even though only the last two of these levels of description in the above list are available to consciousness, all play their part in creating both problems and opportunities for artists.

Despite this, as far as I can ascertain, only the descriptions in ***LTM*** (once known as "***schema***"), the problems and opportunities due to ***constancy phenomena*** and ***comparative looking*** have been given roles in the teaching of drawing and painting from observation.

A short history of the evolution of levels of description.

There follows a small addition to the above discussion, in case it is of interest to those who, like me, have puzzled on how anything so complicated as the human visual system with it need for so many levels and modalities of description could have evolved from the single cells organisms that were the only life forms existing at the dawn of life on earth.

Clearly, coming to a complete answer would require a large number of additions to our current knowledge, but it seems to me that a coherent, even if woefully incomplete, explanation could start with the fact that scientist

tell us that the earliest known single cell organisms were both sensitive to light and capable of moving either towards or away from it. My suggestion is that an accumulation of cells with these properties into multi-cellular '*lumps*' with both surface and interior layers, would provide a good foundation for the future development of a human retina (and, indeed the retinas of all mammals).

Significantly, the cells on the inside of the multicellular lump would not be exposed to light. The only way they could be activated would be by means of energies coming from already energised light-sensitive cells. If the surface layer of light energised cells were indeed able to pass their energy to these interior cells, it seems reasonable to speculate that the interior cells would, in their turn, be capable of passing the newly acquired energy on to neighbouring cells. If this were to be the case, there would be no reason why this energy transfer could not take place in all directions, both sideways, to neighbouring cells in the same layer, and onwards to cells in the next layer. Moreover, the fact that neighbouring cells would be passing energy laterally in both directions, means that there would be a degree of ***lateral inhibition*** and, consequently, the possibility of passing on a mosaic of cell-generated energies corresponding to the mosaic of light energies striking its surface. Moreover the fact that cells inside the lump would be passing cell generated energies both towards and back from deeper cell layers means that it would automatically provide the structure necessary for both of ***feed-forward*** and of ***feedback***. It is difficult to avoid the thought that a cellular lump with these properties would have much in common with the human ***retina***.

Perhaps more pertinently, if the surface of the lump comprised 18 X 18 light sensitive cells, it would have much the same properties as Paul Bach y Rita's 18 X 18 array of solenoid sensors. That is to say, the array would have analogous properties to those which could activate a pattern of neural activity that enabled blind people to "*see"*.

Perhaps it is being a little precipitate to use the word "*see*". But perhaps not, for it seems reasonable to suppose that even this primitive organism would be capable of:

- Making '***vague***' and '***crude***' distinctions between objects
- Detecting the presence of separate objects

- Distinguishing between objects that are still and those that are moving.
- Gauging their direction of travel.

All of these can be described as vestigial forms of ***recognition***, surely the base-plate for any visual system that can "*make sense*" and "*make use*" of the visual world. Surely also, both these capacities are implied in our everyday use of the word "*see*".

In short, with all these possibilities, it is credible to think of our multi-cellular lump as having the potential to provide a good platform for the gradual evolution of the more complex manifestations of visual perception that have since evolved in humans an other animals. Looking at it in this way can also help us to have a sense how different species might experience the phenomenon of "***seeing***".

Levels of description (3: artists practice) *Levels of description*" is a phrase used by both scientists and artists, but far from always in the same ways.. For this reason the different meanings will be given a separate headings. The focus of this *Glossary* entry is on its meaning for artists engaged in drawing or painting from observation.

Here, the phrase *"levels of description"* refers either to characteristics of objects and parts of the objects (e.g. Trees, trunks, branches, twigs, leaves, etc.) or to the abstract-relations (relativities of hue, saturation, lightness, length, orientation, surface-form, etc.). It is with these that artists must engage when seeking to achieve accuracy in drawings or paintings made from observation. To explain the universal difficulties artists of all levels will face in trying to do so, it is necessary to emphasise some of the consequences of the fact that all visual processing starts with ***recognition***, before progressing through a number of stages, often including a number of iterations of the ***analytic-looking cycle***.

The number of iterations of the ***analytic-looking cycle*** used depends on the nature of the task and on its spatial and temporal context. For example:

- If the ***context*** is the open door of a ***familiar*** wardrobe, in a familiar room, a red blur can trigger the ***recognition*** of a ***familiar*** dress without further information-gathering activity. Once ***recognised*** a minimum of additional looking is necessary for going to the wardrobe, taking the dress out of it and putting it on.

- Making use of a ***less familiar*** object in a less familiar ***context***, would require more information and, accordingly, more looking activity.

In either case, or in any other situation, the function of ***recognition*** in enabling tasks is to access the ***action instructions in long term memory*** necessary for accomplishing them.

In the case of ***drawing from observation***, recognising the ***object-type*** can be enough to trigger ***action instruction***s based on information residing in ***long-term memory***, without further recourse to ***analytic-looking***. This being the case, the outcome in terms of accuracy would depend on the degree of correspondence between the parameters of the object being drawn and the information available relating to the ***object-type***. For example if it model were to be a round ball, the correspondence would be high and, without further looking, anyone with the skill of drawing circles could make an accurate drawing of its contour on the basis of existing knowledge.

However, spherical objects are unique in that changes in viewing conditions do not effect the shape of their contour. The situation is different with any other three dimensional object. For example, if a drawing of a children's building block were to be made by a professional artist who had internalized the rules of linear perspective, the result could well be sufficiently realistic to be mistaken for one that had been drawn from ***observation*** (even though it would almost certainly fail to represent accurately the particularities and relativities due to the actual viewing conditions). In contrast, the memory of a seven year old child might contain no instructions relevant to drawing cubes and might have to fall back on ***tactile memories*** of times playing with its building blocks. In which case, it might draw a number of connected rectangles. If so, it would be a typical example of an "***intellectually realistic***" children's drawing.[22]

But how should the realistic looking drawing made by the skilled professional based on ***recognition*** alone be characterised? From the above it should be clear that, although unlikely to be described as any such thing by psychologists of perception, it would be just as ***intellectually realistic*** as the child's.

To get nearer to accuracy, artists of ***all skill levels*** would have to use the ***analytic-looking cycle*** to go down the ***levels of description***. In the case of the cube, this would require looking at ***relativities of length, orientation and shape***, with particular attention being given to the angles found at ***junctions***.

22 Phillips, Hobbs and Pratt, 1979.

Nor would the situation be any different if the object in the process of being depicted were to be a life class model. ***Recognition*** could enable either a child or a skilled professional to make an intellectually realistic drawing. The only difference would be that the drawing of the child would be "*childlike*" whereas that of the professional might be sufficiently realistic for viewers to assume it to be an accurate representation.

To improve accuracy the only option for either child and adult would be to activate the ***analytic looking cycle*** and to use it to go down the ***levels of description***. Doing so will involve breaking the task up into separately recognisable parts. For example, when representing the life drawing model, a start might be made on the head, followed by the neck and shoulders, and next the arms, etc., etc. Each of these parts could be ***recognised*** as ***object-types*** in their own right and drawn in an ***intellectually realistic*** manner. As before the child's rendering would be childlike while the adult's might deceive viewers into erroneously believing it to be accurate. If either the child or adult wanted to improve their rendering, it would be necessary to activate the ***analytic-looking cycle*** as a means of descending further down the levels of description, until a level was reached at which the contents of ***long-term memory*** corresponded more closely to the actuality of appearances.

An example of this possibility is the aforementioned round ball whose circular shape can be draw accurately from ***memory*** without additional ***analytic-looking***. However, ***long-term memory*** has no information relative to its actual size**.** The straight line provides another example of an element whose shape it is possible be to draw accurately from ***memory***. But in this case the ***long-term memory*** cannot have information about either its actual ***length*** or its actual ***orientation***.

And there is the nub of the matter. What cannot be stored in a permanent memory are the relativities of size, length, orientation and curvature, since all of these vary infinitely with viewing conditions.

To estimate relativities it is necessary to make ***comparisons***. Since it outputs from the ***recognition systems*** have no dimensions, another source of information is required. This is found temporarily stored in ***Visual Area 1***. In other words, it makes use of the same information-source as used by the ***recognition systems***. R***ecognition*** requires ***multimodal processing*** (the first use), which necessitates breaking up the image into unanalysable modalities. ***Analysis*** requires access to a source of analysable information

(the second use). In this case all the information coming up the ***optic nerve*** from the ***retina***.

One of the advantages of ***comparisons*** is that they invariably force attention in the direction of ***differences*** and, accordingly, of lower ***levels of description***, whether these be in term of object-parts or abstract relations.

In order to find the near-symmetries, it is necessary to take sections of the contour of the model from out of their ***context***, a procedure that artists call ***chunking***. Two chunking principles advocated in this book are to:

1. Look for changes in direction at junctions between different parts of the object being drawn, whether these be obvious (as at corners between the adjacent faces of a cube), or extremely subtle (as in the changes in direction of the contour of a nude life class model, due to intersections of muscles (such as those indicated by the blue-green arrows in *Figure 8, Chapter 11*).
2. Section contours by reference to ***in front/behind relations*** as in the nineteen examples indicated in *Chapter 10, Figures 1 - 7* (which break up the contour of the tree trunk into manageable chunks) or those indicated by the white arrows in *Chapter 11*, *Figure 8* (which perform the same function for the life class model).

It hardly needs adding that ***sectioning***, ***chunking*** or ***separating from context*** all involve a simplification of the elements under analysis and, thereby, a descent in the ***level of description***. Nor should it be necessary to point out that doing so increases the likelihood that ***intellectually realistic*** drawings of them will approach accuracy in a similar way to that in which ***intellectually realistic*** drawings of spheres and straight lines approach accuracy. Two ways of selecting useful chunks are:

1. To look for sudden changes in the direction of the contour the object (as when a branch grows out from a tree trunk or a jaw line fits onto a neck).
2. To identify ***in front/behind relations*** between the contours of the object being drawn and the contours of elements that it overlaps in the scene behind it (as with intersections between the wall top and bottom and the tree trunk in *Figure 1, Chapter 10* and between the arm in front of the thigh and the thigh of the young woman in *Figure 2, Chapter 4*).

And, a third more generally approach is:

3. Considering ***how things fit together*** and using your conclusions to direct attention. Examples of fitting together would be (parts to wholes, muscle structures to muscle structures and edges of objects behind into edges of objects in front).

Whichever approach is chosen, comparisons between ***near-symmetrical chunk***s will force a descent in the levels of description which will help artists to approach their goal of ***accuracy in drawings from observation***.

Life's Learning Journey: The life of each of us can be described in terms of an extended "*learning journey*" starting in the womb and continuing to the present moment. What we learn is and ever increasing range of ***habits***. It is important to realise that everything we do is ***habit-based***. ***Good habits*** can be defined as "***skills***" and ***bad habits*** as "***maladaptive skills***". All learning involves three elements:

1. Interaction with a ***context*** (whether this be the current physical environment or with information stored in ***memory***).
2. The ***feedback*** it generates.
3. Reactions to the ***feedback*** based on judgements by the ***feel-system***.

Light Box: A box with a glass top that is illuminated from inside, which enables the tracing of images on paper that is too opaque to trace through directly.

Lightness is a word used by scientists to mean the same thing as the word "***value***" in American English and "***tone***" in British English. In this series of books the scientific usage is preferred. It is also used in preference to two other words that are sometimes confused with it. They are:

- "*Intensity*" is an ***absolute value*** that corresponds to measurements by light meters. It is of only marginal interest to artists, who need to give priority to ***relativities*** on the ***lightness/darkness*** continuum since these are the only kind of measurement that the ***eye/brain*** is capable of computing.
- "*Brightness*" is a word that is often erroneously used as equivalent to "*lightness*", but a ***bright*** colour can have less ***lightness*** than one that is perceived as being ***less bright***. For example, light seen through a ***translucent surface*** can seem ***brighter*** than light that is reflected off ***opaque surfaces,*** even though, when directly compared, the reflected-light can seem both ***less bright*** and ***lighter***. For more on this, see

under "***brightness***".

In "*Painting with Light and Colour*" much is said about drawings that explore ***shadows***, ***shading*** and ***whole-field lightness relations***. The phrase ***lightness drawings*** is used to describe these in preference to the more common "***tonal drawings***" or "***value drawings***".

Light-Sensitive Receptors. Physicists describe ***light*** in terms of electromagnetic energy, wavelengths and photons, but none of these have ***colour***. As the scientists of visual perception had come to realise by the start of the nineteenth century, colour is made in the head, by ***neural systems*** in the ***eye/brain***. The first stage of this process occurs in the retina by means of the activation of over 150 million light-sensitive receptors, of which some seven million are concentrated in the ***fovea***. The receptors are of four types: three types of ***cone receptor*** and one type of ***rod receptor***. All of these respond to a greater or lesser extent to all wavelengths of light, but have different sensitivities with respect to both wavelength and intensity.

Relative to the ***rod receptors***, all three types of ***cone receptor*** require a greater intensity of light to activate them. Relative to each other the main difference lies in their ***wavelength-sensitivity***. Thus one type of cone is more sensitive to relatively shorter wavelengths, a second to longer wavelengths and a third to slightly longer ones still. To simplify matters, they are usually described as responding to "***short***", "***medium***" and "***long***" wavelengths.

The *rod receptor**s*** are activated by lower levels of intensity and have a peak sensitivity between those of the "***short***" and "***medium***" cone receptors. This extra sensitivity is necessary because there are layers of light-impeding blood vessels, neurons and neural processes between them and the incoming light (as shown in *Figures 7 and 8*).

The reason why there are so few ***rod receptors*** in the ***fovea*** is that they would be bleached out and, consequently, useless by normal daylight. The fact that there are some ***rod receptors*** in the fovea shows that they are needed when the levels of illumination are too low for the ***cone receptors*** to be stimulated. When the level of illumination is neither too high nor too low and both ***cones*** and ***rods*** to be active, the ***rods*** contribute to the perceived ***colour*** of surfaces.

By contrast the presence of the extra-foveal light-impeding layers mean that the cones have reduced sensitivity in the periphery..

The 150 million or extra-foveal ***rod receptors***, as interconnected into various sizes of ***receptive-field,*** are used in the neural computations that provide information about ***ambient illumination***, ***surface-form***, ***3D spatial separation*** and both ***spatial and temporal colour-constancy***. A probable explanation of the existence of the sparsely distributed ***extra foveal cone receptors*** is that they also are required for these computations.

Finally, the combination of rod receptors and variable sizes of receptive field is required for providing the information necessary if ***texture*** is to be used as one of the modalities of information used in the ***multimodal processing*** that enables ***recognition***.

Line Drawings are drawings made with lines but without shading. The ***eye/brain*** has different ***visual systems*** for the analysis shape and surface. One is used exclusively for analysing ***edges, contours*** and relations between them, while the other finds information about ***surface-form***, ***texture, 3D separation*** and ***ambient illumination.***. This volume *"Drawing on Both Sides of the Brain*" deals only with the former. A great deal of in-depth information on the use of shading in ***monochromatic*** drawings from observation is available in "*Painting with Light and Colour"*.

Linear Perspective (1): Brunelleschi, his pupil Alberti, Piero sella Francesco, Uccello, Leonardo de Vinci and other architects and artists of the Fifteenth Century worked out ***rules*** that enabled the construction of images of buildings and other forms without referring to a model. These were based on the well known fact that increases in viewing distances result in objects taking up a smaller part of the visual field and that the size of their image on the retina diminishes in a regular manner. These ***rules*** not only took into account the hypothetical distance between viewers and the objects being created, but also both the distance between them and the picture-surface and the angle at which the picture-surface was to be viewed. Their originators never thought of them as aids to ***drawing from observation***, a task for which they are ill suited. Much more on the reasons why in *PART 6* of "*Drawing on Both Sides of the Brain*."

Linear Perspective (2): It is common knowledge that objects appear to get smaller with increases in the distance from the person viewing them. Accordingly any two objects of the same size are viewed at different distance, the nearer one will appear as larger and the further on as smaller. This same law applies to the edges of rectangles and influences their perceived shape

such that they appear to be trapezoids with the nearer edge larger and the further edge shorter. They also took into account the ***eye-line*** of the viewer, according to the rule that edges above the ***eye-line*** slope down, away from the viewer, and edges above it, slope up away from him or her. However, two factors complicate matters.

- The rate of decrease in perceived size is progressive. Thus while a hand held near to the eyes can take up twice the space as one held at arms length, a hand that is five metres away will be only very slightly larger than one held at five and a half metres. The result is that the lines characterising the receding edged of rectangles will always be curved, although this may only be noticeable when the near edge is relatively near and the far edge, relatively far.
- As shown in *Chapter 16 (?)*, When objects are looked at through a frame, the distance between the eyes of the viewer and the frame can make a very noticeable difference to the perceived size of objects according to the rule, the further the distance between the viewer and the frame, the larger objects seen through it will appear to be.

Literal Accuracy is a term which, along with ***photographic accuracy***, is equivalent to what this book refers to as "***measured reality***".

Longsightedness is known to experts as "*hyperopia*" or, in older people, as "*presbyopia*". Both mean being able to focus less well on near objects than on far ones. The problem of ***longsightedness*** is more common in older people because for everyone the inner lens of the eye becomes rigid with age and can no longer be used to correct for near-sighted tasks such as reading. It is when this happens that the condition is called "*presbyopia*".

Measuring Objects: (*See also "Drawing on Both Sides of the Brain", Chapter 2, "The Renaissance and the Academic method"*). Measurements can be made with instruments, by the eye aided by instruments or by the unaided eye. They can be made:

- On the object itself, by means of measurements made with a ruler or tape measure to find the proportions of different parts of the human body relative to one another.
- By using either (a) a pencil or paint brush held in front of a scene being drawn and using a thumb or finger as a measuring gauge (as illustrated in *"Drawing on Both Sides of the Brain", Chapter 2*, *Figure 5)* or (b) a

perspective frame with its rectangular grid and corresponding squared up paper (as illustrated in the same volume*, Chapter 2*, *Figure 3*).

- By means of the ***analytic-looking cycle***.

All three methods have serious shortcomings:

1. Measurements on the object itself cannot take into account distortions of appearance due to the combination of viewing distance and viewing angle which can range from subtle to huge. Also measurements on one object cannot necessarily be used for drawings of another similar object (for example, when drawing the human figure, the number of heads relative to the height from the ground to the top of the head can vary significantly between different people).
2. Using a pencil as a measuring instrument as illustrated in should work in theory but is fraught with difficulty in practice, since it is extremely difficult to keep both the eye and pencil completely still and any movement of either will play havoc with the measurements (See illustration and caption in "*Drawing on Both sides of the Brain*", *Figure 5, Chapter 2*). The perspective frame as originally used[23] is much more reliable because it has both a chin rest and a reference grid, but it is far from easy to use since the need for the eye to be to be kept totally still means that it can be difficult to deal with the peripheries of the image. It is also time consuming and mechanical, both of which features seriously interfere with expressive line production.

   The much used modern descendent of the perspective frame, consisting of a framed grid that is held freehand, suffers the same disadvantages as the pencil used as a measuring instrument, although it can be used to frame off parts of a scene when considering compositional possibilities.
3. The unaided eye is poor at making the necessary measurements of relativities. For more on this see "***Measuring with the Eyes***" in this *Glossar*y. For why this is the case and for ways of circumventing the problems it causes see "*Drawing with Feeling*" the first of the two books in *"Drawing on Both Sides of the Brain"*.

Making Sense: The primary function of eye/brain systems. The other two of its functions, namely ***recognition*** and ***making use***, could not take place without the ***knowledge*** provided by the process of ***making sense*** having been

23

stored in ***memory***.

Making Use: It helps a great deal in the understanding of visual processing to remember that its function is not to upload complete images, but rather to "*make use of*" the streams and patterns of light-carried information that are continuously coming into the eye. If this were not the case it is difficult to see how evolution could have managed to produce the miracle of visual perception in all its riches, with its key devices of the ***constancies***, ***context*** and ***minimal cues***.

Mark-Making: Every mark-making movement of the drawing instrument and every brush stroke has to be organised by the brain. Thus, as illustrated in *Figure 1* , ***mark-making*** occurs after ***recognition*** on the basis of information stored in the ***context and feeling based memory***. Accordingly, as with ***analytic looking***, it is essentially ***habit-driven*** and can only achieve ***accuracy*** if the knowledge stored in memory corresponds to outward appearances, as in the case of straight edges or the outline of spheres. Otherwise, the rule is the simpler the curvature, the more likely to approach ***accuracy***. This is a reason why ***chunking*** helps when analysing complex curves.

Masters of the Italian Renaissance: The list is long and would include Masaccio, Della Francesca, Uccello, Leonardo da Vinci, Botticcelli, Bellini, Titian and Michelangelo. Their importance in art history is more than a reflection of the widespread admiration people have had for the quality of their works. It is also due to their role as pioneers of a new approach to drawing and painting, which involved research into the nature of appearances with particular reference to ***anatomy*** and ***perspective*** (both linear and aerial). Their findings which came to be known as "***the laws***", were later to be codified and taught by the ***Academies***. Also codified by them were the ***rules of composition*** that they adopted, which came to be known as "***the rules***".

Both ***the laws*** and ***the rules*** came to be seen as either misleading or unnecessarily restrictive by the ***Impressionists,*** whose reevaluation of them was one of the factors that contributed to the ***paradigm shift*** that launched ***Modernism in Painting***.

Measured Reality. In this book the "*measuring*" that produces **"*measured reality*"** is the measuring done by artists when looking at the subject matter from a particular viewpoint. It is associated with *traditional artistic practices* that were developed in the ***Italian Renaissance***. Some of the most important of

these are presented in *"Drawing on Both Sides of the Brain", Chapter 2.* Many of these used some form of ***tracing***, whether through a ***tracing glass,*** on a ***mirror*** or on the projected image produced by a ***camera obscura***. Others sought to derive ***laws*** from the measurements taken from these traced images and came up with the rules of ***linear perspective*** and ***anatomy***.

This kind of "***measured reality***" is not at all the same as that produced by making measurements on actual objects in the real, three dimensional world, in other words ones that require the use of rulers and protractors. Nor is it the same as the "***experienced reality***" of everyday vision, since this is subject to all the influences of ***visual processing***, which produces the distortions due to (a) viewing matters from a ***single viewpoint*** and (b) the ***constancie***s.

Measuring with the Eyes: The experiments on copying accuracy that I did at the University of Stirling showed that human beings have poor capacities for measuring with their eyes. Even when given the seemingly simple task of copying unfamiliar, randomly arranged groups of two, four or six of straight lines "*as accurately as possible*", the statistical analysis of their performance showed both skilled and unskilled adults averaging errors of 10% for relative length, 10% for relative position and 5° for relative orientation. However, these averages make the situation seem better than it actually is for, although when the compared lines were near together in terms or length and orientation the errors were much less, when they were far apart, they were much greater (for example, errors of around 20% and 10° were not uncommon). Also, when faced with the much more complex three dimensional world, errors can only too easily be much larger than that.

Memory: All activities, all skills, all knowledge, all learning and all creativity require the use of ***memory***. The skills required for ***drawing from observation*** comprise ***visual analytic skills*** and ***visually mediated manual skills***. Both are made possible by combinations of four kinds of ***memory***. These are:

1. ***Iconic memory***. Every occasion that a pattern of light arrives at the ***retina*** it activates an analogous pattern of neural activity. This endures only until the next pattern of light arrives and replaces it. Meanwhile the ***eyeball*** is slowly rotating ("***gliding***") or jumping about ("***saccading***) with the result that, even if the object under analysis is static (as is likely to be the case the case when ***drawing from observation***), the information being picked up will be changing. Consequently each pattern of input has a very short life span indeed (the time taken for

the energy in the light to be transformed into a neural impulse). However, despite its brevity, the process of transition between one pattern and the next allows for the two inputs to be compared by means of ***lateral inhibition***. The ***same/difference*** information that is generated in this way provides the basis for all the ***neural computations*** that underpin ***visual processing***. As logic makes clear, none of this could happen if the first pattern of neural activity left no trace and it is this that has been named "***iconic memory***". It hardly need to be added that this kind of memory is far too fragile to be consciously kept in mind.

2. ***Short term visual memory***. *Figure 1* shows a region labelled "*visual area 1- twice used information source.*" As its label suggests this performs a double function: It provides information for both ***recognition systems*** and ***analytic-looking systems***. Since, as the diagram shows, the ***analysis*** does not occur until after ***recognition*** has taken place, the ***information*** upon which ***recognition*** was based has to be kept in store pending its analysis. This storage facility has been named "***short-term visual memory***." Although this is more stable than the fleeting *iconic memory,* it too has to give way to a next stage of processing, which disrupts it. However, it is not only the arrival of ***new visual inputs*** that does this for ***short-term visual memory*** is also disrupted by ***mental activity***. For example, it is disrupted by counting backward.[24] Just as significantly for artists, it is disrupted by the ***knowledge-guided processes*** involved in the ***organisation of the action*** of line drawing. Take the example of an artist being asked to measure visually the relative lengths of two abutting lines, and then draw them. One of the lines has to be drawn first and the process of planning and executing it disrupts the memory of and, consequently, the accurate planning and executing of the second.

   Since this kind of disruption seemed to be a matter of crucial relevance to the way artists use their eyes when drawing, I did controlled experiments at the *University of Stirling* to investigate its effects in more detail. While confirming the fragility of ***short-term visual memory***, these showed that, nevertheless, some other kind of memory persisted. Thus, while the visual measuring activity was of no help with guiding the output of the second line, it had a positive effect on the

24 W. A. Phillips

accuracy of subsequent ***information pick-up***. This finding has been backed up and elaborated upon by evidence provided over many years by students doing the drawing lesson described in "*Drawing on the Both Sides of the Brain*", *Chapters 9-11*. What both the formal experiments and the drawing lesson students showed was that looking back at the relativities after having drawn the first line of any two that are being compared, enables significantly more ***rapid pick-up*** of the information required for guiding the ***action instructions*** necessary for accurate line production. Further investigation showed that making preliminary visual measurements of a sequence of relativities (what I have come to call "*casing the joint*"), helps with the speed and accuracy of subsequent information pick up for all of them.

Another consistent finding was that if a student spends time analysing the different relativities, angles and junctions in the way advised in the drawing lesson, the fact that they have done so means that they can make a second drawing that is equally or even more accurate in a much shorter time. *Figures 1 - 3* in *"Drawing on Both Sides of the Brain", Chapter 11*, shows a complex drawing being repeated three times. The first effort took three hours to complete, the first repetition took half an hour and the second repetition took ten minutes. The level of drawing accuracy remains high in all three. Nor was this an exceptional result. I have seen it repeated what must by now be hundreds of times, both in drawings of trees and in drawings of the model in the figure drawing class.

But the drawing that regularly most surprises everybody is the one that is produced ***from memory,*** soon after the ten minute drawing has been completed. As in the example illustrated in *"Drawing on Both Sides of the Brain", Chapter 11, Figure 4*, students remember almost everything (indeed, they have been known to add details that they had previously noticed but not drawn). After the figure-drawing session the students who have participated in it test each other by asking each other which of the drawings produced during the session were done with the aid of looking and which from memory. They find that it is not necessarily evident which is which.

3. **Working memory in practice**: Clearly in the above description of analysing and drawing line relativities there is evidence for a visual

storage capacity that is less fragile than ***short-term visual memory***. It must be stable enough to survive not only throughout the ***knowledge-guided*** structuring of ***line output instructions*** but also during much other mental activity (for example, that associated with all the palaver of replacing sheets of paper and reengaging with the model, not to mention the inevitable accumulation of intervening thought processes of a wide variety of kinds, whether or not related to the drawing experience. Clearly, it is a kind of memory that is invaluable for guiding the ongoing eye/hand coordination skills required for the above task.

Analogous temporary, task-related memory stores are required for all knowledge guided activity whatever the domain. Accordingly, it can be included under the catch-all name of "***working memory***".

We will return to the longer term implications of the place of ***working memory*** in visually guided skills under the heading of "***long-term memory"***. For the moment it is time for a more theoretical approach to "***working memory***".

4. **Working memory in theory**: *Figure 1* focuses on the main process that make up the "***Analytic-looking Cycle***". It shows that ***analytic-looking*** occurs only after ***recognition*** and that ***targeted eye-movements*** are directed from ***memory stores*** situated well away from current visual inputs and with no direct connection to them.

   It also carries the implication that ***analytic-looking*** is by no means the only activity directed in this way. Indeed, all actions are guided by instructions residing in memory stores, including those that produce the marks made when ***drawing from observation***.

   When we ask what is the nature of these instructions, we are confronted by the variability of appearances in nature which ensured that no two objects or parts of objects are ever the same, not even the same object when viewed on different occasions, unless we go down to the level of the ***visual primitives***, their basic building blocks.

   Perhaps even more important no two ***relationships*** between objects, between parts of objects or even between ***visual primitives*** are ever the same. Each has to be judged separately and knitted together, as if for the first time, by a sequence of ***action-instructions*** that will determine the complex push-pull of the muscle structures which control

line-output. Since this judgment requires taking into account relationships between at least four variables (relative length, relative orientation, relative position and characteristics of curvature) and sustaining the information as long as it is still required for organising head, body, arm, hand and finger movements required, temporarily ***sustainable complex memories*** are needed. However, since every line drawn requires the processing of a different set of relationships, the usefulness of the memory structure required is limited. Inevitably it will have to be replaced after the completion of each usage. The name given to memories that serve the purpose of gathering together the information necessary for ***organising task-related actions*** in this way is "***working memory***".

5. **Short-term feeling memory**: In order to draw a line such that it is a certain amount longer or shorter than another previously drawn line, the memory of the first line must be held in mind. This can be a ***visual memory*** as described above and/or a ***feeling memory*** that holds on to the feel of the relativities. As with ***short term visual memory***, this task-specific feeling-memory will be masked by any intervening line-production activity. Accordingly, hesitations that occur in the course of drawing the second line will obliterate the *short-term feeling memory* of the first line. A similar problem occurs when drawing relative positions on the page or relative orientations. Dithering renders the memory of what came before useless. This is of great significance for any one trying to get the best out of the ***feeling-based drawing lesson*** found in *"Drawing on Both Sides of the Brain", Chapters 9 -11*. Dithering will not prevent those who follow it from achieving accuracy, but it will seriously interfere with the objective of training the ***feel-system,*** with all the many benefits that doing so can bring.
6. ***Long-term memory*** is represented in *Figure 1* by the box labelled "*context and feeling based memory reflecting whole of each individuals life experience*". It not only contains information relating to the ***properties of*** objects that have been encountered in the past (e.g. Round, red and slightly squishy) and to the history of ***interactions*** with them (e.g. Locating, picking up, putting in mouth and chewing), but also to the history of ***feelings*** relating to them (e.g. Childhood memories of picking tomatoes in the family garden with a parent or of

eating a tomato and basil salad on a specially memorable occasion). All these components of ***long-term memory*** influence both the way we feel about whatever it is we are looking at and what we notice about it. They ensure that each person experiences the visual world in ways that differ from the experiences of each and every other person.

An interesting issue relating to ***long-term memory*** arise from the above descriptions of the use of ***short-term visual memory*** and ***working memory*** when making line drawings from observation. It relates to the evidence that a great deal of ***knowledge*** is stored at least semi permanently in the memory of students as a result of drawing a specific scene or model several times in the manner advocated in the ***feeling based drawing lesson*** described in *"Drawing on Both Sides of the Brain", Chapters 9 and 10.*

When first asked to do this task, none of the students expected to do well at it. It seemed to them that their memory of what they had just drawn was much too vague, even though they had concentrated with high levels of attention on every relativity of length, angle and curvature and on the characteristic of every junction in the scene they had just depicted three times over. Accordingly, they were surprised to find that no sooner had they made the effort to recall a first relativity, they found that memories popped up not only to help them with that, but also to set them on the way to a second relativity. As if by magic, they found another dose of information surfacing from memory to help them with that too and, indeed, with each subsequent relativity they came across, until eventually a drawing had emerged that contained much the same amount of information as that to be found in the previous, visually guided ones, to which it bore a remarkable resemblance. Expressed in a slightly different way, what they found was that each newly confronted relationship provides ***context*** that enabled the recall of the information necessary for completing a subsequent one. In this process they were also helped because, as time passed and the emerging drawing grew in complexity, memories surfaced relating to an ever increasing number of cross-references that they had made when drawing from observation.

The interesting issue mentioned earlier is the nature of the memory the students were consulting. Was it ***working memory*** or ***long-term***

memory? It might help in deciding the answer to think about finding your way by car along a reasonably complex route that you have been along many times over many years. As you drive along everything seems familiar and you have no problem arriving at your destination, but could you have recalled all the details from memory before you started? And, to the extent that you can, would it not be the case that one detail provides the context which helps you onto the next? That is what I find.

And if instead of considering a visually guided journey, you think about ***ideas*** you have been discussing or have come across in a book. Do not these come back to you a bit at a time, with one thing leading onto another? Again, that is what I experience.

In both these cases, the process of recall is exactly like the process of drawing from memory after three drawings from observation, but the memory traces that support it have remained serviceable for a very long time.

So how does all this relate to ***skill*** development? One thing we know about skills is that they are long lasting, which means they require ***long-term memory***. We also know that, if they are not working to our satisfaction, they can be extremely difficult to adjust. We talk of "*bad habits*" and it is common knowledge how difficult they are to correct. The ability to draw from observation is clearly a ***skill*** and, like all skills, depends on guidance by instructions coming from ***long-term memory***. So what can these consist of since drawing from observation always means depicting unfamiliar concatenations of line-length, line-orientation and line-curvature relativities. The only answer that would enable ***accuracy*** is that the instructions relate to the only aspect of appearances that is familiar, namely the most basic building blocks of visual experience known as the ***visual primitives***. In terms of the analogy of driving a car, as long as we have a route map, all we need to know in order to get to our destination is how to negotiate corners, junctions and unexpected eventualities. As the map of the London Underground shows, the route map only needs to indicate the topology of the situation, based on significant stopping places and points of choice (the nodes). No accurate measure of either distance or direction is required. The same applies to driving a car. A topological

map in the head is all that is required to get to a desired destination. No need for accuracy, except when it comes to negotiating curves in the road or junctions. The same applies to drawing from observation. If the subject matter is a familiar object-type we have a ***long-term memory*** of the general layout (topological map)[25] which provides the context within which estimates of local ***relativities*** and ***curvatures*** can be made and attention can be given to the particularities of junctions. In all cases, use can be made of ***visual analytic strategies*** that have experience of dealing with relations between ***visual primitives***.

Minimal Cues: As explained below under "***Multimodal Processing***" and in *Chapter 4* of *"Drawing on Both Sides of the Brain"*, ***recognition*** is made possible by means of ***cross-correlations*** between numbers of extremely crude (highly generalised) classifications, each based on information coming from a ***different modality*** *of* ***independently varying*** information that in isolation would be far too ambiguous to be of much use in drawing from observation. It also explains the importance of ***context*** as a means of further disambiguation. A corollary of the efficacy of this powerful combination is that the ***eye/brain*** can often make sense from a minimal number of what otherwise would be highly ambiguous cues.

This state of affairs has its disadvantages and its advantages:

- An example of a disadvantage is that it enables us to ***make sense*** of ill observed, crudely produced drawings.
- An example of an advantage is that artists can explore the power of understatement. For instance, instead of feeling it necessary to record every nuance of shape and lightness when making a portrait, they can seek to capture the essence of the person being portrayed by exploiting the power of *minimal cues*. It is surprising how few marks are necessary to suggest the required combination of likeness and character. History shows that a massive degree of "*leaving out*" is a characteristic of the drawings that have provoked the most admiration, whether from "*Old Masters*" like Holbein, Dürer and Leonardo da Vinci or by ***Modernist Painters*** like Toulouse-Lautrec, Matisse and Picasso.

Mistakes. The word "***mistake***" carries with it the connotations of being undesirable and needing correction. In the context of the search for accuracy

25 Located in the hippocampus (see *Figure 16)*..

in drawings made from observation, this means (a) feeling bad about unintended differences between model and copy and (b) being motivated to reduce them. Unfortunately negative feelings can interfere with learning, particularly if they are amplified to the level of "*shame*" or if they give rise to a sense of "*inadequacy*". Such responses are particularly inappropriate because, ***since mistakes cannot be made on purpose***, identifying them is evidence of attention having been drawn to unpredictable differences between model and copy. Not only does this entail a small but significant ***expansion of awareness*** but it also provides the ***feedback*** that is necessary for ***learning***.

But ***mistakes*** are useful in another way. One that is particularly useful to teachers. The value of using the criterion of *"**literal accuracy***" when drawing from observation lies in its lack of ambiguity: Everyone can agree whether or not something is a ***mistake***, including both teachers and students. Drawing lessons, such as those described in *"Drawing on Both Sides of the Brain", Chapter 9-11* would not get very far if this were the not case.

In contrast, the question as to what is a "***mistake***" as applied to "***experienced reality***" is much more difficult to pin down, as, indeed, is any criteria other than ***accuracy***, particularly ones that relate to ***aesthetic values***. As we all know differences of opinion about what is "*good*" and what is "*bad*" can be extremely difficult to resolve.

Modernism in Painting. The word "***Modernism***" is used in connection with many different disciplines, including architecture, literature, music and painting. Despite having so much in common in terms of history and catalytic interdisciplinary discussion, it doesn't have quite the same meaning in any of these. It is for this reason that in both "*Drawing on Both Sides of the Brain*" and "*Painting with Light and Colour*" the phrases *"**Modernism in Painting**"* and *"**Modernist Painters**"* are regularly preferred to the words "*Modernism*" or "*Modernist*" alone.

Modernism in Painting can be linked with the interrelated ***industrial, scientific and social revolutions*** of the eighteenth and nineteenth centuries. All of these played a part in preparing the ground for:

- A questioning of the accepted rules of composition, laws of nature and values as taught in the Academies.
- A radical change in the focus of artists' interest from "***measured reality***"

to "***experienced reality***".

- A new emphasis on mark-making both as an expression of the individuality of the artist and as a way of emphasising the physicality of the picture surface.

All but one of the main pioneers of these changes met for discussion in the café Guerbois in Paris in the mid 1860s. They included Manet, Monet, Renoir and Cézanne. The one not present, but quite as important as the others, is Berthe Morisot. The next generation, which included Toulouse-Lautrec, Van Gogh, Emile Bernard, Gauguin and Seurat, took the new ideas important steps further.

It is these pioneers of radically new approaches to painting who are described in this series of books as the "***Early Modernist Painters***". They paved the way for even more radical departures in the hands of such artists as Bonnard, Matisse, Kandinsky, Mondrian, Malevitch, Picasso, Robert & Sonia Delaunay, Nolde and many more. By the early years of the twentieth century virtually all the different strands of the developments in painting up to the present day had been set on their way, including ***Conceptual Art*** and ***Postmodernism***.

For more on the subject of ***Modernism in Paintin***g see *Chapter 3* of *"Drawing on Both Sides of the Brain"* and *Chapter 6* of *"Fresh Perspectives on Creativity*".

Modernist Painters: In this book the ***Impressionists*** are often referred to as "***the first Modernist Painters***" for it was they that set the ***Modernist revolution in painting*** on its way. Later artists continued the process, notably, Toulouse-Lautrec, Seurat, Van Gogh, Gauguin, Cézanne, Matisse, Picasso, Bonnard, Kandinsky, Malevitch, Mondrian, Duchamp, the artists within the Dada and Surrealist movements, Pollock, Rothko, Kelly and many others, right up to the present day.

Monochromatic means made using only one colour, as are all drawings using, pencil, ink or charcoal whether alone or in combination.

Motion parallax: provides a ***viewing distance*** cue based on the fact that when we move towards objects we perceive those that are closer to us as moving faster than those that are further away.

Multimodal Processing is key to the way that the eye/brain achieves **"*recogni-***

tion". Its power resides in its use of ***cross-correlations*** between ***independently varying modalities of information***. The reason why these are crucial to ***recognition*** is that they can extract surprisingly concise classifications from highly ambiguous inputs, ones that when considered separately could relate to large numbers of different objects. The example used in "*Painting with Colour and Light*" is the combination of "*round*, "*red*" and "*slightly squishy*". In a survey, almost everyone who was asked what these three words brought to mind answered either "*a tomato*" (the overwhelming majority) or "*a red rubber ball*" (a small number). This is just one example of the working of a general principle which is used by the eye and the brain at all levels of description. For example:

- The power of *multimodal processing* is key to ***colour perception***. As is well known, colour processing starts in the ***fovea*** where are to be found three cone receptors-types, each of which is sensitive to a different but overlapping range of wavelengths of light: All are sensitive to all the wavelengths but peak in different places. Each on its own could only tell us of the presence of light and its intensity (very crude information) but in combination they can set the eye/brain on the way to being able to discriminate between a huge number of colours (very precise information).
- Multimodal processing is also key to the next stage of colour processing. The wavelength information provided by the retina travels up the optic nerve to the visual area at the back of the brain and, within this, to the processing area known as V4 (*Visual Area 4*). Here are located twenty-two different cell-types, each of which responds to one and only one of twenty-two different pigment colours (amongst which are included "black" and "white"). It is ***cross-correlations*** between these independently varying sources of information that provide our everyday experience of colour and enables us to discriminate precisely between millions of colours.
- There are two big differences between the response pattern of the V4 cells as compared with those of wavelength sensitive cells in the ***fovea***.
    1. The cells in V4 only respond to the specific colours within a narrow band of wavelengths, while those in the ***retina*** respond to light of all wavelengths.

2. Whereas varying the wavelength-combination of the light that is illuminating either a single uniformly coloured surface or an isolated patch of colour within a ***multicoloured display*** results in corresponding variations in the colour appearance, if the patch of colour is illuminated along with other colours in a ***multicoloured display*** (for an example, see the *Figure 17*) then the perceived colour will be the same no matter what the wavelength combination of the illuminating light, just so long as it contains some proportion, however small, of all the visible wavelengths. In other words, in this case, we experience "***colour constancy***".

An in-depth examination of the processes that lead to ***colour constancy*** reveals that these depend importantly on ***multimodal processing***. A first step in achieving it is the separation of ***surface-reflection*** from ***body-colour***. This necessitates computing the rate of change across surfaces and, thereby, distinguishing between sudden changes (edges of body colours), slow-varying ones (flat surfaces) and relatively faster ones (other surface forms). The information provided by this computation is much enhanced by making cross-correlations between inputs from different sizes of ***receptive field***, each of which provides an independently varying source of information.

- Differences in the output from different sizes of ***receptive-field*** also provide independently varying sources of information about the ***texture***. If the colour of a region of a surface is unvarying, then all ***receptive fields*** responding to it will provide the same information. If the surface is textured, then small receptive fields will provide different information to larger ones. Correlations between the different outputs from the various different sizes provide information about various different degrees of ***texture*** that can be vital for ***recognition***. It is another case of ***multimodal processing***.

These examples far from exhaust the influence of ***multimodal processing***. It occurs at every level of visual processing, even at the stage of ***lateral inhibition*** between the ***receptor cells*** in the retina, which divides the input into what is the ***same*** and what is ***different*** and, thereby, provides a pair of *independently varying modalities* of information.

Amongst the plethora of examples of ***multimodal processing*** that contrib-

utes to visual perception, the contribution of nonvisual ***sensory input systems*** is worth particular mention. The way these can support visual recognition systems was already implied in the "*round", "red"* and *"slightly squishy*" example, which requires both visual and ***touch*** sensors. ***Smell*** is another sensory modality that can complement visual sources of information in arriving at ***recognition***. For example, it could help the ***eye/brain*** to distinguish between a tomato and a red rubber ball.

Another key to the way that the eye/brain achieves **"*recognition***", namely "***context***", can be seen as an expression of the same principle of ***multimodal processing***. Its usefulness with respect to the eye/brain's ability to ***classify*** lies in its ability to ***cross-correlate*** outputs from the ***recognition systems*** with ***independently varying modalities*** of ***information***, stored in ***long-term memory***.

Multicoloured Display: See *Figure 21* in the *"Section on Diagrams".*

Near-Symmetries: While true ***symmetries*** (see the section on ***Symmetry*** and *Figure 17a* the *"Section on Diagrams"*) are extremely rare in the visual world, *near-symmetries* are abundant. They are more useful than true ***symmetries*** as aids to ***drawing from observation*** because comparisons between two similar but slightly different things draws attention to differences between them and, thereby, to aspects of appearances that would otherwise be overlooked.

Nearly every species of animal or plant can be described in terms of two halves that are approximately symmetrical around a central axis. Think of a tree, a leaf, a flower, a bird, a spider, a horse or a human being. Also approximately symmetrical are the parts of the body. For example, in the case of human beings: not only the two eyes, the two ears, the two shoulders, the two hands, etc., but also the two sides of the mouth, of the nose, of the head, of the body, etc.. Thus, for example comparisons between two shoulders will reveal:

- Which is the longer.
- Which slopes the most and by how much.
- Differences in the way they fit into the neck.
- Differences in curvatures.

An analogous list could be made using comparisons between different parts

of the contour of many manufactured objects, even ones which have actually ***symmetrical*** structures (for example, most chairs, tables, bowls, vases, windows, doors, lawn mowers, television sets, cars, etc.). The reason why actually ***symmetrical*** objects can be lumped in with ***near-symmetrical*** ones concerns the nature of ***visual perception*** and the difficulties put in the way of artists by the visual distortions it engenders, in particular, those aspects of it that give us ***linear perspective***. The knowledge that no two actually vertical or horizontal edges can both be viewed as vertical or horizontal at the same time and that no angle is at 90° should alert artists to the fact that very careful analysis is needed using a combination of ***comparative-looking*** and reference to ***context***.

Near symmetries are also abundant when an object is divided into sections of the kind produced by ***chunking***.*"Drawing on Both Sides of the Brain", Chapter 10* suggests nineteen ways of ***chunking*** the contour of the tree illustrated in *Figure 1* in *Chapter 9;* and *Figure 8* in *Chapter 11* even more ways of chunking the contour of the model, who first appears in *Figure 2* in *Chapter 6.* Both also show a number of angles at the junctions between the intersecting contours. Every one of these segments and every one of these angles can be compared with any of the others, whether on the same side or the opposite side of the tree trunk or model's body, thus providing a large number of ***near-symmetries***, whether they be of translation, rotation or reflection. As the drawing lesson described in *"Drawing on Both Sides of the Brain", Chapters 9 - 11* points out these can be used for making judgments of relative length, relative orientation and relative curvature. However, although any two chunked segments, whether near to or far from one another, can be treated as *near-symmetries*, some comparisons are likely to help artists more than others. The reason why is indicated by the findings of the *Stirling University* drawing experiments from which we learn that the more similar and the nearer in proximity the dimensions being compared, the more reliable assessments based on them are likely to be. They also show that, in general, the further from true ***symmetry*** they are, the less useful they are likely to be. This explains the importance of the "*near*" part of the compound "***near-symmetry***".

Negative Shapes: If we regard the contours of objects or of their images as "*positive*", then the space between them can be described as "*negative*". If this space is bounded on all sides, it can be described a "*negative shape*". Ac-

cordingly, the shape shaded grey in *Figure 3, Chapter 5,* which is defined by the wall top, the right hand side of the tree, the gutter and the side of the house can be described as a "*negative shape*". Similarly, in *Figure 8, Chapter 11,* the dark triangular shape between the body, the thigh and the arm of the model can be described as a "*negative shape*". See *Chapter 5* for the advantages and the important disadvantages of calling attention to *negative shapes* as a drawing aid. There it is argued that substituting the phrase "***enclosed shapes***" would remove the more profound of the disadvantages.

Neuron: A cell with neural processes that link it to other neurons. The result is the creation of ***neural networks***.

Neural networks: Networks of interconnecting neurons, necessary for the creation of ***neural system***s.

Nerve Fibres: provide the means by which neural information is transported from cell to cell and region to region around the body. All the nerve fibres throughout the body are interconnected and together constitute the ***nervous system***. Subdivisions of this mediate the ***neural processing*** that underpins all the different ***skills.*** These are know as "***neural systems***".

Neural Systems: The totality of the interconnected *nerve fibres* that enable ***visual perception*** can be described as the ***visual system***. Within this are subgroups of interconnected ***nerve fibres*** that can be described as ***visual sub-systems***. Between them these enable the conversion of patterns of light into the patterns of neural activity that set in motion the processes diagrammed in *Figure 1* , including ***recognition***, ***analytic-looking*** and the ***organisation of visually guided actions*** *(there presented as line and mark production).* Thus we talk of the ***recognition-system***, the ***analytic-looking system*** and the ***organisation-of-action system.*** In addition there are analogous systems that deal with all other aspects of ***sensory input*** and these can be described as ***sensory-input systems***.

In order to make use of the patterns of neural activity, the eye/brain has make computations based on them. These are known as ***neural computations***.

Neural Computations: The computations made by ***neural-systems*** in order to extract meaning from and make use of the patterns of information provided by the ***sensory input systems***.

Nonfigurative Art: See the sections on ***abstract art*** and the word "***figurative***" **.**

Nonobjective Art: See the sections on ***abstract art*** and the word "***figurative***".

Object-Type: Amongst the many amazing capacities of the ***eye/brain*** none is more astonishing than that of being able to ***recognise*** objects as being the same even though the patterns of light representing them on the retina are regularly different, often substantially so. Thus we can ***recognise*** the same object on different occasions, from different points of view and under different lightning conditions. More remarkably still it can ***recognise*** different examples of the same ***object-type*** even though it has a significantly different form. Thus we can recognise cups, chairs or dresses of a multitude of different designs, or trees, fields or dogs of a huge variety of shapes and sizes, etc.

Old brain: The brain took time to evolve. The latest part of it to take on its present form was given the Latin name of ***neocortex,*** which can be translated into English as "***new brain***". This fits like a hood around the well established, more primitive parts, which in the interests of simplification can be lumped together as the"*old brain*". These include the ***hippocampus***, the ***amygdala*** and the ***frontal eye fields***, all of which play a key role in ***drawing from observation*** and ***training the feel system***. For more on this subject see *Figures 14 and 15* and the captions beneath them.

Optic Nerve: The bundle of approximately one million nerve fibres that connects the ***retina*** to ***visual area 1***.

Organisation of actions and thoughts: The function of the brain is to organise appropriate responses to its environment, via the use of physical and mental skills. Theorising about how brains ***organise actions and thoughts*** needs to take this fundamental fact into account.

Luckily for theorists the prelude to all ***action-instructions*** is ***recognition*** and the ***context*** given by ongoing action-objectives enormously simplifies the requirements for ***recognising***. This is because it limits the information required by the brain at any one time to that which is relevant to the current context. One example used in these series of books is the glimpse of red that is sufficient to both identify and locate a familiar red dress in a familiar wardrobe. Putting it on requires experience of putting on dresses which provides a context of looking that again enormously simplifies the situation.

Painting: There are many different painted surfaces of different contents, shapes, sizes and locations that have been made over the millennia, for so many different reasons, in so many different ways, all of which can be referred to as

"***paintings***". To avoid confusion some simplification is required. Thus, for the purposes of this book the definition of a ***painting*** is:

> "*A collection of colours and textures on a flat, normally rectangular surface that can be interpreted as existing in an* ***illusory pictorial space***".

Historically this ***illusory space*** has usually had a figurative content to enhance its sense of pictorial depth, but in the 20th century artists have explored the depth-creating potential of nonfigurative arrangements of colours.

Later they set themselves to make paintings in which ***illusory pictorial space*** is eliminated, but felt that they had failed until the idea of painting the whole picture-surface with one colour emerged. Thus, the idea of Mondrian that his "*spiritual space*" or of Jackson Pollock that his "*space within the picture surface*" somehow eliminated ***illusion*** are examples of ***self-deception*** and fit the above definition of a panting. However, when all the surfaces of a picture support are painted with one colour, the result is arguably better defined as a "*sculpture*" (a three dimensional object presented as a work of art) and is so defined in these books. For more on this see the section on ***Postmodernism***.

Pantograph: Produces an enlarged version of an image by means of a simple system of connected levers. For a drawing of it see *Figure 17, Chapter 2*.

Paradigm Shift: A fundamental change in approach or underlying assumptions. In Western European art history two particularly important paradigm shifts stand out: The first by the artists of the ***Italian Renaissance*** in the fifteenth century and, the second, by the early ***Modernist Painters*** towards the end of the nineteenth century.

Pencil used as a Measuring Device: The caption for *Figure 5, Chapter 2* explains the use and abuse of this much used aid to measurement. In principle it should work, but in practice it can only too easily lead to significant errors. It is a treacherous friend.

P**ersonal Expression**: A basic premise of this series of books is that truly ***personal expression*** can be equated with ***creativity***. The argument put forward is that, since all human beings are unique in their combination of heredity and life experiences, manifestation of this uniqueness must be creative.

This conclusion can be enlarged upon with reference to:

1. *Figure 1* , which shows that the ***context and feeling based memory,*** which is built up over a lifetime, has a central role both in determining the ***analytic-looking*** strategies (that determine what we "see") and in the organisation of all ***action*** instructions (that determine what we do), including those that guide mark-making and line production.
2. The section on the ***Feel-System*** explains both that ***learning*** cannot happen without ***value judgments***, and that it is the ***feel-system*** which provide the ***criteria*** of "*good/right*" and "*bad/wrong*" upon which these are based.

Taken together, the importance of ***memory*** as built up over a lifetime and of the influence of the ***feel system*** in determining what it contains, mean that Each and every individual:

- Perceives, feels and thinks in unique ways.
- Has an advantage over all other individuals with respect to his or her personal capacity for ***seeing in new ways***, ***uniqueness of personal expression*** and potential for ***creativity***.
- Can extend his or her horizons by learning from the unique way of seeing of any other person.

Also that:

- What we learn from others will always be influenced and, therefore, modified by our own history of seeing and doing. It can never be a matter of cloning their experience or ideas into ours.

In these books it is assumed that ***personal expression*** and ***creativity*** are the natural fruit of these factors.

Perspective Frame, A device for helping artists to obtain an exact copy of subject matter seen through a grid of wires or strings attached to a frame. See the illustrations and caption for *Figure 2a* and *Figure 3, Chapter 2*. Notice the chin rest which is used to ensure the artists eye is kept in exactly the same viewing angle and viewing distance with respect to both the frame and the model being viewed through it. This stability is necessary if an accurate copy is to be made. This is why both a hand held grid and a ***pencil used as a measuring instrument*** can only too easily lead to serious distortion.

Photograph. See *Chapter 7*, which discusses the pros and cons of using photographic images as models when drawing from observation.

Photographic Accuracy: In this book ***photographic accuracy*** is taken to be equivalent to both ***literal accuracy*** and "***measured reality***.

Planning of Actions: *Figure 1* shows that in the planning of ***visually guided actions***, ***recognition*** precedes access to ***knowledge*** residing in the ***context and feeling based memory***. It also shows that this is the case whether the actions concern ***analytic-looking***, ***movement*** of body parts or ***mental manipulations***. To be more precise, information residing in patterns of light, having been processed by the retina, is passed up the optic nerve to the ***recognition-systems***. These transform the information using ***multimodal processing*** and pass the outcomes onto the ***context and feeling based memory***, which in its turn triggers previously learnt instructions relating to the task in hand.

One implication of this sequence of processing is that ***action instructions*** are never based directly on current input. They are always influenced by already existing ***habits*** or (as they are likely to be called when working well) ***skills***. This basic fact of the ***organisation of actions*** means that it is not only the ***analytic-looking*** aspects of ***drawing from observation*** that are subject to the constraints that produce "***intellectual realism***" in children's and adult's drawings. It is also the line output and mark making aspects.

If the plan of the artists is to achieve high levels of accuracy, they can do so in one of two ways, namely:

1. By using the strategic ***analytic-looking system on*** its own.
2. By combining the capacities of the ***analytic-looking system*** and the ***feel-system***, with a view to using the ***visual sensing*** of relativities of length, orientation and location as a means of training the ***feel-system*** to play a more direct role in eye/hand coordination.

With time and appropriate practice both can work perfectly well, but the combination of the two systems can have considerable advantages with respect to ***speed*** of output and ***personal expression***.

Pictorial Depth: The illusion of three dimensions in images made on flat surfaces.

Pictorial Dynamics occur (a) between elements on the picture surface whether they be colours, textures, marks or depicted objects and (b) between the picture surface as a physical presence and the contents of illusory pictorial-space.

Picture Support: The surface upon which a drawing or painting is made. In the European tradition this normally means a rectangular flat surface.

Picture-Surface: The fact that paintings are painted on flat surfaces means that the eye/brain is always confronted with cues that indicate the existence of this surface. There are a two main reasons why these have been important to artists. In general, they:

- Impede a sense of ***illusory pictorial space***. Accordingly, artists before the coming of the Impressionists, tried to remove all visible traces of the picture-surface.
- Create an ***ambiguity*** between the picture-surface and ***illusory pictorial space***.

Pictorial Elements: Everything visible that goes into making of a drawing or a painting.

Postmodernism. In 1968 there was an exhibition in the *Metropolitan Museum of Modern Art, New York* under the title of "*The Art of the Real*". It can be argued that this represented the logical end of the strand in ***Modernism in Painting*** in which artists explored the ***real surface/illusory space*** dynamic. Originally the importance of the ***real-surface*** to the early ***Modernist Painters*** was that awareness of it prevented what they regarded as the "*sin*" of deceiving the eye, in the way that they saw photographs as doing. The end came as a result of the idea emerging that, since ***illusory space*** is by definition "*illusory*", it too is a "*sinful*" deception to be avoided at all costs.

However, artists found that trying to eliminate ***illusory space*** from their paintings to be more difficult than they probably expected. After toying with various compromises, such as Mondrian's "*spiritual space*" and Jackson Pollock's "*space within the picture surface*", they concluded that the only painting that does not deceive is a stretched canvas with a uniformly painted surface and visible edges that ensured that it would be perceived as an object in its own right. Only then could it be called "*the art of the real*".

It can be argued that, transformed in this way, the painting became a sculpture. For those who believed that the only satisfactory outcome for ***Modernism in Painting*** was the elimination of illusion, the end of the road for the ***Modernist*** experiment had come. If these were to continue as artists, they would either have to take up sculpture (as did Ellsworth Kelly and many others) or find a new point of departure. For such artists, with their narrow

definition of ***Modernism in Painting***, the only future lay in some kind of ***Postmodernism***.

However, as the section on ***Modernism in Painting*** explains, the strand of ***Modernist experiment*** that had reached a cul-de-sac was far from being the only one. After all, it was only a minority of artists that had a problem with the ***real surface/illusory space illusion***. Others had continued to think that it was of the very essence of painting.

Preconscious Processing: *Figure 1* shows that both ***recognition*** and the ***planning of actions*** take place before the involvement of ***consciousness***. It also shows that both entail the use of ***memory***, which is by definition based on earlier processing unrelated to current input. Since this is the source of the actions involved in ***visual analysis***, it follows that ***analytic-looking*** is directed by information other than that which is currently coming onto the eyes. The same applies to ***mark-making***. In other words

- We "***know***" what it is we are looking at before we become aware of it.
- Our ***actions*** are not based on information currently coming from object we are looking at, but upon the knowledge-base we have relating to experiences of previous actions taken in relation to it.

Primary Light Sources: can be defined as light sources that generate their own energy. This distinguishes them from ***secondary light sources*** which can be defined as surfaces that require an external energy source to activate their light giving properties. Since translucent surfaces absorb some wavelengths from the wavelength-combination that enters them and scatter a high proportion of the remainder out the other side, it can be questioned whether these should be described as "***primary***" or a "***secondary***" light sources.

This question even applies to the light of the sun for, by the time this arrives at the eyes of viewers on the surface of the Earth, its light has been scattered about due to interactions with particles in the atmosphere. It is because the shorter wavelengths are scattered more than the longer ones that the atmosphere has the filtering effect that results in us perceiving the sun as yellowish in daytime. Does this make it a secondary light source?

Primitives of visual Perception (1): These can be defined as (a) the most basic aspect of visual processes or as (b) the most basic aspects of appearances. The first of these definitions is more difficult to explain than the second.

Primitives of visual Perception (2): The most basic aspect of visual process-

ing. The primitives of visual perception play such a fundamental role in all visual perception, even if only at a subconscious level, that many experts have assumed their access to be "*hard wired into the system*". However, this assumption is less easy to sustain if a more complex but less misleading way of describing the visual primitives is used. Thus, they might be characterised as "*those constantly recurring invariable aspects of appearances that are the inevitable products of the genetically determined structure of each new born baby's visual system as modified by its visual experience over the first days, months and years of life*". The only reason why such products can be described as "*hard wired*" is that, after a certain stage in their development, the genetically determined structures routinely enable a body of basic ***neural computations*** that are virtually the same for everybody.[26]

Of all the visual primitives the most basic and most difficult to envisage is the product of the very first stage of visual perception, namely the processes that separate objects from their backgrounds, leaving us with a basic and universal object-description. Attempts at getting a feeling for what the product of these might be like must start with the realisation that it has to take the form of generalisation that is vague enough to apply to all perceivable entities. My best try would be an "*inchoate lump*". However, the necessary formlessness of such an entity does not mean lack of importance. Quite the contrary. The fact that it requires a generalisation that applies to all objects, all object-parts ever come across and, indeed, all describable entities of any kind means it must be more ***familiar*** than any other generalisation. The uniqueness of this all-embracing ***familiarity*** is highly significant: Since ***familiarity*** can be equated with ***recognition***, it follows that the inchoate lump will set the ***eye/brain systems*** onto their course around the ***analytic-looking cycle*** as diagrammed in *Figure 1* . As indicated there, the next step is the access of ***context and feeling-based knowledge***. In this case, the ***knowledge*** in question will consist of instructions as to how to respond to inchoate lumps. These will enable the ***skilled actions*** that guide the ***analytic looking*** behaviour necessary for putting in place the building bocks for more elaborate interpretations.

26 That is to say they are sufficiently similar for scientists to treat them as common and hard wired properties of all ***visual systems of all people*** except those with specific defects such as the lack of a third wavelength sensitive cell in the ***fovea*** which causes "a*nomalous colour vision*", or the varying depth of the eyeball/ and the focussing characteristics of the cornea which causes ***longsightedness*** and ***shortsightedness***, with the former favouring the "*lazy eye"* syndrome (***amblyopia***).

Because the inchoate lump provides a description of all describable entities no matter what their surface-form, their contour-characteristics or their size, and because it is a generalisation that is capable of triggering the ***analytic looking cycle***, it also provides a means of ensuring that ***knowledge-guided looking*** will be possible in all contingencies.

The only other guide to looking available is ***attention-grabbing events*** occurring in the environment. These may occur for their own reasons, or they may be due to the movement of the body, head or eyeballs in relation to the environment. Thus: (a) movements of the body can cause objects to appear unexpectedly from behind other objects, to appear to expand or to change relationships between objects in unpredictable ways and attention grabbing ways, (b) movements of the head can also change relationships between objects in unpredictable ways and (c) rotations of the eyeball can create their own attention-grabbing events by making comparisons between similar but different aspects of appearances and draw attention to unpredictable differences between them. But in all cases, the fact of drawing attention to unpredictable aspects of appearances, no matter what they are, will set the ***knowledge-guided analytic looking system*** in motion and, thereby, access the ***visual primitives*** starting with the inchoate lump.

Primitives of visual Perception (2): **The most basic aspects of appearances.** For the practical purposes of the artist these can be equated with the irreducible characteristics of appearance such as edges, surfaces, colours, levels of lightness, properties of texture and the way these interact to give ***junctions***, ***in front/behind relations*** and ***relativities*** of ***length***, ***orientation***, ***lightness***, ***colour***, etc..

Proportion, Books on anatomy for artists are likely to have illustrations, such as those selected in *Chapter 2, Figures 14* and *15*, which show the proportions of the human body. Others are likely to tell us of ways in which parts of the body can be fitted into geometric shapes: *Chapter 2, Figure 16* shows an early example of this possibility.

A little thought leads to the conclusion that neither the proportions nor the geometric shapes should be taken as the basis for ***drawing from observation***. This is the only conclusion that can be drawn from the facts that:

- All the proportions shown represent ***averages***.
- Different books give different outcomes.

Clearly, if we are trying to find the uniqueness due to individual differences, averages will not do.

A similar conclusion can be reached on the grounds that it is rare to see a model whose proportions are not influenced by the squashings due to ***recession***. For example, a head might be tilted forward or backwards, a seated person might lean back and, from a front view, will have both a receding trunk and receding thighs, arms and hands are most frequently sloping towards or away from the viewer, etc.

However, as with all rules, those of ***proportion*** can be used profitably as ***guides to looking***. A questioning of whether a figure or shape abides by the *rules* followed in almost all cases by a search for ways in which it deviates from them, can be an enormous help in seeing the relativities under examination, in new and more accurate ways.

"**Reality**". When, in the late eighteenth and early nineteenth centuries, scientists of visual perception were accumulating irrefutable evidence that ***colour*** is not a property of surfaces but a construct of the brain and, moreover, that the same is true of experiences based on sensory input of any kind, the question as to what is "***reality***" was thrown open. The physicists provided answers in terms of atoms, molecules and electromagnetic forces which, though making sense, made everything more difficult to imagine. In contrast the ***perceptual scientists*** were more interested in how the brain is able to use information from the sensory systems to construct the seeming *reality* of the visual world we experience, namely the one that we see as stable images containing coloured surfaces and solid, seemingly measurable objects.

What the artists found was that they could think and work in terms of either of two different ***realities***, namely a "***measured reality***" and an "***experienced reality***". With the help of mirrors, tracing glasses, projected images and, even measuring by eye, the former gave few problems. ***Experienced reality*** was a different matter. The more the artists tried to pin it down the more it proved to be elusive. They found themselves faced with a veritable "*shifting sands of experience*".

More on these alternative "*realities"* can be found in the sections on "***measured reality***" and "***experienced reality***".

Receptive Fields are provided by numbers of interconnected ***cells*** that operate as a groups to provide averages of the inputs to them. Because they both vary

in size and overlap one another extensively, they provide ***independently varying*** sources of information about the same regions of the visual field (*Figure 10* illustrate variations in extent, cell density and overlapping of the ***receptive fields*** of three classes of ***amacrine cells*** found in the ***retina***). As a result, they are able to perform key functions in ***sensory processing***. Thus:

- The availability of different receptive field sizes enables us to experience properties of the ***contours*** both of objects and of ***cast shadows***. In particular, their softness or hardness is indicated by the range of responses of different receptive-field sizes.
- The availability of different receptive field sizes enables us to discriminate between different ***textures***. This is because each receptive field size can give different readings from the same region of a surface. For example, while all receptive field sizes will give the same average for a uniform surface, different ones will produce different averages relating to different parts of a nonuniform one.
- The smallest receptive fields provide information about the slow varying changes in the profile of ***reflected-light*** that tell us about ***surface-form*** (including the flatness of the ***picture-surface***) and about ***surface solidit***y.
- The ***largest receptive fields*** are required for providing information about ***ambient illumination*** and, as a result, for ***temporal colour constancy***.

Recognition (1): function. (See also *Chapter 4, "The Sketch*"). ***Recognition*** is the first step in all visual processing and takes place ***preconsciously***. It can apply to whole scenes, to separate objects, to object parts or to ***primitives of conscious visual perception***. Its role is to enable the visual system to key into appropriate parts of ***memory*** with a view to generating appropriate responses to the recognised item. The responses will comprise instructions that:

- Determine looking strategy (where to look).
- Body movements (what to do and with what parts of the body in order to achieve current objectives).
- Thought processes (what to consider next).

By implication they also determine what instructions are not given, the absence of which determine:

- What is overlooked.

- What is not done.
- What is not thought.

Accordingly, the outcome can be the absence of the instructions that would be required to enable a satisfactory completion of the task in hand. In which case, the only alternative is to fall back on instructions that have been generated for different purposes and which are, consequently, to a greater or lesser extent inappropriate with respect to current needs.

In the case of ***drawing from observation*** this means drawing from memory the parts of objects that have been overlooked. The result will be:

- For young children: drawings of the type that have been classified by developmental psychologists as "***intellectual realism***".
- For unskilled artists: drawings that have been described as "*naive adult*", but which could also be classified as "***intellectually realistic***".
- For skilled artists: drawings that might well deceive viewers, very possibly including the artists themselves, into thinking that they are representing "*what they see*", but which actually can only have been completed with the help of filling in a great deal of information that has been overlooked. If so, no matter how professional the appearance of the drawing, it will have failed to record a corresponding quantity of the unique features of the object or scene in question. Logically they should also be classified as "***intellectually realistic***".

Recognition (2): How the Brain Achieves it. As indicated in *Figure 1* , ***recognition*** occurs ***preconsciously***. Its purpose is not to provide information about the recognised objects, but to access information in ***long term memory*** with a view to initiating previously learnt ***action instructions***. One of the keys to its astonishing efficiency in this respect is that it can operate on the basis of ***minimal cues***, which it is able to do by making use of a combination of ***context*** and ***multimodal processing***. Elsewhere in this series of books the example is given of a woman looking in her wardrobe for her only red dress. The ***context*** is the familiar wardrobe and the knowledge that there is only one red dress in it. In this case all that is needed for recognition is a blur of red. After that come instructions as to how to take it out and put it on. Although these will probably include some looking instructions, these can be ***minimal*** for, in all likelihood, the dress could be put on without any further visual information.

One implication of this is that the fact of *recognition* having taken place, means that the blur of red would at this stage of eye/brain processing be the only visual information from the actual dress available for use. Clearly "*a blur of red*"would not be of much help for drawing the contours of the dress.

In the sections on "***memory***" and "***multimodal processing***" I mention my findings when I asked a large number of people "*What is the first object that comes into your mind when the question is asked 'what is round, red and slightly squishy'"*. Over 90% replied, "*a tomato*". The second most popular answer was "*a round, red, rubber ball*". Notice the question was asked without ***context*** that could have removed this ambiguity. Notice also that if the question had been "*What is the first object that comes into your mind when the question is asked 'what is round'*", the chances would be remote indeed of coming up with either a "*tomato*" or a "*red rubber ball*". The classification depends on the ***cross-correlation*** of all three modalities of information or as the mathematicians describe it, on ***multimodal processing***. Notice also that information about the context could remove all ambiguity. For example round red object in a vegetable shop would not be classified as a red rubber ball, except in very special circumstances.

The key to the efficiency of ***multimodal processing*** with respect to enabling recognition lies in the fact that the cross-correlations provide classifications on the basis of ***crude generalisations*** that are detached from dimensional and other contextual information. One huge advantage of being able to do so is that it goes a long way to solving the problem of recognising objects as being the ***same*** when they are actually ***different***. For example no two tomatoes are actually quite the same shape or colour, nor are they ever viewed either under quite the same viewing or lighting conditions. We can only classify them all as the same thing by not taking these differences into account.

From the point of view of artists this means that ***recognition*** provides absolutely no information that could be used in ***drawing from observation***. The only means of obtaining it is through the mediation of the ***analytic-looking system***. The function of ***recognition*** in the context of ***analytic-looking*** is to access instructions in ***long-term memory*** that will guide appropriate looking behaviour. It is not to provide information that could be represented.

Reflected-light (1) : It is common usage to refer to the combination of what in these books are termed "***body-colour"*** and "***reflected-light"*** as "***reflected-light***" (without a hyphen). It can be speculated that this oversimplification

can be explained at least partly on the grounds that the significance of its composite nature to the understanding of ***our experience of seeing*** is little recognised. It may also be explained partly because of the difficulty of finding an alternative way of referring to the combination. It is for this reason that these books, ***reflected-light*** (without a hyphen) is sometimes used for this purpose.

Reflected-Light (2): *Figure 18* shows white light, containing all the wavelengths, hitting a surface with which it interacts in one of two ways. Thus:

1. Either, it enters inside the surface where it interacts with the pigment particles it encounters such that it is bent by them to a greater or lesser extent. In effect, it is scattered around inside. In the process, some wavelength are absorbed and a proportion of the others are scattered back out again to produce the colour we perceive. This portion of the light is referred to as "***body-colour***" in these books.
2. Or it is reflected directly back from the surface, with the angle of incidence equalling the angle of reflection, in which case it is referred to as "***reflected-light***".

Perceptual scientists have shown how ***eye/brain*** systems disambiguate these two components and, thereby, make both separately available for use by ***recognition systems***. The ***reflected-light*** component provides information about ***surface solidit***y, ***surface-form***, ***in front/behind relations*** and ***ambient illumination***. The information relating to ***ambient illumination*** is also used in the computations that enable ***colour-constancy***. The potential usefulness to artists of having some idea of how the eye/brain achieves the separation is made clear both in the section on ***shadows, shading*** and ***highlights*** as well as in the companion volume on painting. Perhaps most importantly, it can help them if they wish to depict ***illusory pictorial-space***.

Relativities: The skill of ***drawing from observation*** is based on an assessment of ***relativities***, whether these be of shape, size, length, orientation, curvature, lightness, textural characteristics, etc.

A main difficulty faced by artists when attempting to judge these relativities is that human beings are not very good at measuring with their eyes. A major reason for this, what at first sight may seem to be a serious shortcoming, is the ***constancies*** of visual perception, one of the eye/brain's primary strategies for being able to classify different things as being the same. Since art-

ists are trying to assess the very differences in question, their minimization due to the operation of the ***constancies*** is bound to undermine attempts at making ***relativity judgements***.

Fortunately, our visual systems are relatively good at making ***same/different judgments*** between line lengths, shapes, lightnesses, colours, the whole or parts of objects, particularly when:

- The compared elements are situated close to one another.
- The differences between them are small.
- The time taken to make the necessary comparisons is kept short.
- There is no interference from optical illusions.

This is a large part of the reason why ***comparative looking*** is so important.

Another part is that comparisons reveal the "***mistakes***" which provide ***feedback*** and therefore ***learning opportunities***.

Representational: A representational painting or drawing is one that attempts to represent what we see in the visual world around us. The word "***representational***" can be interchanged with the word **"*figurative*"**.

Research at the University of Stirling: The research I did with colleagues at the *University of Stirling* provided a main sources of the originality of these books. It is described in detail in "*What Scientists can Learn from Artists*". Its objective was to study "*how artists use their eyes when drawing and painting*" and it started with the studies of ***drawing skills*** which amongst other things showed *why everyone has difficulty achieving accuracy in drawings made from observation*. Early results suggested extending the inquiry to deal with the more general subject of "*the use of visually acquired information"* with a focus on:

- The ***analytic-looking cycle***.
- The functional requirements for ***recognition***.
- The role of the various categories of ***memory*** in the control of actions, including both those that determine what is brought to attention and what overlooked and how artists make use of use visually-acquired information when drawing from observation.

Retina: *Figure 2* shows that the *retina* is located at the back of the eyeball and *Figures 3 -10* give some idea of the complexity of its structure. Its first

task is to convert patterns of light entering the eye into analogous patterns of neural signals. It does this through the mediation of a mosaic of approximately 150 million interconnected, ***light sensitive receptor cells***. Its next task is to start the process of organising the information contained in these neural signal patterns, with a view to enabling their classification, memorization and use by subsequently accessed visual systems. For this purpose:

- There are four main categories of ***receptor cell***. Although all of these respond to all wavelength of light, each responds differentially to different wavelength-combinations. Three of them are known as ***cone receptors*** and the fourth as ***rod receptors***.
- Every ***receptor cell-type*** is capable of responding differentially to different intensities of light.
- The ***rod receptors*** are distributed all over the retina except in the central fovea. The incoming light only arrives at them after penetrating intervening light absorbing layers of neural processes and blood vessels.
- The cone receptors are overwhelmingly situated in the ***fovea***, where the incoming light is not impeded by intervening light-absorbing neural processes and blood vessels.
- To compensate for the filtering effect of the impeding neural processes and blood vessels, the ***rod receptors*** are much more sensitive to light than the ***cone receptors***. The difference is such that both respond to similar levels of illumination.
- The output from every receptor cell is influenced by the activity of all the other cells to which it is connected by neural processes. This arrangement means that it is useful to think of the retina as a collection of overlapping receptive fields. These vary considerably in size (for example, see *Figure 10*) and for this reason provide a range of independently varying modalities of information that add to the power of ***multimodal processing***.

Revolutions: (See also Chapter 3, "**Modernism**"). The eighteenth and nineteenth centuries saw highly significant and interrelated developments in finance, industry, science, and culture. All three made extremely important contributions to the birth of ***Modernism in Painting***.

- ***Financial Revolution***: The Eighteenth century saw advances in banking and in particular merchant banking, which owed a lot to the eventual victory of the English over the Dutch in a series of seventeenth century naval battles and the not unconnected migration of the Dutch bankers to England which followed the accession of William of Orange as joint sovereign with Mary Stuart upon their marriage. The merchant bankers made a large part of the money which financed the ***Industrial Revolution*** as well as providing the banking skills required for its development.
- ***Industrial Revolution***: Due to a progressive globalization of trading relations with other countries, a related growth in merchant banking and various technological breakthroughs, there was a remarkable expansion of industrial activity during the latter part of the eighteenth century that continued and accelerated in the nineteenth century. The demands of the new industry proved to be a stimulus to scientific experiment and discovery and, in this way, played an important role in what came to be known as the ***scientific revolution***. The availability of wealth to wider sections of society, the increase in size and organisational complexity of conurbations and the rapid expansion of a moneyed middle class created conditions favourable for a ***cultural revolution***.
- ***Scientific Revolution***: It is difficult to give a date to the start of the scientific revolution, but it was well under way by the late seventeenth century. Its relevance to artists was by no means confined to the availability of new pigments developed by scientists for industrial use. Of more fundamental importance was the eighteenth century realisation that ***colour*** is made in the head and its repercussions in terms of the understanding of ***visual perception***. It was due to this breakthrough that the early ***Modernist Painters*** were able to benefit from knowledge of the ***constancies***, of ***simultaneous colour and lightness contrast*** and, more generally, of the difference between ***measured reality*** and ***experienced reality***.
- ***Cultural Revolution***: Amongst the consequences of the *Industrial revolution* was a significant expansion in the numbers of city and town dwelling middle classes and a considerable increase in the wealth available to them. One of the outcomes was that cultural interests and pursuits that, formerly, had only been at the disposal of a tiny section of the population, became available to many more people. Among these was a much wider interest in paintings and their purchase, a development that

led naturally enough to the opening of art galleries.

Amongst the increasingly wealthy middle classes were many that could not afford paintings produced by the time consuming ***academic method***. The result was niche markets for more rapidly produced paintings and for cheaply produced prints, including Japanese woodblock prints. Both were beneficial to the ***early Modernist Painters***.

- ***Modernism in Painting***: See *Chapter 3*, which provides an introduction to this subject. It describes a watershed in painting that was provoked by a number of factors including the arrival of the ***photograph*** (an easy way of producing images), the availability of the ***Japanese woodblock print*** (much appreciated despite breaking most of the ***rules*** set by the ***Academies***), and the new market for cheaper, more rapidly produced art works. The artists response to these developments was a root and branch questioning of the nature and value of their activity. The answers at which they arrived were much influenced by the revolution in the science of ***visual perception*** that highlighted differences between ***measured reality*** and ***experienced reality***.

Rodin: Auguste Rodin, the sculptor, was a pupil of Horace Lecoq Boisbaudran and a lifelong advocate of his teaching methods. *Figure 1* in *Chapter 6, "Contour Drawing or Clam*" which show him using ***CLAM*** and demonstrated rapid pick up of salient information based on a deep knowledge of human anatomy.

Rules: When the early ***Modernist Painters*** challenged the teaching of the ***Academies***, they were questioning the applicability of the ***laws*** of ***aerial and linear perspective*** to real scenes and the ***rules*** of composition developed by the Renaissance masters and their successors. While this distinction is kept to in these books, it should be pointed out that words "***rules***" and "***laws***" are sometimes used interchangeably.

The fact that the early ***Modernist Painters*** found (as anyone who followed their lead would have done) that the ***rules*** as taught in the Academies were too often contradicted by appearances, does not necessarily mean that they should be discarded. The process of ***checking out the validity of any rule***, ***whether right or wrong***, will provide information that might otherwise be overlooked. Questioning the rules that they came to scorn clearly helped Monet, Renoir, Cézanne and the others to see nature in new ways.

Likewise, the chapters on ***Linear Perspective*** *(14 - 19)*, are full of examples of using ***knowledge*** of that subject, not only to reveal its many limitations as a guide to ***drawing from observation*** but also to make clear its power as a tool for ***expanding visual awareness***.

The problem is not the ***rules***, but the fact that they are too often followed blindly. Obviously, if they are always ***wrong***, the result of following them without forethought will always be wrong. But even if they are always ***right*** (which is probably never the case) following them blindly will minimize the chances that any of the ***learning*** necessary for the growth of ***personal awareness*** and ***skill development*** will take place.

Saccades: *Figure 3* illustrates the fact that even when looking steadily at a target, the eyeball is constantly rotating either slowly or more suddenly. The relatively slow movements are called "***glides***" and the more rapid one "***saccade***s". Although it is the ***glides*** that provide the bulk of the information, the ***saccades*** perform the computationally useful task of averaging out the whole-field lightness information. They also enable momentary protection from the disruptive influence of the visual input to the retina, thus providing a vitally important interlude, during which uninterrupted higher level processing can take place.

Same/Different Judgements: Same/difference information provides the computational base for eye/brain processing at all levels. For example:

- In the ***retina***, where ***lateral inhibition*** between the input from neighbouring ***receptor cells*** produces two outputs that provide information as to what their inputs have in common and by how much they differ,
- In consciously initiated higher level procedures, such as those that result from ***comparisons*** used: to identify and correct ***mistakes*** in ***drawings from observation***, to find differences between ***near symmetries*** and to relate current input to information stored in ***memory***.

It is the use of the consciously initiated higher level procedures that provides the basis for learning to ***see in new ways***.

Saturated Colours: A fully saturated colour is often described as a "*pure*" colour. To explain what this means it can helps to refer to the ***theory of the three primaries***, which is based on the idea that all colours are mediated by three types of ***cone receptor*** in the ***retina*** at the back of the eye, each of which responds maximally to different parts of the spectrum of light. A col-

our is described as ***fully saturated*** if it activates no more than two cone receptor types. If a third cone receptor is activated then the colour is to some extent "***desaturated***" or made"*impure*" as a consequence. If all the cone receptors are activated equally then the colour can be characterised as "***maximally desaturated***" or as "***achromatic***".

Such definitions work well for mixtures of red, green and blue coloured lights (the additive primaries), but less well in practice for mixtures of red, yellow and blue pigment-colours (the subtractive primaries). The reason is not that the theory is wrong, but that what can erroneously be taken to be pure pigment colours, actually reflect a spread of wavelengths of light. Thus the reflection profile of a blue pigment may, as well as reflecting the short wavelengths associated with that colour, may include a proportion of longer wavelengths. If so, when it is mixed with a yellow, the colour that results will activate all three cone receptor-types, and, as a result produce a ***desaturated***, or what many might describe as a "*dirty*" green. Similarly, if a red is mixed with a yellow whose reflection profile includes a proportion of green light, the outcome will be a desaturated or by some called a "*dirty"* orange. Or, if a blue is mixed with a red whose reflection profile includes a proportion of orange light the outcome will be a desaturated or by some called dirty purple.

If the reflection profile of a pigment-colour is sufficiently broad that all three receptor-types are stimulated, then that colour is in effect ***desaturated***. Thus, "*Yellow Ochre*" is in effect a desaturated yellow, "*Indian Red*" is in effect a desaturated red and "*Oxide of Chromium Green*" is in effect a desaturated green.

Also, mixing any ***colour*** either with "*black*", "*white*" or "*grey*" will cause it to be "***desaturated***". Likewise, all mixtures containing any proportion of complementary colour or, indeed, of any colour or colours from the opposite side of the ***Colour Circle*** will be "***desaturated***".

A quite separate but extremely widespread and important cause of ***desaturation*** can be explained by reference to *Figure 19* . This illustrates the difference between ***body-colour*** and ***reflected-light*** by showing that, while the wavelength composition of the ***body-colour*** varies according to the proportion of the incident light that is absorbed by the pigment, the ***reflected-light*** remains the same as the incident light. Since this virtually always contains all the wavelengths, in as far as the reflected-light influ-

ences the appearance of a surface, its colour will be desaturated. What this means is that this kind of ***desaturation*** regularly effects the appearance of all surfaces except translucent ones, including all paintings.

Secondary Light Sources (1) can be defined as any visible surface or substance that uses energy from another light source or sources to activate its light emitting properties. The reason you can see them is that light coming from them is shining into your eyes. This is true whether they are ***opaque*** (in which case, as shown in *Figure 21* , the light is both reflected directly from its surface and scattered-back out from inside it) or ***translucent*** (in which case the light that enables us to see it has been scattered out on the opposite side to the light source). This distinguishes ***secondary light sources*** from ***primary light sources***, which generate their own energy.

Secondary Light Sources (2): *Figure 21* shows white light (a continuum containing all the wavelengths of the visible spectrum) hitting a surface and either (a) being reflected directly from it, with the angle of incidence equalling the angle of reflection, or (b) entering inside and interacting with pigment particles within the surface, with some of the wavelengths being absorbed and the remainder, having been scattered about inside, being scattered back out again. Accordingly, every illuminated opaque surface can be described as a light source comprising these two components. Since they require an input of energy from another light source, they are described as "***secondary light sources***".

However, the fact that they are "*secondary*" does not mean that they are any different from primary light sources in the sense that light is emitted from them. The only difference relates to their intensity. The fact that the light that is emitted from surfaces has passed through a process of absorption, means that it is always less intense that the illuminating light. The important point is that, once emitted, the ***secondary light sources*** do shine out and that they do so in all directions.

Since every part of every illuminated surface is a ***secondary light source***, it is safe to say that the number of them in almost any environment is bound to be extremely large: So large that even without the difficulties due to colour and lightness constancy, it would be futile for artists to try and work out the details of the influence of any one of them on appearances. All that can be said is that it can be extremely large, extremely

small or anything in between.

In summary, no matter what other factors are in play, the influence of ***secondary light sources***, will ensure the validity of two rules:

1. *"No two surfaces or regions of surfaces will ever reflect the same combination of wavelengths."*
2. *"The light coming from all surfaces will contain some proportions of all the wavelengths."*

Secondary Light Sources (3): In daylight conditions, whenever the sun is obscured by clouds, all visible surfaces are illuminated by ***secondary light sources***. Likewise, all the surfaces we see in indoor scenes, except those illuminated by artificial lighting, are made visible by ***secondary light sources*** that have shone in through windows or other apertures.

The fact that surfaces in such indoor scenes can appear to be bright and colourful shows that ***secondary light sources*** can combine to produce high levels of intensity. How they influence appearances is almost entirely a matter of context. To give an example: On a sunny day, when clouds are temporarily blocking out the direct light of the sun, a green grass lawn can seem to be a fairly fully ***saturated*** green. However, when the clouds pass over leaving all but the shadowed parts of the lawn bathed in sunlight, the shadowed parts themselves can look pretty black. Yet if we direct a light meter to the black-looking shadows, we would find little difference between the reading it gives, as compared with the one it gave when the sun was behind the clouds. Whether the light meter reading will show the light coming from the shadow to be less or more intense will depend on a number of factors, but it could be either.

Whichever is the case, seeing shadows as "*black*" reinforces a basic lesson that relates to all modalities of ***sensory perception***, namely that what we experience will always depend on the current ***context*** with its particular ***relativities***. Artists who fail to take this into account when ***drawing or painting from observation*** will make life more difficult for themselves. Whatever the nature of appearances, it is as well to remember that there is at least as much ***complexity*** in the light shining out from shadows as there is in any surface directly illuminated by the sun. This is one way of explaining why shadows in paintings should always be made from mixtures containing some proportion of colour from the opposite sides of the ***colour-circle***.

Seeing in New Ways depends on circumventing ***habits of looking***, an achievement that is only possible with the help of interactions with the environment. These can be due to attention-attracting happenings in the external world or generated by movements of the body or body-parts (including rotations of the eyeballs) in relation to the environment. All result in the eyes being presented with the ***same/difference*** information of one kind or another, and it is this that provides the main (if not the only) source of new information available for ***visual perception***.

Self-Expression is a phrase that is too often confused with ***Expressionism***, the name given to the movement which first surfaced in the art literature of the early twentieth century and was characterized by the use of distortion and exaggeration for emotional effect. The list of artists usually described as ***Expressionist*** includes Van Gogh, Munch, Soutine, The German Expressionists (Schmidt-Rottluff, Kirchner, Münter, etc.), Nolde, Kandinsky and the ***American Abstract Expressionists*** (Pollock, Motherwell, Kline, etc.).

However, not everybody has accepted this classification. For example, in 1908 Matisse famously wrote "*Expression for me does not reside in passions glowing in a human face or manifested by violent movement. The entire arrangement of the picture is expression*." For him there was no reason why artists should not wish to express more gentle feelings, for example, those associated with a calm, inner harmony. Certainly gently produced marks can be just as expressive as more vigorously made ones.

In this series of books a more fundamental point is being promoted, namely that the uniqueness of each individual ensures that each person both sees and feels differently about everything that is encountered in his or her experiential world, (including ideas) and that this difference is the engine of the ***creativity*** of the human race. It is the universality of individual uniqueness in this respect that ensures that each and every one of us has the capacity to open the eyes of others to aspects of appearances that they would otherwise overlook. We can rest assured that ***self-expression*** is the natural consequence of being true to oneself, however this manifests itself.

Sense of Surface: This phrase can apply to the experience of seeing both sur-

faces in the ***real world*** (including ***actual picture-surfaces***) and the surfaces of objects in ***illusory pictorial-space***. The conflict between the two has been a key preoccupation for artists whether they are trying to:

- Enhance the experience of illusory space by minimizing cues that indicate the ***actual picture-surface***.
- Eradicate the illusory pictorial space by emphasising the ***actual picture-surface***.
- Create a dynamic between the two.

The possibility of creating a dynamic between the ***actual picture surface*** and ***illusory pictorial-space*** was of central importance to the early ***Modernist Painters*** and has continued to be for large numbers of their successors.

Sensory Input: The eye is not the only source of input to the brain. In addition to the sensors in the ***retina*** there are sensors in the nose, the mouth, the ears, the entire surface of the body and in many locations within it. Thus we can sense: tastes, smells, sounds, gentle or forceful pressures on the skin, temperatures of surfaces we touch and pain in virtually every part of our body. All these sources of sensory input can influence the outcomes of the ***multi-modal processing*** that leads to ***recognition***. Also capable of influencing it are the sensors that monitor the internal state of the body.

Sensory Input Systems: The ***neural systems*** that compute information from the various sources of ***sensory input***.

Shadows, Shading and Highlights: The treatment in these books of these three phenomena, which are of such importance to artists who are interested in drawing or painting from observation, is determined by the discovery that the ***eye/brain*** is deceived into interpreting the rapid dips and increments in the ***reflected-light profile*** that cause these three phenomena to be perceived as "***body-colour***". The ***eye/brain system*** *c*omputing error that is responsible for this deception is key to the way we experience our visual world. If it did not occur ***cast shadows, shading*** and ***highlights*** would remain ***invisible*** to us.

To explain both how the deception comes about and its highly significant implications for artists, it will help to turn to *Figure 21* , which shows what happens when white light containing all the wavelengths of the visible spec-

trum strikes a uniformly pigmented surface. It shows how one part of the light enters into the surface, interacts with the pigment particles and any other particles inside, such that some of its wavelengths are absorbed and the remainder, having been scattered around inside, are scattered back out again into the eyes of viewers. It is this ***scattered-back light*** that eye/brain systems convert into perceptions of "***body colour***".

The remainder of the white light is reflected directly off the surface according to the rule that the angle of incidence equals the angle of reflection. The wavelength combination of this part of the light is the same as that of the incident white light. In other words, it contains the whole spectrum of wavelengths. It is this that is described in these books as "***reflected-light***".

If the uniformly pigmented surface is looked at in isolation, the eye/brain systems are unable to separate out these two components. What they perceive is a confusion of the two. However, if the pigmented surface is a separate region of colour situated in the context of other differently coloured regions, which together make up a ***multicoloured display*** (such as the illustration in *Figure 20* or any multicoloured painting) then the eye/brain systems can separate out the two components. This is very fortunate for if they were unable to achieve the separation, they would also be unable to:

1. Extract the information residing in the ***reflected-light***, which can tell them about ***surface-solidity, surface-form, in front/behind relations*** and ***ambient illumination***.
2. Make the most efficient use of ***colour as a classifying agent***, since classification depends on something being the same in two different locations and/or at two different times, and since the continued presence of the ***reflected-light*** component would mean that no two absorption/reflection profiles would ever fit this condition.

The reason why the ***eye/brain-systems*** need the context of ***multicoloured displays*** to separate out ***body-colour*** from ***reflected-light*** is that its computations depend on the fact that, while the ***profile of reflected-light*** is ***slow-varying*** across uniformly pigmented surfaces, the ***profile of the body-colour***, does not vary at all. No change in it until it crosses a boundary between two differently pigmented colours, at which point each of the three cone receptor-types that are independently monitoring its progress registers either a sudden increase or a sudden dip.

When evolutionary processes made it possible for eye/brain systems to separate out ***body-colour*** from ***surface-reflection***, a choice had to be made as to which of the two would remain visible, and it was ***body-colour*** that prevailed. However, an anomaly arose when it came to the classification of ***cast shadows***. The reason was that the neural algorithm that was evolved to enable the separation classifies sudden dips in the profile of the light scattered-back into the eyes from pigmented surfaces as the borders of ***body-colours***. The anomaly arises because, as shown in the lower part of *Figure 22 ,* ***cast shadows*** are also characterised by sudden dips in the profile of the ***reflected-light***. Since the algorithm used by the eye/brain systems has no way of distinguishing these from sudden dips at the borders between different body-colours, it erroneously classifies the borders of cast shadows as the borders of regions of body-colour.

An analogous classification error is made for ***highlights*** which are produced by sudden ***increments*** in the reflected-light profile. However, it is not only ***sudden dips*** and ***increments*** that lead to erroneous classification. The same mistake is made with respect to the more ***gradual descents and ascents*** in the reflected-light profile that we perceive as ***shading***. To explain how this comes about, it is necessary to define what the eye/brain systems compute as "*sudden change*". For this purpose it is useful to consider the roles of different ***receptive-field sizes*** in the eye/brain systems computations, for it turns out that each size responds differently to the same border. Thus, the smallest receptive fields are sensitive to smaller decreases and increments in the profile of the reflected-light than the larger receptive field sizes. However, this does not mean that the larger sizes are insensitive to such decreases and increments, rather that they are only sensitive to relatively larger ones, which abide by the rule that the larger the receptive-field, the larger the decrease or increment necessary for an edge to be detected.

There are four outcomes from this situation that are of great importance to artists when drawing or painting from observation. All are worth being kept in mind when painting the regions of ***shadow*** and ***shading*** that are erroneously being perceived as regions of ***body-colour***:

1. Since ***reflected-light*** comprises a continuum of all the wavelengths of the visible spectrum at approximately equal intensities, the ***false body-colour*** produced by the sudden and substantial dip in its profile at the edges of ***cast shadows*** will be the outcome of a substantial sub-

traction across an analogous continuum. As shown in the lower part of *Figure 22* , once this has taken place, the reflected-light profile will be slow-varying in the same way as it would on the same surface in the absence of the cast shadow (as shown in the upper part of *Figure 22*). At the other edge of the cast shadow, a sudden increment in the reflected-light will occur that will be of approximately the size as the sudden dip at the other border. The only difference will be due to the invisible slow-varying proportion. Traditionally (before the arrival of the Modernist Painters) artists added ***black*** or ***grey*** to the colour that they were using for the surface in question to represent this sudden loss of intensity across the shaded part of the surface. They used ***black*** if the dip in the reflected-light at the border of the cast shadow was large and they used ***grey*** if the dip was smaller. In doing so they were simply painting what their eyes were telling them, since the residual reflected-light profile was ***invisible***. Also influencing their perception was the degree of fuzziness of the edges according to the rule, *the sharper the edge, the darker the shadow appears to be*. The problem this poses to artists is that the relative hardness or softness of the edge, though having a great influence on appearances, has no influence on the intensity of the light coming from the shaded region it borders. Thus the same intensity of light coming into the eyes from the main body of a cast shadow will be perceived differently if the edge is sharp or fuzzy. So what degree of lightness should be chosen for the colour used to depict it?

Whether a cast shadow is perceived as tending towards ***black*** or ***grey***, the colour we see it as being will be influenced by the ***body-colour*** of the surface upon which it falls. For example, when it falls on a green surface, our perception of the shadow will always have a green component, even when it is so deeply black that this greenness is difficult to detect.

2. It is well known that the perceived degree of the blackness of cast shadows depends to some extent on the difference in intensity at the border between them and adjacent regions of colour (the effect known as ***simultaneous lightness contrast***). It is less well known that it also depends on the number of receptive-field sizes influencing the eye/brain's computations. Thus, the familiar rule, which states that "*the sharper the edge of a shadow, the darker it will appear to be*", can be

supplemented or replaced by a second rule based on the realisation that:

- The smallest sizes of receptive-field compute the smallest visible increments in the reflected-light plus all larger visible increments.
- The medium sizes of receptive-field join with the smallest sizes of receptive-field to compute medium sized visible increments in the reflected-light plus all larger visible increments.
- The largest sized receptive fields join with all the other sizes to compute the largest sized visible increments.

Since the sharpest edges create the darkest cast shadows and since it is only these that activate all receptive-field sizes, the second rule follows: "*The larger the number of different receptive field sizes involved in the detection of the edge, the darker the shadow will be perceived as being*".

3. Although computations based on the smallest size of receptive-field are sensitive to the smallest visible increments, there are yet smaller increments to which they are not sensitive. This ***invisible,*** slow-varying component is important for our ability to make sense of the visual world because it provides a ***sense of surface solidity***. There are many reasons why artists have an interest in finding ways to represent it in their paintings, not least in their depiction of ***cast shadows***. If they were to be unable to do so, the ***blacks*** they used to represent them in their paintings would be perceived as ***surfaceless holes*** of the kind that the young ***Modernist Painters*** saw in the productions of many of their predecessors and sought to avoid at all costs. Their abhorrence of such holes explains why they were so excited to find that Seurat's method of what he called "*painting with light*" solved the ***surfaceless hole problem***. It is also why they were even more delighted when they discovered that the same outcome could be much more easily achieved by following the rule that "*all blacks used to represent shadows in paintings should be mixtures containing some proportion, however small, of complementary colour*". For more on the more generalised version of this rule see the section on *"**The axioms of Marian Bohusz-Szyszko***".
4. The fact that shadows, shading and highlights are perceived as body

colour due to a computing error made by eye/brain systems that depend for their functioning on taking whole-field relations into account, means that the way we perceive them is always ***context-dependent***. Accordingly artists should never look at the colour/lightness of shadows and highlights in ***isolation***, rather they should look at them ***comparatively***. When painting them, they would do well to keep in mind that the visual systems involved will cause each shadow to be perceived as darker than its ***measured reality***. For example if, when painting the shadows and shading on the face of a dark haired woman, you compare them with the darkest parts of the hair (or of any other darker colours in the context), you will almost certainly find that they now appear as being much lighter than you originally supposed. The inverse occurs when looking at highlights which invariably look lighter than a light meter would predict. Indeed, a general rule worth keeping in mind is that "*shadows should always be depicted as being lighter than they appear to be and highlights, as being darker*". There may be exceptions but if the rule is applied to the analysis of scenes, these will reveal themselves (see "*Rules*").

Shortsightedness (*myopia):* **A person who is** *shortsighted* is one for whom near objects are in focus and further objects are blurred. The cause is a combination of the curvature of the cornea and the distance between the front and the back of the eyeball. In the case of short sighted people this distance is relatively long. This means that when they are painting or drawing, their work will be in focus but what they are looking at will not be. Some artists might see this state of affairs as having advantages for those interested in eschewing detail in favour of more general impressions. It might also explain why Monet, Renoir and Cézanne all expressed horror at the idea of wearing spectacles.

Sight-Size corresponds to the size of an image traced on glass, situated at the same distance as that between the eyes and the actual drawing surface. It is easier to compare model and copy at this size because one is comparing like with like.

Sightedness: Eyes vary in their ability to focus on objects. The main variable is the shape of the eyeball which determines the distance between lenses and the retina. The short sighted eyeball is longer from front to back and the long sighted one shorter. Eyeballs of intermediate length provide intermediate

results, including what can be described as "*normal vision*".

- *Short-sightedness* or *myopia* means that near objects are in focus and further objects are not.
- *Long sightedness* or *hyperopia* means far objects are in focus and near objects are not.

A factor which effects sightedness is ageing. varifocal illustrates that, although the main lens of the eye is its front surface (the cornea), it also contains another lens (known as the "***lens***"). This is made of a flexible material such that its shape can be altered by means of a muscle (known as "***ciliary***" muscle) that enables the eye to fine tune the clarity of images. The material of the inner lens becomes less flexible with age, which is why so many people whose vision is excellent when young need to wear spectacles later in life. The value of spectacles is that they can be used to take over the function of the inner lens when it becomes inflexible. The problem is that, unless they are bifocal or varifocal, they only work for one distance: For example, they can help long-sighted people to read but only at the price of blurring their long distance vision.

Spectacles with bifocal or varifocal lenses allow people to see both near and far objects clearly. However, they do so at the expense of distorting the relation between focussed, fovea-based vision and ***peripheral vision***. Although this makes no difference to what people wearing varifocal spectacles can see consciously, it may interfere significantly with ***information pickup*** when ***drawing from observation***, since preconscious peripheral vision is part of the process that paves the way for conscious ***analytic-looking.***

Sketch: The sketch was the second stage in the ***academic method*** of making paintings. It came after the "***idea***" and before the "***studies***", "***ébauche***", the "***image transfer***" and the "***final painting***" for which all these stages had been a preparation. Its purpose was to explore ways of fitting the "***idea***" into a pictorial ***composition***. Over time, the ***Academies*** developed ***rules*** for ***composition***, based on traditions evolved by the "***Old Masters***", and it was in terms of these that academically trained artists sought to implement the *idea*.

When the ***Modernist Painters*** came to question the rules laid down by the academies, they turned to the exploration of other possibilities, but always in the context of a guiding "***idea***". For them the ***sketch*** could be described

as a way of thinking about implementing an ***idea***.

Whatever the rules guiding the sketch there is no need for accuracy or even realism. Indeed the best way of achieving its objective is by means of tentative explorations and rough and ready ***mark making***. For more on this subject see *Chapter 5, The Sketch.*

Study: The study was the third stage in the academic method of making paintings. It came after the "***idea***", and the "***sketches***" and before the "***ébauche***", the "***image transfer***" and the "***final painting***" for which all these stages had been a preparation. Its purpose was to find information relating to the particularities of the appearance of objects to be included in the *final painting*. It involves *using drawing as a tool for finding out about what is being looked at*. It is what the practical books in this series are all about: A title for the series might have been "*How to Make Studies*".

Squaring Up: Grids of lines that divide the surface into small squares can be drawn on photographs or drawings, which can then be copied, square by square onto a ***picture surface,*** on which is drawn an analogous grid. This helps copying accuracy because each of the subdividing squares not only provide vertical and horizontal reference points but also encourage looking at the parts in terms of abstract relations. For examples and more explanation see *Figure 4, Chapter 2* and *Figure 1, Chapter 7.*

Stereopsis: By correlating the slightly different images arriving at the different eyes, the ***eye/brain:***

- Extracts information about ***surface-form***,
- Separates objects from their ***context***
- Produces an experience of three dimensional space.

Since the key to accuracy in drawing is keeping in touch with ***context***, using two eyes while ***drawing from observation*** is a bad idea. In this respect those who have never developed ***stereopsis*** (a syndrome known as ***amblyopia***) have an advantage. Since stereopsis also tells about ***pictures surfaces***, it can inhibit experiences of ***illusory pictorial-space***.

Stroke Direction preference: There is good evidence to show that most people find it easier to draw lines in some directions rather than others. Since the instructions given in the *feeling based drawing lesson* (*Chapters 9-11*) determine the starting point of all lines drawn, it follows that a proportion of

them will have to be drawn in less easy directions. A consequence of this is that following the instructions can lead to line-production difficulties. The remainder of this section explains the reasons for this ***stroke direction preference*** and what can be done to overcome the problems it causes.

While at Cambridge giving a talk to the *Applied Psychology Unit,* I had the good fortune to meet the Australian researcher Peter van Sommers. He was working on his book *Drawing and Cognition*[27] which was to become by far the best work available on the subject, and I was soon to discover that he had a great deal of interest to say about the psychology of drawing. My debt to him is inestimable. Amongst his experiments were a number that focused on the subject of ***stroke direction preferences***. When observing and analysing the behaviour of people in the process of making drawings, Peter had noticed that they often arranged matters so as to be able to draw lines in some particular orientations rather than others. For example, they might either swivel their paper or twist their bodies in order to convert a sloping line into a horizontal one. Indeed, he found that movements of the paper and/or the body with a view to easing stroke production are very common indeed. His video-tape records of line-production behaviour confirmed and elaborated upon these informal observations. Peter also observed consistencies in the hand, wrist and arm positions adopted for drawing lines of particular orientations. In this way, he came to the idea that mechanical constraints might be responsible for the different degrees of difficulty experienced by people drawing lines of different combinations of direction and orientation. To check this out he came up with a series of experiments. As diagrammed in *Figure 28* , the results confirmed the existence of ***stroke direction preference***.

None of this would matter if it were not for the many negative consequences allowing ***stroke-direction preferences*** to dominate drawing practice. Most notably, it will frequently necessitate the drawing instrument being lifted off the paper. The combination of doing this and then looking for an easier stroke direction option is a bad idea for at least four reasons:

1. Movements of the head and/or the paper between different acts of line production are bound to interfere with the artists feel for *whole-field spatial relations,* including those necessary for drawing *angles*.

27 Peter van Sommers, 1984, *"Drawing and Cognition"*, Cambridge University Press, Cambridge

2. *Short-term visual-memory* is disrupted by the mental effort required each time it is necessary to relocate the end points of lines that have already been drawn. As a consequence the relativities being kept in mind are degraded or lost, with potentially catastrophic consequences.
3. Repeated acts of relocation interfere with the *flow of line production* and, therefore, the speed and/or directness of drawing actions.
4. The *training of the feel-system* is impeded because the opportunities for getting a feel for either the angles or the relativities of line lengths being drawn are significantly reduced.

For these four reasons, it is important to resist allowing ***stroke-direction preferences*** to dominate drawing practice.

One way of achieving this objective is to stick firmly to the method of line-production recommended for the *feeling based drawing lesson* described in *Chapters 9-11*. By determining where every line must start, the instructions given dictate the stroke-direction. At first, due to the mechanical constraints on arm movement described by Peter van Sommers, this may cause some awkwardness. However, even though patience and determination may be needed in the early stages, all who follow the method will find that with practice the awkwardness will naturally diminish, if not fall away entirely. One of the main reasons why human species has survived and prospered over the millennia is its capacity for adaptability.

Superior Colliculus: is a part of the ***old brain*** that is implicated in the control of ***eye-movements***. For more on its importance in ***drawing from observation*** see the captions under *Figure 15* .

Surface-Form (1): Surfaces can have many forms. For example they can be flat, curved or undulating. A problem arises because paintings and drawings are made on flat surfaces, while the objects depicted in them are typically situated at varying distances in front of and behind one another. The issue of creating a convincing ***illusory pictorial-space*** despite the flatness of the picture-surface has provided three of the recurring challenges of painting:

1. How to create the illusion of surface-form.
2. How to create the illusion of three-dimensionality.
3. How to exploit the visual tensions due to the incompatibility between perceptions of the flatness of the picture surface and the spatial di-

mension implied by ***illusory pictorial-space***.

Traditionally the first has been dealt with by means of ***shading***, the second by means various ***cognitive cues***, ***aerial perspective*** and ***whole-field colour relations*** and the third in a variety of ways that have played a key role in the history of ***Modernism in Painting***. Thus, before the ***Modernist Painters*** embarked upon their revolution, artists sought to enhance the sense of pictorial-space by minimizing and, as far as possible removing, surface-perception cues entirely. After their arrival on the scene, ***pictorial dynamics*** of the kind produced by the incompatibility of perceptions of (a) the flatness of the actual picture surface and (b) the three-dimensionality of illusory pictorial-space became a major interest.

Surface-Form (2): Since the role of the ***eye/brain systems*** that mediate ***visual perception*** is first to ***make sense of*** and then to ***make use of*** objects, it is evidently very important to be able both to ***characterise*** surfaces and to ***locate*** them. It is also of prime importance to be able do so under as many as possible viewing condition contingencies. Accordingly, it is no surprise to find that several ***eye/brain systems*** have evolved to meet these needs. These can be divided into two categories:

1. Those that can inform about spatial relationships and the surface-forms in the real world but not in illusory pictorial-space. The two most powerful of these systems use ***movement-based cues*** and ***stereopsis*** respectively. Others use ***focus***-based information. Although less powerful these have the advantage of being able to provide information to stationary people who for some reason have one eye inoperative.
2. Those that are able not only to provide information about spatial relationships and surface-forms in the real world, but also to be deceived into providing it in the context of illusory pictorial-space.

In the second category are those that:

- Make use of a variety of ***cognitive cues***,
- Separate out ***surface-reflection*** from ***body-colour*** and use the information contained in it to support perceptions of ***surface-solidity, surface-form, ambient-illumination*** and ***in front/behind relation***s.

Surface-Solidity: The main difference between surfaces perceived by means of

reflected-light and those perceived by means of ***transmitted-light*** is that the former provide viewers with a sense of ***surface-solidarity*** while the latter does not. When ***eye/brain systems*** separate out ***surface-reflection*** from ***body-colour***, they use the information in it to find out about ***surface-form***, which they do by computing changes in the intensity of the reflected-light that occur across surfaces. A key feature of the algorithmic basis of this process is that, while the more rapid changes underpin our ability to see ***edges*** of surfaces, edges of ***body-colours*** and the characteristics of ***surface forms***, the slowest varying modulations, remain ***invisible***. However, although we are not conscious of them in the same way, they provide a vitally important sense of both ***surface-solidity*** and ***spatial location***. The nature of this invisible aspect of visual perception can be deduced by reference to situations in which the slow-varying modulations in the profile of reflected-light are absent. Examples include sources of ***transmitted light***, such as the colours of stain glass windows and the green of a field of newly sprouting leaves of young corn seen against the light. They also include the blue of the sky and the black of seemingly bottomless holes. These not only provide no ***sense of surface*** and no ***sense of location*** but also, as a consequence, what could be described as a magical sense of detachment from all that is around.

This magical sense of freedom from context can be given to paintings by deceiving the ***surface-sensing visual system*** into experiencing the ***picture-surface*** as surfaceless and its contents as having the qualities with which artists can imbue illusory pictorial-space. A large part of "*Painting with Light and Colour*" is given over to explaining how. But a simple recipe to follow is that all colours on the picture surface should be different to all other colours and that the paint used to produce them should always be a mixture containing colours from opposite sides of the ***colour circle*** (see the "***Axioms of Marian Bohusz-Szyszko***").

For monochromatic shaded drawings the recipe has to be modified. The rule of non-repetition remains, but the range of subtle differences necessary to achieve this goal has to be supplied by variations in lightness and texture alone.

Symmetry is a mathematical concept. Two objects are said to be symmetrical to one another if their shape and dimensions exactly correspond. As illustrated in *Diagram 17a*, there are three types of symmetry, namely ***symmetry of translation, symmetry of rotation*** and ***symmetry of reflection***. Thus if an

exact copy of a shape is made in another place, whether in the same orientation (translated) or in a different one (rotated), the two shapes are said to be symmetrical. Also said to be symmetrical are any shape and its mirror image. Accordingly if a circle or a square is divided exactly in half by a vertical line, the two halves are said to be symmetrical with one another. In this case, the dividing line is termed the "***axis of symmetry***".

Pure symmetries never occur in nature and rarely in perceptions of man-made objects. In the case of man made objects, this could be because of intended or unintended variations in shape, due to the way they have been made or modified, but it is more regularly because of variations in appearance due to the distortions that are described by the ***laws of linear perspective***. For example, as a result of ***shape constancy,*** the elliptical seeming tops of spherical objects are never actually elliptical according to ***measured reality:*** The nearer side takes up more space than the further side.

For these reasons our visual systems are rarely confronted by true symmetries. Luckily, "***near symmetries***" are much more useful to artists when drawing from observation, since they provide the opportunity for making the ***same/difference judgements*** that draw attention to aspects of appearance that would otherwise be overlooked.

In the rare cases when an object provides the eye of the observer with true symmetries, as in the case of the sides of the mug and the bowl illustrated in Figure 17c, its relation with its context will invariably provide a rich source o***f near-symmetries***. There are two reasons why this is the case for virtually all objects:

1. Surfaces which vary with lighting conditions. Thus, if in *Figure 17d,* we compare the parts of the surface that abut the edges (*B1 & B2* and *D1 & D2*) of the mug and the bowl, our attention will be drawn to the differences in the shading. The most obvious of these us that both mug and bowl are darker on the left than on the right.
2. Backgrounds to objects almost invariably vary in many ways and, accordingly, so do the relationship between them and the different edges of objects. Thus, in *Figure 17d,* we find multiple differences between the backgrounds that abut the opposite sides of the objects, mostly due to the variations within the reflections but also to the layout of the gaps between the tiles..

Symmetry of Rotation occurs when a shape is rotated relative to itself without being changed.

Symmetry of Translation occurs when a shape is displaced relative to itself without changing its orientation.

Symmetry of Reflection occurs when a shape forms a mirror image relative to itself.

The Theory of Intellectual Realism: was proposed by Luquet in the 1930s and supported by Piaget. It is encapsulated in the aphorism that "*children draw what they know while adults draw what they see*". Research has shown what *Figure 1* illustrates, namely that the only option is to "*draw what you know*". If your aim is limited to making realistic looking depictions and if you have sufficient knowledge of objects stored in your ***long-term memory***, (as do many book illustrators) you may be able achieve what you want without reference to the external world. But if your aim is to capture and learn from the invariable ***uniqueness of appearances***, the only option is to engage your ***visual analytic skills*** in the interests of breaking up the chosen subject-matter into simple units that provide the closest possible fit between ***knowledge*** and ***appearance***, namely, relative lengths, relative distances between features, relative orientations and simple curvatures. Even so there is no escape from "*drawing what you know*" and, accordingly from, "***intellectual realism***".

Thought as Action: *Figure 1* shows how ***recognition*** acts as a staging post to the access of the ***context and feeling-based*** information residing in ***long-term memory*** that is required for the guidance of appropriate reactions. Amongst these are the actions required to produce the vocalizations we know as "speech" and the sub-vocalizations we use when rehearsing words or sentences in our heads, a process that most people would describe as "*thinking*". Indeed, it has been suggested that sub-vocalizations are necessary for ***thought*** or, at least, that they play a part in the evolution of the ***skill of thinking***. For these reasons it is appropriate and useful to think of the ***organisation of thought*** as a subdivision of the ***organisation of action***.

Tone is the word used in British English to mean the same thing as the word "***value***" in American English. Both mean the same thing as the word "***lightness***" as used by scientists of visual perception. In this series of books the scientific usage is preferred. Thus, in them, a tonal or value drawing is one that explores lightness relativities.

Tracing normally involves a sheet of semi transparent paper or glass through which an image can be seen and its outlines followed with a drawing instrument. The only skill required is the ability to track along a line a bit at a time. A near perfect copy of the image can be achieved simply by doing this. No knowledge of the ***shape*** or ***object-type*** being traced is necessary at any stage of the process. No task could be more banal or less creative. However, the fact that we can do it shows a high level of hand/eye coordination and manual dexterity.

Tracing-Glass. A piece of glass through which a view can be seen and on which it can be traced. Its use was advocated by Leonardo da Vinci as a way of achieving an accurate renderings of objects in nature. The glass is held *stationary*, with its surface at a comfortable drawing distance from the artist who must *close one eye* and hold the other *immobile*. If these conditions are fulfilled, tracing on the ***tracing-glass*** is essentially equivalent to normal tracing and will achieve equivalent levels of accuracy. Like tracing, no knowledge relating to the shape of object-type being traced is necessary at any stage of the process. As with normal tracing no task could be more banal or less creative.

Traditional Artistic Practices were developed by the ***old masters*** and sanctioned by the ***academies*** on the evidence of their proven efficacy. They can be divided into three categories:

1. ***Devices*** that enable accuracy in the copying of objects. These include The ***tracing glass***, the ***perspective frame***, the ***camera obscura*** and the ***photograph***. All work because they provide ways of reducing the task of achieving accuracy to a mechanical level. Accordingly as a method they are quite as banal and lacking in creativity as is tracing images on tracing paper.

2. ***Laws*** representing regularities of appearance, also referred to as the "***laws of nature***". By far the most important of these were ***linear*** and ***aerial*** perspective. Both have the shortcoming that regularisation by definition rides roughshod over the individual differences that give the uniqueness of appearances that artists seek to capture when ***drawing from observation***. As explained in the chapters on the subject in "*Drawing with Both Sides of the Brain*", ***linear perspective*** has the disadvantage that it is almost invariably impossible to fit actual scenes into its constructions and, as explained in "*Painting with Light and*

Colour", the rules of ***aerial perspective*** suffer from representing only one of many different variables that can influence the appearance of distant objects.

3. ***Rules of composition***. The problem with these was that the fact that rules had worked in the past did not mean that there were other ones that would work better in different contexts (see, "***Composition***").

Trail and Error: a phrase that characterises one of the main ways in which people learn to draw and paint. Nothing happens if you don't *try* and checking for ***errors*** involves making ***comparisons*** between model and copy that automatically ***draw attention*** to differences between them. Since ***errors*** are unpredictable, this forces looking at aspects of appearances that would otherwise be overlooked and, thereby enables ***seeing in new ways***.

The phrase "***trial and error***" has much the same meaning to the word ***cybernetics***, coined by Norbert Wiener to describe the basis of machine-learning, which he saw as based on ***error correction***. Underpinning his thinking is the assumption that ***error*** can only happen if there is a ***goal***. In these books on drawing and painting, the ***goal*** that allows learning through ***trial and erro***r is "***accuracy***" and the ***goal*** of ***seeking accuracy*** is to enable "***seeing and doing in new ways***".

Transmitted Light: is light that has penetrated a translucent surface and shines out from the other side. In the process, some of its wavelengths will have been absorbed by the pigment within the surface, leaving the remaining wavelengths to determine its perceived colour. Light that has had its wavelength characteristics modified in this way is what enables us to see the green of young leaves facing away from the sunlight and the colours of stain-glass windows viewed from inside a church.

A key difference between the opaque surfaces that we see by light that has come back into our eyes from them and the translucent ones that we see by means of light that has passed through them, is that the former provides a mixture of ***body-colour*** and ***surface-reflection (***see, *Figure 21*), while the latter supplies ***body-colour*** alone. The absence of ***surface-refection*** in the light that has penetrated translucent surfaces means that the information about ***surface-form*** and ***spatial location*** that it supplies to opaque surfaces is also absent. Since this is the case, it should be of no surprise to find that young leaves facing away from the sunlight and the colours of stain-glass

windows viewed from inside a church give the impression being both ***surfaceless*** and unconnected to their ***context***.

An example of ***transmitted-light*** that is not usually classified as such is the light of the sun. This can be described as transmitted because it only arrives at our eyes after having penetrated the atmosphere and because the atmosphere is full of light-scattering particles. These scatter the short wavelength more and longer wavelengths less, thus acting as a filter in much the same way as translucent surface. It is the variability in the scattering that accounts for both the yellowness of the sun and the blueness of the sky. Since surface of the sky hugs the earth, our heads are inside it. Accordingly, since this leaves no possibility of ***surface-reflection,*** the visual experience looking at the blue of the sky is analogous to that of looking at any colour by means of ***transmitted light***. Like the green leaves and the stain glass windows, it provides us the nearest thing we will ever get to an example of pure ***body-colour***.

Trompe l'oeil Paintings are paintings that are sufficiently realistic as to deceive spectators into believing that they are looking at an actual scene in the real world.

Uniqueness of Appearances: Three factors combine to explain why the appearance of every object, every shape and every surface seen in everyday life, whether indoors or outdoors, is virtually certain to be unique:

1. Nature never creates two objects quite the same and the range of different man-made objects is very great indeed since hand-crafted attempts at replication are seldom quite the same as one another and even series made by machines can vary in subtle ways.
2. Objects can be looked at from an infinite variety of viewing angles and viewing distances, all of which have an effect on their appearance.
3. The the appearance of every surface is influenced by infinitely varying combinations of primary and secondary light sources coming from an infinitely varying combinations of angles.

Visual Analytic Skills: *Figure 1* gives insights into the nature of the combination of skills required for ***drawing from observation***. They can be classified under three headings:

1. ***Recognition skills.***
2. ***Visual analytic skills.***

3. ***Line production skills***.

All three are inextricably connected, not only because of their mutual dependence on ***long-term memory*** but also because of their participation in its creation.

One of the keys to the understanding the role of ***recognition*** in ***analytic-looking*** lies in the fact that:

- It is ***preconscious***.
- The information required to enable it has precious little relation with actual visual experience. This is because it is enabled by ***multimodal processing*** based on ***crude generalisations*** that are detached from dimensional and other contextual information (ones that by no stretch of the imagination could be used in drawing from observation).
- Its sole function is to access ***knowledge*** residing in ***long-term memory*** with a view to initiating appropriate responses. In the case of artists ***drawing from observation***, these are ***actions*** that guide either ***line production*** or the ***eye movements*** required for ***focusing attention***.

Once ***recognition*** has fulfilled its function of accessing ***long-term memory***, the information found there relating to the object in question, including action instructions, are available when it comes to ***making use*** of it. From the point of view of artists, this means that, recognised objects can always be drawn from ***memory***. How well this can be done will depend on how much of the knowledge of the object in question relates to the possibility of depicting it. Thus, a seven year old child might make a drawing of a cube with six rectangular faces (possibly based on knowledge gathered from handling children's building bricks), whereas a skilled artist may represent it in correct linear perspective (based on knowledge of the rules relating to that subject). Viewers may mistake the artist's effort for an example of "*drawing what you see*" but, being a ***knowledge-based construction***, it is not and for that reason cannot represent the unique characteristics of any particular cube. To get nearer to a representation of its uniqueness, ***visual analytic skill***s are required. The same will be true for making drawings of all objects.

Visual analysis will always require giving attention to relativities. Depending on the circumstances and doing so may involve head movement (sometimes involving whole-body movement), but it always will require:

- ***Eye-movements***.
- A shift down the ***levels of description*** from the general towards the particular.
- Embarking on further cycles of looking, involving first ***recognition***, then access to ***memory*** followed by ***action instructions***.

Since the information in memory will always consist of ***generalisations*** based on past experience, ***action instructions*** will never relate precisely to the invariably unique characteristics of current appearances. The nearest approach to doing so will require that:

- The focus of attention is on the most basic elements of appearance and relations between them. In practice this might mean focusing on stretches of edge that have been isolated by means of ***chunking***, on ***angles*** at ***junctions***, on simple ***curves*** and on relations between any of these.
- The analysis consists of judging ***relativities*** by means of ***comparative looking***.
- The use of ***near symmetries*** (including those revealed ***by mistakes***) as a means of refining perception.
- Repeated reference to ***Context*** by means of reviewing all lines drawn in relation to as many as necessary of previously drawn reference points.

Value is the word used in American English to mean the same thing as the word "***tone***" in British English. Both mean the same thing as the word "***lightness***" as used by scientists of visual perception. In this series of books the scientific usage is preferred. Thus a ***tonal drawing*** or a ***value drawing*** is one that explores "*lightness relativities*".

Visual area 1 is the area at the back of the brain which receives information coming up the ***optic nerve*** from the ***retina***. In *Figure 1* it is labelled as a "*twice used information resource*", because it is used both by the systems that enable ***recognition*** and by those that mediate ***analytic-looking***.

Visual world: All information that is currently available for use in ***visual perception***.

Whole-field colour relations: Relations between all the colours on the picture surface. These are of prime importance for artists because every region on a picture surface, whether defined by colour, lightness or texture, effects the perception of all the other regions. This is one of the most fundamental

truths of drawing and painting. It is also one which can only too easily be neglected by artists.

Viewing Conditions. ***Recognition*** depends on classifying objects as being the same on different occasions. A major reason why this poses a problem is because the information entering the eyes varies according to viewing conditions. In particular, it varies both with ***viewing distance*** and ***viewing angle,*** and with the ***wavelength-combination*** and the ***intensity*** of the ***illuminating light***, the sources of which will always include a combination of ***secondary light sources***, possibly with the addition of one or more ***primary light sources***.

Visual Processing: The information that comes into the eyes in the form of ever-changing patterns of light waves has to be processed by ***neural systems*** in the ***eye/brain*** with a view to first ***making sense*** and then ***making use*** of it.

Visual sensing: Some people find the idea of sensing relativities with the eyes difficult to understand. They feel that ***sensing*** and ***seeing*** are quite separate processes. Yet vision is regularly described as on of the five senses and the neural computations by which it is achieved are based on input from sensors just as are the other four. The only difference is where the sensors are located and the nature of the energy to which they respond.

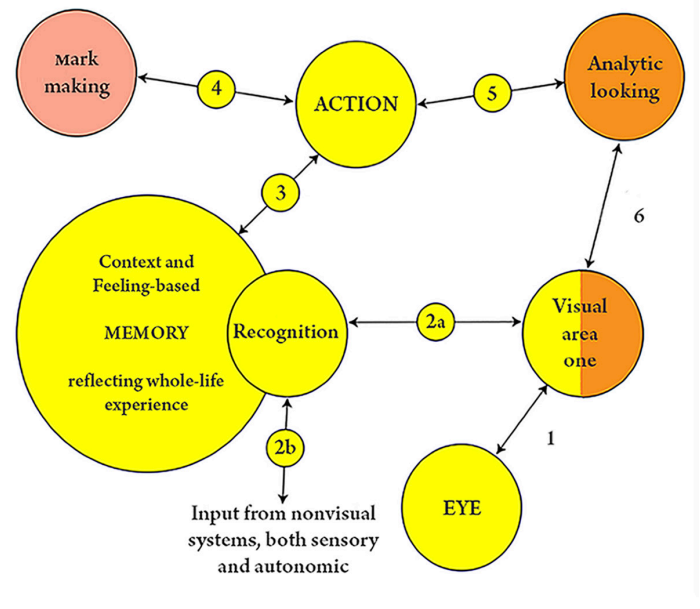
Working Memory: To make use of information picked up by the receptors in the eye or those of any other sensory system it has to be transformed into ***action instructions***. As this transformation cannot be achieved without time (however brief) being spent on collecting together the relevant information, there is a need for a temporary storage facility. It is this that has been given the name of "***working memory***."

GLOSSARY DIAGRAMS (1)

The eye and the brain

The diagrams below and their captions provide a brief introduction to eye/brain systems that play a part in the artistic practices discussed both in the main books and in this Glossary. Figures 2 to 11 concern the often surprising organisation of the different cell-types in the retina with their network of neural connections. It is the activation and activity of these that initiates the process by which the eye/brain is able make practical use of the information contained in the ever-changing patterns of light coming into the eye. Upon leaving the retina, the neural signals travel up the optic nerve to the part of the neocortex known as visual area 1, from whence they spread out and progress in various directions. Figure 1, which can usefully be related to Figure 13, provides a diagrammatic perspective on where they go and how this relates to the processes involved in drawing from observation.

Figure 1 is a flow diagram giving a much oversimplified idea of the flow of information within the analytic-looking cycle (the actual flow is far too complicated represent in such a clear way). In it the coloured discs can be related to regions in the ***neocortex****, as illustrated in Figure 13. Notice that the disc labelled* ***Visual Area 1****, which takes input from the* ***retina*** *via the* ***optic nerve****, is divided into two halves. This division symbolises its double function of providing information (a) to the* ***preconscious*** *processes that enable* ***recognition****, and (b) to the subsequent* ***conscious*** *ones that accompany* ***analytic-looking****.*



Also, the diagram indicates the key role of ***memory stores*** *in enabling both* ***recognition*** *and* ***the organisation of action****. In particular, it calls attention to the importance of* ***context****,* ***feeling*** *and* ***whole-life experience*** *in building them up. The numbers indicate the direction of flow. Notice particularly that* ***recognition*** *and* ***access to memory*** *take place* ***before analysis****. In the language of "****Intellectual Realism****", this means that* we ***"know"****, what we are looking at before we "****see****" (that is to say,"before we are consciously aware of it").* Similarly ***recognition*** *and* ***access to memory*** *take place* ***before*** *the implementation of* ***actions*** *such as those that guide artist when* ***mark making****. The diagram also indicates the role of* ***nonvisual-inputs*** *in enabling* ***recognition****. For example, we may* ***recognise*** *something by its sound, smell or feel* ***before*** *confirming what it is visually.*

*The main complication that is glossed over is the pathways by which the **frontal eye-fields** (situated at the front of the brain) and the **feeling centres** in the mid brain are involved, both when the direction of gaze is consciously driven and when it is determines by attention-catching external events such as unexpected movements or sudden sounds).*

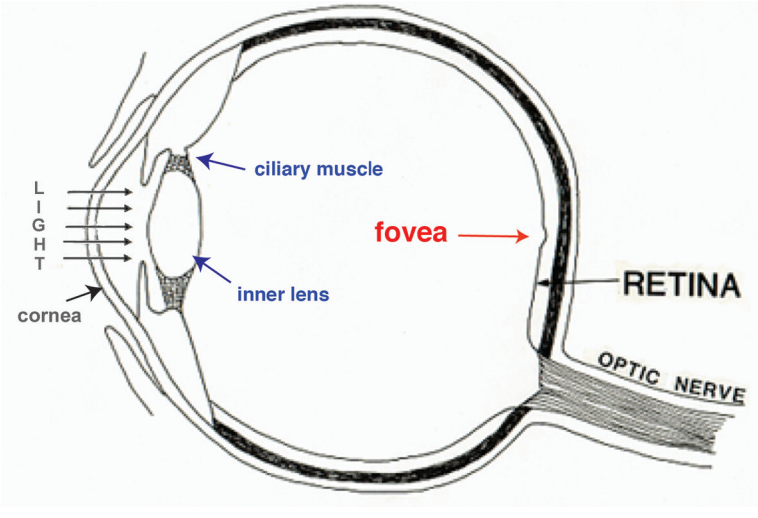


*Figure 2 diagrams the retina at the back of the eye with the size of **fovea** indicated. Before reaching the retina the light that passes through the cornea is focused by two lenses. One of these is the **cornea**, the other, the **inner lens** performs a fine focusing function. The information that has been gathered and processed is passed up the optic nerve to **visual area 1** (see Figure 1).*

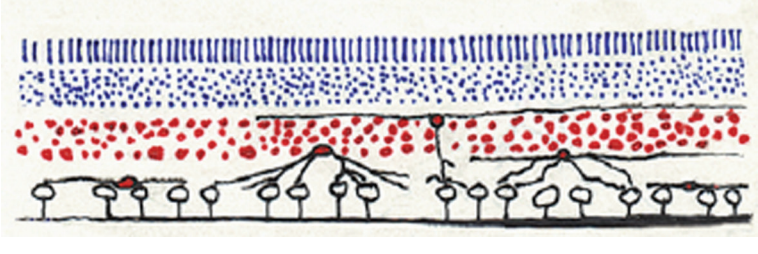


*Figure 3 illustrates the layers of cells in the periphery of the retina. The row of vertical lines at the top represent a small proportion of the approximately **150 million** rod receptors to be found there and the much smaller number of ring shapes at the bottom represent some of the approximately **one million** ganglion cells that channel the output from the retina up optic nerve. The huge difference*

between these two numbers gives an idea of the extent of the organisation of information that has taken place between the two.

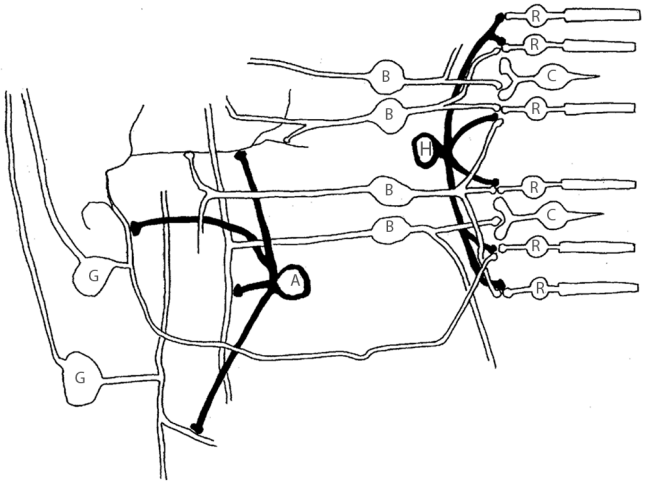


Figure 4 : The cell types that make up the layers of the retina are: ***rod receptors*** *(R),* ***cone receptors*** *(C),* ***horizontal cells*** *(H),* ***bipolar cells*** *(B),* ***amacrine cells*** *(A) and* ***ganglion cells*** *(G). Their purpose is to receive and organise patterns of information before sending them up to* ***visual area 1****.*

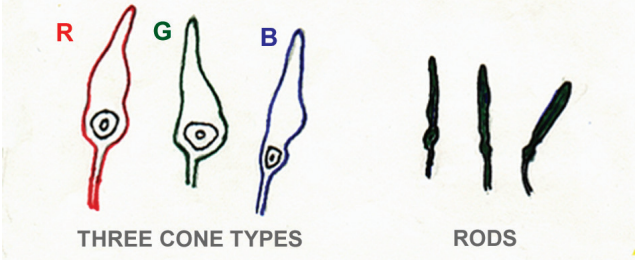


Figure 5 : The three types of ***cone receptor*** *are sensitive to all wavelengths of light, but each is relatively more sensitive in different parts of the spectrum. One is more sensitive to relatively long wavelengths (R), another to intermediate wavelengths (G) and the third to relatively shorter wavelengths (B). The* ***rods*** *are also sensitive to all wavelengths but are most sensitive to wavelengths between the peak sensitivities of the G and the B receptors. The rods are significantly more sensitive to light than the cones.*

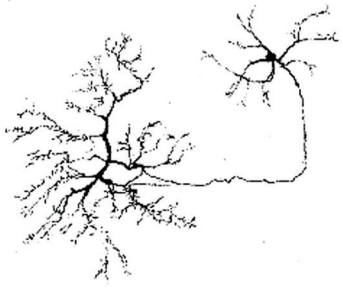


Figure 6: This copy of a drawing by Santiago Ramón y Cajal the pioneering neuroscientist provides a rough idea of the complexity and potential for connectivity of a ***ganglion cell****. His drawings of this and other cell types made clear that widespread interconnectivity is a fundamental property of neural processing.*

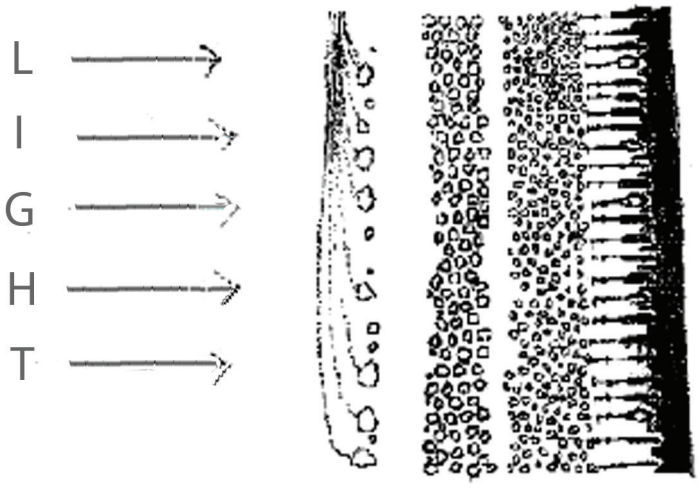


Figure 7 shows light entering periphery of the retina and traversing several layers of cells before arriving at the ***receptors****, which are facing towards the back. The only part of the retina where these light impeding layers are absent in the* ***fovea****.*

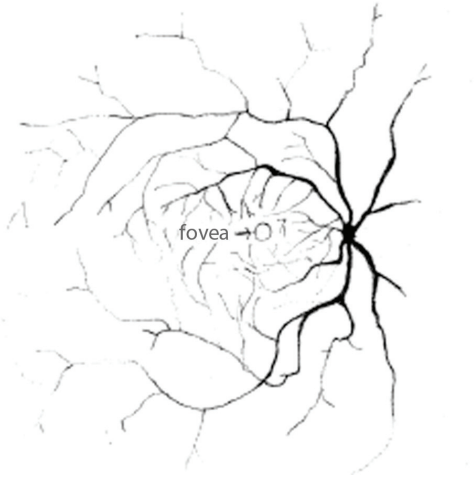


*Figure 8 : illustrates **blood vessels** between the lens and the **retina** that impede light everywhere except for a small region in front of the **fovea**. In this, the layers of light inhibiting cells represented in Figure 7 are absent.*

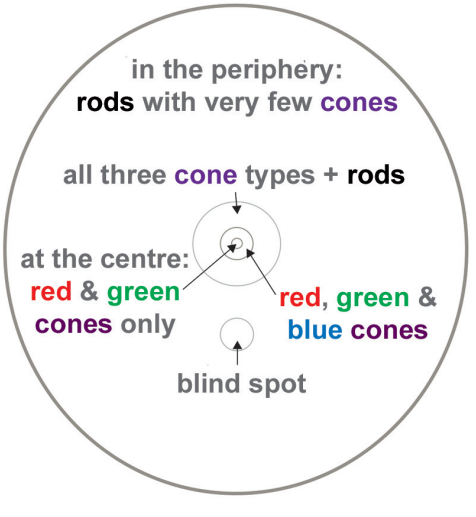


*Figure 9 diagrams the distribution of **rods** and **cones** across the **retina**. Only where the **incoming daylight** is not impeded by intervening **cell layers** (Figure 7) or **blood vessels** (Figure 8) is it strong enough to activate the **cones**. In contrast, it is only where it is impeded by them **t**hat the **rods** are not **bleached out** by its intensity. This is why there are no **rod receptors** in the centre of the **fovea**.*

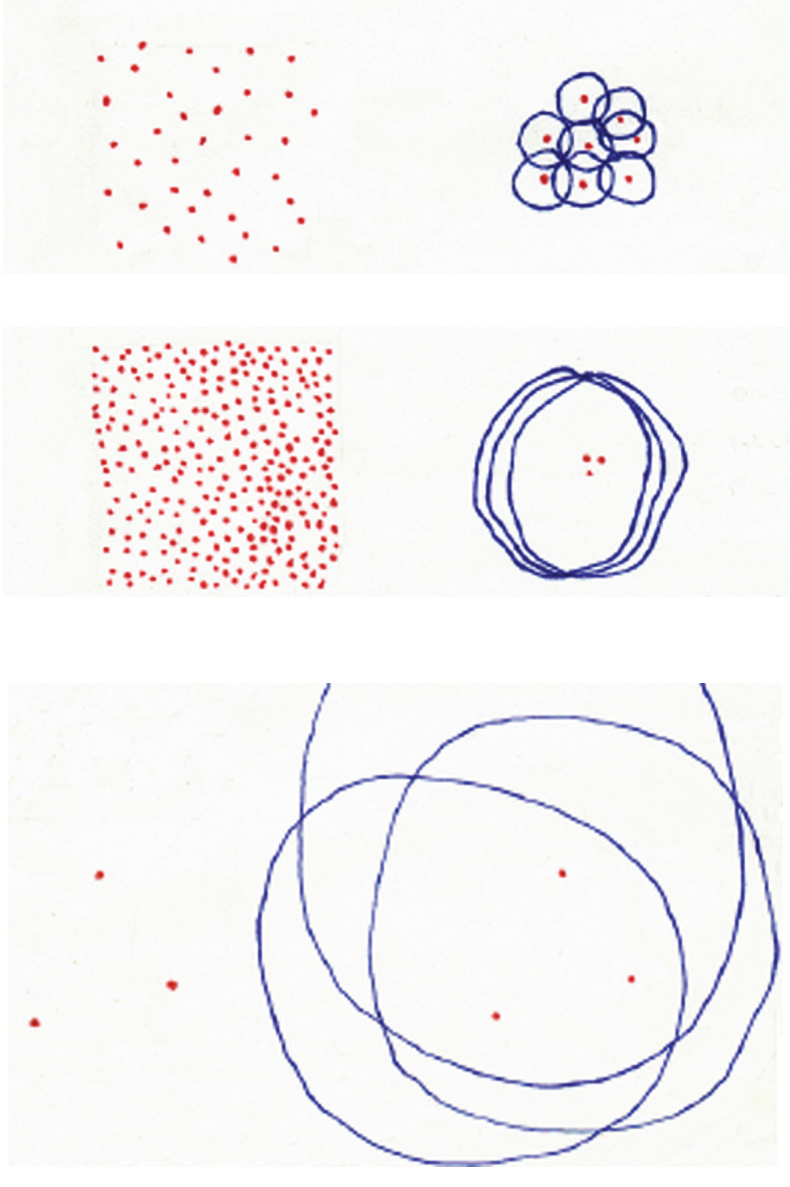


Figure 10 shows a mapping of ***amacrine cells*** *(see Figure 4) that indicates the density of distribution and the size of receptive fields. Three types of them are shown: (a) fairly densely distributed* ***small sized receptive fields*** *(top image); (b) much more densely distributed* ***medium sized receptive fields*** *(middle image); and (c) widely dispersed l****arge sized receptive fields*** *(bottom image).*

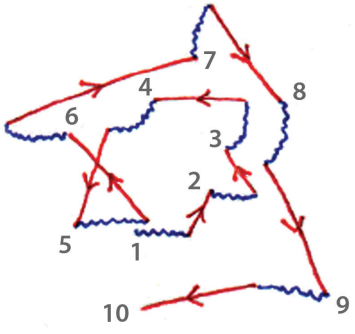


Figure 11 shows a record of typical eye movements in which slow moving ***glides*** *are interspersed with faster moving* ***saccades****. The glides provide a constant stream of* ***same/different information****, while the saccades enable an intermittent averaging of input that is useful for neural computations that require knowledge of the composition of ambient illumination.*

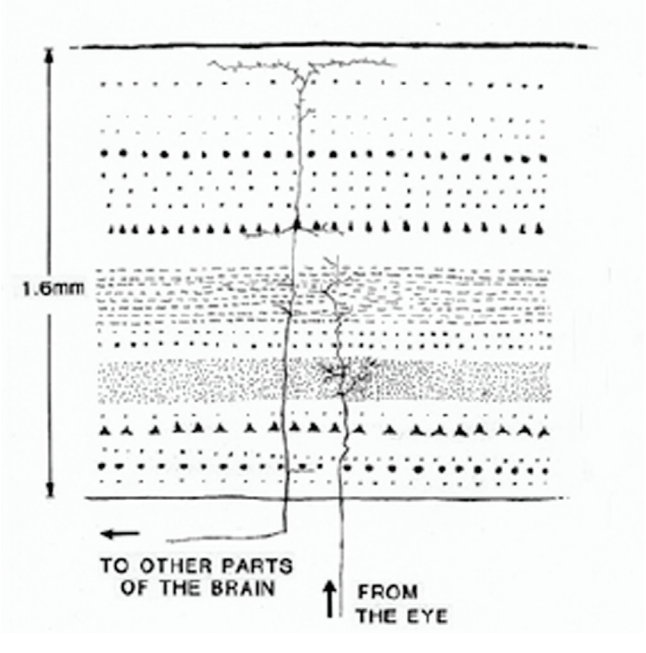


Figure 12 : Diagrams ***cell types****,* ***layers*** *and selected* ***connections*** *in* ***Visual Area 1****. A comparison with Figure 3 provides a graphic illustration of the extra levels of complexity involved in the neural computations that take place in the* ***neocortex****.*

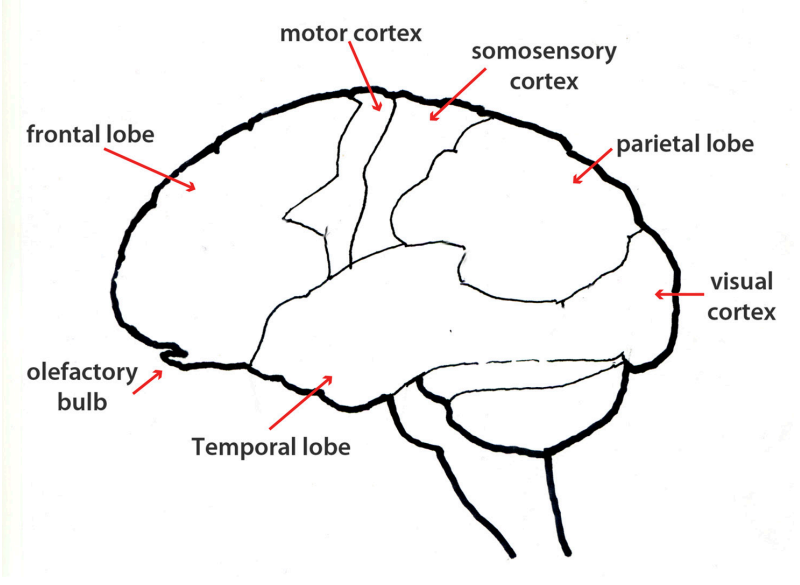


Figure 13 diagrams a number of the functional divisions in the ***neocortex*** *(new brain). These can be related to the stages of the* ***analytic-looking cycle*** *as diagrammed in Figure 1. Thus in Figure 1: (a) the arrow labelled "****visual cortex****" points to the location of "****visual area 1****"; (b) The region from there down to "****temporal lobe****" corresponds to the labels "****preconscious multimodal processing****" and "****recognition****"; (d) The motor cortex mediates "****learnt actions****"; and (d) the parietal lobe underpins "****conscious analytic looking****" and "****the constancies of shape, size, and orientation****".*

*The area in Figure 1 labelled "****context and feeling-based memory reflecting whole life experience"*** *is more difficult to place, but would include the* ***somosensory cortex*** *(an essential part of the "****feel system****"). It would also include parts of the* ***frontal lobe*** *with its links to the emotional centres in the* ***old brain****. These are thought to be involved in the choice between "****good****" and "****bad****" actions and the determination of "****similarities****" and "****differences****" between things or events, both of which are essential to developing the* ***skills*** *that underpin drawing from observation (as explained in Chapters 9 - 11). The frontal lobe is also thought to play an important part in the creation and maintenance of longer term memories.*

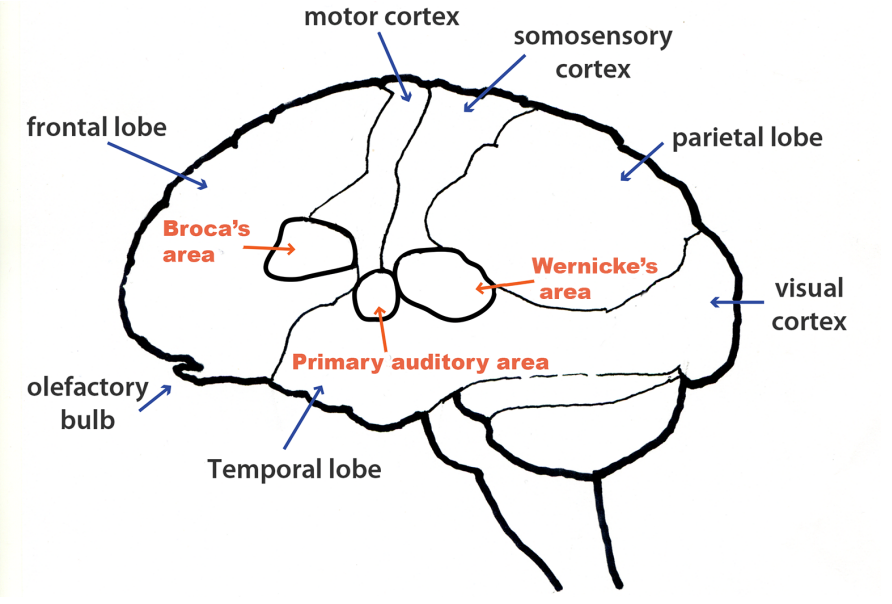


Figure 14 : Making sense and making use of words and sounds.

*Figure 14 is very similar to Figure 13 except that three roughly circular areas have been added to represent the "**primary auditory area**" and two areas that are known after the researchers who first identified their importance, namely Carl Wernicke and Paul Broca. Functionally speaking, (a) the "**primary auditory area**" plays a similar role in the processing and use of sound inputs to that is played by "**visual area 1** for visual inputs, (b) **"Wernicke's area"** mediates "**multimodal processing**" and (c) **"Broca's area"** organises "**sound and verbal outputs**". In other words, the cycle involved in making sense and making use of sounds is very similar to the "**analytic looking cycle**" (see Figure 1). It starts with "**sensory input**", progresses, using "**multimodal processing**", to "**recognition**" and, thereby, to the **context and feeling based, long term memory store which provides the information which enables** to the organisation of "**action instructions"**. These can either lead directly to word and/or thought outputs or to refining analysis of the incoming sounds. As with visual analysis, unfamiliar sounds or words require a descent to the sound primitives.*

It will be noticed that Wernicke's area is well placed for inputs from visual processing systems and, accordingly, for taking advantage of the possibilities of multimodal processing which that offers. For example, a picture of a tree can help a child learn to read the word "tree". In this way, everything is well placed for reciprocal use of visual and oral information.

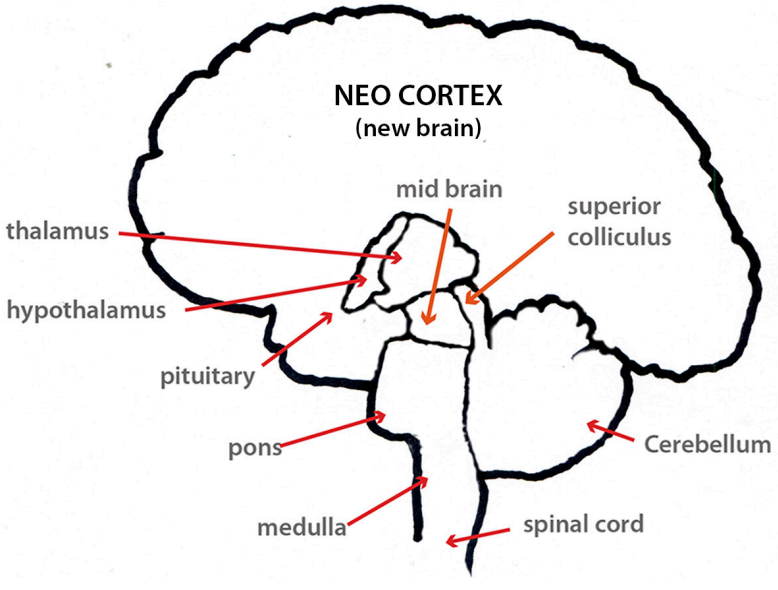


Figure 15 : The old brain.

Figure 15 reminds us that there is much more to the brain than the ***neocortex*** *or* ***new brain*** *which gets its name because it evolved subsequently to the "****old-brain****". One way of emphasising the importance of old-brain function is to observe how well animals with much less well developed, sometimes vestigial neocortexes, get on without it. Despite this lack, they are extremely good at finding their way around, interacting with objects and other animals and being influenced by desire and fear. Two of the arrowed regions in Figure 14 are worth singling out for the part they play in drawing from observation. They are:*

- *The* ***cerebellum*** *which is required for the coordination and fine control of actions such as those required for drawing from observation. Its importance is indicated by its size which is roughly one eighth of the rest of the brain.*
- *The s****uperior colliculus****, in conjunction with other old brain regions, including the* ***hippocampus****, has an important role in the control of the eye movements, whether directed by the* ***analytic-looking system*** *or reacting to movement or change within the environment. In the case of the latter, the information from the retina bypasses the* ***neocortex*** *and significantly*

*it is not subjected to the processes diagrammed in Figure 1 that lead to **recognition**. In the context of **drawing from observation**, when the **analytic-looking system** initiates **comparisons,** differences between the compared features will automatically trigger **eye-movements** that focus attention to otherwise overlooked aspects of appearances.*

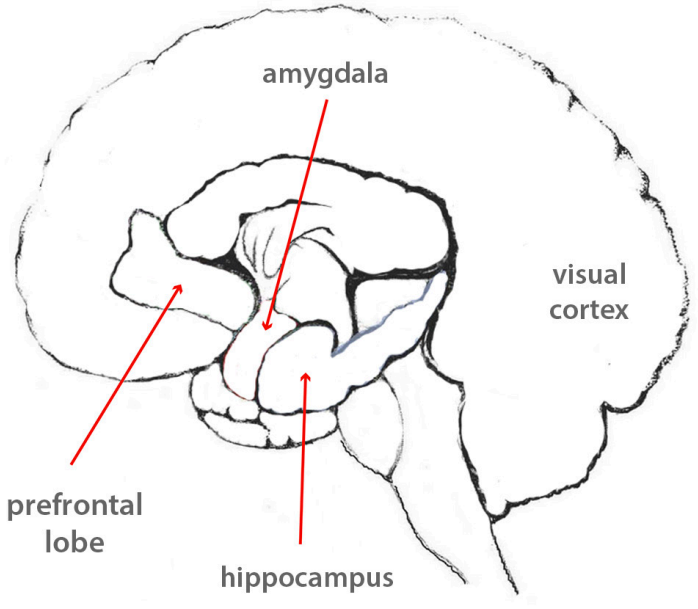


Figure 16 : hippocampus, prefrontal lobe & Amygdala

Figure 16 illustrates two other parts of the old brain that have special functions in the context of drawing from observation. They are:

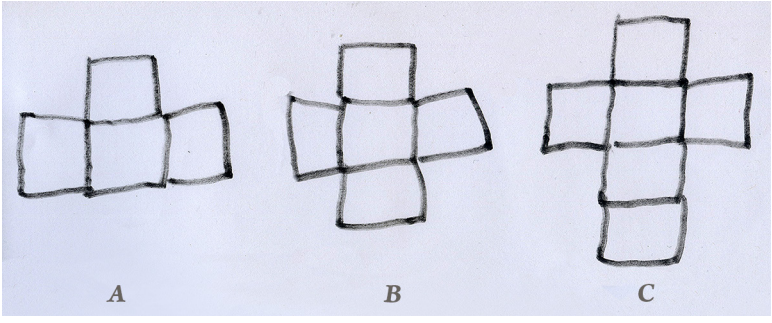
- *The **Amygdala** has been described as is "the integrative centre for emotions, emotional behaviour and motivation" and as such has a key role in the integration of the feelings into the "**context and feeling based memory that is influenced by whole life experience**" diagrammed in Figure 1.*
- *The **hippocampus** is capable of using information from all available modalities of **sensory input**. Its has two key functions. Firstly, it allows us to locate ourselves relative to objects (including our own body parts) and to locate them relative to each other, whether in the real world en-*

vironment and in our imaginations. Secondly, it plays an essential role in laying down and recovering memories. John O'Keefe who pioneered work on the hippocampus also plays basketball. He liked to test himself on being able to retain a sense of the location of the basket when manoeuvring himself and the ball with his back turned to it. When drawing from observation we can keep a sense of the goal while drawing complex curves. This is evident in CLAM drawings of the human figure which, despite their being made without looking at the paper and even after a complete tour of its outline, often finish surprisingly near the starting point. On a smaller scale, the same is true of any complex curve joining two points. The end point can be kept in mind while negotiating the intervening deviations. Likewise, a feeling for relativities of locations (what O'Keefe would call a "map") can be developed for a sequence of marks, such as those made while making either making a ***drawing from observation*** *or a* ***sketch*** *from the imagination.*

- *The* ***hippocampus*** *is located next to the* ***amygdala*** *and accordingly it is not surprising to find that its activity has been associated with the emotions, whether simple of complex, that play a core role in the training and use of the* ***feel system*** *in the context of drawing from observation.*
- *More speculatively, the hippocampus may perform the function in neural computations of a look up table in computer computations. If so it may guide searches within the contents of* ***long term memory****,* ***short term memory*** *and* ***working memory****.*

GLOSSARY DIAGRAMS (2)

Miscellaneous



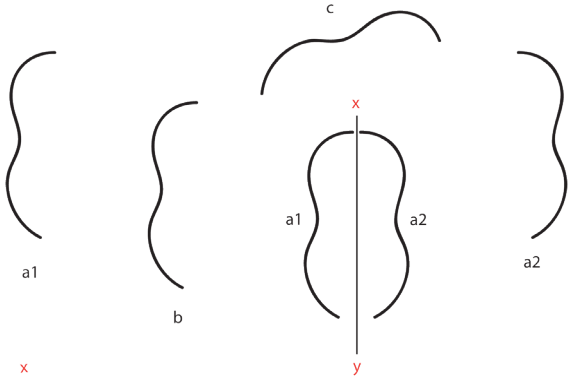


Figure 17a : Illustrates the three symmetries and an axis of symmetry. (1) Other than its different position the shaped line b, is the same as the shaped line a1 in all respects and accordingly provides and example of ***symmetry of translation****; (2) Other than its orientation, the shaped line c, is the same in all respects as the shaped line a1, and accordingly provides an example of* ***symmetry of rotation;*** *(3)The shaped line a2, being a mirror image of the shaped line a1, provides an example of* ***symmetry of reflection.****. Together with shape a1 it makes a compound shape to which can be given a vertical* ***axis of symmetry*** *represented by the line xy.*

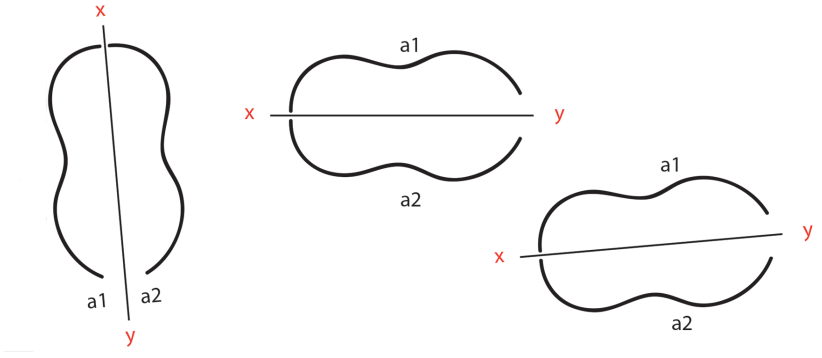


Figure 17b : Illustrates cases in which the axis of symmetry is "near-vertical" (left hand image) and when it is "near-horizontal" (right hand image) To recognise these shapes as being the same the eye/brain internally rotates axes that are near-vertical to vertical and near-horizontal to horizontal (centre image). In the process it measures the extent of the rotation to provide the information about its original orientation that is needed for guiding actions.

Figure 17c : Shows images of a mug and a bowl. Both are machine made and symmetrical in their form. Their purpose here is partly to warn of visual traps, but mainly to illustrate that symmetries provide many opportunities for having attention drawn to contextual differences.

Figure 17d : Shows the same objects as in Figure 17c, but here symmetrical ellipses have been added for the actually asymmetrical top openings. The letters are used as a means of illustrating both actual symmetries (B1/B2 & D1/ D2) and apparent symmetries in Figure 17c (A1/A2 & C1/ C2).

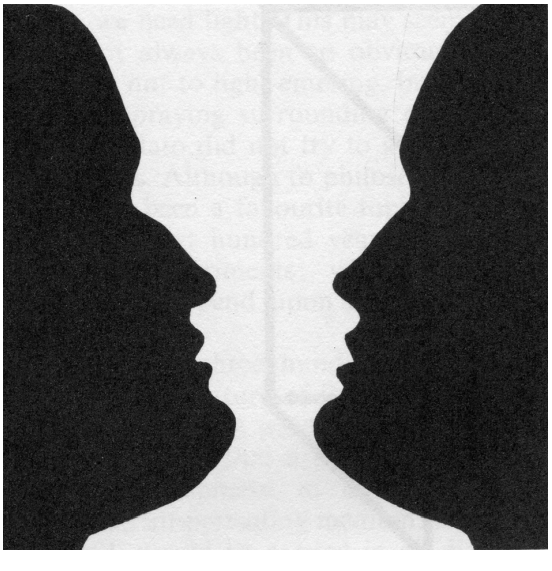


Figure 18 - Vase/Face Illusion. This can be seen as either two silhouetted faces confronting each other, or as a white vase. No matter which of the two is favoured, the other interferes, as can be seen by comparing the situation in

Figure 19, in which the left hand side face has been removed, leaving a blank background.

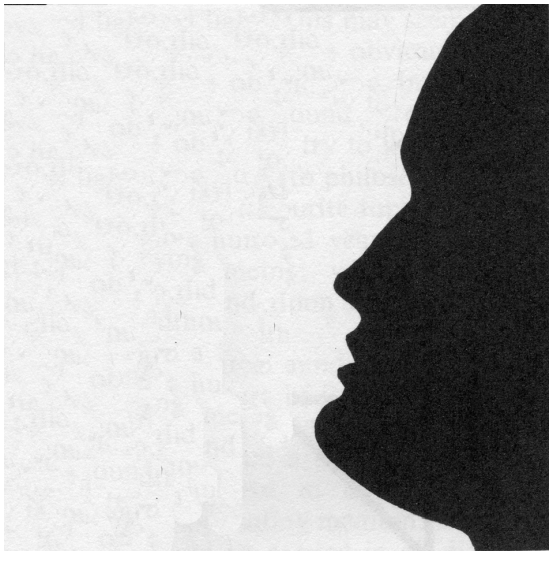


Figure 19 : Face alone.

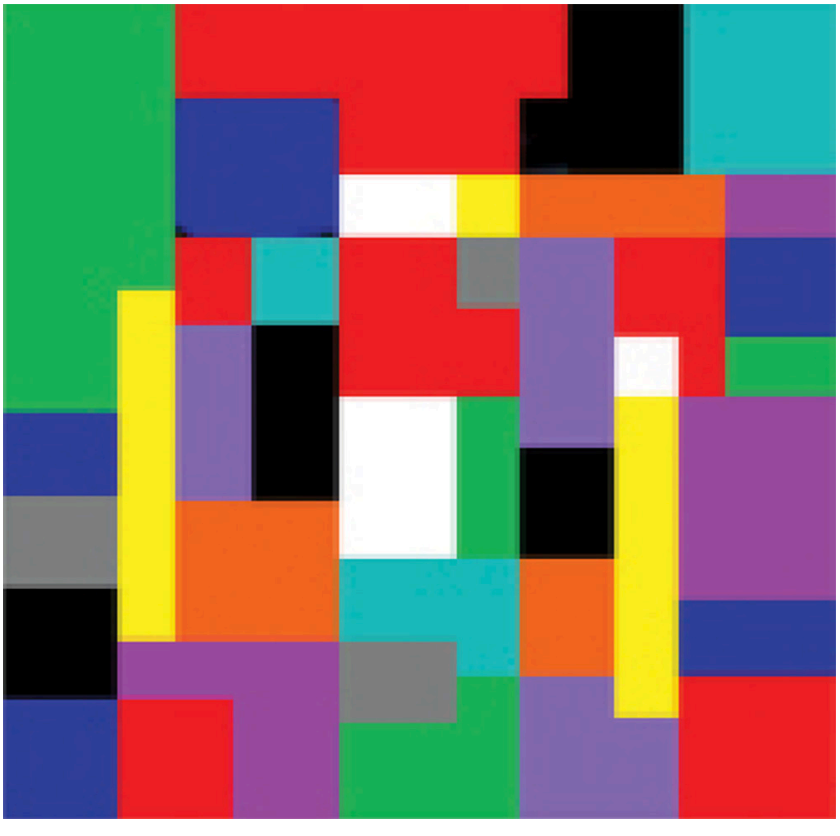


Figure 20: A multicoloured display.

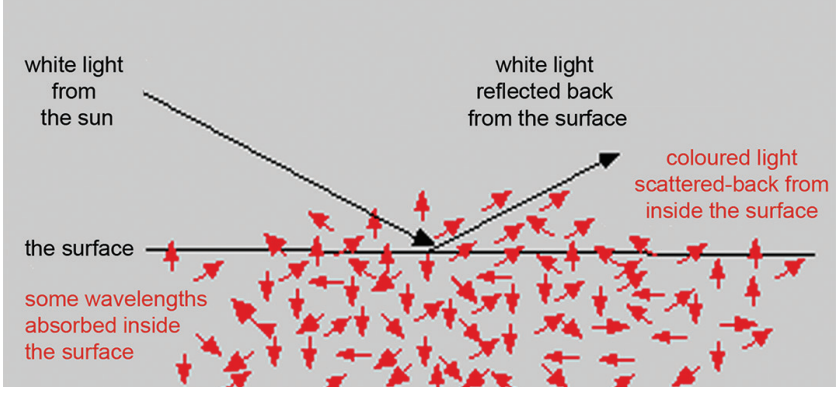


Figure 21 : Body-colour and reflected-light.

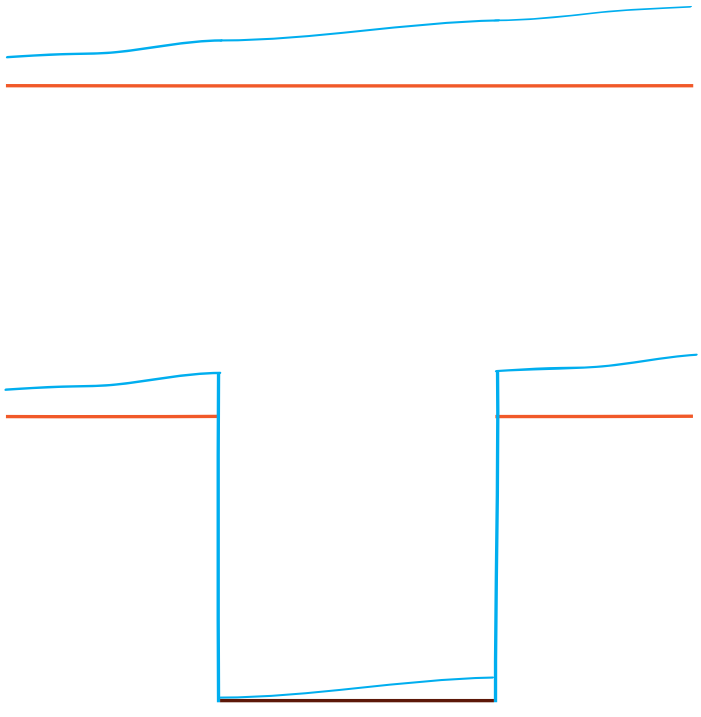


Figure 22 (Diagram A) : Represents the slow-varying intensity-profile of day-time light reflecting from a flat surface of uniform body-colour. Its wavelength composition is determined by the sum of the light sources, primary and secondary, that shine or reflect their light onto the region of surface in question. The result is the continuously varying complex of all the wavelengths of light that can be represented in paintings by adding complementaries into all the paint mixtures used.

Figure 22 (Diagram B): Shows the same surface but now with a sudden dip in the intensity profile of the reflected-light, caused by a cast-shadow. The eye/brain erroneously interprets this as a change in body-colour, rather than of surface-profile, which it classifies as being in the direction of black (here shown as dark brown). This leaves a residue of reflected-light which it separates out from the body colour and computes as being continuous and slow-varying (as in Diagram A). Artists who want to represent this ***separated-out*** *and, as explained elsewhere,* ***invisible*** *component can do so by adding complementaries into the shadow colour they choose.*

Figure 23 : In Bonnard's drawing of Marthe, her thumb is emphasised while the visibility of her facial features is minimised.

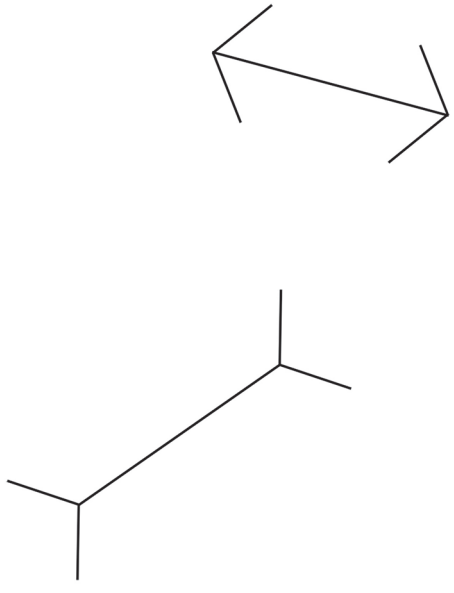


Figure 24 : Müller-Lyer illusion. Which joining line is the longest?

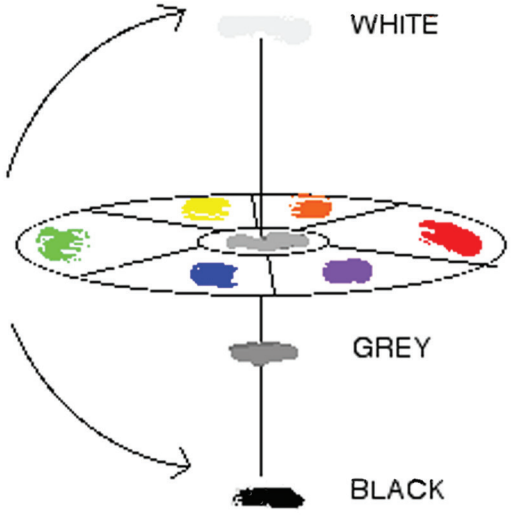


Figure 25 : Transforming a colour circle into a colour sphere.

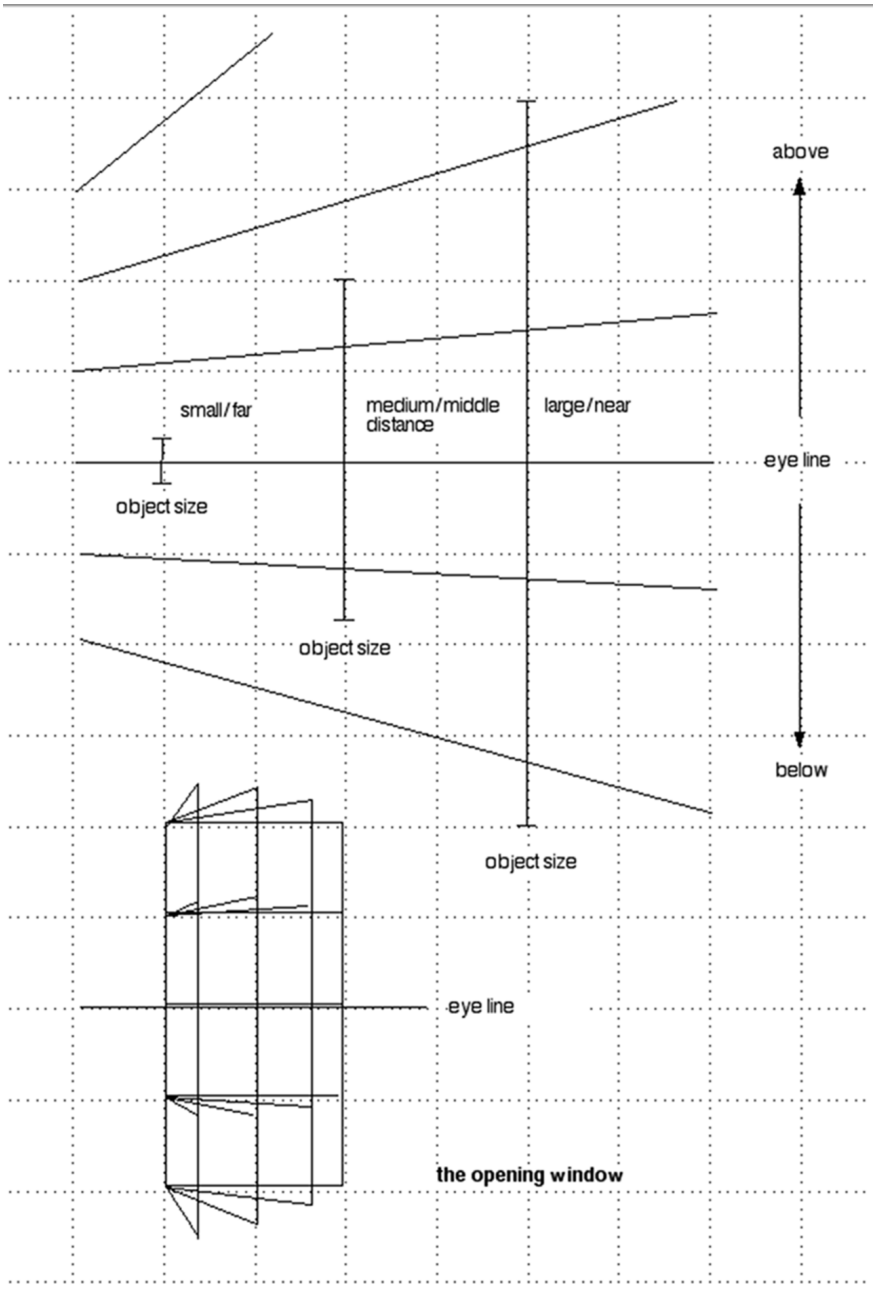


Figure 26 : Perspective grid left side.

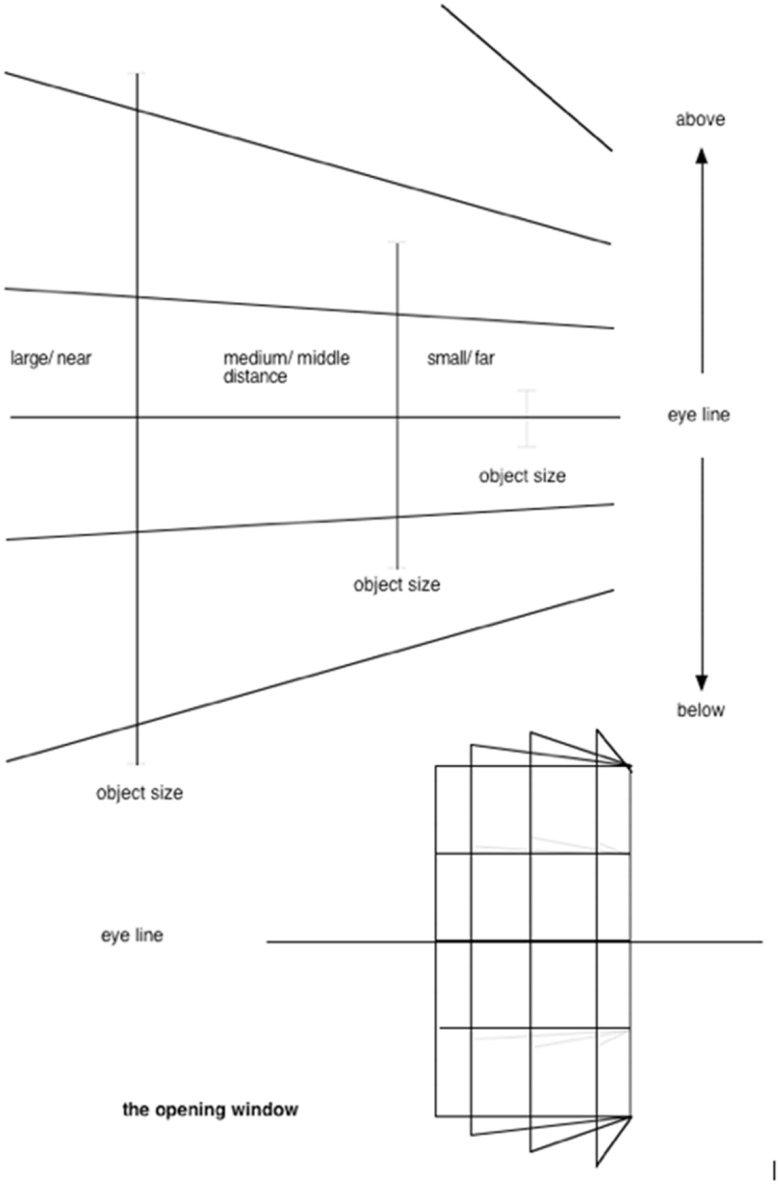


Figure 27 : Perspective grid right side.

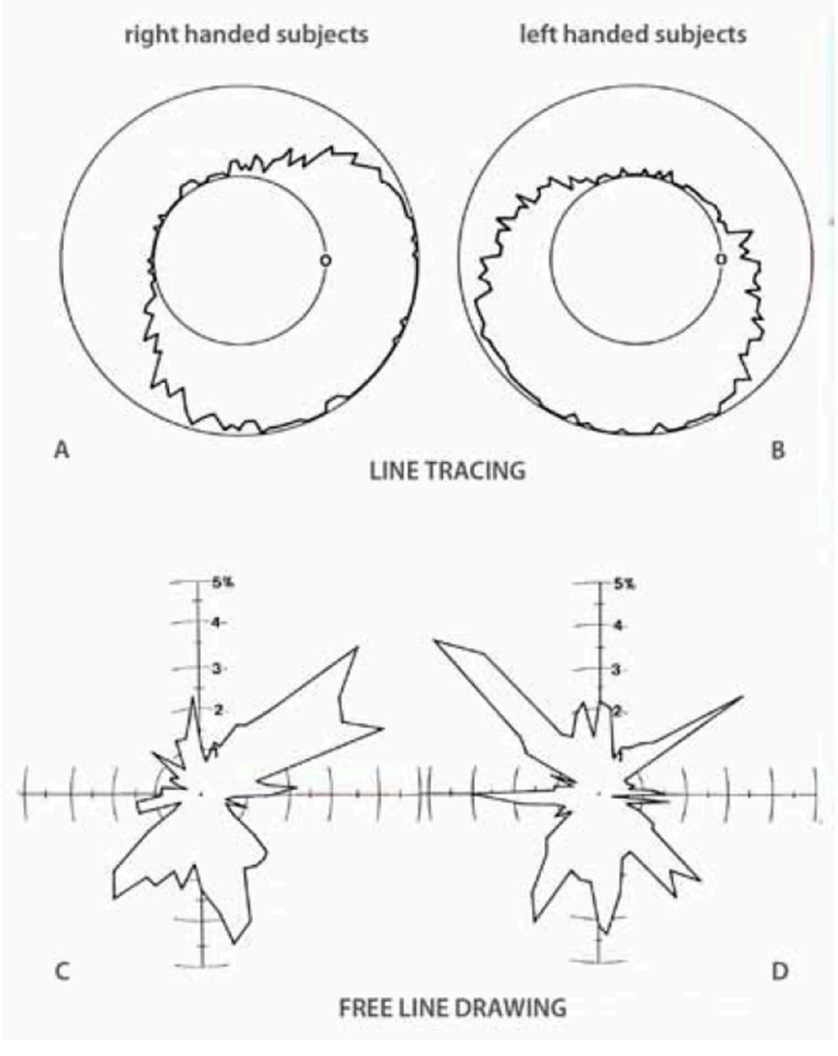


Figure 28 : Diagrams from Peter van Sommers book 'Drawing and Cognition' showing evidence for stroke direction preferences. For the experiment, a piece of A4 paper was covered with fifty-six straight lines (2.4 cm long) at fifty-six different orientations, positioned randomly. The experimental subject's task was to trace all the lines separately. Obviously, any single line can be drawn in one of two directions. Peter's question was, would there be any regularity in the choice of direction, indicating a pattern of stroke-direction preference? Another part of the experimental

design was to compare left and right handed people on the grounds that if his hypothesis were true, the two groups should perform in roughly equal but opposite ways. As a second way of testing the hypothesis, Peter did another study in which the two groups (right and left handed people) were asked to cover an empty piece of paper freehand with short lines, which were to be drawn in all orientations. Figure 26 summarises the experimental results. They strongly support Peter's hypothesis. The top pair of diagrams refer to the tracing over lines condition and at the bottom pair to the free line drawing condition. Without going into too detailed an explanation, it is quite clear that there are patterns in the performances described and that these show a degree of mirror symmetry between right handed people ('A' and 'C') and left handed people ('B' and 'D').

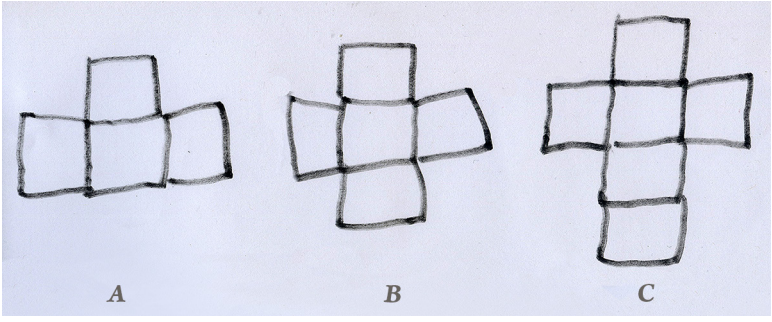


Figure 29a: Three typical copy-types of three dimensional cubes. Notice that they all show a top and at least two sides, even though they can only see one side at a time. B and C show both top and the invisible bottom, while C shows the solution found by a child who asked, "Do you want me to draw the back?" Notice also that none of them have faced up to the connectivity problem.

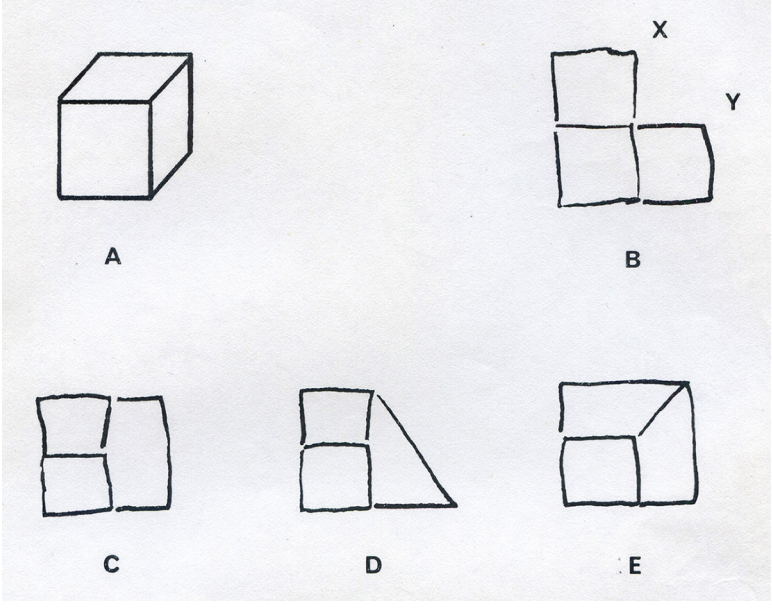


Figure 29b: Typical copy-types by 7 year old children when copying a line drawing of cube 'A'. Copy 'B' shows three conjoined rectangles indicating a lack of connectivity between corners 'X' and 'Y'. Copies 'C', 'D' and 'E' show three typical solutions to the connectivity problem.